13. MARINE WATER QUALITY

This chapter describes the supplementary marine water quality studies undertaken to address changes made to the project description, to take account of additional information, and to respond to specific comments made in submissions on the Arrow LNG Plant EIS (Coffey Environments, 2012).

The chapter presents the findings of a supplementary marine water quality study conducted by Central Queensland University (CQU) (Appendix 5) and supplementary hydrodynamic modelling completed by BMT WBM Pty Ltd (BMT WBM) (Appendix 7).

The marine water quality characteristics described in these studies have been used to inform the existing environmental values for the supplementary coastal processes study and marine and estuarine ecology studies. The findings of the coastal processes study are described in Chapter 14, Coastal Processes. Chapter 15, Marine Ecology, summarises the findings of the marine ecology study; and Chapter 17, Estuarine Ecology (Calliope River), summarises the findings of the estuarine ecology study.

13.1 Studies and Assessments Completed for the EIS

This section outlines the marine water quality studies and impact assessment completed for the Arrow LNG Plant EIS. Chapter 16 of the EIS describes in detail the assessments completed, potential impacts and main conclusions of these studies and assessment.

CQU was engaged from 2010 to 2011 to undertake the marine water quality study (see Appendix 12 of the EIS), which informed the coastal processes, marine water quality, hydrodynamics and legislation assessment undertaken by BMT WBM (see Appendix 8 of the EIS) for the Arrow LNG Plant EIS.

The marine water quality study included a desktop review of previous water quality studies in Port Curtis and a two-part water sampling program conducted by CQU in May 2010 and February 2011. The water quality results were reviewed against project water quality criteria (provided in Table 16.3 of the EIS) and interpreted in the context of long-term findings from previous studies. The project water quality criteria were derived from those set out in the Queensland Water Quality Guidelines (DERM, 2009i) and the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000).

Existing water quality in the vicinity of the Curtis Island project infrastructure was found to be generally good when compared to the greater Port Curtis area, although turbidity levels are naturally elevated due to sediment resuspension by tidal currents. There is some evidence of elevated metal concentrations in Port Curtis but not immediately offshore from the Curtis Island project infrastructure. Turbidity levels were found to exceed project water quality criteria by a factor of three in all samples collected in the Calliope River and offshore from launch site 4N.

The impact assessment identified potential impacts to marine water quality, which included:

- Formation of suspended sediment plumes in the water column from dredging works during construction and subsequent deposition of material on the seafloor.

- Discharge of brine from the desalination plant, process water and, under circumstances exceeding design (e.g., extreme rainfall events), treated sewage effluent to Port Curtis through the proposed outfall at Boatshed Point.
- Accidental discharge of hazardous substances during construction and operations.
- Discharge of sediment-laden runoff from dewatering processes, discharge of hydrostatic test water and associated sediments during the feed gas pipeline testing process, and discharge of treated sewage from the construction camp.
- Formation of sediment plumes as a result of maintenance dredging during operations.

Hydrodynamic dispersion modelling was conducted to predict the behaviour and fate of suspended sediment plumes generated during capital dredging at five locations. Dredge plume simulations indicated that suspended sediment concentrations will build up over the first two weeks of dredging and then reach dynamic equilibrium when sediment plumes are governed by the tidal cycle. Total suspended sediment concentrations were generally highest at the dredge sites and decreased with distance from these locations as plumes dispersed. The rate of plume deposition to the seafloor was also greatest at the dredge location and gradually reduced with distance. Relatively high rates of deposition were predicted in close proximity to the dredging locations due to the rapid settlement to the seafloor of the coarse sand and gravel component of the plume material. The significance of impacts from suspended sediment plumes was assessed to be minor, and the significance of impacts from sediment deposition on the seafloor was assessed to be negligible.

Hydrodynamic modelling of the behaviour and fate of effluent discharged through the outfall at Boatshed Point during operations predicted that impacts on water quality would be localised, with water quality criteria achieved within 10 m from the point of discharge under all hydrodynamic and tidal conditions. Regulatory frameworks (ANZECC/ARMCANZ (2000) and the Queensland Environmental Protection (Water) Policy 2009 (EPP (Water)) allow the establishment of a mixing zone where water quality criteria can be exceeded, provided compliance is achieved at the mixing-zone boundary. Assuming a mixing-zone boundary is set at least 10 m distance from the discharge point, the magnitude and significance of impacts on water quality were assessed to be negligible.

The impact of accidental spills of hazardous substances, such as diesel fuel oils, solvents, paints and hydraulic fluids, on marine water quality is difficult to quantify, as by their nature the volume and location of accidental spills are not known until they occur. The assessment concluded that a spill that caused a change in water quality greater than 30% of existing conditions, over an area exceeding 100 m and for a period between 6 and 12 months would have a medium magnitude of impact on marine water quality, resulting in an impact of minor significance. This does not include large spills, which constitute a major incident and are addressed separately in the EIS in Chapter 29, Hazard and Risk. This hazard would require management in accordance with an oil spill response plan.

The impacts associated with maintenance dredging during operations are expected to be less than those that will occur during construction, as the volume of material to be dredged and the frequency of dredging is expected to be significantly less. Due to uncertainty about the extent and duration of these impacts, the same magnitude of impact from dredging during construction was applied to maintenance dredging, i.e., the magnitude of impact was assessed as low with a resulting minor impact significance.

The impacts to marine water quality during construction from the discharge of sediment-laden runoff from dewatering processes, discharge of hydrostatic test water during the feed gas pipeline testing process, and discharge of treated sewage from the construction camp were all assessed to be of negligible significance.

The EIS commitments to minimise the above potential impacts on marine water quality are repeated in Table 13.1.

Table 13.1 Marine water quality EIS commitments

No.	Commitment
C15.02	Develop a dredge management plan that considers the appropriate water and sediment monitoring data (e.g., current WBDD Project data) and will include:
C15.03	• Requirements for monitoring of water quality.
C15.04	• Actions to be taken to minimise the impacts of dredging on sensitive areas should water quality monitoring data show performance criteria are exceeded. Finalise specific actions in the dredge management plan.
C16.01	Design of the discharge outfall from the LNG plant will include a three-port diffuser at the end of the pipeline located close to the water surface (or the ports angled towards the surface) to maximise dilution of the negatively buoyant discharge stream.
C16.03	Prior to discharge to Port Curtis, test and treat excess water at the mainland tunnel launch site in an onsite water treatment plant to meet water quality criteria.
C16.04	Test and treat all discharges to Port Curtis to meet water quality criteria, as required, prior to discharge.
C16.05	Develop spill response plans to cover marine activities, including all vessel operations.
C16.06	Refuel vessels in designated areas where spill response kits are located.
C13.13	Train all relevant personnel in spill response and recovery procedures.
C16.07	Limit activities on vessels that may cause spillages to the deck to areas where deck water can be routed to and passed through oil/water separators (to meet water quality criteria) before discharge overboard.
C16.08	Store solvents and other oil-based or flammable materials in accordance with applicable Queensland regulations.
C16.09	Maintain a minimum practical inventory of hazardous materials on board vessels.
C16.10	Store on board wastes produced by vessels that cannot be discharged under the MARPOL Convention and then transfer to an approved onshore facility for treatment, reuse, recycling or disposal.
C16.11	Where practical, schedule the timing of maintenance dredging to coincide with the most favourable climatic conditions for minimising impacts to water quality and sediment (i.e., during neap tides when water currents are weakest or periods of calm winds and waves).
C16.12	Source hydrostatic test water from Port Curtis, the town water supply or from fresh water generated in the reverse osmosis plant. Test and treat water to meet water quality criteria as necessary prior to discharge to Port Curtis.
C16.13	Develop a detailed decommissioning plan for the site to include procedures and methods for managing effluent during decommissioning.

13.2 Study Purpose

The supplementary marine water quality study was undertaken to assess changes made to the project description, to review additional water quality data, and to supplement the water quality monitoring conducted for the Arrow LNG Plant EIS. These aspects are discussed below.

13.2.1 Project Description Changes

Project description changes relevant to the supplementary marine water quality study are summarised below.

Marine Infrastructure

The layout of the launch site 1 and the materials offloading facility (MOF) and integrated personnel jetty at Boatshed Point have been revised. Boatshed Point remains the preferred site for the MOF and integrated personnel jetty, and the proposed alternative site at Hamilton Point South has been discontinued. Launch site 1 remains Arrow Energy's preferred option for the mainland launching facilities, with launch site 4N retained as an option. Changes to Boatshed Point and mainland launch site infrastructure are illustrated in figures 4.4 and 4.5 respectively.

Hydrostatic Test Water

The LNG storage tanks and the feed gas pipeline will undergo hydrostatic testing at the completion of construction. Sea water or fresh water will be used for the testing and will be maintained in the tanks for a number of weeks. Biocides and oxygen scavengers may be used to eliminate organic deposits forming in the LNG storage tanks. Hydrostatic test water will be tested and, if necessary, treated before discharge to receiving waters.

The volumes of hydrostatic test water to be discharged to Port Curtis via the Boatshed Point outfall pipeline have been revised. For three LNG tanks (each with a 180,000-m^3 capacity) and for the purposes of modelling the discharge, the worst-case total test volume has been estimated at 360,000 m^3, with each tank having a hydrostatic test volume of approximately 125,000 m^3. The actual total test volume will be less than 360,000 m^3; and the final volume, discharge rate and discharge location will be developed during detailed design.

Dredging Footprint and Volumes

The footprint of the proposed capital dredging locations at the LNG jetty and at the Boatshed Point MOF and integrated personnel jetty have been revised from those presented in the EIS. The revised dredging volumes, depths and methods are provided in Table 6.1 in Chapter 6, Project Description: Dredging.

There have been no changes to the volume of material to be dredged in the Calliope River or at launch site 4N, and the volume has increased slightly at the LNG jetty. The main changes relate to the addition of dredging for an access channel from the Targinie Channel to the Boatshed Point MOF and a swing basin (an additional 165,000 m^3) and enlarged access area around the MOF (an increase from 50,000 m^3 reported in the EIS to 148,000 m^3) (see Figure 6.4).

13.2.2 Additional Information

Additional water quality data for Port Curtis has become available since the EIS was finalised and exhibited. Additional data includes water quality reports published by the Western Basin Dredging and Disposal Project, the Department of Environment and Heritage Protection (EHP, formerly the Department of Environment and Resource Management (DERM)), and proponents of other major projects that are planned or are under construction in Port Curtis.

This additional information informed the design of the water quality sampling program described in Section 13.4.

13.2.3 Submissions

Several submissions on the EIS raised issues relating to marine water quality. The full details of these submissions can be seen in the issue register table in Part B of the Supplementary Report to the EIS, together with responses to specific issues raised.

13.3 Study Method

This section describes the method adopted by CQU for the supplementary marine water quality study. The study method is described in detail in Appendix 5, Marine Water Quality. The method used by BMT WBM to model the dispersion of the hydrostatic test water discharge is described in Appendix 7, Coastal Processes.

13.3.1 Desktop Data Review

CQU conducted a desktop review of water quality data collected by third parties. The review took into account changes to the project description and identified sites that may be affected by the project at which additional water quality sampling was required to supplement existing data.

13.3.2 Water Quality Sampling Program

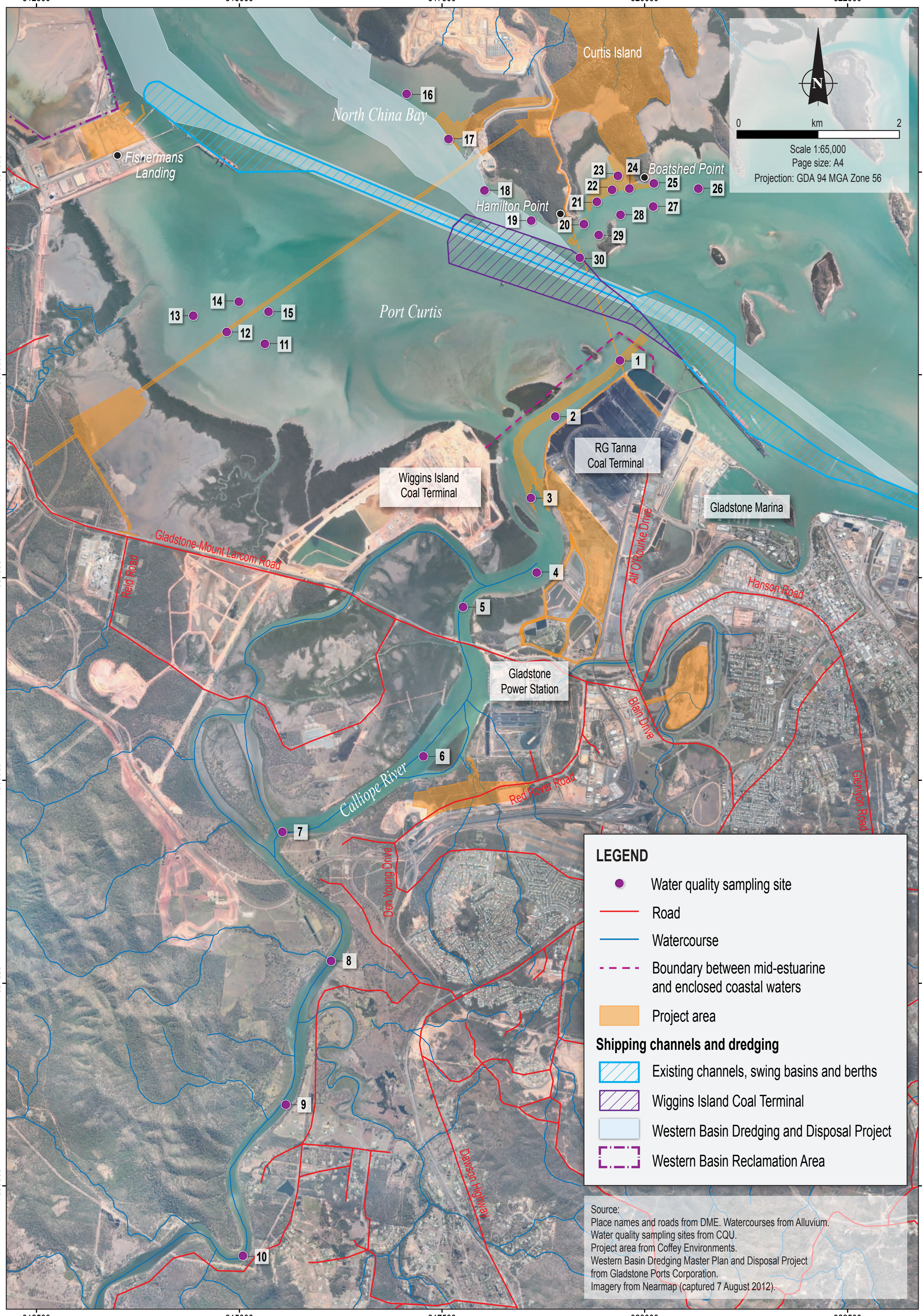
Thirty water quality sampling sites were identified by CQU during the desktop review described in Section 13.3.1. The locations of these sites are shown in Figure 13.1 and are grouped in three main areas:

- Sites 1 to 10 are located along the Calliope River.
- Sites 11 to 15 are located offshore from the mainland tunnel entrance site.
- Sites 16 to 30 are located offshore of Curtis Island from North China Bay to Garden Island.

The marine water quality sampling program was conducted in August and September 2012. At each of the 30 sampling sites:

- Water samples were collected immediately below the surface (i.e., 0.5 m water depth) and immediately above the seafloor (i.e., 0.5 m above the seabed).
- In-situ measurements of temperature, conductivity (and salinity), turbidity, chlorophyll-*a* and dissolved oxygen were obtained using a water quality probe. Measurements were taken at 0.5 m intervals through the entire water column (i.e., from surface to seafloor).

Water sampled and in-situ measurements were collected across the tidal cycle at high, mid and low tide during both spring and neap tides. This allowed water quality to be characterised across a range of tidal conditions.



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Arrow LNG Plant

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Water quality sampling sites

Figure No: 13.1

13.3.3 Sample Analysis

Analyses performed on samples were selected based on project marine water quality criteria and previous sampling conducted for the Arrow LNG Plant EIS and included:

- Total (unfiltered) metals: mercury, iron, silver, aluminium, arsenic, cadmium, chromium, cobalt, copper, manganese, nickel, lead, zinc and vanadium.
- Nutrients (unfiltered): total nitrogen and total phosphorus.
- Nutrients (filtered): ammonia, nitrogen, filtered reactive phosphorus (orthophosphate), and oxidised nitrogen.
- Total suspended solids and total organic carbon.

Marine water quality criteria used in the study were developed during the preparation of the Arrow LNG Plant EIS with the objective of protecting the environmental values outlined in the Queensland EPP (Water). The criteria are derived from those set out in the Queensland Water Quality Guidelines (DERM, 2009) and the ANZECC/ARMCANZ (2000) guidelines. The application of these project marine water quality criteria for the current study does not imply that the criteria will necessarily apply through the life of the project.

Specific criteria may be developed and applied through the conditioning process associated with other statutory approvals, such as dredge management plans or environmental authorities. The guidelines allow for the setting of criteria that take existing water quality into account.

Under the Queensland Water Quality Guidelines, waters within Port Curtis are classified as ‘Enclosed Coastal Waters’ and the Calliope River is defined as ‘Mid-estuarine Waters’ (see Figure 13.1). Water quality criteria for the project are provided in Table 13.2 and vary depending on the waterbody type. Where the Queensland guidelines do not provide guidance values, the ANZECC/ARMCANZ (2000) guidelines were used.

The Queensland and ANZECC/ARMCANZ (2000) guidelines were developed specifically to protect the integrity of aquatic ecosystems. Protection of this environmental value requires application of the most stringent water quality criteria; if these criteria are met, all other environmental values will also be protected.

In some instances, no guideline is specified for a contaminant of interest (i.e., iron, aluminium, arsenic and manganese). These instances generally reflect an absence of adequate scientific data and information to provide a guideline value for that contaminant.

Table 13.2 Marine water quality criteria

Parameter	Target			Source
	Unit	Port Curtis (Enclosed Coastal Waters)	Calliope River (Mid-estuarine Waters)	
Physico-chemical and Nutrients				
Ammonia nitrogen	µg/L	8	10	Queensland Water Quality Guidelines
Oxidised nitrogen	µg/L	3	10	
Organic nitrogen	µg/L	180	260	
Total nitrogen	µg/L	200	300	

Table 13.2 Marine water quality criteria (cont'd)

Parameter	Target			Source
	Unit	**Port Curtis (Enclosed Coastal Waters)**	**Calliope River (Mid-estuarine Waters)**	
Physico-chemical and Nutrients (cont'd)				
Filterable reactive phosphorus	µg/L	6	8	
Total phosphorus	µg/L	20	25	
Chlorophyll-*a*	µg/L	2	4	
Dissolved oxygen	% saturation - lower limit	90	85	Queensland Water Quality Guidelines
	% saturation - upper limit	100	100	
Turbidity	NTU	6	8	
Light penetration	Secchi depth in metres	1.5	1	
Suspended solids	mg/L	15	20	
pH	Lower limit	8	7	
	Upper limit	8.4	8.4	
Metals				
Mercury	µg/L	0.1	0.1	ANZECC/ARMCANZ (2000) guidelines (slightly to moderately disturbed marine waters)
Silver	µg/L	1.4	1.4	
Cadmium	µg/L	0.7	0.7	
Chromium	µg/L	4.4	4.4	
Copper	µg/L	1.3	1.3	
Nickel	µg/L	7.0	7.0	
Lead	µg/L	4.4	4.4	
Zinc	µg/L	15	15	
Cobalt	µg/L	1	1	
Vanadium	µg/L	100	100	

Note: The application of project marine water quality criteria for this assessment does not indicate that these criteria will be applicable through the life of the project. Specific criteria may be applied through conditions associated with other statutory vehicles, such as dredge management plans or environmental authorities.

13.3.4 Advection-Dispersion Modelling: Behaviour and Fate of Dredge Plumes

BMT WBM reviewed and updated the advection-dispersion modelling used in the EIS to predict impacts during dredging against project description changes and updated water quality and sediment baseline data. Updated findings are provided in Section 13.4.4.

BMT WBM also modelled the potential for fine sediments to accumulate following construction of marine facilities at launch site 1 and at Boatshed Point.

13.3.5 Dilution Modelling: Hydrostatic Test Water Discharge

Near-field dilution modelling was undertaken by BMT WBM for the SREIS. Modelling was completed using the three-dimensional Updated Merge (UM3) module of visual plumes to assess potential impacts to water quality resulting from the discharge of hydrostatic test water through the diffuser pipe, which may be installed as an alternative option, located at Boatshed Point. The discharge of hydrostatic test water was not modelled in the studies prepared for the EIS.

The near-field model developed for the studies carried out for the EIS was revised to include the updated water quality conditions. Far-field modelling was not conducted for this study due to the low discharge rates.

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

- Freshwater discharge with a total volume of approximately 125 million litres (ML) for each of the three tanks (120 ML was used as the input parameter for modelling).
- Single maximum discharge flow rate (4,871 m^3/day) consistent with the rate used in the outfall discharge modelling presented in the Arrow LNG Plant EIS (for effluent and wastewater).
- Outfall/diffuser parameters and footprint consistent with the modelling presented in the EIS.
- Ambient parameters at the proposed Boatshed Point outfall based on the additional water quality study findings.
- Current speeds that represented the range of conditions expected at the 10th (low), 50th (median) and 90th (high) percentile velocities during both flood and ebb tidal conditions for each of the neap and spring tide regimes.

A total of 14 scenarios (Table 13.3) were modelled: two representing slack tide conditions and six for neap tide and six for spring tide at the flood and ebb velocities.

Table 13.3 Near-field modelling scenarios

Scenario	Tidal Condition	Tidal State	Ambient Water Velocity
1	Neap Tide	Slack	Nil
2		Ebb	Low (10th percentile)
3			Medium (50th percentile)
4			High (90th percentile)
5		Flood	Low (10th percentile)
6			Medium (50th percentile)
7			High (90th percentile)
8	Spring Tide	Slack	Nil
9		Ebb	Low (10th percentile)
10			Medium (50th percentile)
11			High (90th percentile)
12		Flood	Low (10th percentile)
13			Medium (50th percentile)
14			High (90th percentile)

13.3.6 Study Limitations

The water quality sampling events that occurred in August and September 2012 provide information on the state of water quality at the time and location that samples were obtained. The do not provide an indication of long-term conditions. Additional water quality data from the EIS and other sampling programs in Port Curtis have been used to provide information on long-term water quality variability in the project area. This information may be used to develop project water quality criteria in consultation with the regulator that take into account actual water quality in the project area at the time the relevant Arrow Energy activities commence.

13.3.7 Assessment Method

The modelling results were used to review the findings of the marine water quality impact assessment as presented in the EIS. This review focused on validating the impacts and mitigation measures committed to in the impact assessment for the EIS and on presenting new impacts and mitigation measures where applicable.

Any assessment of impacts on water quality was limited to instances where the findings were inconsistent with those presented in the EIS and followed the method set out in the EIS (significance approach).

13.4 Study Findings

This section summarises the findings of the water quality sampling program conducted by CQU in August 2012 and the review and modelling of dredge plumes and the hydrostatic test water discharge carried out by BMT WBM.

13.4.1 Metals

Copper, zinc and cobalt were the only metals to occur in concentrations exceeding project water quality criteria. The location of sites where exceedences occurred and the number of exceedences at each site is illustrated in Figure 13.2.

The exceedence of zinc (22 µg/L compared to the criteria of 15 µg/L) at site 30 (Hamilton Point) was found to be an isolated occurrence at high tide during spring tides at the bottom of the water column. This exceedence is likely due to increased suspended solids in the water column during spring tides and zinc bound in complexes within the suspended solids.

coffey environments	Date: 10.12.2012 MXT: 7033CC_16_GIS045_v1_1 File Name: 7033_16_F13.02_GIS_VS	Arrow Energy Arrow LNG Plant	arrow energy go further	Summary of metal exceedences	Figure No: 13.2

Concentrations of copper exceeded project water quality criteria (1.3 µg/L) on 47 occasions over the sampling campaign. Concentrations varied from below the limit of detection (1 µg/L) to a maximum concentration of 8 µg/L at site 19 (Hamilton Point). Results indicate exceedences of copper tend to be higher during the spring tidal phase and to occur more frequently in the Port Curtis sampling sites, with 41 instances occurring in Port Curtis compared to six occurrences in the Calliope River. This is potentially due to higher rates of water flow and higher currents occurring during spring tides, which increase the overall resuspension of sediments relative to other phases of the tidal cycle. Metals are often bound in complexes within the suspended material in the water column.

Cobalt concentrations ranged from below the limit of detection (0.2 µg/L) up to 1.6 µg/L at site 18 (Hamilton Point). Cobalt samples were found to exceed project criteria (1 µg/L) on 25 occasions during spring tides at nine of the 15 sampling sites offshore from Curtis Island. These exceedences are likely to be caused by the same factors as exceedences of zinc (i.e., increased levels of suspended sediments during spring tides).

Project water quality criteria have not been established for aluminium, iron, arsenic or manganese as no relevant guideline values have been established for Australian waters. Concentrations of these metals were found to be above the limits of detection (10 µg/L for aluminium, 5 µg/L for iron, 0.5 µg/L for arsenic and 0.5 µg/L for manganese) for all samples. Angel et al. (2012) attributes the occurrence of these metals to natural sources within geological formations and states that previous studies in the area have reported similar concentrations. In addition to natural sources, several anthropogenic sources of metals within the area have been reported in the past. Pope (1994) and Vicente-Beckette et al. (2006) have indicated the presence of arsenic is associated with historic gold workings and cattle dips. Angel et al. (2010) also states that there is not one particular source responsible for elevated metals in Port Curtis.

Concentrations of aluminium were found to be highest in the Port Curtis sampling sites, with a maximum value of 2,190 µg/L at site 18 during spring tides. The lowest concentration was 64 µg/L at site 22 during neap tides. Recent studies have suggested the high and variable concentrations of aluminium in Port Curtis can be attributed to resuspension of contaminated sediments containing aluminosilicates and runoff from surrounding aluminium industries (Angel et al., 2012).

The results indicate that metal concentrations at the locations sampled as part of this study are elevated in comparison to the data presented in the EIS and the project water quality criteria. Results also indicate greater exceedences and higher concentrations of metals in Port Curtis. In particular, water sample results from sampling sites in the vicinity of Hamilton Point and Boatshed Point indicated higher concentrations of metals than water sample results from other Port Curtis sampling sites. Results from the Calliope River, overall, reported the lowest concentrations of metals. Other recent sampling programs conducted in the project area (Angel et al., 2012; EHP, 2012) show results with similar concentrations of metals in Port Curtis to those found by CQU.

13.4.2 Nutrients

Ammonia nitrogen and nitrogen oxides were found to be below the limits of detection (20 µg/L and 20 µg/L respectively) for all samples. Sample analysis procedures for ammonia nitrogen and nitrogen oxides required the water samples to be diluted to allow instrumentation to measure nutrient concentrations. This increased the detection limit by the dilution factor, resulting in detection limits being higher than project water quality criteria.

However, detection limits were similar to recent investigations conducted by EHP (2012), which concluded that concentrations of ammonia nitrogen and nitrogen oxides were well below project water quality criteria. Additionally, WBM (1999) states nutrients in Port Curtis are generally low.

Concentrations of filtered reactive phosphorus, total phosphorus and total nitrogen exceeded project water quality criteria at some sites. The locations of exceedences are illustrated in Figure 13.3.

Values for filtered reactive phosphorus were found to be twice the project criteria in the upper Calliope River sites (sites 7 to 10). This result may indicate upper catchment runoff as the likely source of filtered reactive phosphorus. Exceedences were found to be unrelated to the time of day, tide or depth, indicating a constant supply. Recent studies have reported similar results for filtered reactive phosphorus concentrations in the study area (EHP, 2012).

Values for total phosphorus showed concentrations of up to five times the project criteria (sites 17, 19, 22, 27 and 28). As opposed to filtered reactive phosphorus, all total phosphorus exceedences occurred in Port Curtis and none occurred in the Calliope River. The results were unrelated to the time of day, tide or depth and are similar to the results reported in the EIS.

Total nitrogen was found to exceed the project criteria by greater than 100 times at sampling site 1 for a single sample. This single large exceedence suggests that this sample may have been contaminated during sampling and that the result is likely to be spurious.

Project water quality criteria have not been defined for total organic carbon. Results for total organic carbon were found to range from below the limit of detection of 1,000 µg/L up to 10,000 µg/L at sampling site 1 (lower Calliope River). Apart from the one high concentration at site 1, concentrations of total organic carbon were higher in the upper reaches of Calliope River (between 1,000 µg/L and 1,500 µg/L at sites 7 to 10) than further downstream where concentrations were below the detection limit.

No observable site trends in water quality were evident between tides, water depth or spring or neap tidal phases, indicating a well-mixed system. Sites in the upper Calliope River recorded the highest concentrations for most nutrients and the greatest number of exceedences of the project water quality criteria.

Concentrations of nutrients within Port Curtis varied little between the lower Calliope River, tunnel launch site, and Hamilton Point and Boatshed Point sites. Results are consistent with recent studies in the project area (Radke et al., 2005; BMT WBM, 2011a) and vary little to results from studies presented in the EIS.

13.4.3 Physico-chemical Depth Profiles

The following section describes the physico-chemical depth profiles within the study area.

Temperature

Temperatures were relatively constant at each sampling site, varying less than 1°C for all tidal events and depths. This pattern is consistent with a turbulent and well-mixed environment.

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Summary of nutrient exceedences

Figure No: 13.3

Greater variation in temperatures was observed between sampling sites, with temperatures ranging from 19°C to 25°C. Sampling sites in the upper Calliope River were warmer compared to the lower Calliope River and Port Curtis sites. Recent studies suggest discharges from the Gladstone Power Station as a potential cause of temperature variation in the upper Calliope (DERM, 2011d). All temperatures recorded fall within the long-term ranges defined within the study area (DERM, 2011d).

Chlorophyll-a

The majority of chlorophyll-*a* samples exceeded the project water quality criteria range of 2 to 4 µg/L. Sites where exceedences occurred are illustrated in Figure 13.4. Concentrations of chlorophyll-*a* varied according to site and depth from 1.4 µg/L offshore from the mainland tunnel launch site (site 14) to 4.7 µg/L in the Calliope River (sites 8 and 9).

The greatest number of exceedences occurred at sites in the lower Calliope River and Port Curtis. Chlorophyll-*a* concentrations generally decreased slightly with depth, indicating a well-mixed water column. These results are consistent with previous studies undertaken in the area (BMT WBM, 2011a).

Previous studies indicate that concentrations of chlorophyll-*a* within Port Curtis are particularly variable, with the long term range between 1.0 and 37.4 µg/L (EHP, 2012). All concentrations measured during the water quality sampling program fall within this range.

Conductivity and Salinity

Salinity and conductivity were found to vary temporally (with the tidal cycle) and spatially between sampling sites. Conductivity ranged from 28.60 mS/cm at site 9 in the Calliope River to a maximum of 52.10 mS/cm near the mainland tunnel launch site (site 11). Salinity ranged from 15 parts per thousand (ppt) in the upper Calliope River sites to a maximum of just below 37 ppt at sites around Boatshed Point.

Data available from other studies indicate lower levels of salinity and conductivity in the upper Calliope River, and these are attributed to inflows of fresh water into the upper Calliope River tidal estuary (EHP, 2011).

Results from the water quality sampling program demonstrate greater variability in conductivity and salinity within the study area compared to the studies undertaken for the EIS (BMT WBM, 2011a). This difference may be due to sampling occurring across a greater portion of the tidal range during the most recent sampling program compared to previous sampling.

pH

pH was found to be outside the project water quality criteria range (8 to 8.4) at the majority of sites within Port Curtis where pH varied between sites from 7.45 at site 8 to a maximum 7.97 at site 27 (see Figure 13.4). pH was highest at the Boatshed Point and Hamilton Point sampling sites, with the majority of results being outside project water quality criteria ranges. Overall, sites in the Calliope River had the lowest pH values with no exceedences of project water quality criteria.

The greatest variation in pH between sampling areas occurred during spring tides and may be due to greater flushing occurring within Port Curtis during these tides.

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Overall, results show a greater variation in pH values across the study area when compared to studies conducted for the EIS. Recent studies undertaken by EHP (2012) show a long-term average of 7.1 to 8.7 in the Calliope River and of 7.7 to 8.2 in the greater Gladstone area (i.e., Port Curtis, Fitzroy River, Boat Creek, Calliope River, Auckland Creek, South Trees Inlet, Boyne River and Rodds Bay). All values recorded during the water quality sampling program fall within these long-term ranges.

Dissolved Oxygen

Dissolved oxygen was not recorded at sites 1 to 5 due to equipment failure during neap tides. Equipment was repaired, and dissolved oxygen was measured at all other sites.

Project water quality criteria for dissolved oxygen (90% to 100% in Port Curtis and 85% to 100% in the Calliope River) were exceeded at the majority of sampling sites (see Figure 13.4). Results indicate that the dissolved oxygen percentage was highly dependent on the site and tidal state, ranging from a minimum of between 85% and 90% (at site 10) to a maximum of between 105% and 110% (at sites 6, 7, 8 and 14).

The project water quality criteria were exceeded most often in the vicinity of the mainland tunnel launch site and at Boatshed Point. The least number of exceedences occurred in the Calliope River. These results are consistent with dissolved oxygen results reported in studies completed for the EIS.

Other recent studies show dissolved oxygen levels in Port Curtis and the Calliope River are highly variable. Most long-term records have values between 85% and 105% saturation in Port Curtis and between 55% and 132% in the Calliope River (EHP, 2012).

Turbidity

Turbidity exceeded project water quality criteria at the majority of sites within Port Curtis (see Figure 13.4). Turbidity was approximately eight times the project water quality criteria (of 8 NTU) offshore from Boatshed Point and Hamilton Point, with levels between 26 and 65 NTU recorded at these sites. Turbidity within the Calliope River was not as high as in Port Curtis. Most exceedences within the Calliope River occurred in the lower reaches of the river during neap tides.

Considerable variation in turbidity was observed between the neap and spring tidal phases, with the highest turbidity occurring during spring tides. Currents occurring during spring tides are higher than those occurring during neap tides and are more likely to resuspend seafloor sediment, resulting in higher levels of turbidity during this period (BMT WBM, 2011a). Changes in turbidity across the tidal phase were also recorded during studies conducted for the EIS.

Turbidity levels recorded during the water quality sampling program carried out by CQU are higher in Port Curtis than levels reported in the EIS, although they are within the range of turbidity measured by EHP (2012).

13.4.4 Dredge Plume Modelling

BMT WBM reviewed the dredge plume modelling performed for the EIS in light of changes to the project description.

Dredge volumes at launch site 1 and launch site 4N remain unchanged, and plume modelling results presented in the EIS remain valid for estimating the likely impacts of the dredging program at these sites.

Similarly, dredge plume modelling presented in the EIS for the LNG jetty and Boatshed Point MOF remain valid, provided allowance is made for the longer duration of the dredging program due to the increased volumes of material to be dredged. Dredging for the access channel to the Boatshed Point MOF and the associated swing basin will occur in the same area as dredging for the Boatshed Point MOF. The key change at this site is therefore the lengthening of the period of dredging due to the increased dredge volumes.

Modelling of the potential accumulation of fine sediments following construction focused on the proposed ferry maneuvering basin on the western side of Boatshed Point and near launch site 1 in the Calliope River. The model predicts fine sediment is likely to accumulate in the maneuvering basin at the Boatshed Point MOF at a rate of up to 0.14 m/month and near the roll-on, roll-off berth at a rate of up to 0.2 m/month.

Modelling of siltation near launch site 1 during operations shows that fine sediment is likely to accumulate largely outside the area of dredging and that the maximum siltation rate in a navigation area is up to 0.06 m/month.

13.4.5 Dilution Modelling: Hydrostatic Test Water Discharge

Hydrodynamic modelling for 14 discharge scenarios was conducted to predict the behaviour and fate of the hydrostatic test water. The model assumed that freshwater will be used for testing and therefore used salinity as the key water quality parameter. Characteristics of the receiving water during both spring and neap tidal conditions were estimated using water quality data in the vicinity of Boatshed Point from water quality sampling carried out in 2010 and 2012.

The model provided data on the distances from the outfall where the freshwater (buoyant) plume is diluted to within the range of ambient salinity conditions.

Each discharge scenario was assessed in terms of the distance required to:

- Return to within the range of ambient salinities observed during the March 2010 monitoring program.
- Return to within the range of ambient salinities observed during the August 2012 monitoring program.

The results of these two conditions are presented in Table 13.4 for each discharge scenario.

Table 13.4 Distance to return to ambient salinity

Tidal Condition	Scenario	Ambient Velocity Regime	Distance to Return to Ambient Salinities Observed During Monitoring Program (m)	
			March 2010	August 2012
Neap tide	1	Slack	2.1	5
	2	Ebb Low (10th percentile)	1.7	3.7
	3	Ebb Medium (50th percentile)	1.4	8.6
	4	Ebb High (90th percentile)	2.1	16.5
	5	Flood Low (10th percentile)	1.5	4.7
	6	Flood Medium (50th percentile)	1.4	10.2
	7	Flood High (90th percentile)	1.6	16.3
Spring tide	8	Slack	1.6	2.5
	9	Ebb Low (10th percentile)	1.3	2.1
	10	Ebb Medium (50th percentile)	1.0	2.5
	11	Ebb High (90th percentile)	1.3	3.5
	12	Flood Low (10th percentile)	1.2	1.8
	13	Flood Medium (50th percentile)	1.1	2.6
	14	Flood High (90th percentile)	1.3	3.5

The modelling results presented in Table 13.4 indicate that rapid dilution is achieved for all scenarios within a short distance of the outfall. Salinity returns to ambient levels within no more than 17 m in the most saline background conditions observed in August 2012 during neap tides (i.e., when currents are weakest and dilution potential is lowest) and no more than approximately 2 m in the less saline conditions observed in March 2010, again during neap tides. Salinity levels will return to ambient ranges offshore of Boatshed Point within 10 m of the discharge location for all but three scenarios (under the August 2012 baseline conditions).

13.4.6 Potential Impacts and Management Measures

This section describes impacts to water quality that have changed from those presented in the EIS. Impacts that are new or have changed are:

- Formation of suspended sediment plumes in the water column from dredging works due to differing volumes and locations of material to be dredged.
- Discharge of hydrostatic test water during the LNG tank testing process.
- Deposition of fine sediment at the Boatshed Point and launch site 1 facilities during operations.

Formation of Suspended Sediment Plumes from Dredging

The BMT WBM report (Appendix 8 of the EIS) presented plots of depth-averaged total suspended solids (TSS) concentrations exceeded for a certain percentage of the time during dredging. Lengthening the dredging campaign will increase the time TSS occur in the water column but not the area of impact or the maximum TSS concentrations within the impacted area expected for any tidal condition.

The additional time suspended solids will occur in the water column is in direct proportion to the increased dredging duration. Based on a modelled dredging rate of 500 m^3/h and 24-hour dredging, changes in the estimated effective dredging durations are:

- Boatshed Point MOF and integrated personnel jetty, Boatshed Point MOF access channel and swing basin: 26 effective dredging days (an increase of 12 days from the EIS).
- LNG jetty: 11 effective dredging days (an increase of one day from the EIS).

The longer dredging program will impact on water quality through an increase in the length of time that turbidity is elevated. The concentrations of TSS will not increase as the modelling carried out for the EIS showed that concentrations will build up over the first two weeks of dredging and then reach dynamic equilibrium. The depth of sediment accumulation will be proportionally larger. The significance of impacts from suspended sediment plumes on water quality therefore remains as assessed in the EIS and is minor. The significance of impacts from sediment deposition on the seafloor has been revised and, given the potential increase in sedimentation due to the increased dredging periods, is also minor.

Further characterisation of the material to be dredged (see Chapter 12, Sediment Characterisation) indicates that the dredge materials at Boatshed Point are predominantly silts and clays, which is consistent with the assumptions in the plume dispersion assessment presented in the EIS. The Calliope River site is predominantly sandy. The dredge plume modelling conducted for the EIS (which assumed a higher proportion of silts and clays at this site) are therefore conservative at this site as coarser material (sand) will settle to the seafloor more rapidly than finer material.

Discharge of Hydrostatic Test Water

The worst-case total volume of water required during hydrostatic testing of the feed gas pipeline and LNG tanks has been estimated at 360,000 m^3. The model assumed that fresh water is the preferred test medium and that the test water will be discharged to Port Curtis from the same location as the effluent discharge outfall at Boatshed Point. The model also assumed the maximum rate of discharge will be approximately 4,870 m^3/day over a continuous 74-day period. (The final volume, discharge rate and discharge location will be developed during detailed design.)

Modelling showed discharging fresh water to Port Curtis will reduce salinity within the receiving marine waters in the vicinity of the point of discharge. Discharged hydrostatic test water will rapidly mix with ambient sea water under all tidal conditions, and salinity will return to naturally occurring concentrations within 17 m of the point of discharge. The quantity of the discharge is very small relative to the total tidal exchange within the receiving waters, and the duration of the discharge will be limited.

Based on the modelled assumptions, the discharge will result in localised impacts around the point of discharge within a zone of mixing. The magnitude of this impact in the context of Port Curtis water quality outside of this zone will be negligible, resulting in a significance of impact of negligible.

If sea water is used for the hydrostatic testing, no impacts on salinity in Port Curtis are expected. The characteristics of the discharge test water, including whether fresh or sea water will be used and the nature of any required additives, are expected to be finalised during the detailed design stage of the LNG plant. As stated in the EIS, if biocides or oxygen scavengers are added, the water will be tested and treated to meet the relevant water quality criteria prior to discharge to Port Curtis.

Maintenance Dredging

During operations, fine sediment will deposit at the Boatshed Point and launch site 1, and dredging will be required to maintain shipping access to these facilities. Limited deposition is expected in the Calliope River in navigable areas. Based on the modelled deposition rates, more frequent dredging is likely to be required at Boatshed Point. The actual dredging frequency required to manage this material will be determined on an as-needed basis once capital dredging and construction are completed. The extent of maintenance dredging is not expected to be any greater than for capital dredging.

The impacts of maintenance dredging during operations are therefore expected to be less than those that will occur during construction. The impacts of maintenance dredging on water quality remain as assessed in the EIS and are low in magnitude and of minor significance.

13.5 Conclusion

Numerous water quality monitoring programs have been carried out in Port Curtis and the Calliope River, and they provide updated information on water quality. The supplementary assessment of water quality undertaken in the project area considered these studies and the results of sampling carried out by CQU in August and September 2012.

The results show that a number of water quality parameters lie outside the limits of the project water quality criteria, including total metals (copper and zinc), nutrients (filtered reactive phosphorus, total phosphorus and total nitrogen), physico-chemical parameters (chlorophyll-*a*, dissolved oxygen and pH) and turbidity.

Water quality results are broadly consistent with those presented in the EIS. Exceptions include:

- An overall increase in metal concentrations within the study area relative to results from sites sampled within the study area but at different locations than those sampled during August and September 2012.
- Greater variability in conductivity and salinity within the study area.
- Higher turbidity levels in Port Curtis.

All water quality results are consistent with results from other recent monitoring studies carried out in Port Curtis and fit within long-term ranges reported by EHP (2012).

Changes to the project description that could influence the assessment of water quality presented in the EIS include the increase in volume of the hydrostatic test water discharged to Port Curtis and the changes in dredging footprint and volume at the LNG jetty and Boatshed Point. Impacts to water quality due to increased dredge volumes will be spatially the same as those reported in the EIS but will occur over a longer period of time. Impacts associated with maintenance dredging are consistent with those presented in the EIS. Impacts to water quality from the hydrostatic test water discharge are not significant as water quality criteria will be met close to the point of discharge and will be of limited duration.

Overall, the changes to the project description have a negligible influence on the significance of the predicted impacts to marine water quality in the study area. The predicted impacts and the management measures presented in the EIS remain valid.

The application of the project marine water quality criteria used in the EIS and the current study does not imply that the criteria will apply through the life of the project. Arrow Energy intends to develop water quality criteria in consultation with the regulator that reflect existing water quality conditions in the receiving environment and to implement those criteria through the conditioning process associated with statutory approvals, such as the dredge management plan and specific environmental authorities (C16.14).

Consequently, no material changes to the existing marine water quality commitments presented in the EIS are proposed. One new commitment has been included: to develop project and site specific water quality criteria.

13.6 Commitments Update

Two measures to manage potential marine water quality impacts presented in the EIS have been revised and one new commitment has been added as set out in Table 13.5. All other measures are unchanged and are included in Attachment 7, Commitments Update.

Table 13.5 Commitments update: marine water quality

No.	Commitment	Comment
C16.01A	~~Design~~ If an RO plant is adopted, the design of the brine discharge outfall from the LNG plant will include a three-port diffuser at the end of the pipeline located close to the water surface (or the ports angled towards the surface) to maximise dilution of the negatively buoyant discharge stream.	Minor change to clarify optionality around water supply and waste water disposal.
C13.13A	Train all relevant personnel in spill response and recovery procedures. Common with Chapter 13, Surface Water Hydrology and Water Quality, Chapter 14, Groundwater and Chapter 31, Waste Management.	Typographical error rectified.
C16.14	Develop water quality criteria in consultation with the regulator that reflect existing water quality conditions in the receiving environment, and implement these criteria through the conditioning process associated with statutory approvals, such as the dredge management plan and specific environmental authorities.	New commitment