1 IMPACTS OF SWING BASIN AND CHANNEL CONSTRUCTION

This volume of the Queensland Curtis LNG Project EIS addresses the Terms of Reference requirements for impact assessment of project-related channel and swing basin construction. QGC's assessment relates specifically to its project, but occurs in an embayment and at a time when Gladstone Ports Corporation (GPC) and other project proponents are also conducting assessments of dredging-related impacts. The nature of QCLNG Project-related swing basin and channel construction and other dredging projects is described more completely in *Volume 2, Chapter 14*.

A broad overview of environmental values for the Port of Gladstone region is provided in *Volume 5*. Discussion of marine environmental values in this Volume is restricted to aspects considered specifically relevant to the proposed dredging and land reclamation activities.

This volume contains several references to studies that are currently incomplete, or not yet undertaken. Where these additional works are indicated, they include:

- Studies of a broader, cumulative impact nature, which may be reported in the GPC FL153 or WBSDD Project EISs, and which may be performed by GPC alone or in collaboration with QGC or other project proponents, and
- Studies specific to QCLNG Project dredging, which will be reported in the QGC Supplementary EIS, and will be complementary to those being undertaken by GPC.

1.1 PROJECT ENVIRONMENTAL OBJECTIVE

The project environmental objective for construction of swing basin and channel construction is: to undertake project-related dredging such that adverse impacts to people and the natural environment are minimized.

1.2 METHODOLOGY

The following key activities were undertaken to complete environmental impact assessment for swing basin and channel construction for the Project.

1.2.1 Existing Environmental Values

This section addresses the broader environment within which Project-related dredging may occur. Descriptions are based upon relevant information from existing studies, to a large extent described elsewhere in this EIS, as well as additional studies undertaken specifically by QGC to support this assessment.

Impact Assessment, Mitigation and Management Measures

Impact assessment methodology involved the following phases:

- Phase 1: Scoping
    - Compilation of existing data
    - New studies where appropriate (note: some of the studies are ongoing)
    - Hazard Identification
- Phase 2: Risk Assessment
- Phase 3: Risk Management and Feedback.

In a more general sense, impact analysis followed the process identified for Marine Ecology as described in *Volume 5, Chapter 8.*

1.3 EXISTING ENVIRONMENTAL VALUES

1.3.1 Physical Environmental Values

Summary descriptions of baseline physical environmental conditions are provided in the following sections. For more detail regarding the physical environment of the Port of Gladstone refer to *Volume 5, Chapters 8 and 11.*

1.3.1.1 Coastal Geomorphology

There is a considerable body of work building on the coastal geomorphology of Port Curtis. Data sources detailed below have been listed due to their specific relevance to dredging operations. Additional data sources used in the description of baseline environmental values and predictive tools, such as hydrodynamic modelling, are listed in *Volume 5, Chapter 8*.

- Contaminants in Port Curtis: screening level risk assessment. Technical Report No. 25: Co-operative Research Centre for Coastal Zone, Estuary & Waterway Management. May 2005
- Contaminant pathways in Port Curtis: Final report. Technical Report No.73: Co-operative Research Centre for Coastal Zone, Estuary & Waterway Management. May 2006
- Report on Soils Investigation, Proposed Dredging Works, Existing Shipping Channels, Gladstone. September 2005, Douglas Partners for Central Queensland Ports Authority
- Report on Geotechnical, Environmental and Acid Sulfate Soils Investigation, Proposed Berth 4 Outloading Conveyor and Dredging Clinton Coal Wharf, RG Tanna Coal Terminal, Gladstone. Q8 May 2005, Douglas Partners for Central Queensland Ports Authority
- Offshore Geotechnical Sampling Program Wiggins Island Coal Terminal. 10th June 2006, Revision 3: Connell Hatch for Central Queensland Ports Authority

The dominant underlying geology for the Curtis Island area is the Wandilla Formation of the Curtis Island Group consisting of mudstone, quartz greywacke and pale grey chert. Three distinct geological units are identifiable from the Port of Gladstone area outlined in the Gladstone Special 1:100,000 Geological Map, 2006. These are:

- Quaternary alluvial sediments deposited by the Calliope River,
- Quaternary coastal sediments associated with estuarine channels and banks, supratidal flats, mangroves and coastal grasslands, and
- Late Devonian/Early Carboniferous Curtis Island Group meta sediments forming the basement or bedrock.

1.3.1.2 *Bathymetry*

Port Curtis is a generally shallow coastal embayment but exhibits marked variation in seabed topography. Scouring in areas of highest tidal flows has created channels that are relatively deep – in many areas not requiring dredging. On the other hand, large areas of the bay dry at low tide, the result of long periods of deposition of sediments because of low currents.

The bathymetry in Port Curtis has been modified over the life of Gladstone through the development of shipping channels, land reclamation and coastline armouring. Maintenance dredging of the shipping channels occurs once every few years, with dredged material disposed onshore or deposited at an approved spoil ground located approximately 9 km south-east of Facing Island.

The water depth in the port at low tide ranges from -0 to -12.5 m LAT and from -15 to -18 m LAT at Hamilton Point (see *Volume 5, Chapter 8)* for more detail).

1.3.1.3 *Tides and Currents*

The Port of Gladstone is a macrotidal estuary which experiences large barotropic tides (up to 4 m in range), strong tidal currents and complex tidal interactions. Many of the estuaries have multiple entrances, so tidal circulation patterns are complex. Large tidal banks, mangrove stands and interlaying islands further confuse tidal flows depending on tidal elevations since these components act to store, release and divert tidal waters at different rates and times during the tidal cycle. The overall affect is to create a non-linear tidal behaviour for the broader estuary during large-range tides.

Results from hydrodynamic modelling of the Port of Gladstone region demonstrate that the currents in the estuary are predominantly driven by the effects of the tide[1]. These large tides can generate very strong currents, with velocities reaching up to 2 metres per second in the vicinity of North Channel,

1 Herzfeld M, Parslow J, Andrewartha J, Sakov P and Webster IT (2004) **Hydrodynamic Modelling of the Port Curtis Region – Project CM2.11** Co-operative Research Centre for Coastal Zone, Estuary and Waterway Management Technical Report 7, CSIRO Indooroopilly, Queensland (47pp).

resulting in seabed scouring and sediment transport[2]. The strong tidal flows cause complete vertical mixing so that – other than an increase of turbidity near the seabed – the concentration of dissolved or suspended materials typically shows little variation throughout the water column.

Currents are significantly weaker during the neap flood tide in comparison to the spring flood tide. Large elevation differences exist between locations within North Channel and seaward of Facing Island during times of peak flow (greater than 25 cm).

Hydrodynamic Modelling

Data sources of specific relevance to dredging operations include:

- Hydrodynamic Modelling of the Port Curtis Region CRC for Coastal Zone, Estuary and Waterway Management: Technical Report 7. M. Herzfeld, J. Parslow, J. Andrewartha, P. Sakov and I. T. Webster. CSIRO April 2004
- Hydrodynamic, Plume Dispersion, Sediment Transport and Waves. BMT WBM Pty Ltd. Wiggins Island Coal Terminal supplementary EIS. July 2007
- Gladstone Pacific Nickel Advection Dispersion Modelling: Final Report. BMT WBM for URS. November 2007.

In addition to the hydrodynamic modelling reports listed above, BMT WBM was commissioned by QCLNG to assess certain water quality and hydrodynamic aspects of the proposed dredging activities. BMT WBM has also received additional, related commissions from GPC. Key studies undertaken as part of this work include:

- Collation and review of existing baseline water quality data;
- The collection of additional locally specific baseline water quality data, conducted in 2008;
- Hydrodynamic and advection-dispersion numerical modelling to assess the potential impacts of the construction and operation of proposed channels and basins on receiving water quality;
- Expansion of three-dimensional hydrodynamic modelling in the vicinity of the proposed infrastructure;
- Preliminary hydrodynamic assessment of Fisherman's Landing reclamation options;
- Preliminary Advection-Dispersion Assessment of Reclamations;
- A report on initial dilution of materials released from various types of dredges[3], to inform reporting of the QCLNG sediment sampling and analysis plan as required under the National Assessment Guidelines for Dredging; and

2 Witt C and Morgan C (1999) Stuart oil shale project, Stage 2 EIS marine water quality and flow modelling (11774.R1.2) WBM Oceanics Australia Report

3 BMT WBM 16 July 2009, Initial Dilution Assessments, unpubl. 11 page report to QGC. Refer Attachment 1 to *Volume 6*.

- A brief assessment report on monitoring of the CSD Wombat, a small to medium sized Cutter Suction Dredge undertaking capital dredging near Fisherman's Landing.

1.3.1.4 *Water Quality*

Baseline water quality conditions in the Port of Gladstone (refer *Volume 5 Chapter 8*) are highly variable but generally compare well with the Queensland EPA 2006 Water Quality Guidelines[4]. Water quality is generally relatively poorer at the time of the low tide compared with the high tide, with the majority of nutrient and metal species at these times being associated with particulate (rather than dissolved) phases. Water quality appears to be relatively strongly correlated with tidal state, and hence sediment re-suspension might impact upon the daily scheduling of dredging operations.

Water temperatures in the region vary from 18°C in winter to 29°C in summer (Bureau of Meteorology, Australia 2009). In general, temperature and pH are relatively uniform with depth, and there is relatively little evidence of thermal stratification. Water column pH appears lowest in the Narrows region, and is most likely related to acid inputs from the adjacent mangrove regions[5].

Salinity approximates oceanic seawater values (35.5 ppt), although tends to be higher in the north of the port. This trend might reflect evaporation losses as the area is more sheltered (lesser flushing) than coastal waters[6].

A salinity and pH gradient is evident from low tide to high tide and north to south. Salinity and conductivity are highest and pH lowest at low tide in the northern reaches of the Port of Gladstone. Salinity and conductivity decrease and pH increases further south and as the tide rises.

1.3.1.5 *Turbidity*

In situ turbidity measurements in the port are typically 30 to 40 nephelometric turbidity units (NTU) during spring tides, and 1 to 5 NTU during neap tides. Turbidity appears to increase nearer to the seabed and with increasing tidal velocity, which is most likely due to bed shear stresses and subsequent sediment re-suspension. Total suspended matter (TSM) appears to be controlled by tidal stage and stream flow of major rivers flowing into the harbour, and low chlorophyll-*a* concentrations have also been noted throughout the port[7].

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4 BMT WBM Pty Ltd 2009 Proposed BG LNG Facility EIS Marine Water Quality Assessment. Unpublished.

5 Apte S C, Andersen L E, Andrewartha J R Angel B M, Shearer D, Simpson S L., Stauber J L & Vicente-Beckett, V (2006) Contaminant pathways in Port Curtis: final report. Co-operative Research Centre for Coastal Zone, Estuary and Waterway Management, Brisbane, Qld

6 Apte S C, Andersen L E, Andrewartha J R Angel B M, Shearer D, Simpson S L., Stauber J L & Vicente-Beckett, V (2006) Contaminant pathways in Port Curtis: final report. CRC for Coastal Zone, Estuary and Waterway Management, Brisbane, Qld

7 Dekker A G and Phinn S (2005) Port Curtis and Fitzroy River Estuary Remote Sensing Tasks. CRC for Coastal Zone, Estuary and Waterway Management. Technical Report No. 23

1.3.1.6 *Seabed Sediments*

On average the top 28 cm of intertidal and subtidal sediments in the Port of Gladstone are estimated to have been deposited since 1958, which roughly equates to the beginning of industrial development in Gladstone. The rate of sediment deposition appears to be at least 0.6 cm a year, with depositional zones demonstrated to be largely at the intertidal (mangrove) sites, particularly at the northern Narrows, lower Calliope River and Boyne River areas[8].

The nature of bottom sediments in the Port of Gladstone estuary are variable over small distances (<1.5 km). Median size classes ranged from silt and mud, through sand, to coarse sand and gravel. Median grain size increases significantly with seabed depth. Shallow areas of the bay tend to have finer surface sediments while deeper channels – where higher currents produce scouring – tend to have coarser sands and gravels. Consequently, spatial patterns in sediments broadly reflect patterns in the port bathymetry.

Port Curtis Contaminant Assessments

The Co-operative Research Centre for Coastal Zone, Estuary and Waterway Management (CRC) has conducted a number of surveys[9] of the Port of Gladstone during which marine sediments were sampled and analysed for contaminant concentrations. The results of this work have shown that the surface sediments in the Port of Gladstone are relatively clean with only a few contaminants of concern (primarily metals including arsenic, nickel and chromium) occurring at concentrations above national screening threshold levels. Refer *Figure 6.1.1, Figure* 6.1.2 and *Figure 6.1.3* below for the concentrations found in sampled sediments[10] .

In addition, they found that sediment metal contamination was highly correlated to the percentage of fines at the point of sampling. This finding is in line with other studies, which have also found a relationship between high metal contaminant concentrations and silts, and is in keeping with the higher surface area to volume ratios for these sediments.

Further research, using multiple lines of evidence, has shown that the concentrations of particulate arsenic, chromium and nickel in the benthic sediments of Port Curtis are elevated because of local geology and not from anthropogenic sources[11]. While polycyclic aromatic hydrocarbon (PAH) contaminants in sediments were highest around the industrial area of Gladstone, concentrations at all locations were below Australia and New Zealand Environment and Conservation Council (ANZECC) trigger values.

8 Vincente-Beckett Vicky and Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management (Australia) 2006 Metal and polycyclic aromatic hydrocarbon contaminants in benthic sediments of Port Curtis. Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management, Indooroopilly, Qld

9 Apte S, Duivenvoorden L, Johnson R, Jones M, Revill A, Simpson S, Stauber J, Vicente Beckett V (May 2005). Contaminants in Port Curtis: screening level risk Assessment. Co-operative Research Centre for Coastal Zone, Estuary & Waterway Management.

10 Ibid.

11 Vicente Beckett V and Co-operative Research Centre for Coastal Zone, Estuary and Waterway Management (Australia) 2006 Metal and polycyclic aromatic hydrocarbon contaminants in benthic sediments of Port Curtis. CRC for Coastal Zone, Estuary and Waterway Management, Indooroopilly, Qld

Figure 6.1.1 Arsenic Concentrations in Port Curtis Sediments (mg/kg)

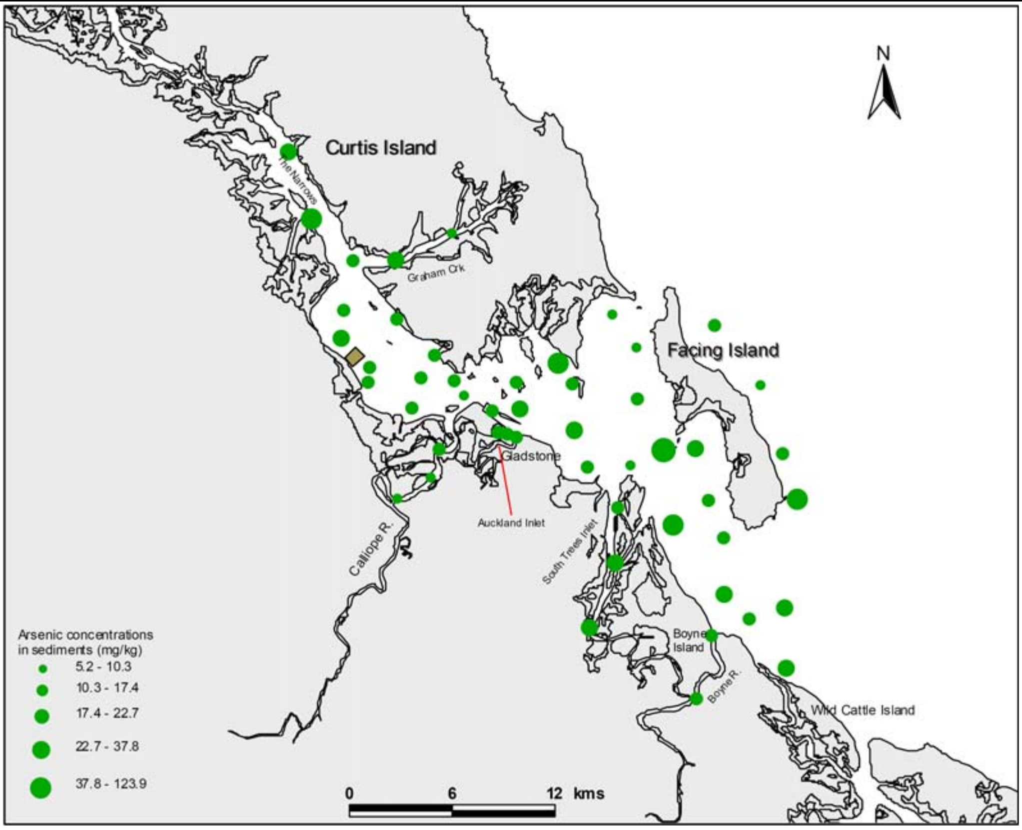


Figure 6.1.2 Nickel Concentrations in Port Curtis Sediments (mg/kg)

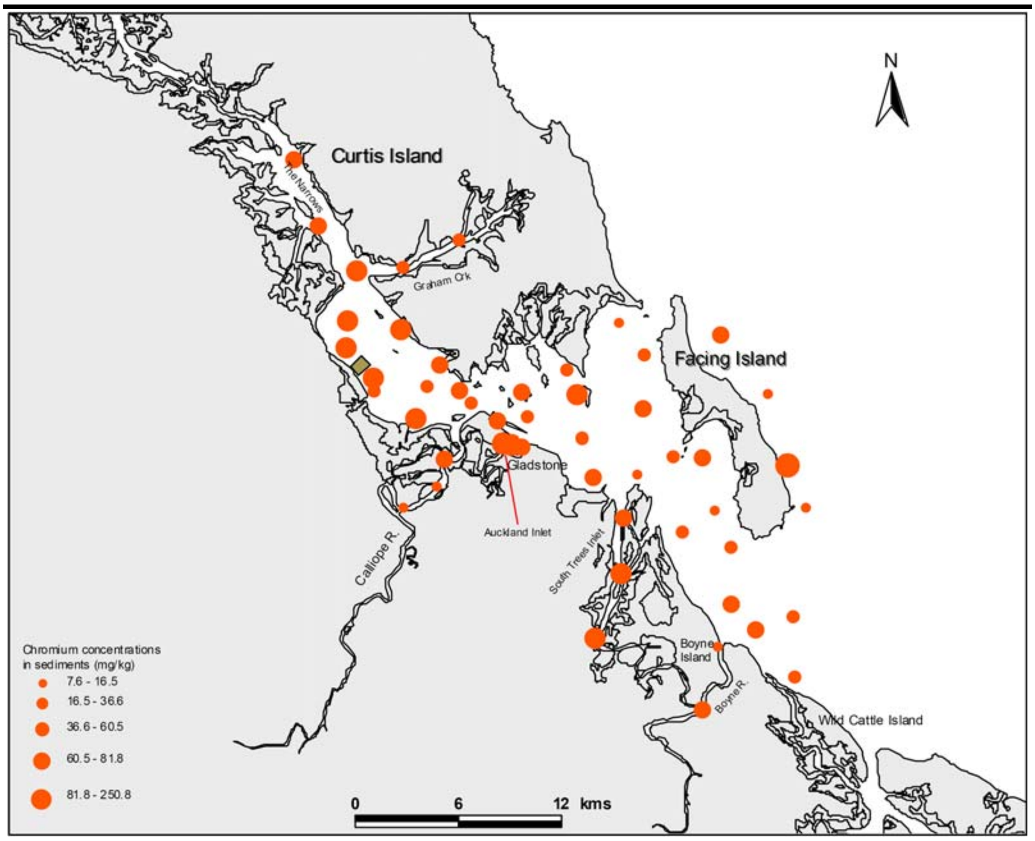
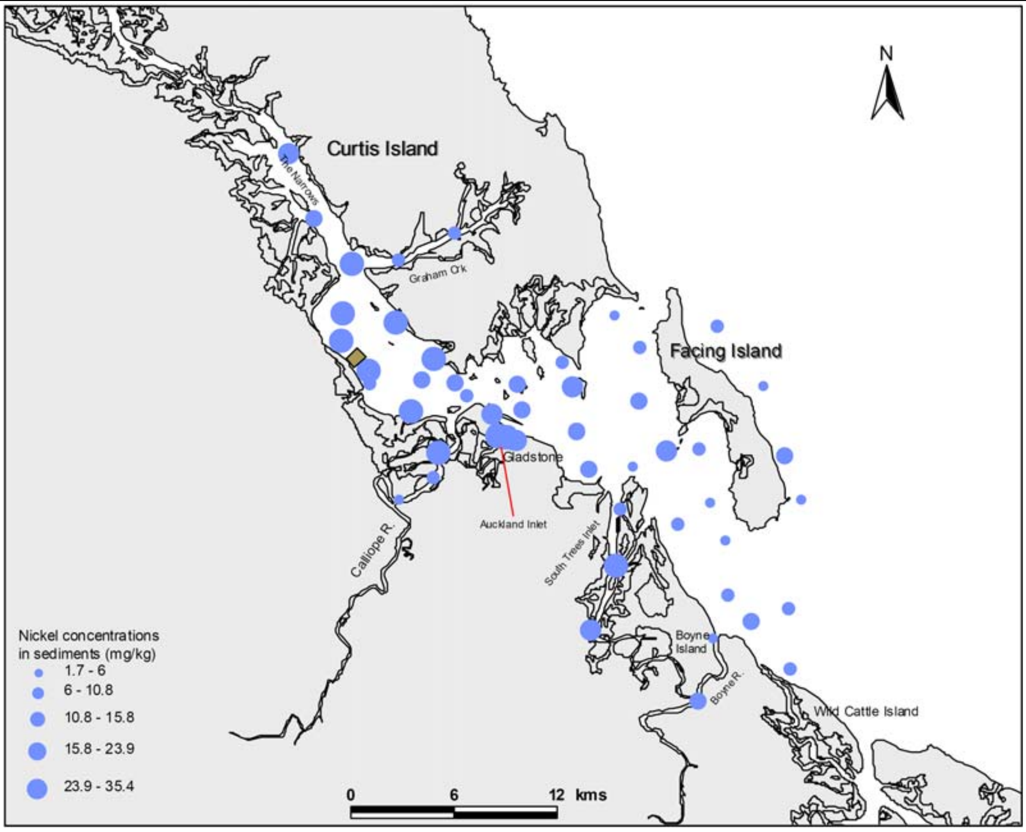


Figure 6.1.3 Chromium Concentrations in Port Curtis Sediments (mg/kg)



Dredging Assessments

Three offshore environmental sampling programs (refer Section *1.3.1.1*) have previously been conducted in preparation for capital dredging programs within the Port of Gladstone. The reports from these studies were reviewed to identify potential issues for the planned dredging program.

All three studies reported test results for metals, metalloids and organic pollutants below published threshold values and mostly below the reporting level of most analytical laboratories. Douglas Partners (two reports) presented results for polycyclic aromatic hydrocarbons (PAH), pesticides and polychlorinated biphenyls (PCB), at or below the respective laboratory Limits of Reporting (LOR).

These results, with the exception of dieldrin and endrin, were below screening levels for marine sediments as prescribed under National Ocean Disposal Guidelines for Dredged Material (NODG, 2002). Two samples, collected from Fisherman's Landing several kilometres north of Clinton Bypass, returned raw concentrations of tributyltin (TBT) above the LOR. These fell below screening levels after applying the standard method for normalisation to one per cent Total Organic Carbon.

All three reports found levels for acid sulfate soils (ASS) below threshold levels using the chromium test.

While some samples comprising silty clays were found to have arsenic levels marginally above screening level, these results were described as common, and therefore of little concern, by the authors, on the basis of similar results reported widely in other studies from eastern Australia.

It should be noted that while some contaminants appeared in Port Curtis in these studies, all were detected using concentrated acid extraction techniques, which determine gross concentration in whole sediments. However, in ecological terms, the important consideration is whether the contaminants are actually available to biota. Samples exhibiting exceedances based on concentrated acid extractions should be retested using a method for determining the bioavailability of contaminants, the potential for ecological harm.

The method commonly employed and recommended under the NOGD is Dilute Acid Extraction (DAE). This method mimics the release of contaminants from ingested particles/sediments as might occur with bottom- foraging species such as skates and rays. In most cases, the concentrations of bio-available contaminants are significantly less than gross concentrations. QGC's own Marine Sediments Study (described below) has incorporated DAE to address this matter.

1.3.1.7 Dredged Material Assessment - Sampling and Analysis Plan

QGC has undertaken its own Marine Sediments Study to inform its impact assessment process. A Sampling and Analysis Plan (SAP) has been developed for the assessment of dredged material associated with the QCLNG Project. QGC has extended this program to provide a wider geographic set of data throughout the Port of Gladstone. The aim of the SAP is:

> "*To describe the marine sediments within areas being investigated for capital dredging works and land reclamation, within Port Curtis, in order to be able to conduct a comprehensive and defensible environmental impact assessment of planned dredging and reclamation*."

Three key objectives were set to achieve this aim:

- to describe the physical characteristics of the sediments in terms of grain size, sediment structure, geological origin and geomorphology,
- to identify and describe the nature (type and concentration) and physical extent of chemical contaminants potentially present in the sediments, which might in turn cause environmental harm, and
- to identify the occurrence of potential acid sulphate soils (PASS) within dredged material that might be used for reclamation in areas surrounding the Western Basin.

The SAP has been designed to comply with the following guidelines and previous studies:

- National Assessment Guidelines for Dredging (NAGD), (DEWHA 2009);
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality; ANZECC/ARMCANZ (2000a, b)
- Assessment of Soil, Sediment and Water Guidelines (DEP 2003)
- National Guidelines on the Investigation Levels for Soil and Groundwater (NEPC 1999)
- Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils in Queensland (QASSIT 1998)
- previous dredged material characterisation programs conducted in Port Curtis.

Survey Rationale

The National Assessment Guidelines for Dredging (NAGD) prescribes the method for determining number of sample locations required for a dredging assessment in a port or locality. The NADG provides the following equation for calculating a suitable sample size for large dredging programs:

$y = 0.025\,x + 15.547$ where: y is the number of sampling stations and x is the volume of dredge material (x 1 000 m^3).

However, NADG also states that the following criteria should be considered when calculating x:

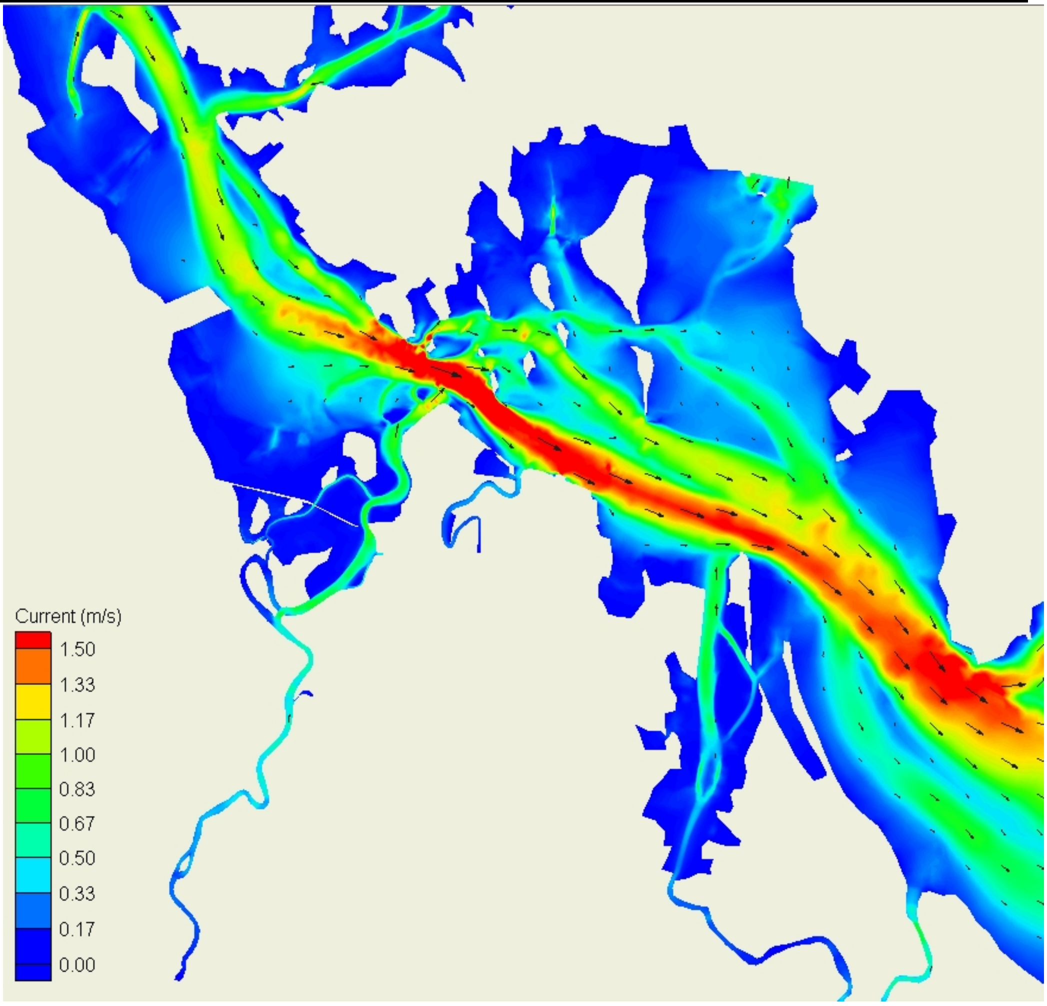
- The volume x refers to contaminated and potentially contaminated dredged material rather than the total dredge volume.
- The volume x is of recent sediments, which could be contaminated, but not the volume of underlying natural geological materials which can be assumed as uncontaminated.

The NAGD goes further to state that some areas may be exempt from testing requirements if the sediments at those locations are composed predominantly of gravel, sand or rock, or any other naturally occurring bottom material with particle sizes larger than silt, but only where this material is found in areas of high current or wave energy where the seabed consists of shifting gravel and sandbars.

Given that there were insufficient data to determine what proportion of the total volume of dredged material might be contaminated, the rationale used for determining the number of sample locations was based on a prioritised-risk-weighted approach, which took into consideration the following criteria:

- total volume of material to be dredged (refer to Volume 2, Chapter 14)
- scheduled timing for the planned dredging (refer to Volume 2, Chapter 14)
- known occurrence of contaminants of concern and their expected concentrations (refer to Section 1.3.1.6)
- peak tidal/current velocities and associated sediment structure (refer Figure 6.1.4).

Figure 6.1.4 Peak Current Velocities During a Typical Spring Tide Peak Ebb Flow, WBM 2008



Despite previous data indicating little anthropogenic contamination, areas of patchy contamination could not be ruled out. Not only does the visible geology of the area imply expected high variability in sediment structure, but there is a diverse range of potential point sources of contamination and a moderately long history of industrial use of Port Curtis.

Some areas within planned dredging footprints are naturally deeper than required. These were eliminated from additional sampling. Likewise, NAGD criteria allow areas with high current velocities and gravelly sediments to be excluded from sampling. This allowed sampling effort to be focussed on the areas most likely to contain contaminants.

An additional weighting factor was applied to reflect the likely staging of dredging works. NAGD guidelines restrict the utility of sediment data to a period of five years, after which new sediment data must be obtained. Stage 1a dredging projects therefore received full weighting while dredging projects for which commencement times are not yet defined received lower weightings. Further assessment of sediments in these latter areas may be required in the future.

The distribution of sites within proposed dredging areas was determined using a 50 m x 50 m grid system overlaid on the proposed dredging footprint. This distribution method follows NAGD recommendations, which suggest the use of an equidistant grid with sufficient total number of cells, or sampling locations, to enable a minimum of a one in four distribution of actual sampling sites to potential sampling locations. *Figure 6.1.5* shows the broader dredging and reclamation stages defined by GPC and used by QGC to prioritise the allocation of marine sediment sampling sites. *Figure 6.1.6* shows the sampling locations cored to assess QCLNG Project-related dredging works in QGC's Marine Sediments Study.

QGC also included within its Marine Sediments Study an examination of acid sulfate soils in the Fisherman's Landing area. This examination, to QASSIT guidelines, focussed primarily on the southern half of the Fisherman's Landing area, reflecting reclamation staging as identified by GPC. A lower intensity of sampling was conducted throughout the remainder of the Fisherman's Landing area (refer *Figure 6.1.6* and *Figure 6.1.7).* These data were provided to GPC under the agreed data sharing arrangement, and it is expected that they will be formally reported in GPC's draft EIS.

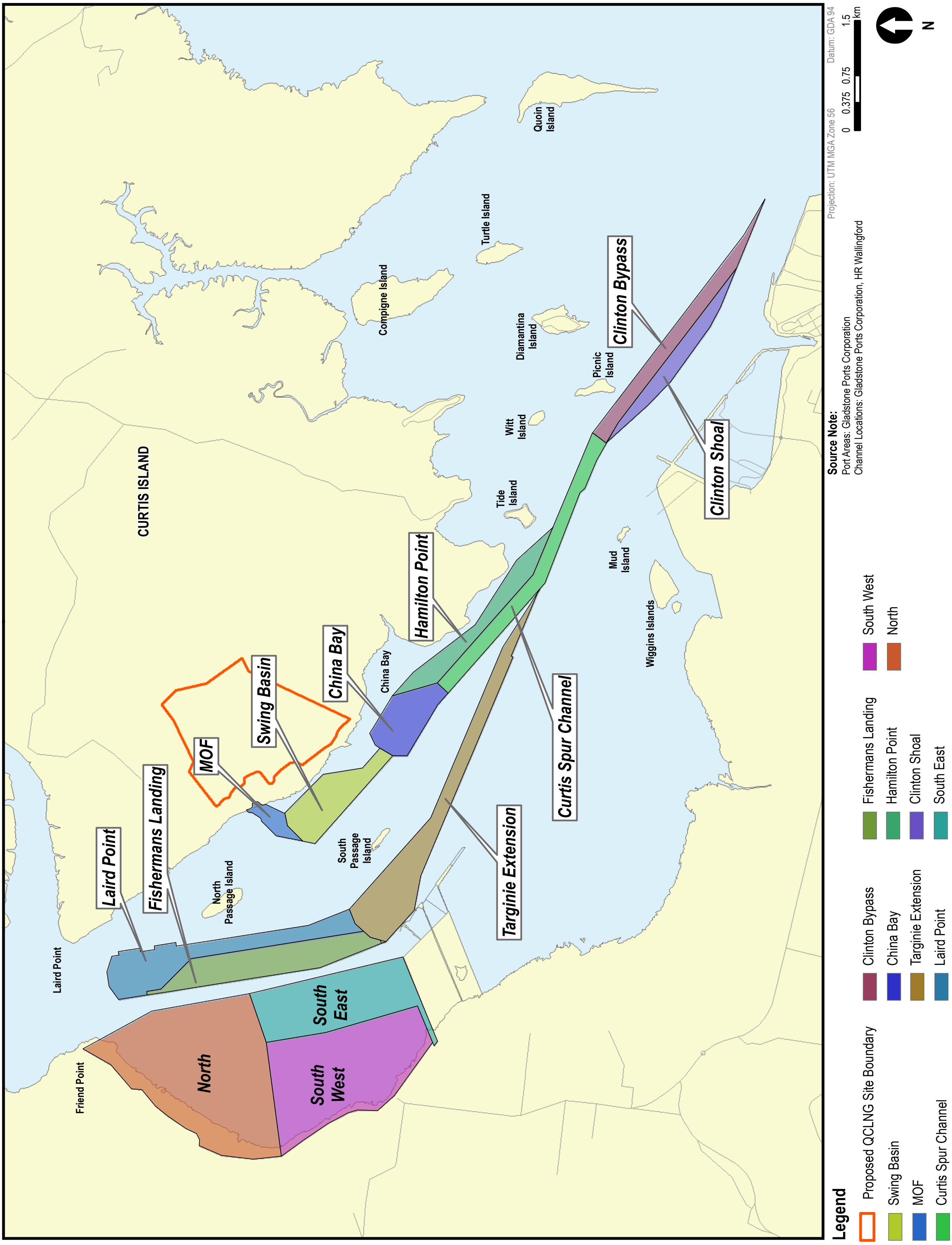
Table 6.1.1 Distribution of Sampling Sites within Identified Reclamation Areas

Reclamation Stage	Area (Ha)	Capacity (M m^{3})	Number of Cores
South-East	153	10	30
South-West	Up to 230	16	90
North	Up to 480	34	30
Total	**480**	**60**	**150**

The locations of acid sulfate sampling holes in the Fisherman's Landing area are shown in *Figure 6.1.7.*

Survey Methods

Recovery of sediment cores for contaminant and geochemical sampling in unconsolidated marine settings requires specialised equipment and techniques. SAP field surveys were undertaken with a spread of drilling or coring vessels and a combination of vibrocoring, push tubes, standard penetration test and rotary drilling methods as appropriate to the soil types encountered. Field teams were supported by land-based office, laboratory and cold-room facilities, housing specialists in soils and sample logging, geographic information services (GIS), data management and project management.



QUEENSLAND CURTIS LNG A BG Group business	Project	Queensland Curtis LNG Project	Title: **QGC Marine Sediment Study - General Locations for Investigations**
	Client	QGC - A BG Group business	
ERM Environmental Resources Management Australia Pty Ltd	Drawn: KP	Volume 6 — Figure 6.1.5	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
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	Date: 25.07.09	Revision 0	

The primary method for sample recovery was continuous vibro-suction coring. Geomorphologic logging and photography was done within controlled laboratory conditions. Field pH screening tests on sediment core samples were conducted onsite, and samples collected for laboratory analyses according to Queensland Acid Sulfate Soils Investigation Team (QASSIT) guidelines. Detailed field logs were converted to an equally detailed broadsheet format including graphic presentation to assist in the assimilation of information (refer *Figure 6.1.8*). Laboratory analyses were added to this graphic format to establish visual relationships between stratigraphic elements and acid sulfate soil chemistry

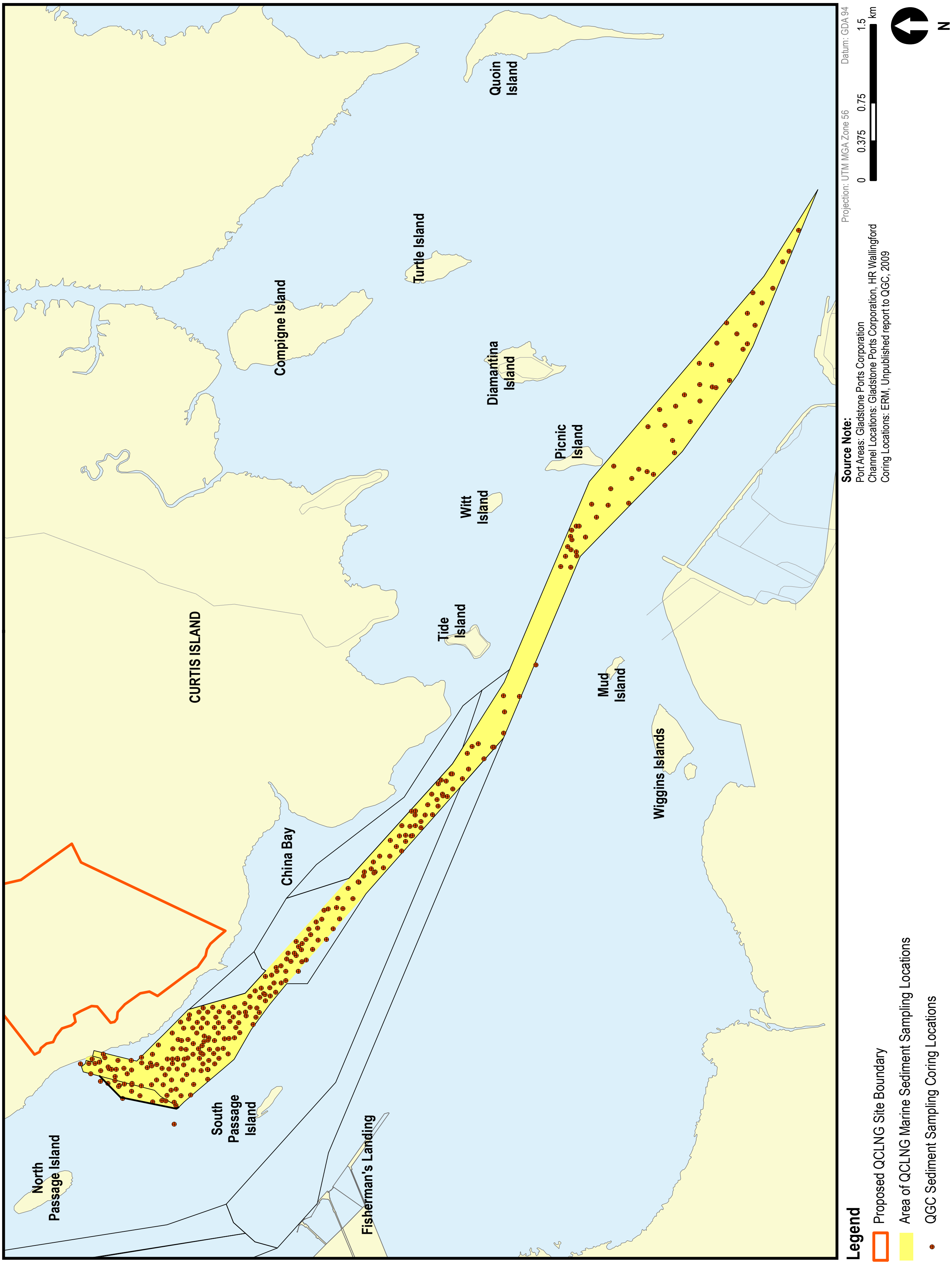
The information captured in the digital logs provides the foundation for the development of a 2D stratigraphic model. This modelling is based on a coastal facies modelling approach, which relies on the practitioner having a sound knowledge of the evolution of coastal depositional systems in response to major sea-level change (refer to *Figure 6.1.9).*

Sediment cores were sub-sampled in on-site laboratories for a range of contaminants, including whole sediment analyses (Phase II of NAGD 2009) plus elutriate and bioavailability analyses (Phase III). Samples were retained at 4°C in a cold room before transport to NATA-accredited external laboratories following full chain-of-custody procedures. The selected laboratories specialised in marine sediment analysis for dredging assessment, and had the capability to undertake ultratrace measurements to meet the Practical Quantitation Limits specified in NAGD.

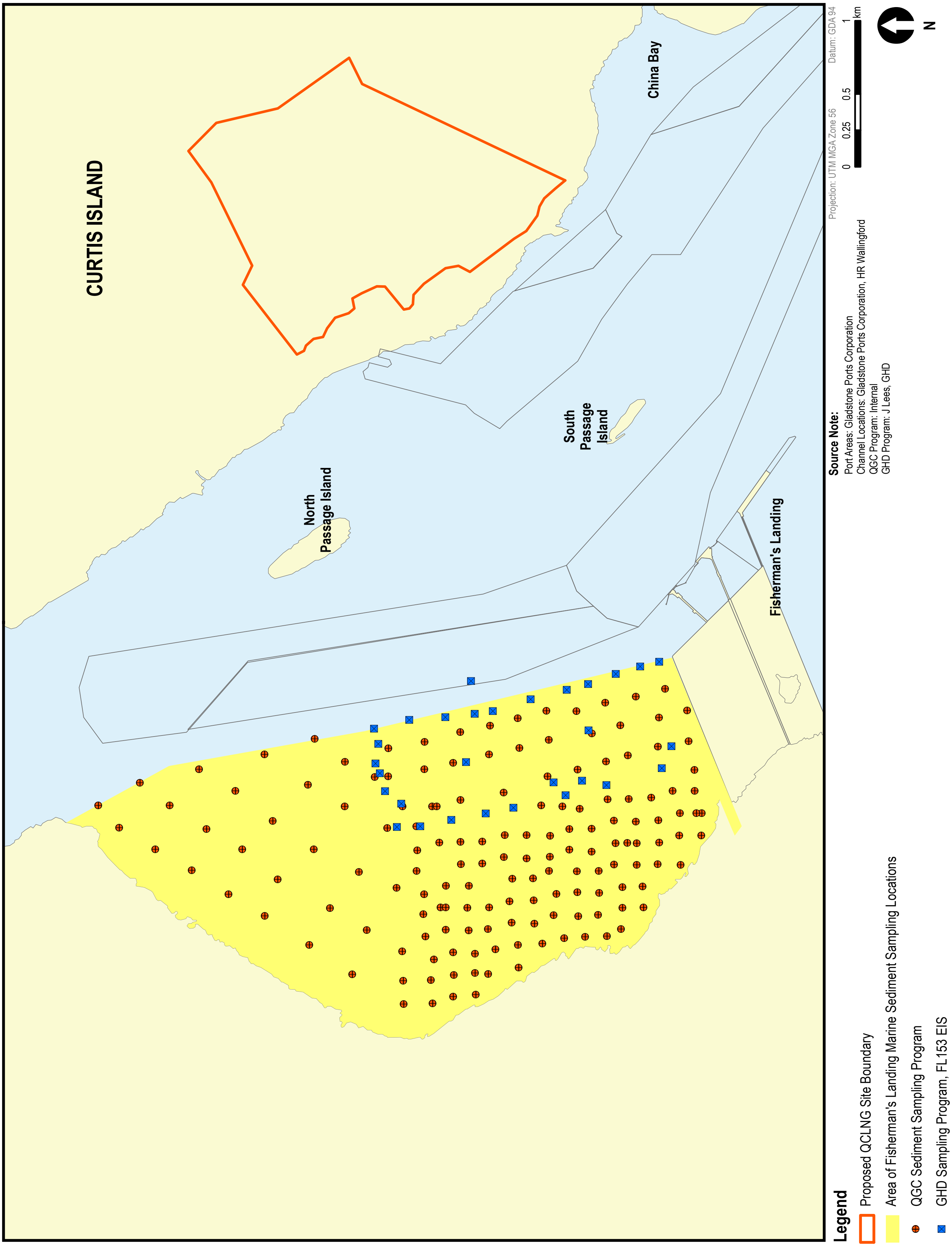
Results

At the time of writing, SAP drilling is nearing completion. Preliminary geomorphological modelling has revealed the following:

- *pre-Holocene substrate* – the old landscape that was exposed before the last (Holocene-age) marine flooding of the area around southern Curtis Island and The Narrows is shown to have substantial relief mimicking the modern variability between channels and intervening islands and banks. In areas, the island extends into the adjacent marine province, forming shelves which are shallowly mantled by Holocene marine sediments. The pre-Holocene sequence is a mature, complex suite of clay and sandy gravel deposits, which are considered to be composed of residual regolith overlying the interbedded Wandilla Formation of which Curtis Island is composed.
- *Holocene sequence* – again the Holocene-age marine sequence is highly variable as a result largely of interaction with the steep antecedent landscape which had the effect of dissecting the marine transgression early in the sequence's development, and directing currents in its later evolution. Representative sedimentary facies include: coarse basal gravels and pebbles associated with backstepping fluvial deposits in the face of the marine transgression, some deposits of estuarine central-basin suspension silt/clays in deeper basin areas, and a predominance of sandy silt/clay and muddy, shelly sand sediments forming the upper sequence.



QUEENSLAND CURTIS LNG A BG Group business	Project: **Queensland Curtis LNG Project** Client: **QGC - A BG Group business**		Title: **QGC Marine Sediment Study - Sampling Locations for QCLNG Project Dredging Assessment**
ERM Environmental Resources Management Australia Pty Ltd	Drawn: JB Approved: BK Date: 25.07.09	**Volume 6** **Figure 6.1.6** File No: 0086165b_EIS_DR_GIS002_F6.1.6 Revision 0	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.



QUEENSLAND CURTIS LNG A BG Group business	Project: Queensland Curtis LNG Project	Title: QGC Marine Sediment Study - Sampling Locations for Fisherman's Landing Acid Sulfate Assessment
	Client: QGC - A BG Group business	
ERM Environmental Resources Management Australia Pty Ltd	Drawn: JB; Volume 6; Figure 6.1.7	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
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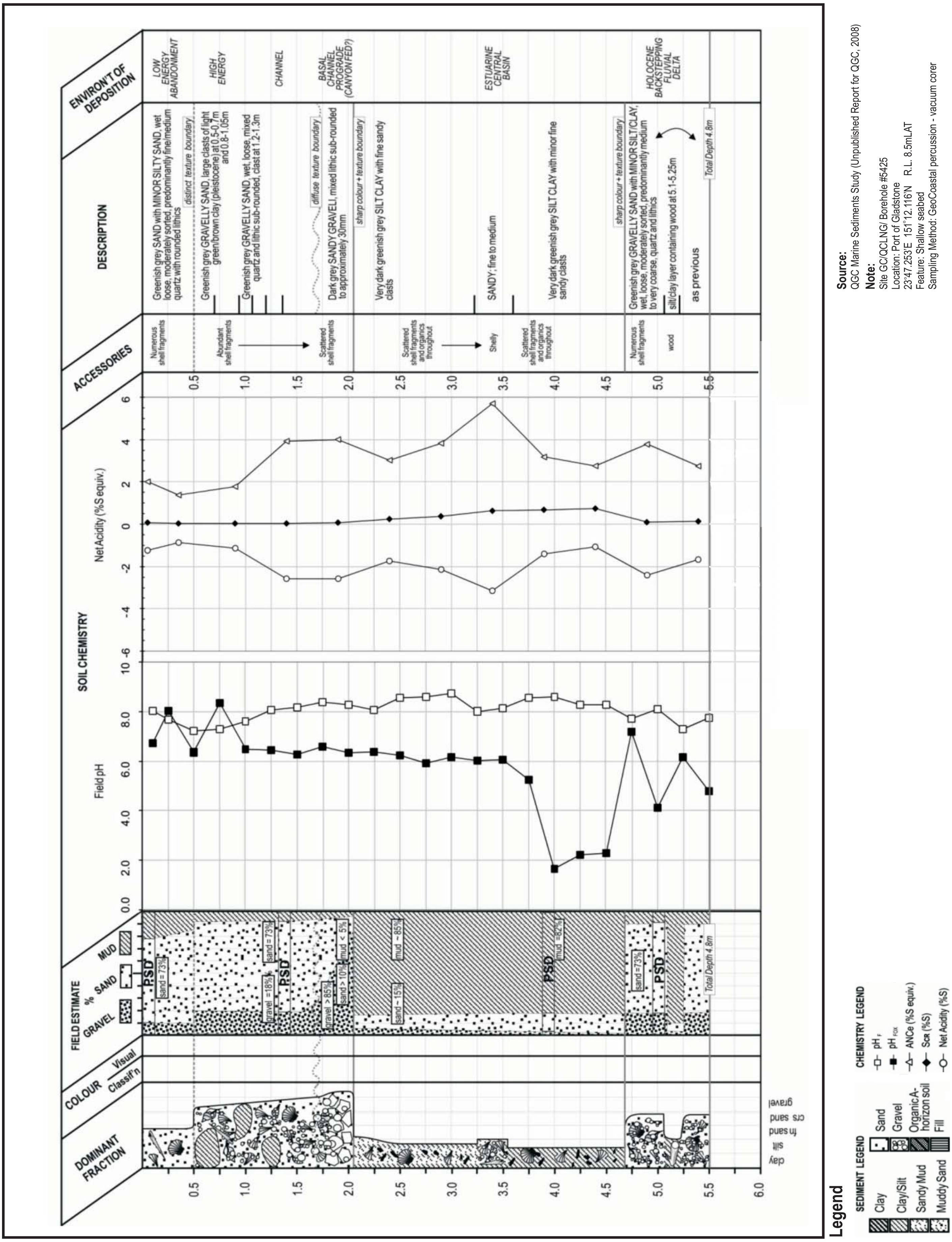
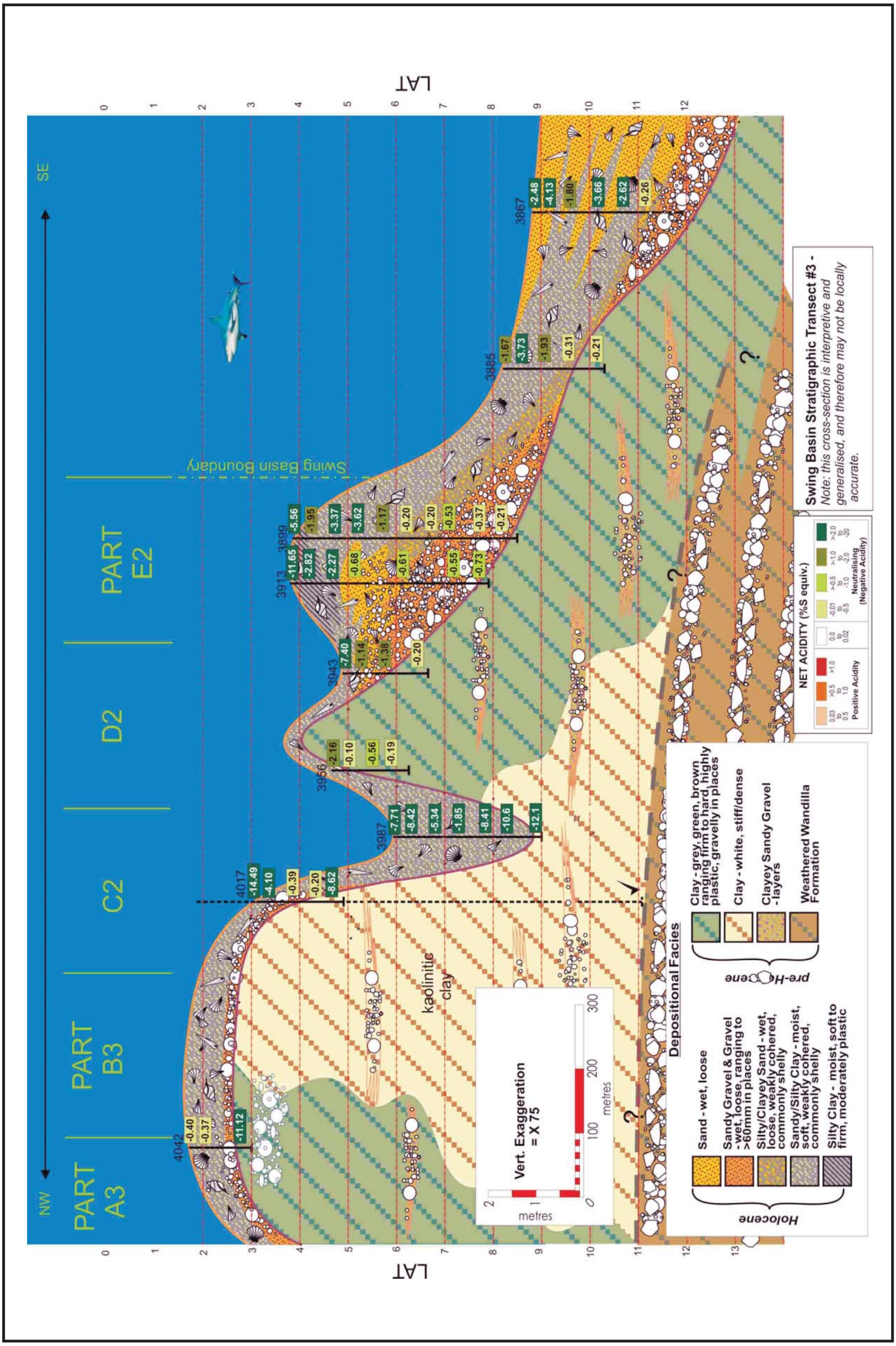


QUEENSLAND CURTIS LNG A BG Group business	Project: Queensland Curtis LNG Project	Title: **Example Digital Bore Log - QGC Marine Sediment Study**
	Client: QGC - A BG Group business	
ERM Environmental Resources Management Australia Pty Ltd	Drawn: JB / Volume 5 / Figure 6.1.8 Approved: RS / File No: 0086165b_EIS_DR_CDR0012_F6.1.8 Date: 31/07/09 / Revision 0	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.



Source:
QGC Marine Sediments Study (Unpublished Report for QGC, 2008)

QUEENSLAND CURTIS LNG – A BG Group business	Project: Queensland Curtis LNG Project
	Client: QGC - A BG Group business

Title: **Example 2D Stratigraphic Model - QGC Marine Sediments Study**

ERM – Environmental Resources Management Australia Pty Ltd	Drawn: JB	Volume 5 — Figure 6.1.9
	Approved: RS	File No: 0086165b_EIS_DR_CDR0011_F6.1.9
	Date: 31/07/09	Revision: 0

Preliminary analytical results using concentrated acid extractions reveal several metals with mild exceedances of NAGD 2009 screening levels in less than 5% of whole sediment samples (refer Section *1.3.1.6*). The upper 95 per cent confidence limits of these metals all fall well beneath the respective screening levels. Dilute acid extraction and analyses of samples where exceedances were recorded also produced values well below the screening levels.

Several samples submitted for nutrient (ammonia) pore-water and elutriate tests returned levels mildly above the ANZECC/ARMCANZ 2000 marine water quality trigger values (refer Section *1.3.1.6*). When subject to the application of Initial Dilution factors (below) in accordance with NAGD methods, these exceedances were, on average, below guideline levels. However, the Initial Dilution factors vary according to the dredging locality, method and tidal state, and each of these exceedances could, under some circumstances, remain over the guideline threshold. *Section 1.4.4.5* discusses appropriate mitigation which shows that these areas can be dredged without exceeding guideline levels.

Initial Dilution factors calculated as per NAGD recommendations[12] are 10:1 for a backhoe working in the materials offloading facility (MOF) area, 20:1 for a trailer suction hopper dredge (TSHD) discharging material in the vicinity of Fisherman's Landing, or 32:1 for a Cutter suction dredge (CSD) operating in the Curtis Spur Channel (BMT WBM, 2009). When the appropriate dilution factor is applied, elutriate concentrations for these contaminants fall well below threshold levels.

Marine sediments have, on average, an excess of acid sulfate neutralising capacity, although results in a few coastal near shore areas exceed Potential ASS thresholds. Blending during the normal dredging process, or blending assisted by selective soil removal strategies is expected to adequately manage acid sulfates for dredged materials to be placed in marine reclaim areas. The only time specialised ASS management strategies are likely to be required is for the initial (-2.8 m LAT) cut for MOF dredging (refer *Volume 2 Chapter 14 Figure 2.14.5*), an area where neutralising capacity appears to be low.

Implications for Impact Assessment

Project-related dredging will encompass a wide range of sediment types, with widely varying physical properties. High spatial variability exists among these sediment types, both laterally and with depth. Contaminant analyses conducted by the time of writing are consistent with the studies cited above which have found Port Curtis to be relatively unaffected by anthropogenic impacts.

The initial assumption that sediments may be treated as clean for the purposes of SAP planning has therefore been supported by findings to date which indicate that there is unlikely to be contaminant-related impacts from dredging of immediate port infrastructure.

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12 BMT WBM 16 July 2009, Initial Dilution Assessments, unpubl. 11 page report to QGC. Refer Attachment 1 to *Volume 6*.

This leaves the primary focus of impact assessment on the physical impacts of sediments (seabed disturbance, sedimentation, suspended sediments and light attraction), with impact prediction and mitigation made more difficult by the wide diversity of sediment types and the small-scale spatial variations in these.

1.3.2 Biological Environment

1.3.2.1 Mangroves

Fourteen species of mangroves are reported from the Port of Gladstone region, and three species (*Acanthus ilicifolius*, *Bruguiera exaristata* and *Xylocarpus moluccensis*) occur at the southern limit of their distribution. Mangroves are dominant in the mid to upper intertidal zones; fringing much of the mainland and Curtis Island coasts. Extensive mangrove habitat extends along the Curtis Island coastline from Graham Creek to Hamilton Point[13]. Mangrove assemblages in the Port of Gladstone are monitored by the Port Curtis Integrated Monitoring Program (PCIMP) and are considered to be in a healthy condition at most locations.

Amongst the studies that QGC has commissioned is one using a multispectral airborne scanner to facilitate automatic classification of mangrove community types. This method, summarised in *Section 1.4.2.5*, is not intended to replace the conventional methods already used for long term mangrove mapping by PCIMP. Instead, it is part of a program of method development that will continue to be refined until dredging commences, and will then be used to facilitate rapid reappraisals of mangrove communities as part of the relevant dredging EMP.

1.3.2.2 Benthic Primary Producers

Six seagrass species have been identified in the Port of Gladstone: *Halodule uninervis, Halophila ovalis, Halophila decipiens, Halophila minor, Halophila spinulosa,* and *Zostera capricorni*.

The Port of Gladstone – Rodd's Bay seagrass communities are of regional significance due to the next nearest extensive meadows being found at Hervey Bay, 220 km to the south and Shoalwater Bay, 220 km to the north. A total of 7 246 ha of intertidal seagrass beds have been identified within the Port of Gladstone – Rodd's Bay Dugong Protection Area (DPA), with an additional 6 332 ha in deepwater areas (>5 m Mean Sea Level) identified to the east and south of Facing Island[14].

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13 Danaher K, Rasheed M A and Thomas R (2005) **The Intertidal Wetlands of Port Curtis.** Department of Primary Industries and Fisheries Information Series QI05031

14 Rasheed M A, Thomas R, Roelofs A J, Neil K M and Kerville S P (2003) Port Curtis and Rodd's Bay Seagrass and Benthic Macro-Invertebrate Community Baseline Survey, November/December 2002. DPI Information Series Q103058

Within the Port, the majority of seagrass communities are in the Pelican Banks/Quoin Island area between Facing and Curtis islands. Significant banks also exist between The Narrows and the Calliope River mouth and southwards along the coast to the southern port limits. Seagrass distributions from 2002 are shown in *Volume 5, Chapter 8, Figures 5.8.5* and *5.8.10* (in relation to the Dugong Protected Area). Results of 2007 surveys (confined only to those seagrass beds resurveyed in the long term monitoring program) are shown in *Figure 6.1.10*.

Many of these communities are close to a number of industrial activities within the port, including shipping channels, the RG Tanna Coal Terminal, Queensland Alumina Limited and Fisherman's Landing. No deepwater seagrass communities are known to occur within the inner port area.

To date, seagrass studies have not focused on the intertidal/subtidal areas to the west of Curtis Island, and therefore there is limited information relating to seagrass density, richness and species composition in this part of the harbour. However, there is significant information for the areas to the north and south of Fisherman's Landing. During a recent monitoring program (2002-07) shifts in the community structure and composition were not uncommon, with meadows varying significantly, among year and location, in terms of percentage cover, biomass and species composition[15]. For more detail regarding seagrass meadows in the Port of Gladstone, refer to *Volume 5 Chapter 8.*

The healthy *Zostera capricorni* communities identified in the 2007 monitoring (*Figure 6.1.10* shows only those seagrass beds actually monitored in the annual program) are likely to provide an important refuge for fish and crustacean species, and are recognised as key nursery areas for many commercial species. The seagrass meadows around Wiggins Island, in particular, appear to be heavily utilised by dugong on the basis of observed feeding trails at a majority of monitored sites.

Macroalgae are only a minor component of the benthic communities in the Port of Gladstone region. Macroalgal cover is generally low, and there is no distinctive macroalgal community within the port regions. While significant areas of macroalgae are absent, coastal seagrass meadows have been observed to support a relatively high percentage cover of filamentous green algae[16].

QGC has initiated a multispectral scanning project for quantifying marine primary production. This is assessed as a possible tool for assisting in responding management of impacts to seagrass and macroalgal communities. Further details of this evaluation are included in *Section 1.4.2.5* below.

15 Alquezar R, Small K, Hendry R (2007) Port Curtis Biomonitoring programme: macroinvertebrate, mangrove and seagrass surveys November 2006. A report to Queensland Energy Resource Limited. Centre for Environmental Management, Central Queensland University, Gladstone, QLD

16 Rasheed M A, Thomas R, Roelofs, A J, Neil K M and Kerville S P (2003) Port Curtis and Rodd's Bay Seagrass and Benthic Macro-Invertebrate Community Baseline Survey, November/December 2002. DPI Information Series Q103058

Microalgae live within the sediment, and form part of the local and regional fish production cycle. In the Port of Gladstone area, microalgae occur in lagoons, estuaries, sandbanks, mudbanks, saltmarshes and soft seabeds.

1.3.2.3 *Invertebrates (including corals)*

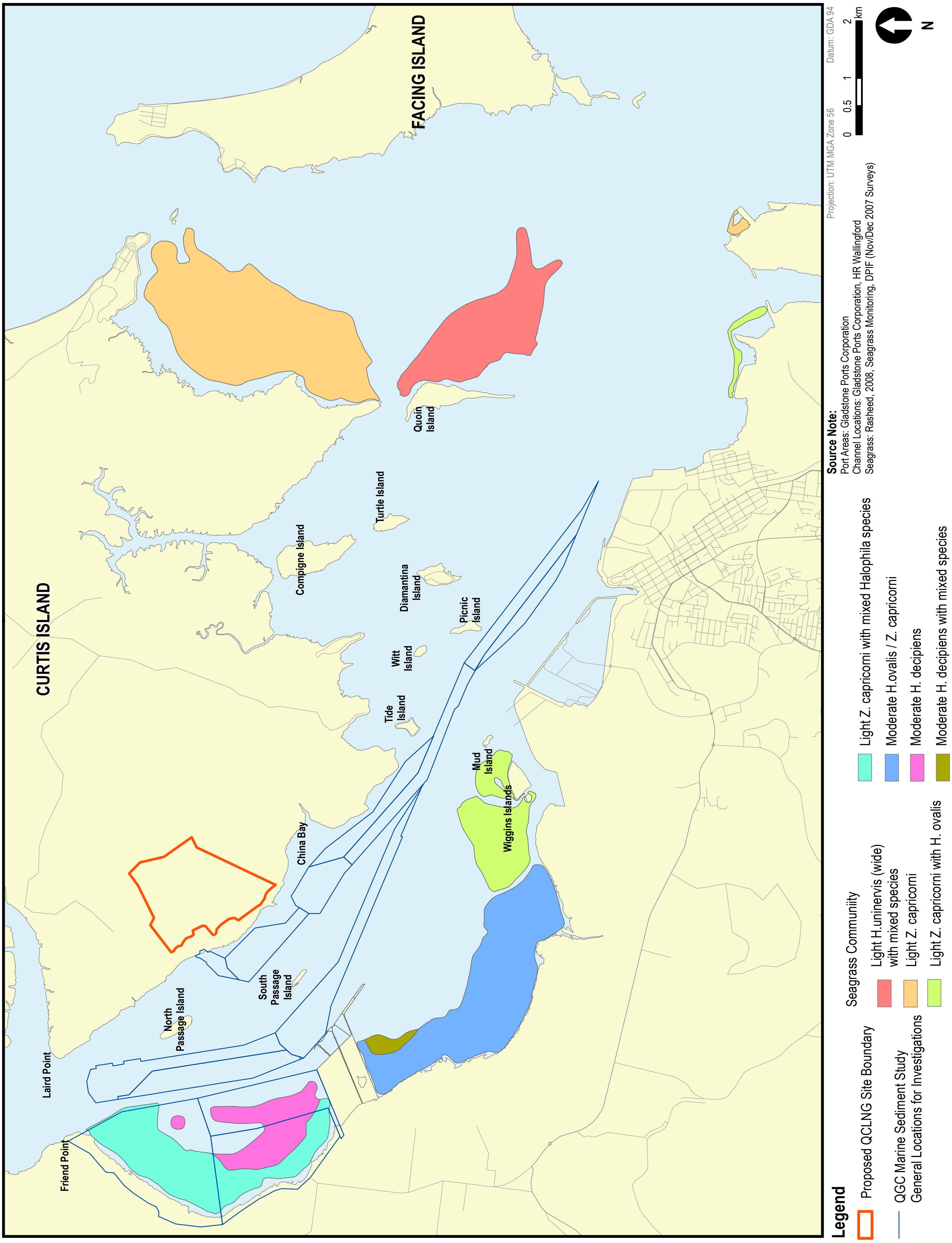
Whilst a large number of small reef structures are gazetted within Port Curtis, the most significant coral reefs in the region are those of the Capricorn and Bunker groups, 50 km to 110 km east of Gladstone. Two regions (98 ha and 158 ha) of low coral reef bommies and associated mixed coral reef community, interspersed with bare substrate, have been identified on the seaward side of Facing Island.

There is approximately 1 500 ha of deep water (greater than 5 m of water) in the Western Basin (west of Barney Point). High-density benthic communities occupy approximately 50% of this area (738 ha), extending along Targinie Channel from Fisherman's Landing, through the Clinton Bypass and south to approximately South Trees Island. Similar communities exist outside of the Western Basin in a narrow strip running inside Facing Island and East Bank (refer to *Volume 5, Chapter 8, Figure 5.8.8*). These high-density communities generally consisted of rubble reef dominated either by sponges, soft coral, hard coral, hydroids, bryozoans and gorgonians with a mix of other benthic taxa [17].

Medium-density benthic communities in the deep channel area from the mouth of The Narrows at Graham Creek to Fisherman's Landing consisted of rubble reef dominated by bivalves, ascidians, bryozoans and hard corals with low numbers of other taxa. These occupied approximately 30% (440 ha) of the deep waters in the Western Basin.

The remaining 20% (308 ha) of Western Basin deep water communities is an open/low density region dominated by open substrate with a low density of varied species.

17 Rasheed MA, R Thomas, AJ Roeleofs KM Neil and SP Kerville (2003). Port Curtis and Rodds Bay seagrass and benthic macroinvertebrate community baseline survey, November/December 2002. QDPI Information Series QI03058 (DPI, Cairns)



QUEENSLAND CURTIS LNG A BG Group business	Project	Queensland Curtis LNG Project	Title: **Key Seagrass Monitoring Sites in the Port of Gladstone, North of South Trees Point (DPI 2007)**
	Client	QGC - A BG Group business	
ERM Environmental Resources Management Australia Pty Ltd	Drawn: KP	Volume 6 — Figure 6.1.10	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved: BK	File No: 0086165b_EIS_DR_GIS005_F6.1.10	
	Date: 25.07.09	Revision 0	

Developed hard coral assemblages are supported on a number of sites within Port Curtis, the most significant of which are the rocky reef substrate sites between Facing and Curtis islands[18,19] and north of Targinie Creek in rocky parts of the Narrows Channel[20]. Soft corals, anemones, fan worms, sponges and tunicates[21] occur on the south side of Picnic Island. A few small, isolated hard corals occur (mostly *Favidae* and *Goniopora*) within the Port of Gladstone, but these do not combine or provide adequate structure (height and extent) to form significant reef habitat for reef-associated species[22].

The strong tidal regime in the Port of Gladstone gives rise to naturally high turbidity levels and, as such, the species found within this location are well adapted to high sediment loads and scour within/from the water column. Infaunal communities inhabiting the soft sediments of the Port of Gladstone are well studied, both spatially and temporally. Filter-feeding organisms dominate infaunal communities and account for more than half of the total abundance and nearly 30 per cent of total species richness[23].

Deposit-feeding organisms were also common (>25 per cent of total abundance and nearly 35 per cent of total species diversity). Polychaete worms, molluscs and crustaceans together accounted for more than 86 per cent of the individuals and 83 per cent of the species collected. Other less common taxa identified included echinoderms; cnidarians; sea spiders; and ribbon, round, peanut and flatworms. The bivalve mollusc *Carditella torresi* was the most abundant species, accounting for more than 14 per cent of the total infaunal abundance, principally within subtidal sites. Few other species could be considered numerically dominant.

1.3.2.4 Fish

The fish assemblage of the Port of Gladstone is considered to be diverse with 180 species recorded from the Port of Gladstone and Calliope River, including a number of regulated species and species of commercial and recreational value.

A survey of demersal fish species of the estuarine and marine environments of the Port of Gladstone identified 88 species, but two small schooling species dominate. The numerically dominant species identified in the port were ponyfish (*Leiognathus equulus*) and herring (*Herklotsichthys castelnaui*),

18 URS (2007) **Gladstone Nickel Project Environmental Impact Statement.** Public EIS report prepared on behalf of Gladstone Pacific Nickel by URS Australia Pty Ltd, Brisbane, Qld

19 Dames and Moore (1998) **Comalco Alumina Project Gladstone: Impact Assessment Study – Environmental Impact Statement**. Public EIS report produced by Dames and Brisbane (now URS Australia Pty Ltd), Brisbane, Qld

20 URS (2007) **Gladstone Nickel Project Environmental Impact Statement**. Public EIS report prepared on behalf of Gladstone Pacific Nickel by URS Australia Pty Ltd, Brisbane, Qld

21 URS (2007) **Gladstone Nickel Project Environmental Impact Statement**. Public EIS report prepared on behalf of Gladstone Pacific Nickel by URS Australia Pty Ltd, Brisbane, Qld

22 URS (2007) **Gladstone Nickel Project Environmental Impact Statement**. Public EIS report prepared on behalf of Gladstone Pacific Nickel by URS Australia Pty Ltd, Brisbane, Qld

23 Currie D R and Small K J (2005) Macrobenthic community responses to long-term environmental change in an east Australian subtropical estuary. Estuarine, Coastal and Shelf Science, 63: 315-331

which in combination comprised about half the total catch by trawl netting fisheries.

A study of recreational angler catches[24] found that the most common species caught in the port was whiting (largely *Sillago ciliato*).

1.3.2.5 *Marine Reptiles*

As detailed in *Volume 5 Chapter 8* six species of marine turtle potentially occur in or around the Port of Gladstone. Three species – green (*Chelonia mydas*), loggerhead (*Caretta caretta*) and flatback (*Natator depressus*) – are known to breed in the area. Although rare, the estuarine crocodile (*Crocodylus porosus*) also potentially occurs within the area.

Important turtle nesting beaches for flatback turtles *(Natator depressus)* have been identified on the east coast of Curtis Island and Facing Island and further south at Tannum Sands (approximately 15 km south of Gladstone)[25,26]. The majority of turtle nesting on Curtis Island occurs on South End Beach[27]. There are no known turtle nesting beaches within close proximity (5 km) to the proposed Western Basin channel or swing basin areas.

Green turtles have been regularly observed within the seagrass meadows particularly on Pelican Banks (eastern side of Curtis Island)[28]. The Curtis Island flatback turtle nesting population has maintained an approximately constant size over the 35 years since monitoring began[29].

Sea snakes are highly mobile and can cover large distances. Sea snakes occur in a wide variety of habitats, with some species found mostly on coral reefs, whereas others are found over sandy and muddy areas of seabed. Many species are specialist feeders that are restricted to the specific habitats used by their prey. The distribution of sea snake species is highly variable and thought to be influenced by seasonal factors[30]. Little is known of the distribution of individual species, and sea snake ecology, population sizes and dynamics are poorly understood.

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24 Platten, R. (2004). Historical trends in recreational fishing catches in the Gladstone region. Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management.

25 Limpus C J, McLaren M, McLaren G and Knuckey B. (2006) Queensland Turtle Conservation Project: Curtis Island and Woongarra Coast Flatback Turtle Studies, 2005-2006. Queensland Environmental Protection Agency, ISSN 1449–194X

26 Queensland Environmental Protection Agency (QEPA) (2003) Curtis Coast Regional Coastal Management Plan. Environmental Protection Agency and Queensland Parks and Wildlife Service, ISBN 0-9751106-2-4

27 Limpus C J, McLaren M, McLaren G and Knuckey B. (2006) Queensland Turtle Conservation Project: Curtis Island and Woongarra Coast Flatback Turtle Studies, 2005-2006. Queensland Environmental Protection Agency, ISSN 1449–194X

28 Taylor H, Rasheed M, Dew K. and Sankey T. (2007) Long Term Seagrass Monitoring in Port Curtis and Rodd's Bay, Gladstone, November 2006. Queensland: Queensland Department of Primary Industries and Fisheries Publication PR07-2774.

29 Limpus C J, McLaren M, McLaren G and Knuckey B. (2006) Queensland Turtle Conservation Project: Curtis Island and Woongarra Coast Flatback Turtle Studies, 2005-2006. Queensland Environmental Protection Agency, ISSN 1449–194X

30 Great Barrier Reef Marine Park Authority (2005) The State of the Great Barrier Reef: Reptiles. Available at: www.gbrmpa.gov.au/corp_site/info_services/publications/sotr/latest_updates/marine_reptiles [last accessed 17.12.2008]

GPC is understood to have undertaken aerial surveys of reptiles and mammals within Port Curtis in the past few months, although this work is currently unreported.

1.3.2.6 *Dugong*

Survey results from November 2005 estimated a total of 183 (±66) dugong in the Port of Gladstone area. Dugong feeding activity has been observed from seagrass monitoring[31] and benthic habitat surveys in the Port[32]. The highest density of dugong feeding trails have been observed at Wiggins Island although feeding trails have also been regularly observed at Quoin Island, Pelican Banks, South Trees and the intertidal meadows to the north and south of Fisherman's Landing[33].

GPC has recently conducted a new set of aerial surveys for dugong and other megafauna, and it is expected that this work will be published in GPC's Draft EIS.

The value of the Port of Gladstone seagrass meadows to the local dugong population has resulted in the declaration of the Rodd's Bay Dugong Protection Area (DPA) [34] (refer *Volume 5 Chapter 8*). The Rodd's Bay DPA encompasses the majority of Southern Curtis Island waters from The Narrows south of Graham Creek and east to Facing Island.

While recent studies suggest that dugong numbers have stabilised along the entire eastern coast of Queensland during the past two decades[35], individual dugong populations within defined regions, such as the Port of Gladstone, have been observed to fluctuate over shorter periods. This fluctuation has been largely attributed to natural changes in seagrass habitats, which might be an important factor in assessing the impacts of dredging and land reclamation in terms of habitat losses.

1.3.2.7 *Cetaceans*

Twelve species of cetacean are known to occur in the Curtis region (refer *Volume 5 Chapter 8*). While the large, oceanic species are unlikely to visit the inner port, a number of delphinids, including snubfin dolphin (*Orcaella heinsohni*), Indo-Pacific humpback dolphin *(Sousa chinensis),* Indian Ocean

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31 Taylor H, Rasheed M, Dew K. and Sankey T. (2007) Long Term Seagrass Monitoring in Port Curtis and Rodd's Bay, Gladstone – November 2006. Queensland Department of Primary Industries and Fisheries Publication PR07-2774

32 Rasheed M A, McKenna S A, Taylor H A and Sankey T L (2008) Long term seagrass monitoring in Port Curtis and Rodd's Bay, Gladstone – October 2007. DPI&F Publication PR07- 3271 (DPI&F, Cairns)

33 Rasheed M A, McKenna S A, Taylor H A and Sankey T L (2008) Long term seagrass monitoring in Port Curtis **and Rodd's Bay, Gladstone – October 2007**. DPI&F Publication PR07- 3271 (DPI&F, Cairns)

34 Coles R G, Lee Long W J, Squire B A, Squire L C and Bibby J M (1987) **Distribution of seagrasses and associated juvenile commercial penaeid prawns in north-eastern Queensland waters**. Aust J Mar Freshwater Res, 38: 103–119

35 Marsh H and Lawler I R (2006) **Dugong distribution and abundance on the urban coast of Queensland: a basis for management**. Marine and Tropical Science Research Facility Interim Projects 2005-06 FINAL Report Project 2:

bottlenose dolphin *(Tursiops aduncus)* and the bottlenose dolphin *(Tursiops truncate ss. str.)* are all likely to occur at various times.

The snubfin dolphin and Indo-acific humpback dolphin are the two most likely species to be observed in the port. The Indo-Pacific humpback dolphin usually inhabits shallow coastal waters less than 20 m deep, and are often associated with rivers and estuarine systems, enclosed bays and coastal lagoons[36].

Previous studies have shown that the Indo–Pacific humpback dolphin coexist with coastal development in places such as Cleveland Bay, Townsville. The snubfin dolphin is endemic to Australia and is known to occur close to rivermouths[37]. Their preference for nearshore, estuarine waters is likely related to the productivity of these tropical coastal areas[38]. There is no published information available for either species in the Port of Gladstone region.

Although unlikely to enter the port, humpback whales (*Megaptera novaeangliae*) migrate annually past the Port of Gladstone en route to and from the Great Barrier Reef. While the closest aggregation area to the Port of Gladstone is at Hervey Bay[39], approximately 220 km south, the Great Barrier Reef is a critical habitat used for calving and resting during the austral winter months. Given the offshore nature of this species and the known distances from the Port of Gladstone area, this species is not expected to be a key sensitive receptor for this Project.

1.3.2.8 Shorebirds and Seabirds

Approximately 70 per cent of the shorebird species inhabiting the Port of Gladstone region are internationally significant migratory species listed under the Japan-Australia Migratory Bird Agreement (JAMBA), China-Australia Migratory Bird Agreement (CAMBA) and Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA) (refer *Volume 5 Chapter 8.3*). The Port of Gladstone region is recognised as an important staging area for a number of these species during their annual migrations, although no areas of Port Curtis warranted listing as JAMBA, CAMBA or ROKAMBA sites. Two habitats are especially important to shorebirds: low-tide feeding areas comprising exposed tidal flats, and high-tide roosting areas comprising coastal saltflats, sand spits and the mangrove fringe.

Offshore islands in the Capricorn Group, approximately 75 km from Gladstone, provide support for up to three-quarters of the total seabird

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36 Parra G J (2006) Resource partitioning in sympatric delphinids: Space use and habitat preferences of Australian snubfin and Indo-Pacific humpback dolphins. Journal of Animal Ecology 75:862-874.

37 Parra G J, Azuma C, Preen A R, Corkeron P J and Marsh H (2002) **Distribution of Irrawaddy Dolphins, *Orcaella brevirostris*, in Australian waters**. Raffles Bulletin of Zoology, Supplement10, pp 141-154.

38 Parra G J (2006) Resource partitioning in sympatric delphinids: Space use and habitat preferences of Australian snubfin and Indo-Pacific humpback dolphins. Journal of Animal Ecology 75:862-874.

39 Chaloupka M., Osmond M. and Kaufman G. (1999) Estimating seasonal abundance trends and survival rates of humpback whales in Hervey Bay (east coast of Australia). Marine Ecology Progress Series, 184, 291-301

biomass of the Great Barrier Reef[40]. The islands provide key roosting and feeding sites for a range of seabirds and shorebirds, including the little tern (*Sterna albifrons*) and sooty oystercatcher.

North Reef provides habitat for colonies of crested terns (*Sterna bergii*), roseate terns (*Sterna dougallii*), black-naped terns (*Sterna sumatrana*) and shearwaters. Masthead Island approximately 60 kms from Gladstone is a nationally important seabird nesting site due to high species diversity and numbers (including shearwaters, noddies, bridled terns (*Sterna anaethetus*), roseate terns, black-naped terns and silver gulls (*Larus novaehollandiae*)[41].

1.4 EVALUATION OF IMPACTS, MITIGATION AND MANAGEMENT MEASURES

Prediction of impacts is an objective attempt in determining the potential effects of a proposed project, and its associated activities, on the ecological and anthropogenic components of the environment (i.e. physical, biological, social, socio-economic etc). Impact prediction is based on existing information relating to the action, potential modes of impacts and receptors involved in each identified interaction.

It is important to note that impact prediction takes into account any mitigation or control measures that are part of the project design/project plan. Additional mitigation measures aimed at further reducing predicted impacts are then proposed where necessary or as appropriate.

Risk Assessment framework

A risk-based approach to impact assessment is becoming more common in Australia, and while there are no regulations prescribing a specific approach for conducting an impact assessment, a number of key oil & gas industry documents from the Australia Petroleum Production and Exploration Association (APPEA) suggest that the assessment of environmental risks is integral to the process.

The APPEA Code of Environmental Practice states that:

- The assessment of the risks to, and impacts on, the environment is an integral part of the planning process for activities associated with the exploration, production and export of oil and gas.
- Environmental legislation requires an assessment of the impact the activities will have on the environment of the area, including assessing the risk of impact.
- It is necessary to identify risks (likelihood and consequence) to the

40 Queensland Environmental Protection Agency (2003) **Curtis Coast Regional Coastal Management Plan**. Environmental Protection Agency and Queensland Parks and Wildlife Service, ISBN 0-9751106-2-4

41 Queensland Environmental Protection Agency (2003) **Curtis Coast Regional Coastal Management Plan**. Environmental Protection Agency and Queensland Parks and Wildlife Service, ISBN 0-9751106-2-4

environment and the appropriate mitigation measures so that the risks can be reduced to as low as reasonably practical, are in accordance with legislation and are acceptable.

- The risk assessment process should be adapted for each activity, project or operation to ensure that the assessment, no matter how simple or informal, should be able to demonstrate by a documented formal risk assessment process that the environmental risks were assessed and company management accepted the resultant level of managed risks.

On this basis, a risk-based approach has been applied to the impact assessment process for this project.

Risk estimates are summarised in *Table 6.1.2* and *Table 6.1.3* below.

Table 6.1.2 Hazard Identification

	Mode								Receptor																							
	Short-Term					Long-Term			Physical								Biological															
	Sediment Mobilisation & Settlement (SS)	Contaminant Release (CS)	Fauna Interactions (F)	Noise (N)	Light emissions (L)	Introduced Marine Species (IMS)	Habitat Loss (Ha)	Changes to Hydrodynamics Regimes (Hy)	Geomorphology		Bathymetry		Sediment Quality		Water Quality		Mangroves		Benthic Primary Producers		Invertebrates and Corals		Fish		Marine Reptiles		Dugong		Cetaceans		Shorebirds and Seabirds	
ACTIVITIES																																
Dredging Operations																																
Backhoe Dredge (BHD)	x	x		x	x	x	x	x		Hy		Hy	CS	HY	SS	Hy	SS		SS	Ha	SS	Hy	SS	Ha	SS	F	SS	N	F		N	
										Ha		Ha			CS		CS		CS	Hy	CS	IM S	CS	Hy	CS		CS	Ha	N		L	
Hopper Barge	x	x	x	x	x	x								CS	SS		SS		SS		SS	IM S	SS		SS	F	SS	N	F		N	
															CS		CS		CS		CS		CS		CS		CS		N		L	
Cutter Suction Dredge (CSD)	x	x	x	x	x	x	x	x		Hy		Hy	CS	Hy	SS	Hy	SS		SS	Ha	SS	Hy	SS	Ha	SS	F	SS	N	F		N	
										Ha		Ha			CS		CS		CS	Hy	CS	IM S	CS	Hy	CS		CS	Ha	N		L	
Sediment Transport Pipe	x	x		x									CS		SS		SS		SS	Ha	SS	Hy	SS	Ha	SS	F	SS	N	F		N	
															CS		CS		CS	Hy	CS		CS	Hy	CS		CS		N		L	
Trailer Suction Hopper Dredge (TSHD)	x	x	x	x	x	x	x	x		Hy		Hy	CS	Hy	SS	Hy	SS		SS	Ha	SS	Hy	SS	Ha	SS	F	SS	N	F		N	
										Ha		Ha			CS		CS		CS	Hy	CS	IM S	CS	Hy	CS		CS	Ha	N		L	
Vessel Operations			x	x	x	x							CS		CS							IM S	N		F		F		F		N	
																									N		N		N		L	
Reclamation																																
Bund Construction	x	x	x	x	x		x	x		Hy		Hy	CS	Hy	SS	Hy	SS	Ha	SS	Ha	SS	Ha	SS	Ha		Ha		Ha			Ha	
										Ha		Ha			CS		CS	Hy	CS	Hy	CS	Hy	CS	Hy		Hy		Hy				
Sediment Rehandling	x	x	x	x	x								CS		CS		SS		SS		SS		SS									
																	CS		CS		CS		CS									
Pond Dewatering	x	x						x		Hy		Hy	CS	Hy	SS	Hy	SS		SS		SS		SS									
										Ha		Ha			CS		CS		CS		CS		CS									

Table 6.1.3 Risk Matrix for Dredging and Reclamation Activities

Receptor	Physical				Ecology							
Hazard	Geomorphology	Bathymetry	Sediment Quality	Water Quality	Mangroves	Benthic Primary Producers	Invertebrates and Corals	Fish	Marine Reptiles	Dugong	Cetaceans	Shorebirds and Seabirds
Phase												
Dredging Operations												
Dredging Activity (All Methods)	Major	Minor	Major	Minor		Major	Major	Minor	Minor	Minor		
Permanent Structures (Nav Markers)	Negligible	Negligible			Negligible	Negligible	Negligible	Negligible				
Temporary Structure (incl vessel movements)			Minor	Minor		Moderate	Moderate	Minor	Moderate	Moderate	Negligible	Negligible
Hopper Dewatering				Moderate		Moderate	Moderate	Minor				
Liquid Waste/ Domestic Sewage				Moderate		Minor	Minor	Negligible				
Airborne Noise Emissions/ Vibrations									Minor		Moderate	Minor
Subsea Noise Emissions/ Vibrations								Minor	Moderate	Moderate		
Light Emissions								Negligible	Negligible		Minor	Minor
General Waste			Negligible	Negligible		Negligible	Negligible	Negligible				
Construction & Operations of Land Reclamation												
Permanent Structure	Minor	Moderate			Moderate	Major	Negligible	Negligible		Major	Minor	
Temporary Structure			Minor	Minor		Moderate	Moderate	Negligible	Moderate	Major	Negligible	Minor
Airborne Noise Emissions/ Vibrations									Minor		Moderate	Minor
Subsea Noise Emissions/ Vibrations								Negligible	Moderate	Moderate		
Chemical Discharge				Moderate	Minor	Negligible	Minor	Minor	Negligible	Negligible		
Reclamation Dewatering				Moderate		Minor	Minor	Minor				
General Waste			Negligible	Negligible		Negligible	Negligible	Negligible				
Accidental Events												
Lube and Hydraulic Oil Spills			Minor	Minor	Minor	Minor	Minor	Minor	Minor	Minor	Minor	Minor
Chemical Spills			Minor	Minor	Minor	Minor	Minor	Minor	Minor	Minor	Minor	Minor
Diesel Spills			Major	Major	Major	Major	Major	Moderate	Moderate	Moderate	Moderate	Major

Risk	
Positive Effect	An impact that represents an improvement on the baseline or introduces a new desirable factor
Negligible Effect	Magnitude of change comparable to natural variation
Minor Impact	Detectable but not significant
Moderate Impact	Significant; amenable to mitigation; should be mitigated where practicable
Major Impact	Significant; amenable to mitigation; must be mitigated
Critical Impact	Intolerable; not amenable to mitigation; alternatives must be identified; project stopper

Outline of Impact Evaluations

Table 6.1.4 identifies the sections in this chapter that describe specific dredging-related environmental impacts.

Table 6.1.4 Outline of Impact Evaluations

Impact Type	***Section***
Changes to the Hydrodynamic Regime	1.4.1
Sediment Mobilisation and Settling	1.4.2
Habitat Loss	1.4.3
Release of Contaminants	1.4.4
Fauna Interactions	1.4.5
Noise and Vibration	1.4.6
Introduced Marine Species	1.4.7
Vessel (Collision) Management	1.4.8

1.4.1 Changes to the Hydrodynamic Regime

1.4.1.1 Sources and Characteristics

The dredging of a new channel to service the LNG Facility will add to the existing channel infrastructure of the Port of Gladstone. The reclamation of additional areas north of Fisherman's Landing will potentially provide land for future development. However, other reclaimed areas in the port have often been developed to include open space and recreational areas.

Impact sources include significant changes to the bathymetry of subtidal areas, particularly increased depth and width in the new shipping channels, loss of tidal storage volumes from the intertidal and mangrove areas north of Fisherman's Landing following reclamation, and subsequent changes to shoreline configurations. The sources, extent and nature of these changes are described in greater detail in *Volume 5, Chapter 8* with summaries provided here. It should be noted that Climate change mitigation measures including allowances for potential storm surge, a rise in sea level and increased wave action have been incorporated into the design of the Swing Basin and Channel.

MOF, Curtis Spur Channel and Swing Basin

QGC's port-related facilities require dredging and removal of significant portions of the seabed, which will alter the flow characteristics in this area. The construction of access roads, ramps and decks to the MOF will include the establishment of sheet piled or rock structures which will intercept and divert water flows.

Fisherman's Landing Reclamation Area

Raising of the seabed from sub-tidal and inter-tidal to an elevated landform will intercept and divert water flows in this area. These works may occur independently of the QCLNG Project, according to referral documents submitted for the FL153 and WBSDD projects by GPC (refer *Chapter 1.4.2* for a discussion of this).

1.4.1.2 Extent of Impacts

MOF, Curtis Spur Channel and Swing Basin

Bathymetry changes will be permanent. As much of the harbour is a working port, the seabed topography has already been modified extensively by previous dredging to create a network of shipping channels, swing basins and berths. Flow impacts from proposed works will occur within the dredged footprint and in places to several hundred metres beyond the perimeter of dredging. Built structures associated with the MOF, occurring across the intertidal and shallow subtidal zone, will influence water flowing along the shoreline on flooding and ebbing tides, with BMT WBM modelling predictions (refer *Volume 5 Chapter 11)* implying impacts to approximately 200m away from these structures.

Fisherman's Landing Reclamation Area

The coastal geomorphology of the shoreline in the area north of Fisherman's Landing will be modified considerably by the potential reclamation of additional areas using dredge spoil. Direct bathymetry changes will be permanent, and therefore any impacts to hydrodynamics will be permanent. Where these impacts include reduction of flow velocities, sediment deposition may cause progressive shallowing and lead to further hydrodynamic changes. Conversely, scouring and deepening of the natural bathymetry may occur where currents are exacerbated by the new structures. BMT WBM (2009) predict that currents will be increased around the northern end of the reclamation area for reclamation scenarios FL153 and FL1b (refer *Volume 5, Chapter 8.)* In reclamation scenario FL2, and to a lesser extent in the other reclamation scenarios, velocity increases extend into the main channel running past Fisherman's Landing.

1.4.1.3 *Description of Impacts*

MOF, Curtis Spur Channel and Swing Basin

Volume 5 Chapter 11 describes impacts on the coastal environment in detail and these are summarised below:

- There were negligible direct impacts on flushing behaviour with and without the QCLNG Project.
- Neither the solid or piled options for the MOF are expected to have any significant direct impact on shoreline processes adjacent to the LNG Facility. The solid option will generate small localised zones of reduced waves on either side, depending on the direction of approach. Currents in the shallow intertidal area are low, and the solid option as well as the adjacent dredging will create localised quiescent zones. As such, there may be small localised sediment build up adjacent to MOF facilities and siltation of the dredged areas.
- The potential for sand transport in the vicinity of the proposed QGC Swing Basin is similar to the adjacent Fisherman's Landing Swing Basin area, and is considerably lower than experienced at the Clinton Wharves further to the south-east. The developed case sedimentation rate into the existing Targinie Channel and Targinie Swing Basin are both reduced relative to the base case. Predicted sedimentation rates in the Santos Gladstone LNG (GLNG) Swing Basin and approach channel are generally lower than existing dredged areas further to the south-east. Net sedimentation rates, summed across all areas, remain the same.

The siltation of fines under low flow conditions is addressed in *Volume 5 Chapter 11* and is summarised below:

- Shear stresses are predicted to reduce slightly in the existing Fisherman's Landing Swing Basin. It is predicted there will be a potential increase for fine-silt deposition with minor direct impact due to the Project.
- In the proposed QGC Swing Basin, bed shear stresses are significantly reduced by the proposed dredging. Over most of the Swing Basin area, moderate bed shear stresses are still experienced during spring tide flows, which will limit the potential for silt deposition.
- Very low tidal energy conditions and hence bed shear stresses are predicted in the western extremity of the QGC Swing Basin, and as a result this area will probably experience higher levels of fine-sediment deposition.
- Low tidal energy conditions and hence bed shear stresses are predicted in the eastern berth area of the QGC Swing Basin. As a result this area will probably experience fine-sediment deposition, however, regular shipping movements could tend to mobilise fine sediment and reduce the siltation potential.
- Very low tidal energy conditions and hence bed shear stresses are predicted in the MOF dredged areas. As a result, it could be expected that

these areas will experience higher levels of fine-sediment deposition. Furthermore, the landward portions of the dredged areas are in the intertidal zone and hence even small wave chop may mobilise fine sediments on the shallow areas adjacent, increasing the siltation potential. This may be offset by regular vessel movements tending to remobilise fine sediments.

Fisherman's Landing

Maximum changes low- and high-water behaviours associated with various Fisherman's Landing reclamation options were predicted to be in the order of 4.5 cm or less, with low-water changes the greatest (refer *Volume 5, Chapter 11*). The greatest water level differences (4.5 cm at The Narrows) are for reclamation scenario FL2, involving a full reclamation of Fisherman's Landing (to Friend Point) in the absence of any further channel deepening in the adjacent area (refer *Volume 5 Chapter 11.5.7.4*). Water level differences are approximately halved (2.8 cm) for reclamation of only the southern half of Fisherman's Landing (scenario FL1b). Additional modelling performed by BMT WBM for scenarios combining reclamation with contemporaneous channel dredging indicate that water level variations become minor under scenarios where channel deepening coincides with reclamation (T McAlister, pers. comm.). In the light of GPC's WBSDD Project Referral, there would appear to be no foreseeable circumstance where reclamation would occur independently of channel construction, and therefore these water level impacts are not expected to occur.

A 30-minute time shift in phasing of tides was also observed between the Reference Case and the various reclamation options at the high- and low-tide times. This phase shift was, however, not regular.

Overall changes in water surface elevations between the various reclamation cases and the QGC Reference Case are greatest during mid-ebb tides (rather than at low- or high-water). Differences of up to 11 cm are predicted within the main channel north-west of the QGC Reference Case Swing Basin, for example. However, these are largely due to the phase shift described previously.

The spring tide range is reduced by up to 1 per cent within the main channel to the north-west of the proposed QGC Swing Basin for the FL2 reclamation option. The neap tide range is reduced by up to 1.3 per cent in The Narrows for the FL2 reclamation option. Option FL153 is predicted to have the least direct impact on tidal water levels at the selected extraction locations.

Impacts of reclamation on flow velocities (refer *Volume 5, Chapter 11*) vary in space and intensity with time. General patterns show decreases in velocity magnitudes downstream (south-east) of the Fisherman's Landing reclamation site(s), within the main channel. Velocities induced by the proposed channels within various reclamation options (those that involve islands) are greater than those at the same locations in the QGC scenario, due to channelling of tidal flows. Some significant residual velocities around the northern end of the FL153 scenario reclamation area are predicted.

The impact of the various reclamation options is negligible upstream (north) of Friend Point. Within the QGC and GLNG swing basins, the occurrence of velocity magnitudes greater than 0.20 m/s is predicted to be increased by approximately 4 per cent to 6 per cent, the maximum change being predicted for reclamation FL2.

1.4.1.4 Receptors Affected

Impacts to flow velocities, water levels, tidal ranges etc are likely only to affect marine communities living at the extremities of their natural range. Variations to extreme (low tide and high tide) water level variations have the potential to affect mangrove and saltmarsh communities near the high tide mark, and seagrasses if their low-tide exposure was significantly altered. These communities provide important habitat and food sources for a wide range of animals, but particularly dugong, turtles, fish and invertebrates.

1.4.1.5 Management and Mitigation Measures

MOF, Curtis Spur Channel and Swing Basin and Fisherman's Landing Reclamation Area

Other than management of re-suspended sediment and its indirect effects (sedimentation, light attenuation etc), there's little that can be done to ameliorate the impacts of hydrodynamic impacts. GPC is expected to address Fisherman's Landing reclamation scenarios more widely in its Western Basin Strategic Dredge Disposal Project (WBSDD) Project EIS, and on the basis that impacts to water level changes in The Narrows are influenced by the relative staging of reclamation and channel development, it will be important for this work to include an examination of these scheduling implications.

1.4.1.6 Level of Risk

Based on findings set out in *Volume 5, Chapter 8* the impacts to hydrodynamics and marine water quality from the Project are characterised as being short-term (related to construction stages), with major local impacts from the dredging works with increased TSS (see *s.1.4.2* below). These increases are within the bounds of natural variability of the system and are not expected to have any significant direct impacts on marine environmental values of water. Providing reclamation of Fisherman's Landing is conducted contemporaneously with channel deepening, water level changes in The Narrows will be negligible. The environmental values of the Project area will be protected by balancing reclamation-related water level changes with the compensatory changes resulting from channel deepening.

Thus the dredging and reclamation operations planned for the Port of Gladstone are unlikely to have a significant impact on the existing hydrodynamics regime in the harbour *(*refer *Volume 5, Chapter 8)*.

Refer to *Section 1.4.3* for a discussion of secondary impacts to sensitive receptors such as mangroves and seagrass caused by suspended sediments and reclamation. Impacts to World Heritage values are discussed in *Section 1.6.3*.

1.4.1.7 *Cumulative Impact Scenario*

QGC's cumulative impact scenario combines QCLNG Project-related dredging with:

- the Wiggins Island Coal Terminal (WICT) Project,
- GLNG's proposed dredging, and
- Stage 1b of the Targinie Extension

The combined impact of these projects being undertaken in parallel or sequentially is currently being modelled by QGC.

1.4.2 Sediment Mobilisation and Settling

1.4.2.1 *Sources and Characteristics*

The sediments of Port Curtis are highly variable in their nature and distribution. Particle sizes range from cobble, gravel and sands, which pose little threat in terms of re-suspension, to silts and clays. At progressively smaller sizes these particles become more difficult to deal with in terms of impact management.

The main sources for sediment mobilisation will be from grabbing from the back hoe dredge (BHD), CSD, TSHD; hopper barge dewatering; sediment transport pipe leaks; and reclamation dewatering. In some cases in may also be necessary to consider spoil rehandling from hopper barges or TSHDs. As previously outlined (refer *Volume 5, Chapter 8*) the sediment characteristics in the Port of Gladstone vary considerably across the proposed dredging footprint. Similarly, due to operational constraints, the methods of dredging employed will likely vary during the schedule.

A number of dredging activities can result in an increase in turbidity if finer sediments are encountered. These activities include:

- using an overflow system that releases material into the water column,
- using a bypass system that releases material into the water column,
- propellers dislodging seabed material and mixing this into the water column,
- propellers dispersing overflow or bypass waters before they have a chance to settle,
- cutter-head rotation entraining material and dispersing it in the water column, and
- drag-head movement mixing seabed material into the water column.

BMT WBM was commissioned to produce a sediment transport fate model, for the area near the LNG Facility site on Curtis Island, to quantify the potential impact of sediment mobilisation on ambient water quality conditions, and to understand the possible spatial extent of sediment plumes potentially generated by dredging operations. This work is reported in detail in *Volume 5 Chapter 8*.

It should be noted that several of the assumptions for this model were based on previous dredging activity and dredge plume modelling undertaken in the port. For this model, a suspended sediment settling rate of 1 m/day has been adopted which is equivalent to the settling rate of fine silty material. This sediment size fraction is expected to be the dominant material to be resuspended in the water column. A CSD was assumed as the dredging method with an estimated sediment mobilisation rate of 1.5 kg per second[42,43].

Scheduling issues, the stiffness of some materials and the overall volumes of material to be dredged are likely to result in one or more large capacity dredges being utilised for much of the work. For example, works currently being undertaken in Targinie Channel are using the *Wombat*, with much of this work having an effective production rate of 350 m^3/hr – 400 m^3/hr. By contrast a large CSD can move 3,000 m^3/hr, and up to 6,000 m^3/hr in sandy materials, and a spread of one large CSD and one medium CSD may comfortably move 5,000 m^3/hr. Similarly, maintenance dredging has historically been performed by the *Brisbane*, a TSHD with 1,500 m^3 hopper capacity. Given the size of the Stage 1 dredging program, it is possible that a large TSHD of 30,000 m^3 to 38,000 m^3 hopper capacity may be employed.

Capital dredging in areas of unconsolidated Holocene sediments may also involve a larger proportion of fine silts and clays than previously encountered elsewhere in the port. An analysis of preliminary SAP results implies a common sediment composition, as indicated in *Table 6.1.5.*

Table 6.1.5 Typical sediment composition, Western Basin area

Category	Size	% composition
Cobble	> 6 cm	<1 %
Gravel	> 2 mm	17 %
Sand	> 0.06 mm	49 %
Silt	> 2 μm	13 %
Clay	< 2 μm	21 %

42 BMT WBM Pty Ltd 2009 Proposed BG LNG Facility EIS Marine Water Quality Assessment. Unpublished

43 CIRIA (2000), Scoping the Assessment of Sediment Plumes from Dredging. CIRIA Publication C547

Assumptions regarding sediment release source strengths, advection and dispersion therefore need to be verified. The assumed sediment source rate (1.5 kg/s) is likely to be relevant for a small CSD, or one working predominantly in sands. On the other hand, larger and more modern dredges may be more effective in reducing rates of fugitive sediment release. Further modelling would be necessary to accurately determine the likely sediment mobilisation and settlement patterns that might arise from the proposed dredging program.

Backhoe Hopper Dredge Operations

Volumes of dredged material removed using BHD (< 1 million m^3) are likely to be relatively small in comparison to TSHD (approximately 1 to 2 million m^3) or CSD (approximately 12 to 14 million m^3). This sediment will be deposited directly to trucks (if on-site disposal) or into hopper barges, which would be transported to the reclamation area before rehandling. Dewatering of hopper barges for BHD is likely to be minimal as the method does not employ suction or require the formation of a slurry to transfer sediment from the dredge head to the barge. Rehandling at the reclamation area is likely to occur using a second excavator located on the bund wall.

Cutter Suction Dredge Operations

Relocation of dredged material is likely to be via floating or submerged hydraulic pipeline supported by a number of booster pumps, which will be dependent on the distance between the dredge head and the reclamation area. Booster pumps are especially likely to be required to facilitate continual transfer of sediment types, such as sands and gravel, which can be difficult to maintain in slurry form and which are expected in the planned dredged material.

Dredging in Areas Where Hydraulic Placement is not an Option

The nature of sediments and the distance to a Fisherman's Landing reclamation area impose important operational constraints on dredging. Coarse gravels are difficult to pump over large distances without accumulating in and blocking discharge lines. On the basis of results to date, it appears that the practical limit for pumping from a CSD may be 5 km. This means that hydraulic placement in Fisherman's Landing may not be feasible for areas south of China Bay. The only options are:

- An alternative spoil disposal location
  - Within 5 km of Clinton Bypass, where a CSD could be used
  - Further than 5 km, where a TSHD could be used; or
- Dredge with a hopper system whereby filled hoppers can be relocated to the remote placement site
  - BHD filling self-propelled or dumb barges
  - CSD filling self-propelled or dumb barges
  - TSHD

BHDs typically produce a high solids content, and hoppers could be filled by a BHD with little release of sediment-laden water. Sediment-water mixtures loaded into barges by a CSD or a TSHD are likely to need to overflow until economical loads are achieved (refer Overflow Dredging, below).

These three dredge types also have significant consequences in terms of production rates (BHD is slow, CSD or TSHD is fast) and manoeuvrability with respect to shipping, an important consideration in the active channels near Clinton Bypass and the future WICT swing basin. A TSHD is fully manoeuvrable, a CSD is more difficult to manoeuvre, and a BHD is the most difficult to manoeuvre.

Unloading of filled hoppers

After relocating a filled hopper to the reclamation site there are several options for unloading:

- Grab or excavator – a hopper barge filled by a BHD or a CSD can be manoeuvred close to an excavator, which can place material directly into a reclamation area, or into trucks tipping into the reclamation area.
- Direct pumping - a TSHD can usually pump sand and gravel mixtures directly from its hopper. Areas south of China Bay contain a large percentage of sands and gravels, but some areas contain significant clay deposits and are unlikely to be suitable for pumped discharge.
- Bottom-dumping, with rehandling – a split hopper barge or TSHD can discharge into a rehandling pit, whereupon a BHD or CSD would rehandle into the reclamation area

Rehandling

At this stage, it is unknown whether a temporary rehandling site would be located within or adjacent to the reclamation area. While presenting a greater challenge in terms of engineering and construction, the use of a rehandling bed semi-enclosed by the perimeter of the reclamation area would potentially circumvent the generation of high intensity plumes and the requirement for a sea-dumping permit. Rehandling at a location adjacent to but outside of the reclamation area is likely to require a sea dumping permit, and is likely to require strict controls on operations to reduce plume formation to an acceptable level.

Overflow Dredging

Allowing a hopper to overflow is an effective way of filling the hopper with sediments and therefore optimising a load. It also results in the discharge of water bearing a relatively high suspended sediments load. Discharge concentrations may be no more than generated at the cutting face by a grab, cutter-head or drag-head, but the additional volume of released material needs to be considered when planning sediment plume management strategies.

WBM Initial Dilution Modelling

QGC has commissioned work by BMT WBM to examine the Initial Dilution phase of dredged sediments in Port Curtis, with a view to:

- Satisfying NAGD requirements for an 'initial dilution' factor to be used in the risk assessment phase of any contaminant which might exceed NAGD guidelines; and
- Developing management strategies to limit the formation of high intensity plumes.

This work is reported in more detail under 'Management and Mitigation', below.

1.4.2.2 Extent of Impacts

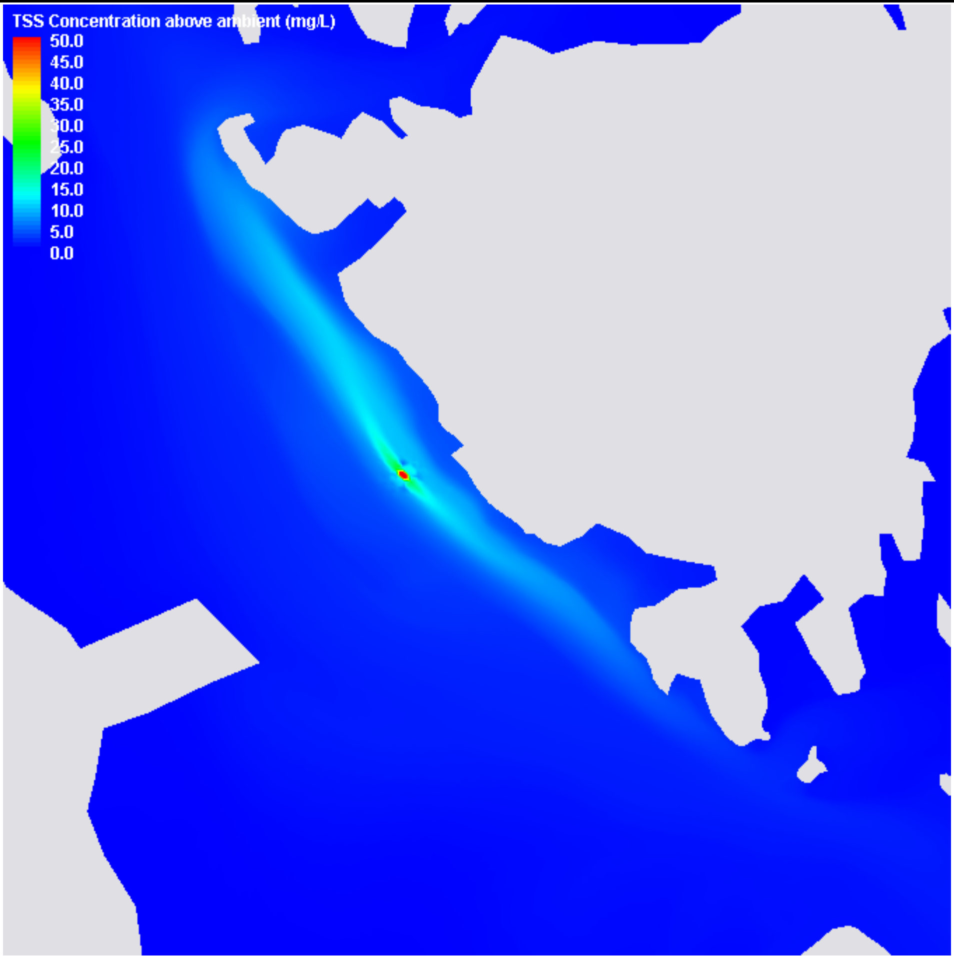
Modelling results predicted elevated total suspended solids (TSS) levels for an area around the proposed channel CSD dredging work with an estimated extent of approximately 800 m by 250 m during neap tides, and approximately 400 m by 150 m during spring tides (refer *Figure 6.1.11*). Outside this area, maximum levels fall to levels in the order of 25 mg/L. When compared with typical background levels for this part of the port it is apparent that, while high, the predicted levels fall within the existing range of variability. Further afield, the model predicts maximum TSS levels to be less than 8 mg/L.

The model suggests that turbidity levels will be undetectable from ambient conditions at distances beyond 4 km – 5 km from the QGC site.

BHD will be primarily employed in shallow areas around the MOF (refer *Volume 5, Chapter 8*). The same method might need to be employed in other areas posing technical difficulty for dredging by the preferred CSD and TSHD methods. This might include areas where accumulations of large gravel or cobble lead to blockages of TSD or CSD pumps or at distant locations which prevent the deployment of the CSD spread. Current velocities in these shallow areas are relatively slow, and therefore the extent of plumes is likely to be smaller than modelled for a CSD.

QGC is examining TSHD operations between Clinton Bypass and Hamilton Point, and this may lead to further modelling studies.

Figure 6.1.11 Average Total Suspended Solids Increases, Due to Capital Dredging Works – Neap Tide[44]



Scheduling

The shortest time within which QCLNG Project-related dredging could be accomplished (with two large CSDs) is approximately one year. If one large CSD were used with BHD and TSHD methods used selectively and in parallel, dredging would take approximately two years.

Other than its intended use on the QCLNG Project, the MOF will likely be deployed only for small components of the QCLNG dredging program.

It is likely that the CSD will operate 24 hours a day, seven days a week for the duration of the Project, with the exception of scheduled maintenance and unexpected breakdowns. Estimated down-time and frequency of maintenance shutdowns are currently being determined. Ideally, the commencement of CSD operations will likely be eight to 10 months after the start of BHD dredging activities.

Scheduling for the TSHD will be contingent on a number of factors, including

44 BMT WBM Pty Ltd (2009), Proposed BG LNG Facility EIS Marine Water Quality Assessment. Unpublished Report

shipping traffic, tidal conditions, staging of construction and dredging progress at other locations within vicinity of the Project. More detail regarding the schedule for TSHD will be provided as available.

1.4.2.3 *Description of Impacts*

Sediment re-suspension from dredging activities is assessed in *Volume 5, Chapter 11.* In the case of swing basin dredging, greater concentrations were realised during neap tides, where dispersion was less as a result of reduced tidal velocities. An immediate impact zone of around several hundred metres in scale was identified during these times and, outside this area, maximum additional TSS concentrations of approximately 25 mg/L were predicted (over ambient). These values are in the order of the natural variability of TSS concentrations across the site. Concentration increases during spring tides were generally less than during neap tides.

Similar behaviour was observed in the model results for the pipeline construction scenario across The Narrows. The immediate impact zones were, again, in the order of hundreds of metres in dimension during neap tides (and considerably smaller during spring tides), with maximum additional TSS concentrations outside this zone of 15 to 17 mg/L.

Water quality, in terms of sediment load, is a major determinant of the condition and productivity of marine systems and as such increased turbidity can cause significant ecosystem affects. Suspended sediment particles control the transport, reactivity and availability of substances, including both nutrients and contaminants, in the marine environment, and subsequently play a crucial role in linking benthic and pelagic communities.

The most obvious effect of increased turbidity is an increase in light attenuation, which has significant implications for the productivity of benthic primary producers (BPP), such as seagrasses and macroalgae. Mobilised sediments can also smother benthic organisms, such as molluscs and sessile filter feeders, as they settle. Suspended and settling sediments can also cause biological harm through mechanical impairment, resulting in higher energy expenditure requirements for self-cleaning, and in physical abrasion.

"Photic depth" is the term used to refer to the depth of penetration of sunlight sufficient to enable photosynthesis to occur. Photic depth is defined as the depth at which light intensity falls to one per cent of that at the surface (also called euphotic depth). Since the photic zone is the region where primary productivity occurs in coastal and estuarine marine systems, the ability for light to penetrate to the seabed is imperative for seagrass and macroalgal productivity. Photic depth depends on the extent of light attenuation in the water column, and this can be greatly affected by relatively small changes in turbidity.

Suspended sediments can also be deposited as tides withdraw from intertidal areas. Vegetation can become coated in a layer of fine sediments. If this is sufficient to reduce incident light levels on tissue surfaces, its results will be similar to the loss of light via water-column attenuation. If seagrasses were dependent on a photosynthesis window during periods of exposure (there is some evidence that they are not) then the combination of water column attenuation and low-tide coating might have adverse synergistic effects on seagrass health.

1.4.2.4 *Receptors Affected*

Changes in the hydrodynamic regime have the potential to cause erosion of the shoreline in some areas and subsequent deposition of sediments on sensitive habitats, such as seagrass. Transport of sediment due to erosion might also affect water quality (i.e. turbidity) and reduce light attenuation, which might in turn affect seagrass health.

Consequently, elevated suspended sediment levels are likely to be a major stressor to water quality during dredging and reclamation operations. Benthic primary producers, such as seagrass and macroalgae can be highly susceptible to adverse changes to turbidity levels, through decreased light penetration, increased sedimentation rates, higher ambient water temperatures and increased biological oxygen demand (refer to *Volume 5 Chapter 8*). Adverse changes to these habitat conditions can have significant effects on health, distribution and abundance.

Given the mobility of sensitive, protected biological receptors such as turtles and dugong, no direct impacts are expected from reclamation or suspended sediments. However, seagrass is a key benthic primary producer, and a number of marine fauna species are dependent on the seagrass distribution and health in the Port of Gladstone area. Secondary receptors of impacts associated with sediment mobilisation and settlement therefore include all marine species with lifecycles and trophic pathways associated with seagrass meadows and macroalgal distribution. Such species include adult green turtles and most turtle hatchlings, fish, invertebrates and dugong (*Dugong dugon*). Dugong might be particularly susceptible on a local scale to secondary impacts associated with sediment mobilisation and settling due to their reliance on seagrass meadows in the Western Basin for feeding and other activities.

Impacts to seagrasses and mangroves are addressed in *Section 1.4.3* below. Further studies may be required on the nature of secondary impacts to sensitive, protected biological receptors, if modelling of light attenuation impacts to seagrasses reveals significant risks to seagrass beds from suspended sediments.

1.4.2.5 *Management and Mitigation Measures*

QGC has conducted a major Marine Sediments Study of Port Curtis to inform its decisions about impact assessment and impact management of Project-related dredging. Part of this study has included determination, by a hydrodynamic modelling study, of ‘Initial Dilution’ characteristics of dredges operating within various parts of the Western Basin.

The initial dilution study (BMT WBM) looked at predictions over a two week tidal window encompassing spring and neap tide conditions (refer *Figure 6.1.12)*. Model outputs are presented for the immediate point of release, and for plumes which have dispersed over a period of four hours, as required by the National Assessment Guidelines for Dredging (NAGD). The effect of the four-hour dispersion window on plume concentrations can be seen clearly in *Figure 6.1.13* where peak plume intensity reduces from approximately 5 % of the source concentration to approximately 0.5 % of the source concentration.

Results are presented for the following scenarios:

- A BHD operating close to the shore in the MOF area (refer *Figure 6.1.14*)
- Dispersal of sediments at the cutter-head of a medium-large CSD operating in mid-channel within the Curtis Spur Channel (refer *Figure 6.1.15*)
- The tail-water discharged from a Fisherman's Landing reclamation area from the same CSD (refer *Figure 6.1.16*), and
- An unconfined rehandling operation conducted by a medium-large TSHD bottom-dumping on the seabed in the vicinity of Fisherman's Landing (refer *Figure 6.1.17*).

As will be immediately seen, plume dilutions are extremely variable over time, and there are marked differences between the different dredging operations modelled. *Table* 6.1.6 summarises these findings:

Table 6.1.6 Plume Initial Dilution calculations, Port Curtis Dredging Operations

Dredging operation	Source dilution at release point	Source dilution after four hours of 'Initial Dilution' (NAGD)
BHD at MOF	1:1,000 – 1: 10,000	1:10,000 – 1: 100,000
CSD mid-channel (cutter)	1:1,000 – 1: 10,000	1:20,000 – 1: 200,000
CSD tail-water (Fisherman's Landing)	1:20 – 1: 200	1:200 – 1: 2,000
TSHD rehandling at Fisherman's Landing	1:1 – 1: 100	1:10 – 1: 1,000

Figure 6.1.12 - Initial Dilution Study - Tidal Levels during Modelled Period

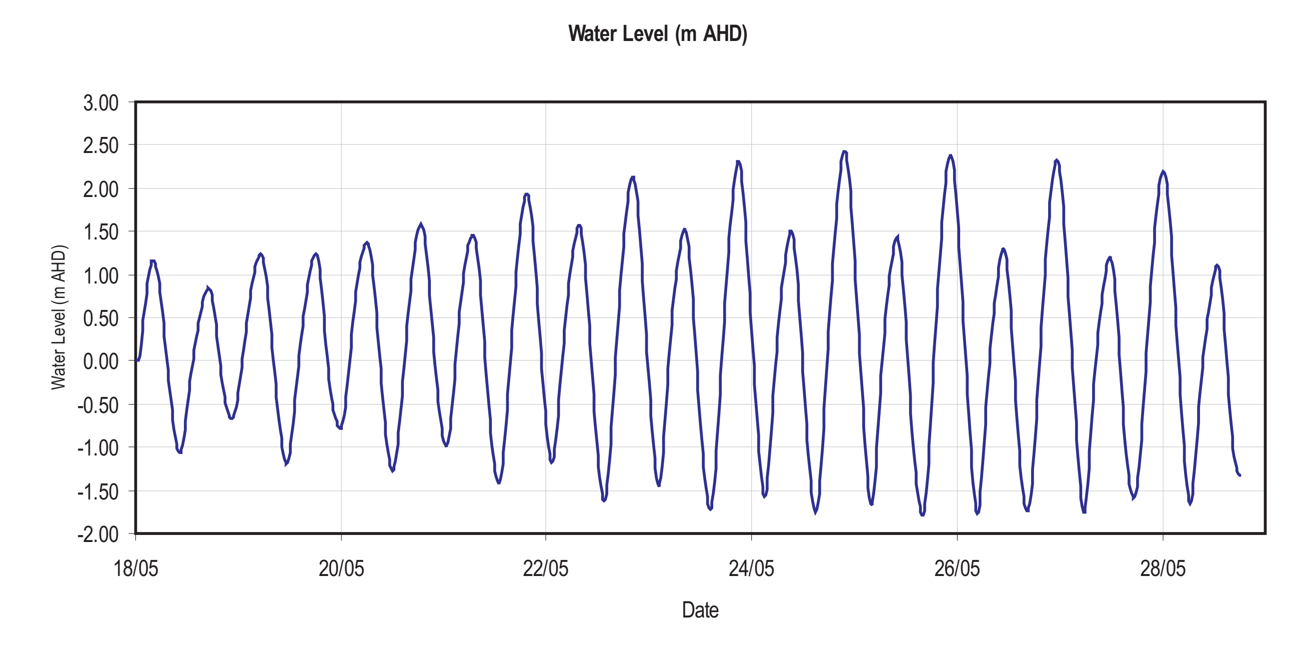
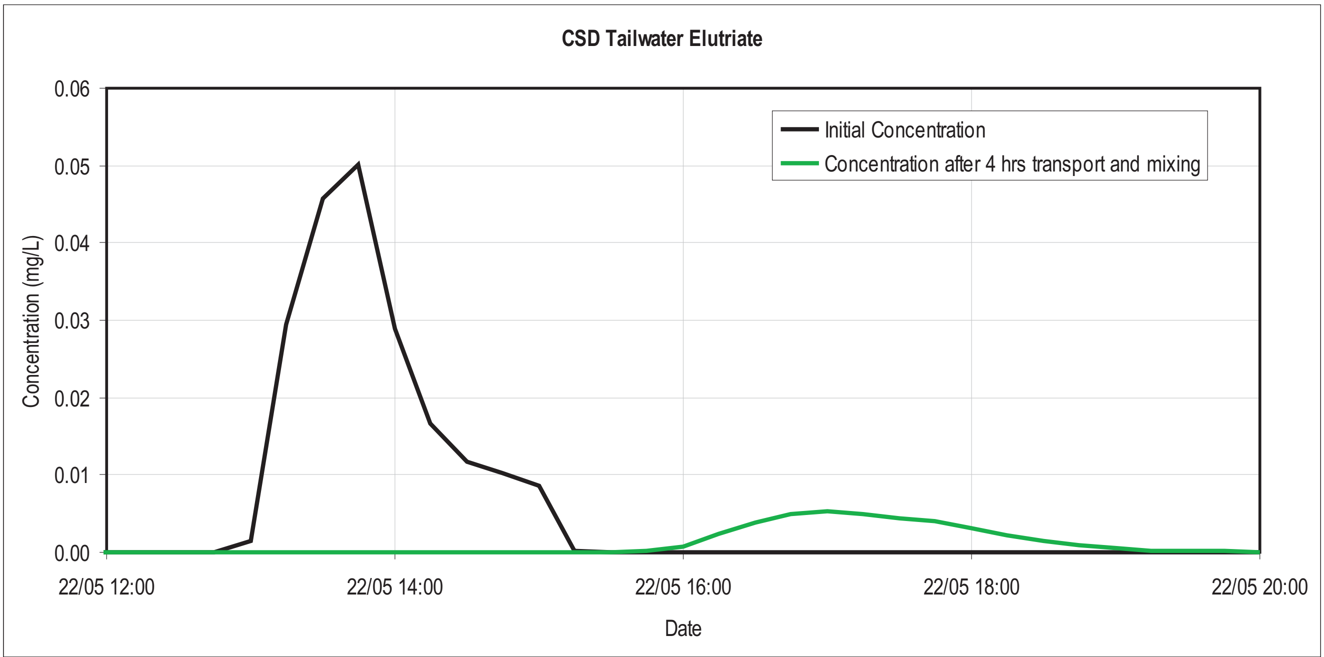


Figure 6.1.13 - Initial Dilution Modelling of the Effect of Transport and Dispersion on CSD tailwater



Source:
BMT WBM Pty Ltd, 2009. Unpublished Draft Report to QGC, July 2009.

QUEENSLAND CURTIS LNG A BG Group business	Project: Queensland Curtis LNG Project		Title: **Dilution Study: Modelled Period and Representative Dilution after 4 hours**
	Client: QGC - A BG Group business		
ERM Environmental Resources Management Australia Pty Ltd	Drawn: JB	**Volume 6** **Figure 6.1.12 & 6.1.13**	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
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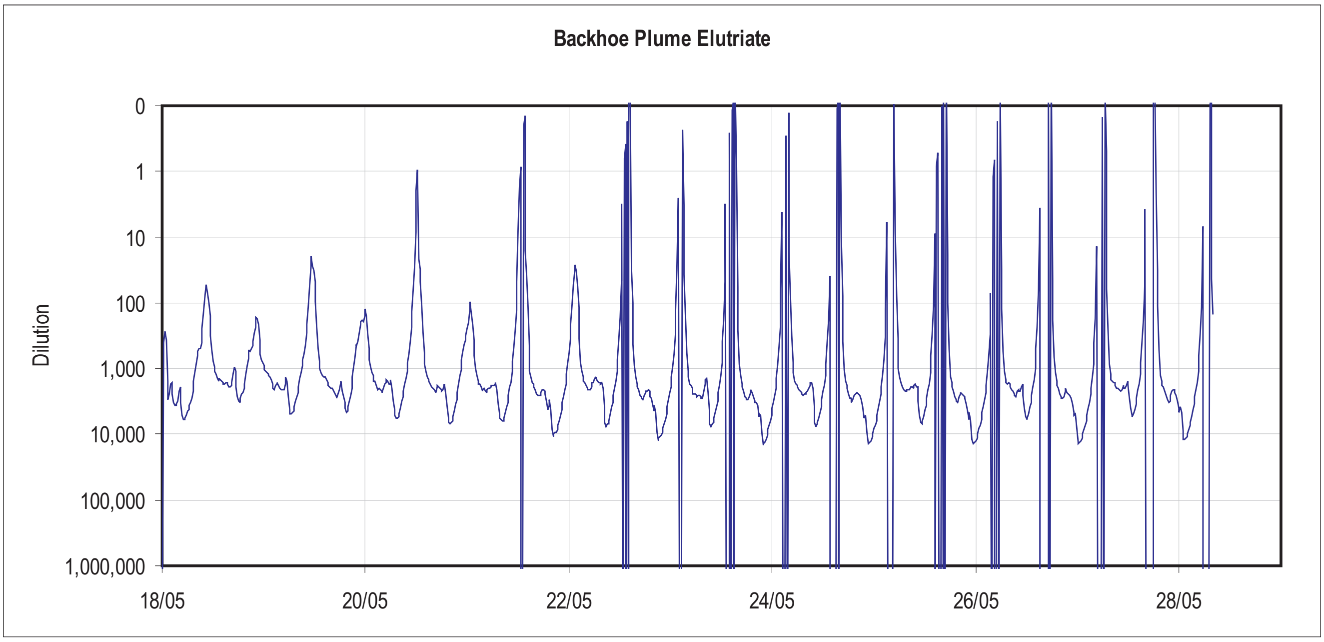
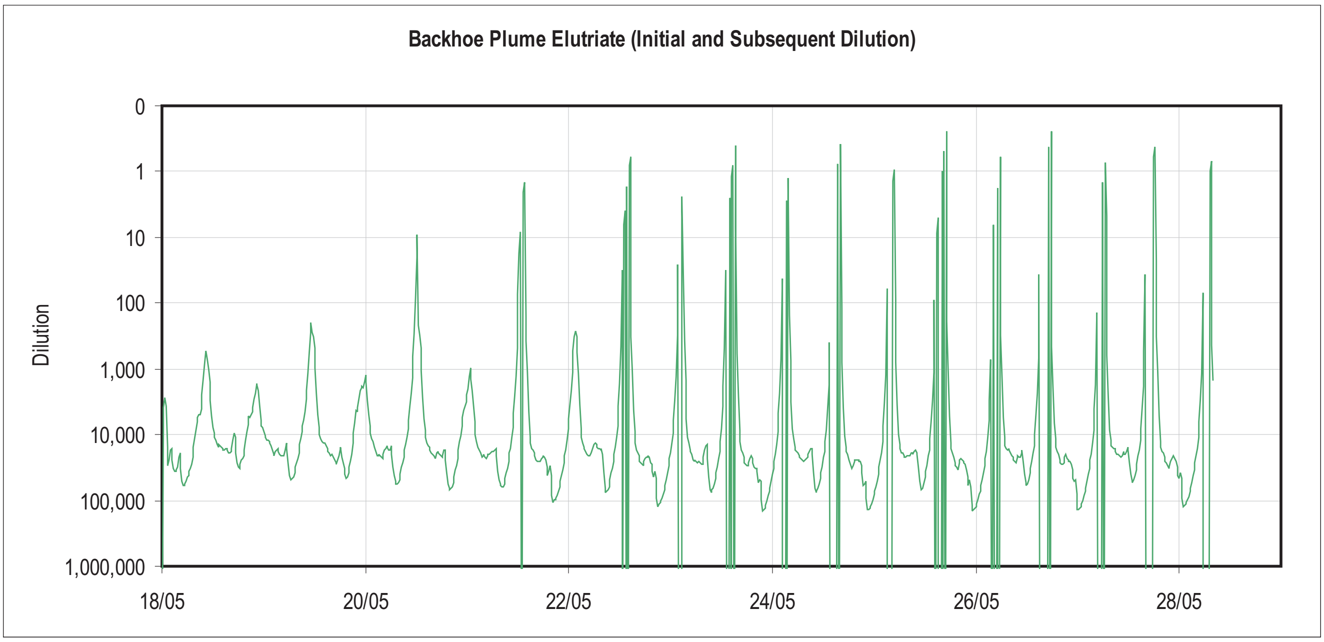
	Date: 22/07/09	Revision: 0	





Source:
BMT WBM Pty Ltd, 2009. Unpublished Draft Report to QGC, July 2009.

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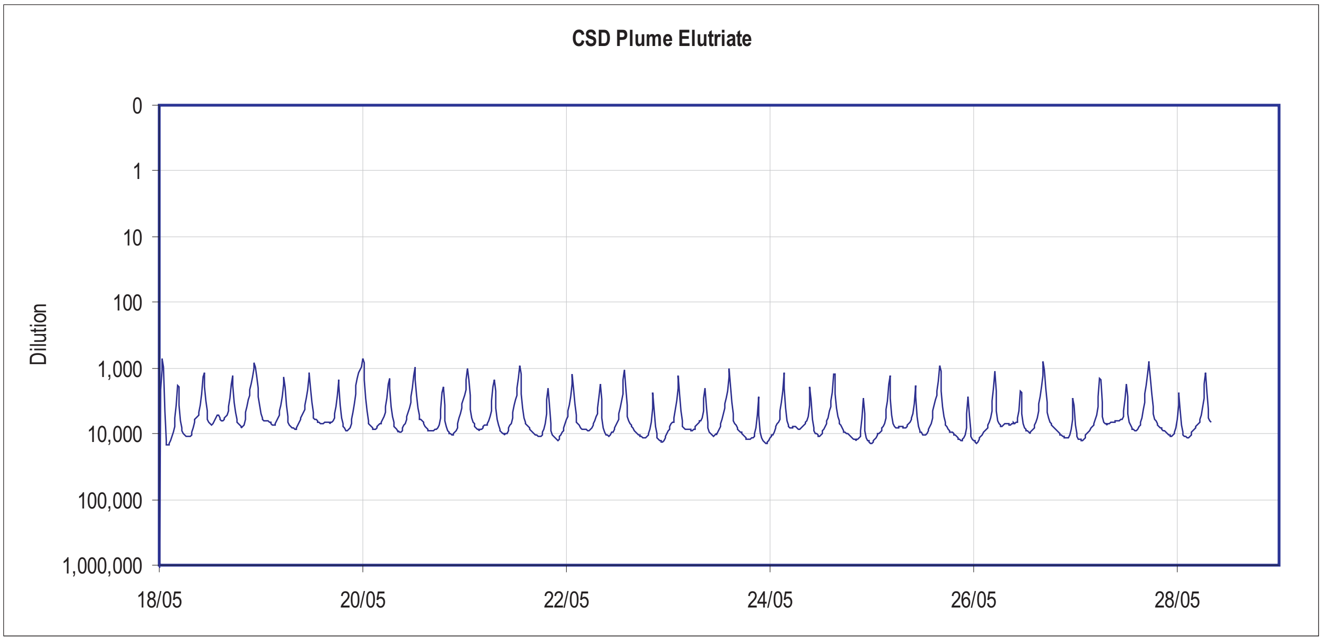
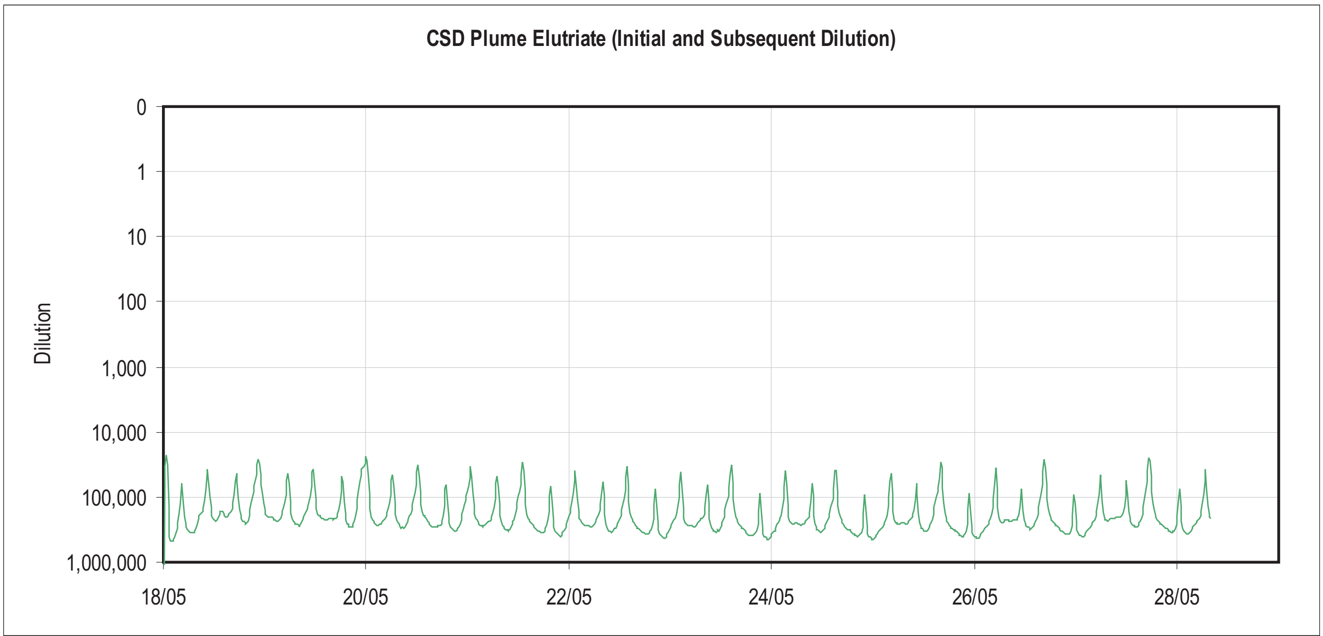
Volume 6	Figure 6.1.14
File No:	0086165b_EIS_DR_CDR004_F6.1.14
Revision	0

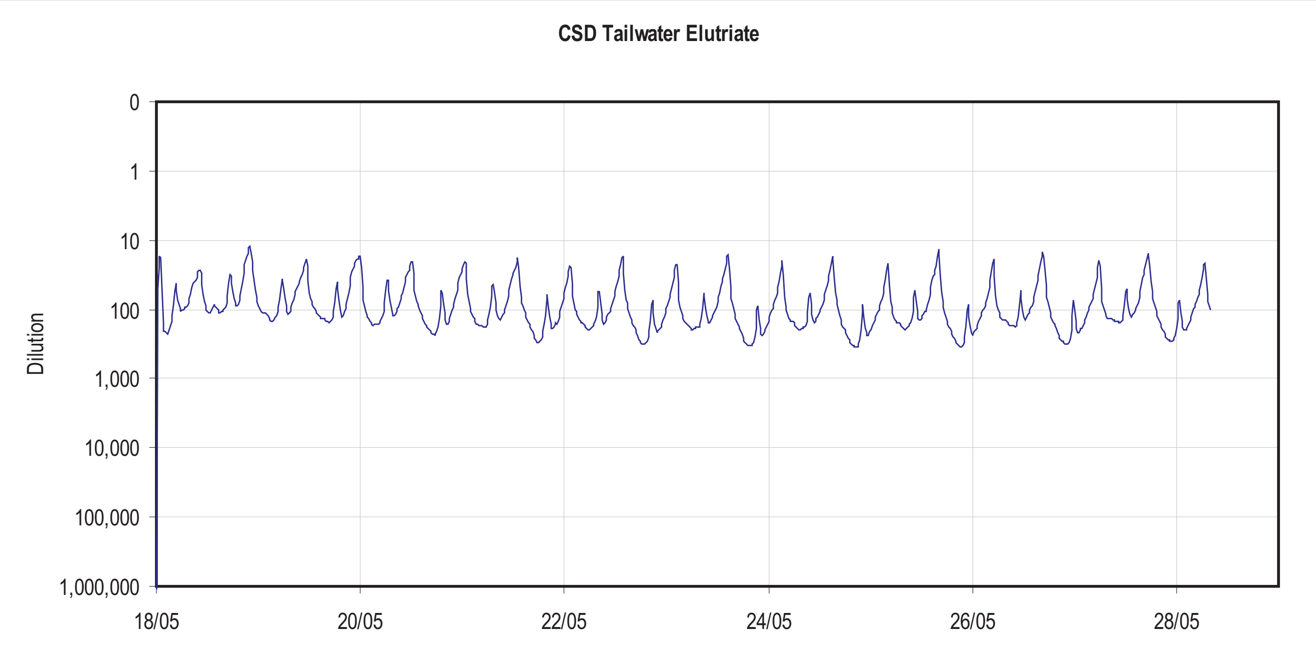
Title **Dilution of Backhoe Plumes, at the Release Site and in four-hour ‘Initial Dilution’ Period**

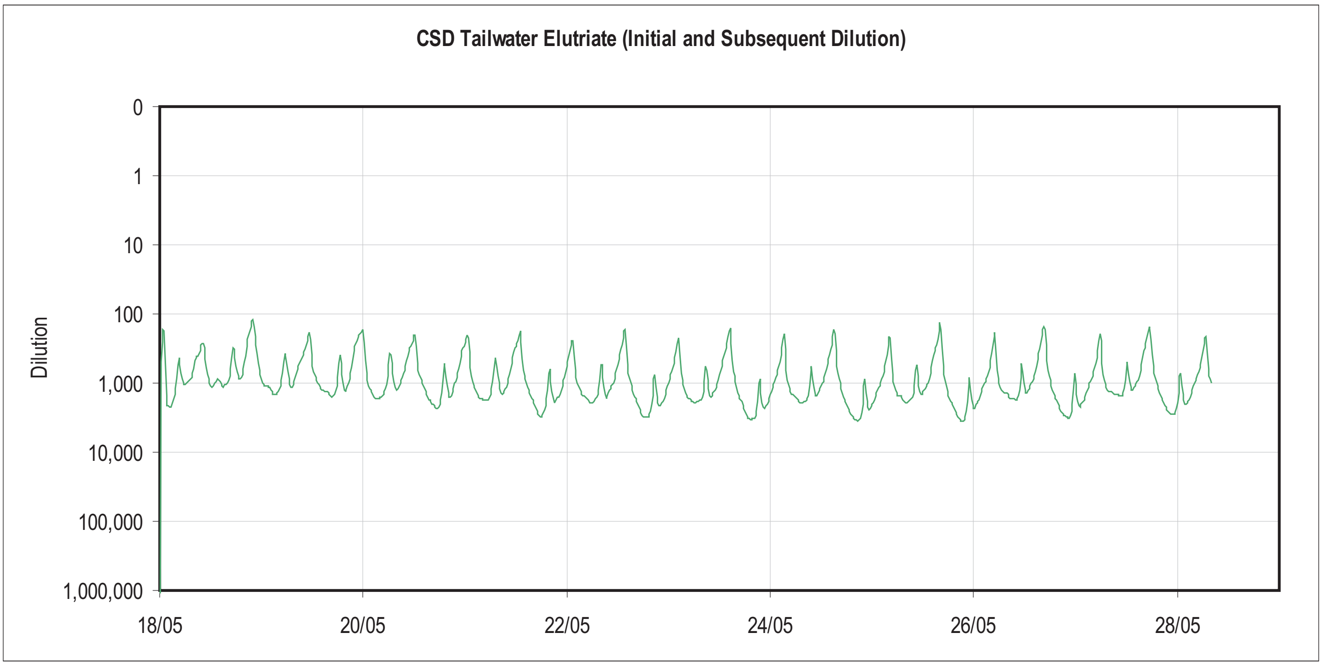




Source:
BMT WBM Pty Ltd, 2009. Unpublished Draft Report to QGC, July 2009.

QUEENSLAND CURTIS LNG A BG Group business	Project: Queensland Curtis LNG Project Client: QGC - A BG Group business	Title: **Dilution of Cutter Suction Dredge Cutterhead Plumes at the Release Site and in a four-hour 'Initial Dilution' Period**
ERM Environmental Resources Management Australia Pty Ltd	Drawn: JB Approved: BK Date: 22/07/09	Volume 6 — Figure 6.1.15 File No: 0086165b_EIS_DR_CDR005_F6.1.15 Revision: 0





Source:
BMT WBM Pty Ltd, 2009. Unpublished Draft Report to QGC, July 2009.

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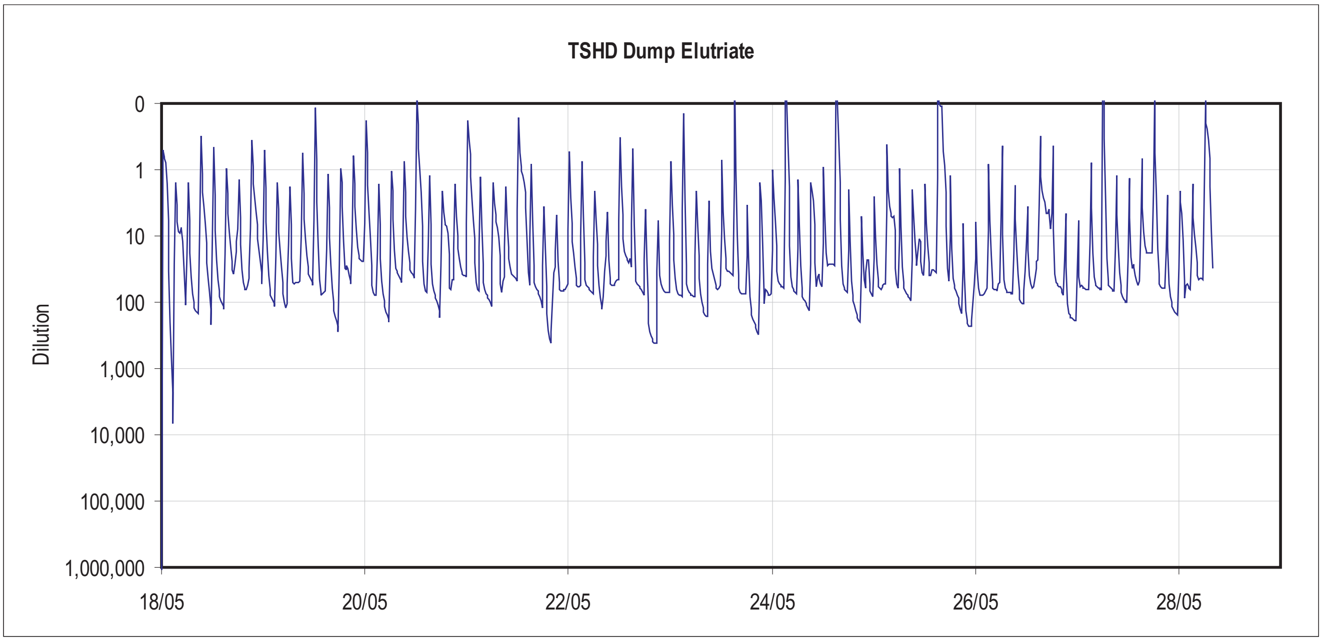
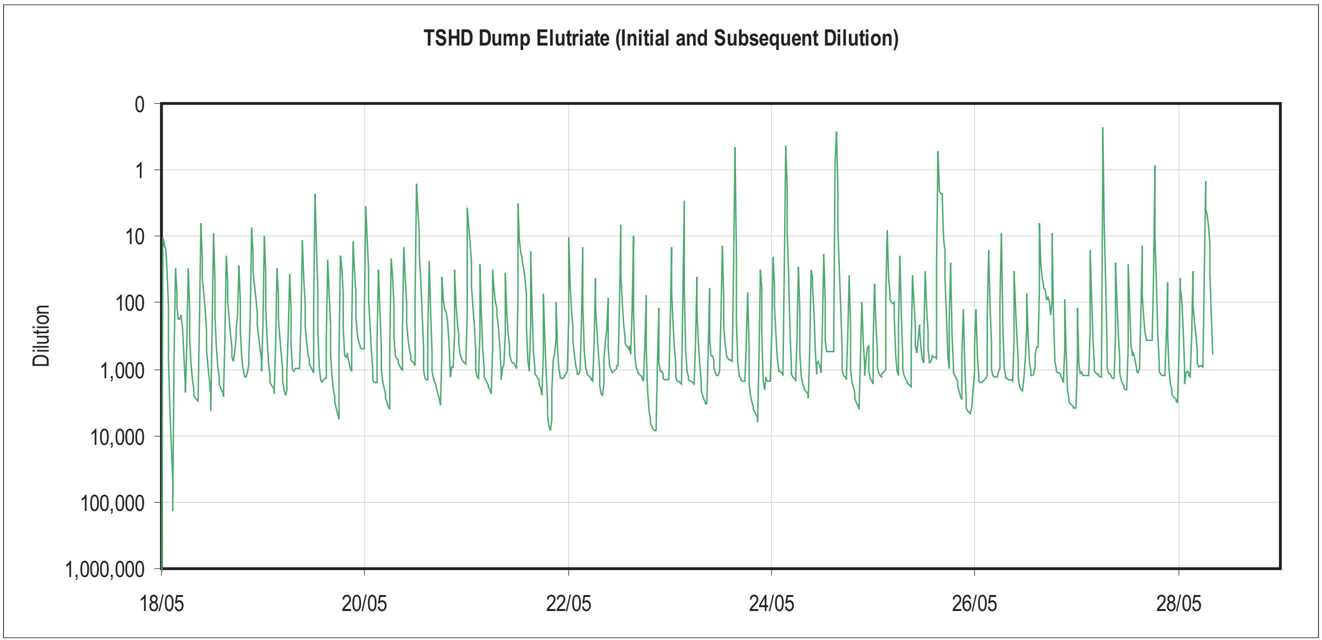
Project	Queensland Curtis LNG Project		
Client	QGC - A BG Group business		
Drawn	JB	Volume 6	Figure 6.1.16
Approved	BK	File No:	0086165b_EIS_DR_CDR006_F6.1.16
Date	22/07/09	Revision	0

Title **Dilution of Cutter Suction Dredge Tailwater Plumes at the Release Site and in a four-hour 'Initial Dilution' Period**





Source:
BMT WBM Pty Ltd, 2009. Unpublished Draft Report to QGC, July 2009.

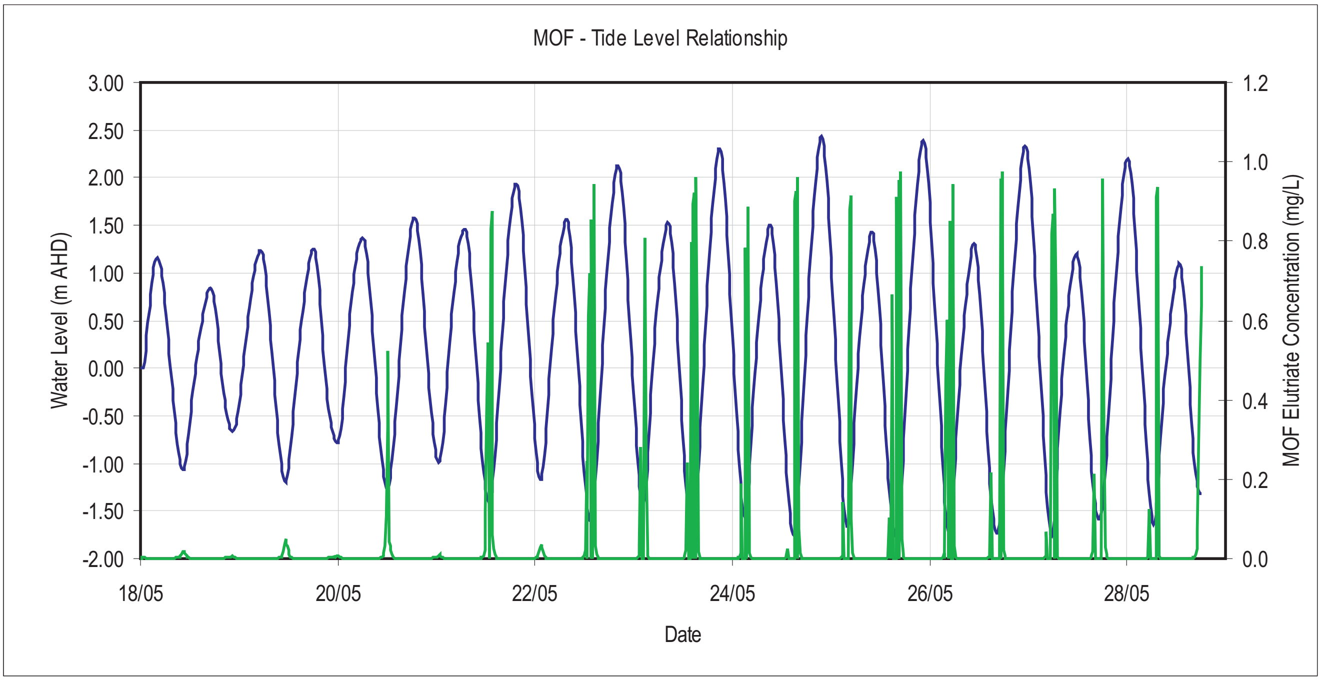
QUEENSLAND CURTIS LNG A BG Group business	Project: Queensland Curtis LNG Project Client: QGC - A BG Group business	Title: **Dilution of Trailer Suction Hopper Dredge Discharge Plumes at the Release Site and in a four-hour 'Initial Dilution' Period**
ERM Environmental Resources Management Australia Pty Ltd	Drawn: JB — **Volume 6** — **Figure 6.1.17** Approved: BK — File No: 0086165b_EIS_DR_CDR007_F6.1.17 Date: 22/07/09 — Revision: 0	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.

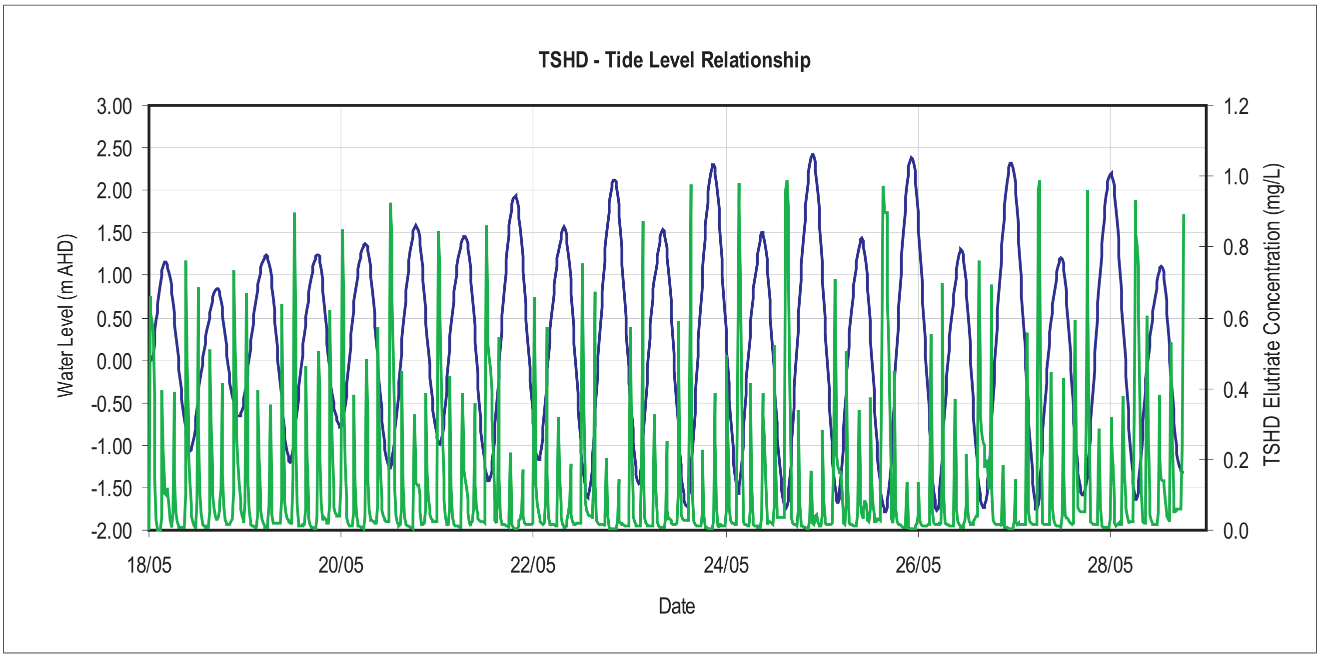
It is important to demonstrate an ability to manage dredging operations in such a way that turbid plume formation does not exceed critical ecological thresholds. QGC has initiated a number of studies which may be utilized as part of a detailed monitoring program for benthic primary producers[45]. As an early part of this, BMT WBM's Initial Dilution modelling has been extended to identify conditions under which the highest intensity plumes are generated. These are shown for MOF dredging and for TSHD rehandling in *Figure 6.1.18.* Maximum plume intensity occurs approximately 60 minutes to 90 minutes either side of low water. This suggests an operational mechanism (reduced effort at periods of low water) which would reduce plume intensity in the vicinity of the dredge. MOF modelling implies this approach is not necessary in neap tides, but TSHD modelling suggests the operational control is required for both neap and spring tides.

In another study in progress, BMT WBM has been monitoring the cutter head plumes of the CSD *Wombat*, currently undertaking a capital dredging campaign at the southern end of the Fisherman's Landing swing basin. *Figure 6.1.19* shows a series of monitoring transects perpendicular to the flow of a flood tide, and extending equally beyond the dredge plume. Sections A and B show relatively high plume concentrations near the surface and seabed, extending down-current to approximately 200 m of the operating dredge. Plumes at 300 m and 400 m down-current have dissipated considerably and occur predominantly in the upper layer. Unlike fixed nephelometer deployments, these measurements represent suspended solids and provide a visualisation of lateral dispersal, and can be integrated to yield fluxes across the cross-section of a plume. When matched with knowledge of relationships between suspended solids loads and turbidity, these datasets become a key input to the calibration of models that examine plume dispersion and light attenuation for benthic primary producer communities.

The relationship between turbidity and suspended solids has been examined for CSD dredging in the Fisherman's Landing area in *Figure 6.1.20.* Contrary to anecdotal observations that there is a poor relationship between the two, these data show a strong underlying relationship which can be used to predict turbidity from suspended solids levels. The dataset also reveals fundamental differences between 'natural' turbidity and that generated by the CSD. Data points from the dredge plume lie above the line of best fit, consistent with the dredge having disturbed a larger class of particle sizes that would be present in a 'natural' plume of similar intensity.

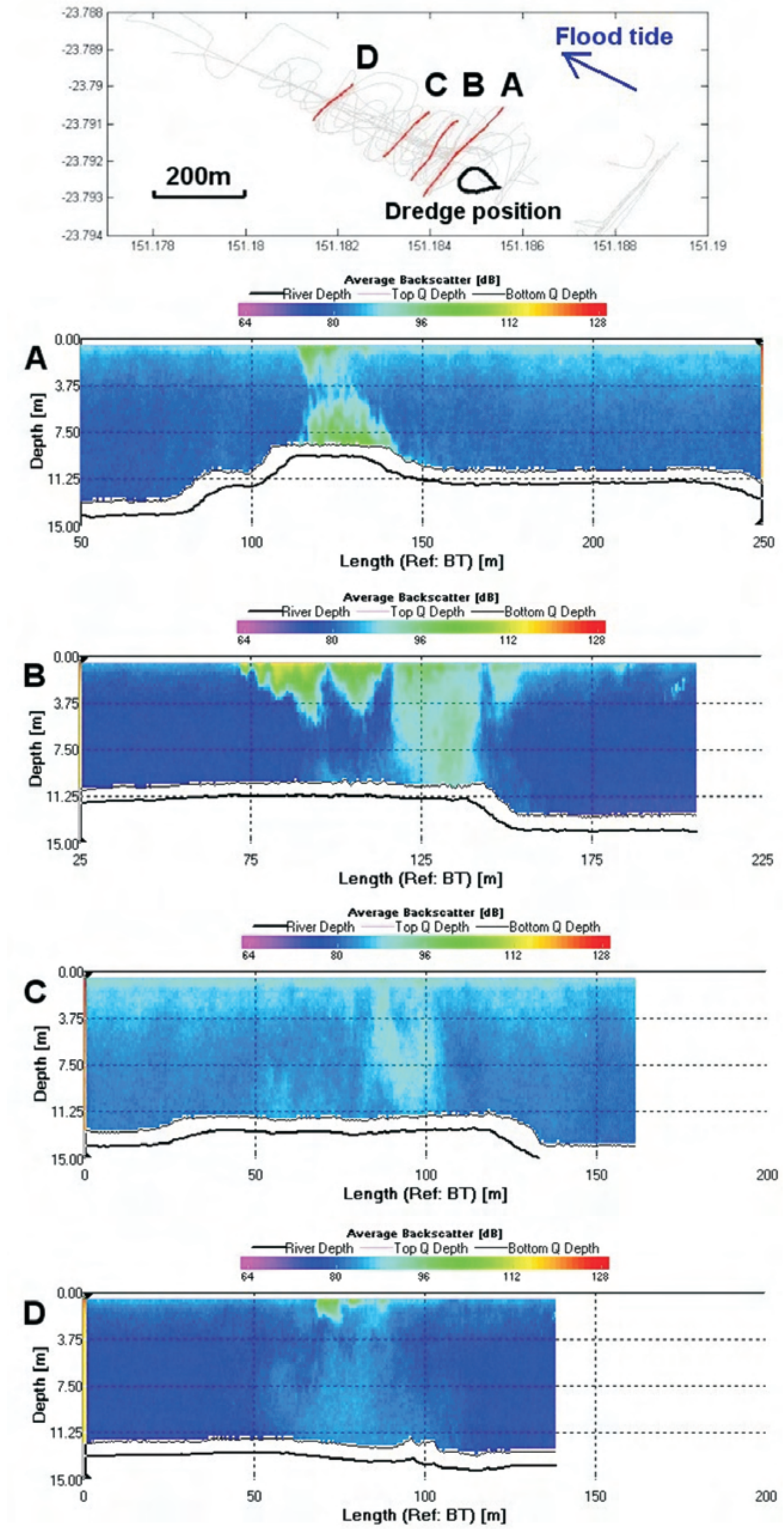
45 Whether port-wide, an expansion of existing programs, or via PCIMP.





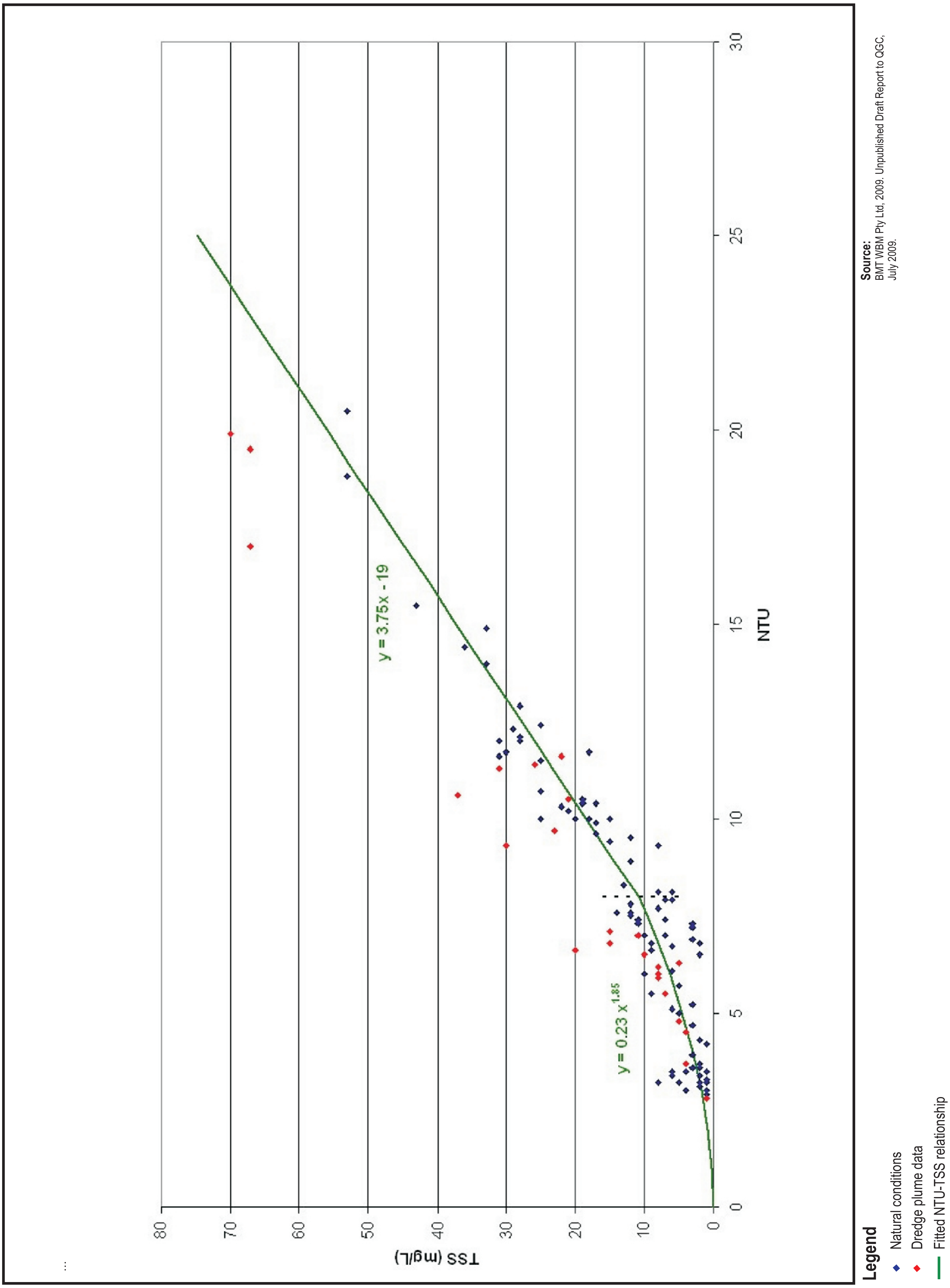
Source:
BMT WBM Pty Ltd, 2009. Unpublished Draft Report to QGC, July 2009.

QUEENSLAND CURTIS LNG A BG Group business	Project	Queensland Curtis LNG Project	Title **Relationship between Tidal Height and Plume Concentrations for Backhoe Dredge Operating in MOF Area and TSHD Dumping at Fisherman's Landing**
	Client	QGC - A BG Group business	
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB	**Volume 6** **Figure 6.1.18**	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved BK	File No: 0086165b_EIS_DR_CDR008_F6.1.18	
	Date 22/07/09	Revision 0	



Source:
BMT WBM Pty Ltd, 2009. Unpublished Draft Report to QGC, July 2009.

QUEENSLAND CURTIS LNG A BG Group business	Project: Queensland Curtis LNG Project Client: QGC - A BG Group business		Title: **Acoustic Doppler Current Profiler Backscatter Imaging of Dredging Plumes from CSD *Wombat***
ERM Environmental Resources Management Australia Pty Ltd	Drawn: JB Approved: BK Date: 22/07/09	**Volume 6** **Figure 6.1.19** File No: 0086165b_EIS_DR_CDR001_F6.1.19 Revision 0	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.



QUEENSLAND CURTIS LNG A BG Group business	Project: Queensland Curtis LNG Project Client: QGC - A BG Group business		Title: **Relationship between Suspended Sediments (TSS mg/L) and Turbidity (Nephelometric Turbidity Units) for Natural and Dredged Waters of Port Curtis**
ERM Environmental Resources Management Australia Pty Ltd	Drawn: JB Approved: BK Date: 22/07/09	**Volume 6** **Figure 6.1.20** File No: 0086165b_EIS_DR_CDR002_F6.1.20 Revision 0	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.

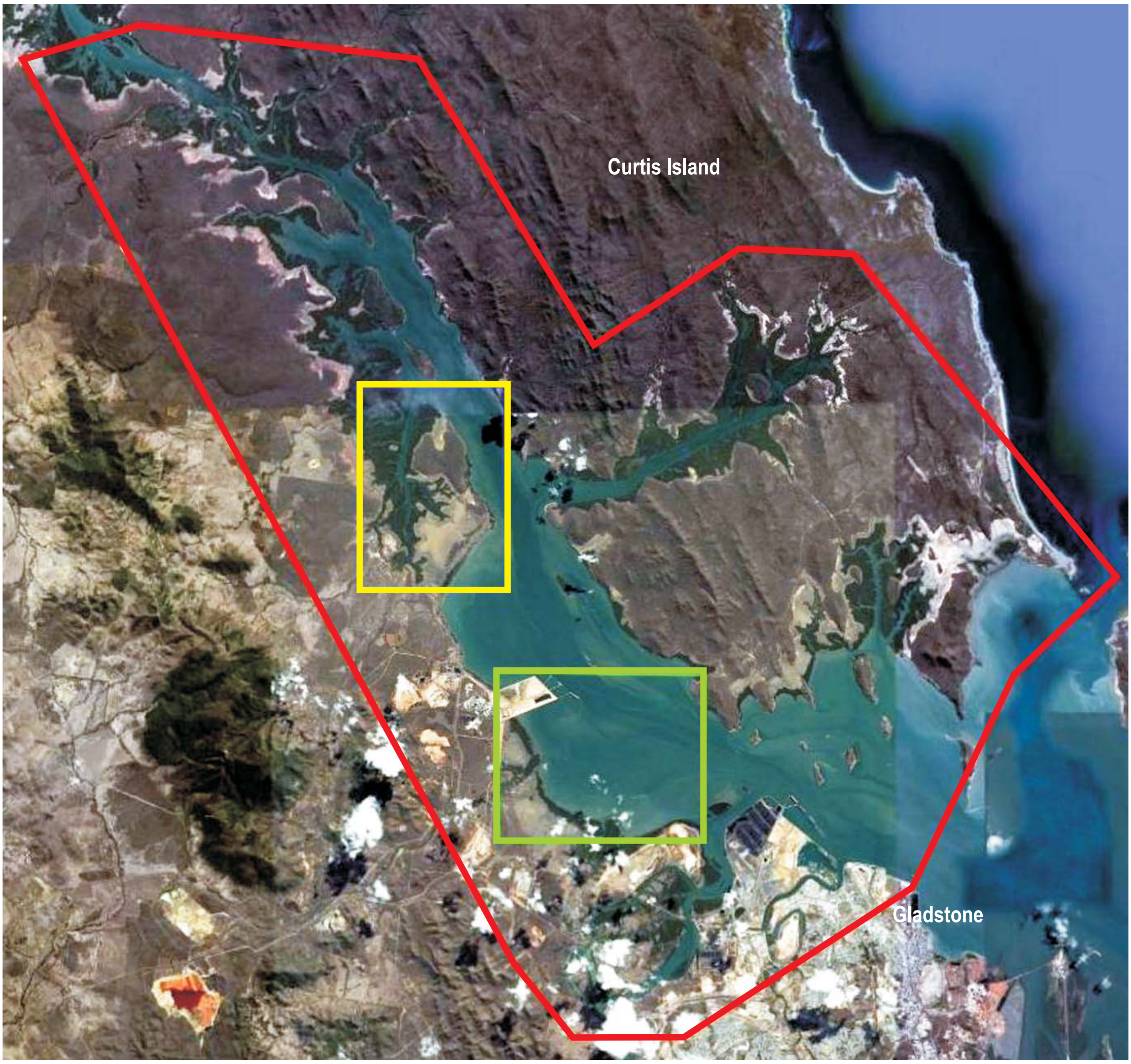
In another study, QGC is investigating the utility of an airborne multi-spectral scanner for rapid assessment of habitat quality. This method utilized a pixel size of 0.5 m to permit accurate mapping, and is believed to have utility for the monitoring of both mangrove and seagrass community health.

Figure 6.1.21 shows a portion of The Narrows and Western Basin area surveyed by an airborne scanner in May 2009. Preliminary results are shown in *Figure 6.1.22* which depicts the 'training area' in natural colour, false-colour enhancement based on chlorophylls, and machine-classified into community types. A similar training area has been established for intertidal seagrasses, and while May is an inappropriate time to judge maximum season abundances, the purpose of the method is to permit rapid assessment of relative changes in condition from one area of Port Curtis to another.

These preliminary data sets provide confidence that a well structured investigative program can generate a series of rule-based management controls that will allow model predictions to be verified, and plumes to be managed. This will enable a responsive, performance-based management plan to detect potential significant increases in stress levels among primary producers.

Planned mitigation strategies include a hierarchical escalation of notification and increased surveillance, recommendations on modified dredging practices, and mandatory intervention in dredging methods. Operational controls, to be implemented only in response to exceedance of agreed warning thresholds, include measures such as:

- reducing the duration of overflow dredging
- relocating an overflowing dredge to portions of the dredge footprint where plume generation is less of a problem (coarser materials, consolidated clays etc, better flushing, weaker currents)
- programming routine maintenance down-time into high risk periods
- adjusting flow rates, cutter speeds, swing speeds etc to optimize loads
- silt curtains (for intertidal BHD works)
- flow-control in reclamation area weir boxes
- if necessary, temporary stoppages.



Legend

- Study Area
- Mangrove Classification Training Area
- Seagrass Imagery Sample Area

Source:
ERM, unpublished Report to QGC, July 2009.

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Project	Queensland Curtis LNG Project		
Client	QGC - A BG Group business		
Drawn	JB	Volume 6	Figure 6.1.21
Approved	BK	File No:	0086165b_EIS_DR_CDR009_F6.1.21
Date	22/07/09	Revision	0

Title **Multispectral Scanner Habitat Mapping for Marine Vegetation - Study Area**

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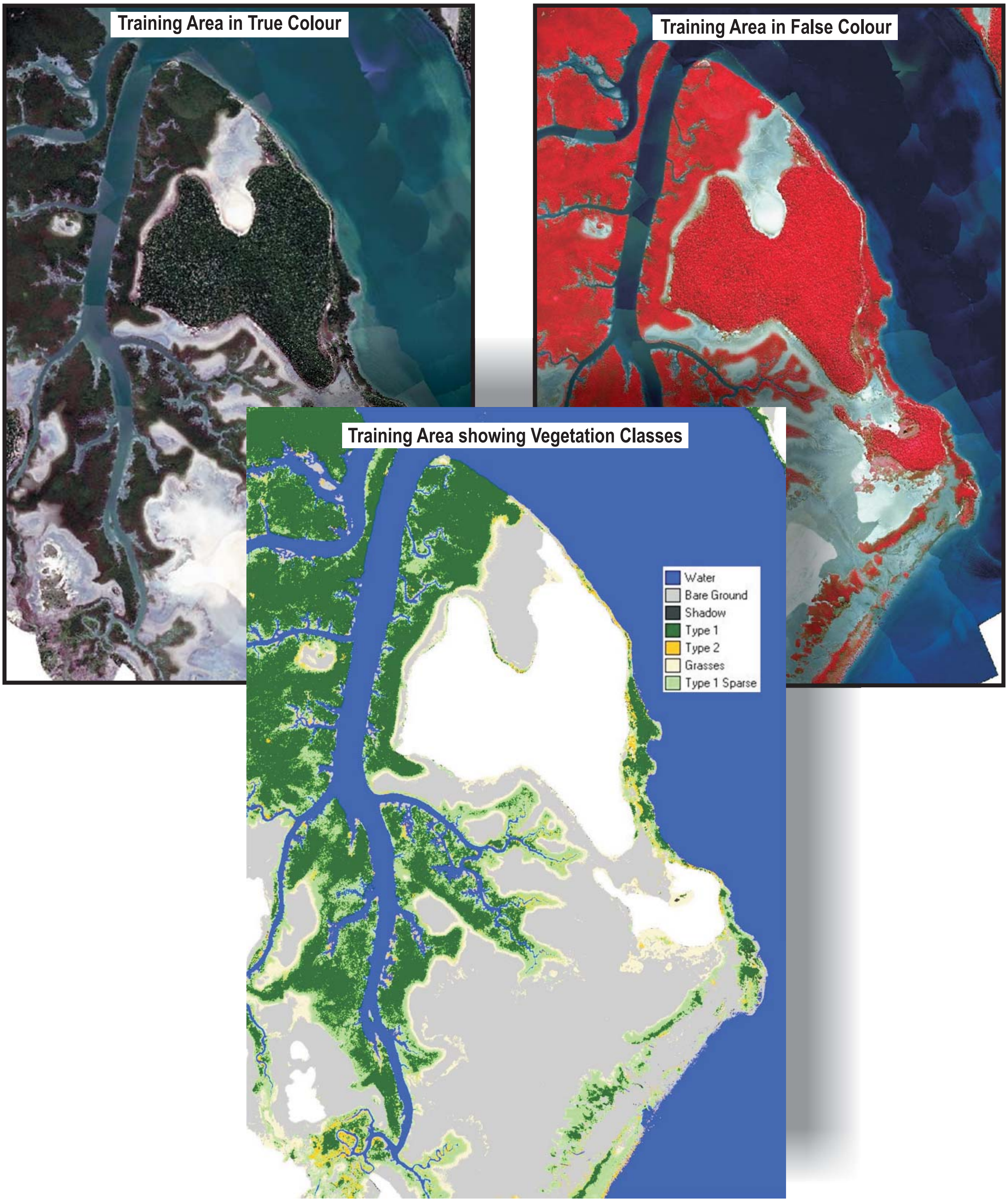

Source:
ERM, unpublished Report to QGC, July 2009.

QUEENSLAND CURTIS LNG
A BG Group business

Project	Queensland Curtis LNG Project	Title	**Habitat Classification Based on Multispectral Scanner Methods**
Client	QGC - A BG Group business		
Drawn JB	**Volume 6**	**Figure 6.1.22**	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
Approved BK	File No:	0086165b_EIS_DR_CDR010_F6.1.22	
Date 22/07/09	Revision 0		

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1.4.2.6 *Level of Risk*

It is highly probable that short periods of relatively high rates of sediment mobilisation might occur at various times and locations (e.g. when silts are encountered), which in turn will have varying impacts on water quality conditions dependent on location, tidal state and current velocities.

Benthic communities in dredged areas of the channel and swing basin footprints will be heavily impacted.

However, large dredging programs are routinely conducted in sensitive habitats[46], and fundamental approaches to monitoring and management controls for adjacent communities are well established. These controls need to be 'localized', but it is unlikely that novel methods will need to be developed to permit effective dredge management.

QGC will continue to develop a Dredging EMP in consultation with GPC.

Managed in such a manner, risks of unacceptable impacts are considered to be low.

1.4.2.7 *Cumulative Impact Scenario*

Reclamation

QGC's 'cumulative impact scenario' (*Volume 2 Chapter 14*) describes a situation where GPC's referrals for FL153 and the WBSDD Project may lead to development of the Fisherman's Landing area for other projects, independently or ahead of QCLNG's Project. In this case, reclamation associated with the QCLNG Project will have no incremental impact beyond those associated with the FL153 and WBSDD projects.

If all 'cumulative impact scenario' projects (WICT, GLNG, GPC Stage 1b and QCLNG) were to proceed in a similar period, there would be no incremental increase in reclamation area, as the land area required is governed largely by the area required for dewatering of dredged spoil .

Dredging

QGC's 'cumulative impact scenario' describes a possible scenario where WICT, GLNG and GPC's Stage 1b dredging are all conducted in a similar timeframe, either sequentially or in parallel. GPC is examining these and subsequent stages of WBSDD development.

Other than the cumulative effect of bathymetric changes from WICT, GLNG

46 Port of Townsville (Benson LJ, PM Goldsworthy, IR Butler and J Oliver (Eds), Townsville Port Authority Capital Dredging Works 1993: Environmental Monitoring Program. Townsville Port Authority, Townsville); Hay Point (http://www.gbrmpa.gov.au/corp_site/management/eim/project_examples/hay_point accessed 4 August 2009), with reference to "Project Outcomes" section; Port of Karumba (Karumba Dredging 1996 Environmental Monitoring Report. EcoPorts Monograph series No. 6 March 1997 : editors S. Hillman and S Raaymakers)

and Stage 1b dredging, which may produce minor differences in water velocities, levels and tidal ranges, the greatest significance of the QGC cumulative scenario is that dredging may increase to approximately 30 million m^3 rather than the approximately 13.5 million m^3 of QCLNG Project-related dredging.

Other than quantitatively, there is relatively little difference between the additional 'cumulative' dredging and QGC's dredging:

- QGC's Marine Sediment Study has included geochemical sampling in all 'cumulative' stages. QGC has overseen the preparation of stratigraphic interpretations for the entire Western Basin. While formal reporting of that work will be handled by GPC, a preliminary examination of the data suggests that soil characteristics are very similar.
- QGC's dredging extends from Clinton Bypass, through parts of Targinie Channel destined to absorbed into the WICT swing basin, and through the entire Stage 1a(i) (GLNG) channel before reaching Stage 1a(ii) (QGC). Modelling and impact assessment have therefore considered all areas of Stage 1 other than the northern half of Targinie Channel. This area is within 5 km of Fisherman's Landing and it is therefore possible to dredge using a CSD and hydraulic placement, a more benign method than the use of hoppers, overflow and rehandling likely to be required for the Clinton Bypass area.
- The WICT EIS[47] describes a CSD placing material hydraulically into an adjacent land disposal area, a method that is relatively simple to manage.
- Sensitive receptors in all cases will focus on benthic primary producers and the secondary impacts of their potential loss on animals such as dugong.
- All programs are of a sufficient size to warrant similar environmental controls to manage impacts to benthic primary producers.
- All programs, if conducted independently, require approximately one year of dredging, that being sufficient duration to encounter and adapt dredging strategies to the full suite of lunar, seasonal and annual variations.
- The physiological mechanisms by which impacts occur are likely to be virtually identical, and thus the nature and trigger levels for ecological thresholds are likely to be identical.
- EMP requirements, methods, and management procedures are therefore likely to require similar approaches, efficacy testing, approvals, and oversight mechanisms.
- If all four programs were to occur sequentially with a single large CSD they would take almost 4 years to complete and the maximum dredging intensity would be the same for all. If additional equipment were brought in the overall works program may be accelerated, with a proportional

47 Wiggins Island Coal Terminal, refer http://www.dip.qld.gov.au/projects/mining-and-mineral-processing/coal/wiggins-island-coal-terminal.html, accessed 4 August 2009.

increase in the maximum dredging intensity. This scenario is similar to the multiple-dredges scenarios examined by QGC.

- It therefore appears that there is relatively little to differentiate the QCLNG Project and QGC's cumulative impact scenarios, beyond just the extended timeframe over which impacts would need to be managed.

1.4.3 Habitat Loss

1.4.3.1 Sources and Characteristics

Habitat loss can be expected during dredging and reclamation. Much of this will be temporary as disturbed intertidal and subtidal habitats become re-colonised by marine biota following the completion of dredging activities and as water quality conditions return to normal enabling impacted alga, seagrass and epifauna to re-establish within their normal previous distribution ranges.

Permanent habitat loss can be expected, primarily in relation to the planned reclamation activities, but also through the clearing of fringing coastal vegetation and the installation of permanent structures such as navigation markers, the MOF and product loading facilities. The installation of such structures is likely to provide partial habitat offsets, although the faunal communities which might benefit from these new surfaces are likely to different species than those affected by the preceding habitat losses.

1.4.3.2 Extent of Impacts

The area north of Fisherman's Landing is proposed for land reclamation using dredged material relocated from the Western Basin. The final extent and configuration of the reclaim area is not known, although GPC's EPBC Referral document identifies the entire Fisherman's Landing area for eventual reclamation. Four potential configuration options are present and discussed in detail in *Volume 5 Chapter 8.*

Significant areas of subtidal habitats, including seagrass meadows, intertidal mudflats and benthic macro-invertebrate communities, will be affected by the proposed shipping channel and swing basin footprints. Some of these effects will be temporary and some will be permanent.

The extent of QCLNG Project-related impacts will depend heavily on the timing and sequencing of other projects. If works described in GPC's FL153 and WBSDD Project referrals, or GLNG's Draft EIS proceed independently of the QCLNG Project, then incremental impacts of dredging and reclamation associated with QCLNG's Project will be minor.

Seagrasses

As depicted in *Volume 5 Chapter 8* substantial seagrass meadows occur in the area north of Fisherman's Landing, consisting of *Halophila* sp and *Zostera* sp assemblages[48]. Depending on which reclamation scenario is implemented, reclamation of land in this area will result in the substantial or complete loss of Fisherman's Landing seagrasses. Detailed information regarding the extent and health of these areas is not available, so it is not possible to assess the indirect impact of the loss of this area as potential dugong foraging and fish habitat. However it is possible to describe these losses in terms of regional seagrass communities.

Rasheed et al. (2003)[49] conducted the first detailed mapping of seagrass communities in Port Curtis and Rodd's Bay, extending from The Narrows Crossing in the north to Rodd's Bay in the south, and eastwards to the Port Limits. They described a total of 13 578 ha of seagrass communities, including 6 332 ha of 'deep water' seagrasses (waters deeper than 5 m below MSL). Most coastal (shallow water, less than 5 m deep at MSL) communities (68% by area) were dominated by *Zostera capricorni*. *Halodule uninervis* communities were the second most abundant (25 % by area), and a minor area of seagrass beds (7 % of the total area, or 517 ha) were dominated by *Halophila,* a known pioneer species.

Rasheed et al. (2008)[50] reported on the monitoring of 13 representative seagrass beds totalling (in 2002) 2 755 ha, resurveyed annually between 2002 and 2007. These resurveyed beds changed (sometimes markedly) in area and composition, but as a whole, varied between 82% and 92% of their 2002 size through to 2007, with the lowest total area recorded in 2004.

Table 6.1.7 below shows the amount of seagrasses likely to be lost within dredging and reclamation footprints. Given the interplay between the timing of various projects mooted for the Western Basin, and GPC's current impact assessment processes for works which would proceed with or without the QCLNG Project, it should be recognised that the described losses may occur independently of the QCLNG Project. It should be noted that there are **no** seagrasses known to exist within Curtis Spur Channel footprints, and therefore all 'Lost' seagrasses relate to the reclamation of the Fisherman's Landing area as indicated in GPC's EPBC Referral. Community types among these lost seagrasses include:

- 310 ha of the relatively common Zostera communities, representing 6 % of this type of seagrass community within Port Curtis and Rodd's Bay, and

48 Danaher K F, Rasheed M A, and Thomas R (2005). **The intertidal wetlands of Port Curtis**. Information Series QI05031. Department of Primary Industries and Fisheries, Queensland

49 Rasheed, MA, R Thomas, AJ Roelofs, KM Neil and SP Kerville, 2003 Port Curtis and Rodd's Bay Seagrass and Benthic Macro-Invertebrate Community Baseline Survey, November/December 2002. DPI Information Series QI03058 (DPI, Cairns), 47 pp.

50 Rasheed MA, SA McKenna, HA Taylor and TL Sankey, (2008). Long Term Seagrass Monitoring in Port Curtis and Rodd's Bay, Gladstone – October 2007. DPI&F Publication PR07-3271 (DPI&F, Cairns), 32 pp.

- 153 ha of the less common Halophila communities, representing 30% of this community type.

In the event that only the southern portion of Fisherman's Landing were reclaimed, these losses would reduce to approximately 3% for *Zostera* communities, but would remain near to 30% for *Halophila* communities.

Table 6.6 also shows 'at risk' seagrasses, defined here as any seagrasses within the Western Basin, south of The Narrows. The most recent published seagrass report did not remeasure the area of all seagrass beds in the Western Basin (only the six annual monitoring beds), and therefore estimates of 2007 abundance were made by pro rata adjustment of the relevant 2002 areas in the same ratio as now exists (2007 survey) for beds monitored annually since 2002.

Likewise, if only 2 755 ha of the 2002-surveyed coastal seagrasses were regularly monitored, and these had decreased to 2 499 ha in 2007, the implication is that the 7 246 ha of the total 2002 community would now be approximately 6 573 ha in size. On this basis, at least for the GPC WBSDD Project Scenario involving reclamation of the entire Fisherman's Landing area, total seagrasses lost to dredging or reclamation footprints will amount to 463 ha, or 7.0% of coastal seagrasses. 'At risk' seagrasses amount to 746 ha, or another approximately 11.3% of coastal seagrasses.

Table 6.1.7 Seagrass Habitat Losses Associated with Dredging and Reclamation

Seagrass Habitat Type	AREA (ha)	
	Lost	At Risk
Light Z. capricorni with H. ovalis	310	646
Moderate H. decipiens	153	
Moderate H. ovalis/ Z. capricorni		12
Light - moderate H. decipiens		66
Light - moderate Z. capricorni		22
Seagrass Total	**463**	**746**

Mangroves

Mangroves fringe the western shore of Port Curtis from the existing Fisherman's Landing area north to Laird Point. A large proportion, if not all, of these are likely to be lost depending on the configuration chosen for the reclamation area. The degree of mangrove removal will be dependent on the construction methods for the reclamation area.

Table 6.1.8 Mangrove Habitat Losses Associated with QCLNG Project Dredging

Mangrove	AREA (ha)	
	Lost	At Risk
Mangrove Total	**47.5**	**336**

Direct loss of mangrove habitat adjacent to the Fisherman's Landing reclamation area is estimated at approximately 45 ha (refer *Table 6.1.8*). A further 2.5 ha of mangrove stands occurring along the shoreline at the proposed QGC LNG facility site can be expected to be cleared or lost during the construction phase, though some of this is expected to be temporary as mangroves are likely to return, in time, over some of the affected area. Thus 47.5 ha or approximately 1.6 % of local mangroves (excluding mangroves north of The Narrows) are expected to be lost. A further 336 ha or 11.0 % appears at short term risk of temporary impacts associated with sedimentation following dredging activities.

Other Benthic Communities

According to the 2002 surveys of deep water (greater than 5 m) communities by Rasheed et al.[51] the Curtis Spur Channel is almost entirely occupied by a low density community comprising open substrate and a small number of benthic taxa. Approximately 122 ha of this community (refer *Table 6.1.9*) falls within the proposed channel footprint, although not all of these areas will be lost following dredging (see discussion below). Given the close proximity of this entire area to channel dredging, it is possible that dredging-related impacts will extend laterally to all areas of this community. However, the nature of impacts is likely to be minor, and may not produce a long term change in 'at risk' areas or even those directly within the channel footprint. The majority of the area is open sand and mud substrates. Rasheed et al. describe this same community as already occurring in portions of the turning basin for the Clinton wharves and the southern half of Targinie Channel, and therefore it is considered likely that this community will recover and co-exist with ongoing shipping operations.

The entire medium density rubble reef region in the Western Basin lies in the main channel running to the west of the Passage islands. This is far enough from QCLNG Project dredging operations to reduce the risk of smothering, and current velocities are frequently strong enough to remove finer sedimentation. These areas are therefore not at risk from the QCLNG Project.

High density scallop and rubble reef exists within the broader Targinie Channel and south as afar as South Trees Island. Clinton Bypass lies within this area. The natural seabed level in approximately one quarter of this area is already deeper than required, and will not need any dredging. Given that

51 Rasheed MA, R Thomas, AJ Roeleofs KM Neil and SP Kerville (2003). Port Curtis and Rodds Bay seagrass and benthic macroinvertebrate community baseline survey, November/December 2002. QDPI Information Series QI03058 (DPI, Cairns)

these communities have co-existed with shipping, it is expected that they will continue to co-exist in these areas. High density rubble reef communities will be lost for dredged areas (up to approximately 45 ha). Sedimentation impacts may extend into the immediate area surrounding zone, potentially affecting a similar area. However the very high water currents in this area are considered likely to quickly remove any loose sediments, and that communities will recover within several years.

Table 6.1.9 Deep Water Benthic Communities Losses Associated with Dredging

Deep water (> 5 m MSL) Communities	AREA (ha)		
	Lost	**At Risk**	**Total**
Low density, open substrate, varied taxa	Up to 122	186	308
Medium density rubble reef, bivalves, ascidians, bryozoans, hard coral	0	0	440
High density scallop/rubble reef dominated by bivalves with mix of reef taxa	Up to 45	45	738

Benthic communities in shallower parts of the Western Basin may experience changes in depth of up to 13 m, with some areas presently identified as intertidal zones likely to become shipping channels (portions of the eastern margin of the QCLNG swing basin and MOF access channel) with a final depth of -13 m LAT. Such changes will permanently change the community structure and trophic pathways of benthic communities inhabiting these locations.

1.4.3.3 Description of Impacts

Habitat loss impacts will occur as a result of the removal of seabed sediments which provide a substrate and nutrients for infauna, epifauna and marine flora. The sediments which are mobilised into the water column from this same process may then impact on marine habitats otherwise removed from the dredging locations through changes to water quality and subsequent settlement downstream from the dredge location. Clearing of coastal fringe vegetation will be required and represents a direct impact to these habitats while adjacent intertidal habitats are likely to be affected by subsequent changes to existing biological and geochemical processes which are supported by fringing vegetation types.

1.4.3.4 Receptors Affected

Seagrasses are known to be susceptible to water quality changes including increased light attenuation (shading, which reduces photosynthesis and productivity), changes to the water temperatures in shallow embayments as a result of increased turbidity and subsequent heat absorption, and by smothering following sediment settling (sedimentation). Direct impacts to seagrasses are anticipated only in dredging or reclamation footprints. The absence of seagrasses in dredging footprints means that direct impacts will be limited to the reclamation area. Additional modelling is required to identify the extent of secondary light-related impacts to 'at-risk' seagrass beds.

Mangroves are likely to be impacted directly through clearing, changes to hydrodynamics regimes as a result of changes to seabed profiles and through the installation of reclamation bunds which will create barriers to tidal movement or overland water flows. Sediment erosion and deposition patterns are also likely to be affected as a result of the physical changes to seabed and shoreline profiles and subsequent tidal flows. Direct impacts to mangroves from swing basin and channel construction will occur only in relation to reclamation for placement of dredged material, and for construction of MOF access. The potential for secondary impacts related to sedimentation will be examined in a subsequent phase of modelling.

Mangrove and seagrass habitats are of key importance to many fish and invertebrate communities as they provide feeding, breeding and nursery grounds for animals such as dugongs, turtles, fish, crabs and prawns. Impacts to these secondary receptors, including impacts on regional populations, will be examined in greater detail when light-related modelling work is undertaken.

1.4.3.5 Management and Mitigation Measures

The most significant impacts from development of the QCLNG Project Swing Basin and Channel will potentially be on aspects of marine ecology.

Final layouts and design of shoreline facilities will, among other things, take into consideration the loss of important habitats to ensure clearing and direct permanent impacts are minimised. This may include the design of the MOF, product loading facilities and reclamation areas such that sections of fringing mangroves are not cleared and that tidal access and flooding regimes are maintained as best as possible. Reclamation designs need to be optimised to limit the losses of regionally significant seagrass beds. This exercise should be preceded by an examination of the significance of *Halophila*-dominated seagrass beds, 30 % of which would be lost by full reclamation of the Fisherman's Landing area.

Given that the last synoptic assessment of seagrasses in the Western Basin occurred in 2002, further seagrass surveys are required to better define the current nature and extent of 'at risk' seagrass communities.

Reclamation of areas north of Fisherman's Landing may involve the removal of some areas of coastal vegetation. Further modelling will also be required to test the likely impacts to hydrodynamics regimes as a result of changes to seabed and shoreline profiles. Sediment transport, erosion and deposition models may also assist in accurately predicting the affects of the planned works in terms of anticipated impacts to mangrove and seagrass distribution across the broader port area.

As disposal of dredge material taken for the development of the Swing Basin and Channel is likely to be within either the FL 153 development or WBSDD development the assessment of impacts on terrestrial ecology is more appropriately discussed in the EISs for those projects.

Close monitoring of sediment mobilisation and dredge plume dispersion is likely to be required to ensure any increases in turbidity do not exceed levels which might have an adverse impact on resident benthic communities in the harbour. Operational controls may be built into dredge management planning to ensure that scheduling can be managed in response to unacceptable increases in turbidity, such as cessation of operations, or movement of dredge vessels to alternative locations within the Port.

Silt curtains, often used to mitigate the effects of suspended sediments in low energy environments, are not appropriate throughout most of the swing basin and channel construction site and reclamation area, where currents regularly exceed 0.5 m/sec. However, silt curtains may be feasible in nearshore areas potentially affected by MOF access construction, where water velocities are much lower. QGC is examining the potential use of silt curtains in these areas, either around the operating dredge equipment, or deployed at sensitive receptors such as the nearshore seagrass beds identified on the Curtis Island coastline adjacent to the QGC site by Rasheed et al., 2003. Additional information from these investigations may be incorporated in detailed EMPs currently being considered and ultimately dependent on dredging techniques approved.

QGC is currently undertaking a mangrove mapping study using multispectral techniques in order to provide a quantifiable baseline and enable accurate change detection over the lifetime of the dredging works and LNG facility operations. Preliminary results of this study are encouraging both in terms of classifying and quantifying the extent of mangrove community sub-types and in terms of mangrove coverage and health indicators. The mapping has been undertaken using imagery with a digital resolution of 0.5 m per pixel which enables the identification and registration of individual trees if required and will provide a powerful tool for ongoing monitoring efforts. *Figure 6.1.21* and *Figure 6.1.22* provide examples of the results from this study.

Multispectral analysis of subtidal vegetation including seagrass, macroalgae and algal mats is not as straight forward as it is for terrestrial vegetation, however a similar study is being undertaken to determine the feasibility of using multi-spectral techniques to map the intertidal and shallow subtidal seagrass communities in Port Curtis. Preliminary results from this study are encouraging because they suggest a method which could yield a useful automated classification with high spatial resolution, with a rapid (several day) turn-around from data request to interpretation. Further work would be required to confirm the utility and efficacy of this or alternative ‘rapid response’ habitat survey techniques in the waters of Port Curtis.

Management and mitigation controls will be implemented in relation to sediment relocation activities and reclamation pond overflows to minimise the risk associated with remobilisation or suspension of dredge sediments at the relocation point. These controls may include:

- The assessment, optimisation and close management of overflow rates for trailer hopper barges and subsequent scheduling of discharge frequencies to minimise the potential impacts to water turbidity.
- Where dredged sediments are relatively consolidated the relocation of dredge material from hopper barges may occur through “bottom-dumping” into accessible reclamation areas.
- Where dredged material is highly mobile or unconsolidated, this material may be relocated into enclosed reclamation ponds by pumping via sediment transport hoses.

1.4.3.6 *Level of Risk*

While it cannot be quantified at this stage, it is highly likely that significant local impacts will be experienced by mangroves, seagrass, dugong, fish and invertebrate populations present in the port as a result of habitat loss at the proposed reclamation area. These matters are being examined in a broader regional context by impact assessment studies currently being undertaken by GPC, which consider the possible contemporaneous development of several projects within the Western Basin.

While these changes might be significant in terms of local species composition, the impact to benthic productivity and species abundance cannot yet be determined. When considered at the scale of the entire Western Basin, the impact of these changes on benthic populations is likely to be ameliorated, but may still be regionally significant.

It is expected that GPC’s EIS process will examine the range of alternatives which might reduce the risk of habitat loss and its secondary impacts.

Risk mitigation methods will be documented in a Dredging EMP to be developed and agreed in consultation with regulators and proponents of contemporaneous dredging projects. This EMP is likely to include an hierarchical sequence of surveillance and management responses to predicted impacts, and to include surveillance techniques and contingency planning to ensure that any unforeseen effects are detected and appropriately responded to. Further detail on this Dredging EMP is included in *Section 1.5*.

1.4.3.7 *Cumulative Impact Scenario*

Reclamation

The key element of habitat loss relates to seagrass communities lost as a result of the proposed Fisherman’s Landing reclamation footprint. Given GPC’s planned FL153 and WBSDD projects, the QCLNG Project represents no incremental losses due to reclamation.

Similarly, if the QCLNG Project were approved first and were followed sequentially by the WICT, GLNG and GPC Stage 1b works, the cumulative requirement for reclamation areas (for dewatering and placement of dredged material) would be no different. In other words, the area required for reclamation and dewatering, governed largely by dewatering pond sizes, is the same, whether for the QCLNG Project alone, or for all stages within the QCLNG cumulative impact scenario.

Dredging

The primary difference between QCLNG Project-related dredging and the QGC cumulative dredging scenario is the increase in total dredge volume from approximately 13.5 million m^3 to approximately 30 million m^3. If QCLNG's dredging and other WICT/Stage 1 dredging were conducted in a similar timeframe (concurrently or sequentially) then dredging intensity or duration must be increased. The Ecological Thresholds approach to EMP design will dictate the maximum intensity of dredging at any one time, which will in turn define the minimum duration over which dredging can be conducted. With QCLNG's dredging likely to take one to two years, its EMP must necessarily define Ecological Thresholds which address seasonal and inter-annual constraints. The cumulative scenario is therefore qualitatively similar to QCLNG's dredging program, and will be governed by the same Ecological Thresholds as apply to QGC's dredging.

There are relatively few opportunities for cumulative impacts to be qualitatively different than those for QGC's dredging. The only identifiable mechanism is that the potential exists at some point during the WICT and Stage 1 dredging programs, that cumulative changes to the hydrodynamics regime in the port may cause mangrove and seagrass communities in otherwise unaffected parts of the bay become impacted. Similarly, coastal geomorphologic processes associated with sediment erosion and deposition patterns could be altered following dredging and reclamation under the cumulative impact scenario in such a way as to cause long-term effects in the harbour. Impact assessment undertaken to date in preliminary works by BMT WBM indicates that there is a low likelihood of such changes to the hydrodynamics of the Western Basin.

Further modelling and predictive work is being done around the final configuration and scheduling of the cumulative dredging scenario to identify any other risks. Monitoring of key indicators such as tidal height, sedimentation rates and seagrass and mangrove health indicators will also be performed to enable early detection of any unforeseen effects of the dredging program.

1.4.4 Release of Contaminants

1.4.4.1 Sources and Characteristics

Potential contaminant sources include sediments, sediment pore water (including ammonia released from disturbed sediments with high organic content, often found in areas adjacent to mangroves) and PASS. Sampling to date has demonstrated that Port Curtis sediments are quite clean with respect to anthropogenically sourced contaminants, and that even naturally occurring 'contaminants' are below guideline levels in all but a few minor cases (see below).

Types of contaminants known or suspected to be present in Port Curtis include: metals and metalloids (arsenic, nickel, zinc, chromium and copper); organo-metals (tributyltin); volatile organic compounds (BTEX, TPHs), pesticides and organo-chlorines (including dieldrin, endrin). Most of these potential contaminants would be expected to be found in recent (post-European industrial development) surface deposits of sediments, which might be mobilised by dredging activities.

Many of the identified contaminants typically occur in dissolved form, however, some metals, metalloids and organo-metals can also occur as particulate matter. The principal pathway for particulate contaminant release is via the mobilisation of contaminated sediments. As discussed in *Section 1.4.2*, sediment mobilisation might occur from a range of activities. In dredging operations the release of dissolved contaminants is likely to occur via suspension of sediments in the water column (releasing an 'elutriate'), from the release of water contained within the voids of sediments (pore-water) when sediments are mobilised. These releases would occur during seabed disturbance at the dredge head, during overflow or bottom dumping from dredges of barges, and from dewatering of reclamation ponds.

In all cases, sediment mobilisation is likely to be at its highest levels when the dredged material consists of a high proportion of fines (such as clays and silts). The distribution of particulate contaminants, particularly metals, throughout the port is highly correlated with the occurrence of fine sediments (<60 μm diameter). Releases can be exacerbated by chemical processes such as acidification if potential acid sulphate soils are exposed to air.

Contaminants could also potentially be released through accidental spills and discharges.

Acid Sulfates

PASS sediment needs to be handled appropriately to prevent the formation of acid runoff and potential impacts to aquatic flora and fauna. In particular, PASS sediments must remain wet if oxidization is to be prevented and acid production to be avoided. If oxidation is permitted, impacts can be direct (high acidity waters stressing and killing marine life) and indirect (high acidity mobilising otherwise bound and inert contaminants), which can move into coastal waterways via runoff and reclamation pond dewatering.

An Acid Sulfate EMP will be developed to ensure that any PASS soils exposed to air (e.g., via reclamation) are managed correctly to avoid acid production.

Preliminary results from QGC's Marine Sediments Study suggest significant volumes of PASS occur in the planned dredged material, although there is also a strong excess of buffering capacity in most sediments. Based on these findings, it would appear that most areas to be dredged, if placed into reclamation, can be adequately blended through the dredging and hydraulic placement process so that specific treatment measures are not required. The only area likely to require special attention is in the upper intertidal zone, where the PASS-affected sediments are thinner, PASS levels are higher, neutralising capacity is lower, and where scheduling of dredging for early vessel access may not permit adequate blending. These areas will be the prime focus of the ASS EMP.

Contaminants

Contaminant analysis results from this investigation support the findings of previous studies which indicate the sediments in the Port are relatively uncontaminated and that contaminants predominantly found across the harbour are likely to be naturally occurring background concentrations. With the exception of ammonia (discussed below) the contaminants predominantly detected in the current investigation included arsenic, copper, nickel and cadmium. Arsenic was detected above NAGD screening levels in approximately 5% of samples analysed, however average concentrations of arsenic were below guideline levels in each of the dredging stages that were investigated. In the case of arsenic, copper and nickel less than one percent of samples returned results above the screening levels. Cadmium occurred above the NAGD screening level at only one location. In all cases, Upper Confidence Limits calculated in accordance with NAGD methods are below the relevant threshold criteria.

Ammonia

Ammonia is a naturally occurring 'contaminant', a by-product of the decay of high organic-content sediments. High ammonia levels are commonly encountered in sediments historically associated with mangrove and seagrass communities. If released from disturbed sediments in high concentrations, it can be rapidly (within minutes or hours) toxic to fish and invertebrates. Over longer time periods (days) it can also promote primary productivity and thus algal blooms.

Two areas of QCLNG's proposed dredging have ammonia levels which exceed NAGD levels.

MOF Area

Pore-water ammonia levels were assessed in four samples from the MOF access area, an area where dredging is likely to be performed using a backhoe. One of these four samples yielded a concentration of 3.5 mg/kg (the NAGD threshold is 1 mg/kg). Elutriate testing on this sample indicated a level of 1.4 mg/kg for release of this pore-water via sediment resuspension. When the Initial Dilution factors determined in BMT WBM's recent study (refer *Section 1.4.2.5*) are applied, this value falls below the critical threshold.

However, these Initial Dilutions are not achieved around low spring tides, implying a need to look more closely at the management of these potential impacts.

It is possible that further investigation (currently under way) will reveal that the volume of affected material is small enough that it will be blended by the grab dredging process. It is also possible that the total amount released will be less than the sustained production rates assumed in BMT WBM's modelling calculations, with the effect that actual dilutions will be greater than predicted by BMT WBM.

If this is not the case, then two simple operational mitigations exist. The affected area may be small enough to be targeted during neap tide or other periods when Initial Dilutions meet or exceed the BMT WBM averages stated in Section *1.4.2.5*. If it is not possible to remove the entire affected volume under conditions of high flushing, then it will be necessary to cease dredging operation for the low flushing periods within an hour of low spring tides.

Targinie Channel Transit Area

Several pore-water ammonia levels exceeded guidelines in the small portion of Targinie Channel which would be transited by a vessel having travelled through Clinton Bypass and about to turn into Curtis Spur Channel. Pore-water concentrations ranged from 5 mg/kg to 11 mg/kg. Elutriate tests revealed concentrations between 1.3 mg/kg and 3.4 mg/kg.

This part of the channel is likely to be too far from Port Curtis to be dredged using a CSD with hydraulic placement. While the maximum clay content observed in the corresponding samples was 42 %, typical clay levels were 10 % to 20 %, implying that this material may be dredged with a TSHD, with discharge directly to the reclamation area via hydraulic pump-out. Under this scenario the TSHD initial dilutions for bottom dumping and rehandling are not appropriate, and need to be substituted with those for CSD tail-water discharges. Since these are typically in the range of 1:200 or 1:2 000, concentrations will easily fall below thresholds.

If this material were to be considered for offshore disposal, the high initial dilutions expected from discharge in 25 m or greater water depths would mean that ammonia exposure risks would be negligible.

Accidental Spills and Releases

Accidental spills and releases of chemicals and fuels present another potential source of contamination. Significant volumes of marine diesel and associated fuels and lubricants are likely to be used by the various vessels during the dredging operations. Vessels will require regular refuelling, and are likely to store small volumes of lubricants and cleaning fluids on board during normal operations.

In most cases, accidental spills will likely be small volumes, which are either quickly contained by the crew of the vessel or via a dedicated fuel spill response vessel. For very small spills, the high tidal current velocities are likely to disperse the spill before it causes significant environmental harm or can otherwise be dealt with.

1.4.4.2 *Extent of Impacts*

Arsenic, nickel and chromium have been reported to occur sporadically throughout the port at concentrations above NAGD screening levels. Preliminary results from the current sediment study indicate no clear trends in the geographic or stratigraphic distribution of these 'contaminants' across the port. This observation is similar to that reported elsewhere on the east coast of Australia, leading to the conclusion that these are normal concentrations of naturally occurring metals. The detection of elevated metal concentrations in the deeper sediments supports the notion that contaminant levels are predominantly due to background occurrence.

While these metal concentrations appear to be naturally high background levels, the release of significant volumes of sediment containing high concentrations of these metals has the potential to cause short-term and localised toxicological effects.

However, results from hydrodynamic modelling suggest that TSS levels drop quickly from the point of dispersion (e.g. dredge head or dewatering outfall) to levels within the range of normal variability. This outcome suggests that the release and dispersion of particulate contaminants as a result of the mobilisation of surface sediments are unlikely to differ significantly from existing conditions.

As described above, elevated ammonia levels are unlikely to cause any adverse impacts if handled as described.

Reclamation of new areas using dredge material which has been contaminated can cause future land contamination issues. However, extensive testing of the material to be excavated for the Swing Basin and Channel has indicated that the material is clean and uncontaminated, and therefore contaminated land will not be created by reclamation using this material.

1.4.4.3 *Description of Impacts*

Anoxic and hypoxic conditions caused by anaerobic organisms in sediments with high organic matter can result in the formation of hydrogen sulfide and ammonia gas, which can also be toxic to fish and other organisms. The sudden release of ammonia from the pore water of these sediments following dredging and relocation can cause localised toxicological affects resulting in environmental harm, particularly if flushing rates and water circulation are also low at the time of release.

Conversely, the build-up of such conditions in restricted waterways such as land reclamation ponds can cause impacts on a larger scale, including major fish kills. This can occur either following the sudden release of water from reclamation ponds into the natural environment, or if schools of fish are trapped within the ponds after incoming tides. Similarly, the build-up of acidified reclamation pond water through the oxidation of acid sulfate soils (if exposed to the air) can also result in sudden and significant kills of fish and other marine fauna if released into the environment.

1.4.4.4 Receptors Affected

Mangroves are highly susceptible to oil exposure; oiling can kill them within a few weeks to several months. Lighter oils such as diesel are more acutely toxic to mangroves than heavier oils. Although weathering generally lowers oil toxicity, mangroves can suffer long-term impacts at the cellular and population level. Fringing mangroves dominate the intertidal zones around Curtis Island and the mainland, and potential impacts from a spill are considered high around this area because of the sensitivity of mangroves to oiling and the difficulties with clean-up attempts.

1.4.4.5 Management and Mitigation Measures

Sediment Contaminants

Thus far, results from the current sediment study indicate that sediments occurring within the port comply with guidelines, or can be readily dredged and managed to comply with guidelines for water quality and benthic community impacts.

Sediment handling will be subject to a detailed EMP to ensure that the potential for impact is well managed. Amongst other measures, this will specify a sampling program to be undertaken at the reclamation site or other sediment deposition areas to confirm the effective treatment and/or containment of any contaminants. One of the monitoring methods to be employed will be additional sites for membrane-based heavy metal detectors used successfully in the past few years by the PCIMP monitoring initiative.

Potential Acid Sulfate Soils

Initial sediment characterisation results suggest the presence of PASS, which will require neutralisation before being placed in reclamation areas. However the largest proportion of the sediments surveyed appear to hold significant alkalinity or neutralising capacity, and therefore the prevention of sediment acidification can be managed through operational control of dredging activity to ensure individual hopper loads have suitable natural neutralising capacity to avoid the need for further treatment.

An additional precaution that will be further investigated is the possible requirement that all areas identified as containing PASS be dredged as early as possible during the schedule and subsequently relocated when the reclamation ponds are at their deepest. This will ensure that no PASS can be exposed to air where it might oxidise and affect the environment.

Hydrocarbons

Hydrocarbons will be handled on a regular basis during all dredging operations, creating a potential risk to the environment in the event of a spill or loss of containment. The likely operations when a spill or loss of containment might occur include:

- refuelling (bunkering)
- storage and handling of oils, grease and chemicals
- breakdown of mechanical and hydraulic equipment and machinery.
- All refuelling will be carried out according to QGC operating standards and requirements.
- Refuelling of vessels will most likely occur when tied up alongside a berth in the Port of Gladstone, and therefore the chance of an oil spill under these circumstances is minimal. The following mitigation procedures are intended to reduce the risks to as low as reasonably possible:
- A work instruction will be prepared providing clear guidelines for refuelling operations to ensure the potential risk of a loss of containment is minimised.
- Bunkering will preferably take place during daytime and will not be permitted during adverse weather conditions. Guidance will be sought from GPC regarding safe weather conditions for refuelling.
- Fuel coupling and fuel levels will be continuously monitored and bunded during refuelling to avoid overflow.
- Hydrocarbon spill kits (including oil booms, absorbent pads and oil-dispersing detergents) will be maintained on all dredges and major vessels, and dedicated staff on each vessel will be trained in the appropriate and effective use of these kits.
- The master of each vessel will be responsible for all refuelling operations and for directing staff at all times during bunkering. The master will also be

responsible for reporting any spill of fuel, oil or chemicals into the marine environment and for ensuring spill equipment is deployed in a timely and effective manner if required.

- The bulk of all oil and grease will be stored in tanks onboard dredge vessels. Smaller volumes stored on other vessels will be contained in drums below deck, whenever possible. If oils cannot be stored below deck they will be retained within bunded areas to contain any leaks or spills. Spill response kits will be maintained close to hydrocarbon storage areas to enable rapid response in the event of a loss of containment.

All chemicals, detergents etc. will be stored below deck in appropriate containers and bunded deck stores. Daily hydrocarbon and chemical containment inspections will be carried out as part of vessel onboard standard operating procedures to ensure no loss of containment.

Solid waste

Domestic rubbish will be placed in rubbish bins or skips and recycled or disposed of by a licensed contractor and taken to an appropriate waste disposal or transfer station. Empty oil and chemical containers, such as metal or plastic drums, will be returned to the supplier for reuse or recycled where possible. Absorbent material used to mop up minor oil or chemical spills will be disposed of appropriately as contaminated material.

Sewage

No raw sewage from the dredge or support vessels will be disposed to the marine environment while operating in the port.

1.4.4.6 Level of Risk

On the basis of existing knowledge regarding the presence of contaminants in the Port of Gladstone sediments, it appears unlikely that significant environmental impacts would occur as a result of contamination. The risk of this form of impact occurring is likely to be negligible if appropriate management and mitigation of sediments and sediment handling operations are implemented. Likewise, while there is some risk of fuel or chemical spills occurring, appropriate management and mitigation measures should ensure that the environmental impacts of such an occurrence are negligible.

If hydrocarbon storage and transfer and shipping movements are strictly managed, the likelihood of a significant fuel or oil spill is small, but the consequence can be quite severe, resulting in a relatively high significance value for this type of impact. As a substantial amount of QGC's Project-related dredging activity is to occur in close proximity to mangroves, it will adopt the strictest and highly monitored operational controls relating to hydrocarbon and vessel management as part of the management plans developed for this project.

1.4.4.7 *Cumulative Impact Scenario*

The cumulative impact of contaminant releases are expected to be relatively minimal due to the low expected average concentrations and the wide distribution of sediments with contaminant concentrations above guideline screening levels.

The primary issue in managing and reducing or avoiding impacts associated with PASS is the neutralising capacity of the remaining sediments. Intensive sampling has been conducted across the dredging area and therefore the distribution of PASS both geographically and stratigraphically is relatively well understood. Initial results suggest that the net acidity of sediments across the harbour is such that PASS can be neutralised naturally, negating the need for treatment at the time of relocation. This knowledge will enable the dredging schedule to be managed such that PASS and net-basic sediments are dredged in relative volumes so as to promote the natural neutralising capacity of the sediments.

While naturally occurring contaminants such as metals appear in concentrations above guideline screening levels, the average concentrations of sediments likely to be dredged under this scenario appear to be well below potentially toxic concentrations. Due to the dilution factor of suction dredging techniques it is highly unlikely that contaminants could become further concentrated as a result of dredging activity. On the contrary, when an appropriate dilution factor is applied to even the highest concentrations recorded in the current study, expected concentrations of contaminants, which might be released into the water column, fall well below the screening levels set out in the NAGD.

The cumulative impact scenario for hydrocarbon spills is also unlikely to present any significant increase in environmental risk, due to the relatively small volumes of hydrocarbons which are likely to be held by dredges and support vessels.

1.4.5 *Fauna Interactions*

1.4.5.1 *Sources and Characteristics*

Fauna interactions might take the form of direct and indirect interference. Indirect interactions encompass the full range of impacts relating to changes to animal behaviour associated with the presence and movement of marine vessels and infrastructure, including changes to foraging, migrating, mating and breeding behaviours that might otherwise have taken place in the absence of such operations.

Possible forms of direct interactions include vessel-hull and propeller strike; entanglement and entrapment of organisms by temporary and permanent structures, including but not restricted to floating sediment transport pipes, vessel and barge moorings; reclamation bunding; and entrapment and entrainment of organisms by suction and grab operations of dredge heads.

Entrapment of large marine fauna in reclamation ponds is highly unlikely due to their relatively high mobility, observed ability to navigate through complex coastal formations and likely avoidance behaviour. The potential impact of this occurrence is considered to be negligible.

1.4.5.2 *Extent of Impacts*

Although considerable shipping already exists in Gladstone Harbour, there is limited vessel movement in the vicinity of the proposed dredging works planned for the western basin, with the exception of the existing Fisherman's Landing site. Increases in shipping traffic during dredging operations are likely to increase the risk of impact on the marine environment.

Vessels operating in the area during dredging will include one or more barge mounted BHD, CSD, and TSHD dredges and various support vessels such as tugs, barges, crew transfer and supply boats.

Anticipated vessels movements during dredging operations can be summarised as the following:

- dredge movements before, during and following dredge operations;
- Tug and pilot boat operation to support safe passage of barges and dredges;
- Barge / ferry to and from the construction docks / ferry terminals on the mainland and Curtis Island associated with the transportation of construction and operations equipment and personnel between the dredge vessels and the shore; and,
- Support vessel movements associated with the installation and maintenance of temporary and permanent structures including sediment transport pipes, barge and dredge mooring systems and navigation markers.

Dredge operations comprise the mooring of barges; mooring/dynamic positioning of dredge vessels such as CSDs and TSHDs; and the active crushing, mobilisation and extraction of seabed sediments via the dredge head. In the case of CSD and TSHD dredges, the dredge- or drag head uses suction to extract the sediments once mobilised from the seafloor and the vacuum created to extract the large volumes of mobilised sediment are sufficient to entrain small to medium sided marine fauna such as fish, sea snakes and turtles.

1.4.5.3 *Description of Impacts*

Vessel movements can disturb animals such as dugong, marine turtles and cetaceans from their habitat, interfere with behaviour or result in injury or death as a result of boat strikes. Boat strike generally results when there is a large number of fast or fast small pleasure craft (e.g., less than six metres long) operating in shallow water. The depth of water may prevent the animals from avoiding the vessel. Dredge vessels, however, are large and slow moving and for the most part will be moored or supported by tug vessels whilst in the port.

Temporary physical structures such as mooring systems and sediment transport pipes can result in fauna interactions through entanglement, entrapment and by creating temporary barriers to important habitat such as feeding grounds. Turtles and dugongs can become entangled in mooring ropes and anchor lines while sediment transport pipes can cut across marine passageways and may impede or interfere with fauna movements around the bay.

In addition to vessel movements and temporary structures, the operation of dredges adds to the extent of potential impacts associated with fauna interactions. Dredge operations can impact marine fauna directly through entrapment, entrainment and entanglement. Of particular relevance is the potential for marine fauna such as turtles and fish to become entrained in the operating dredge head. Dredging activities also pose risks to marine turtles with fatalities caused by cutter suction and trailer hopper dredges using suction drag heads. Other species that may be at risk from dredging include dugongs and sea snakes.

Noise, light and sediment suspension associated with dredge operations can also indirectly impact on marine fauna however these aspects are dealt with in separate sections.

1.4.5.4 *Receptors Affected*

The presence of dredges and their support vessels within the Port of Gladstone area has the potential to interfere with the movement of turtles, dugong and cetaceans which are particularly susceptible to vessel strikes.

Direct interactions between vessels and dugong are unlikely due to the slow cruising speeds of most vessels utilised for dredging operations. However, collisions and boat strikes have been recorded elsewhere[52] for the type of boating traffic which is typical of highly used recreational and commercial waters such as Port Curtis. Fatalities are unlikely to affect the local population[53]. However, the Dredging EMP will identify any restricted speed

52 Hodgson A J, Marsh H (2007) Response of dugongs to boat traffic: the risk of disturbance and displacement. Journal of Experimental Marine Biology and Ecology 340:50–61

53 www.unep.org

zones necessary to protect dugong, and any training necessary for the crew of high speed support vessels who are not locally experienced. With training in marine mammal behaviour and surveillance, the incidence of vessel collision with dugong will be reduced for dredging support vessels to the same risk levels currently experienced for other high speed vessel operations within Port Curtis.

Dolphins are likely to be able to avoid vessels due to their highly mobile nature. Speed controls and marine mammal observers will assist in mitigating any impact on dolphin populations from vessel strikes and avoidance behaviour.

Physical injury and death of marine fauna resulting from entrainment via suction drag heads is expected to be rare. While turtle fatalities caused by dredging in shipping channels have been recorded in other parts of the world, the capture and mortality of sea turtles has primarily been documented from hopper dredge operations that use trailing suction drag heads[54]. Incidental takes of sea turtles from cutter suction or other types of dredges are less likely. The extent of the potential risk of injury or fatality of turtles will therefore depend on the type of dredge being used, but is expected to be small. In the event that TSHDs are required for portions of the proposed development, turtle excluding devices (TEDs) fitted to drag heads can be used to limit accidental interactions. There is also the slight possibility of injury or death of marine turtles from the dredge cutter as turtles occasionally sleep on the seabed. However, the noise and vibration from the dredge head (refer *Section 1.4.6*) would suggest this is unlikely to occur.

Given the highly mobile nature of sea snakes and the fact that the dredging area has not been identified as important sea snake habitat, impacts to sea snakes are unlikely.

1.4.5.5 Management and Mitigation Measures

Marine fauna, including dugong, cetaceans and turtles are expected to exhibit avoidance behaviours, due to the noise and vibrations generated by the active dredge vessels, and are therefore unlikely to remain in proximity to the dredge. As a precaution, the following management strategies will be implemented to minimise the likelihood of direct adverse marine fauna interactions:

- Modelling of underwater sound for multi-dredge operational scenarios to determine effective separation distances and to optimise placement of elements such as booster pumps.
- Before the start of dredging activities, all dredging contractors and support crew will receive an HSSE induction detailing the types of marine

54 Dickerson D, Wolters M, Theriot C, and Slay C (2004). Dredging impacts on sea turtles in the Southeastern USA: A historical review of protection. In Csiti, A. ed. Proceedings of the World Dredging Congress XVII: Dredging in a Sensitive Environment, Hamburg, Germany, 27 September 1 October 2004. World Dredging Conference, October 2004, Germany

receptors potentially encountered in the Port of Gladstone, including identification cards for key marine fauna species, such as dugong and turtles. High risk zones and times will be identified and appropriate vessel speed and observer restrictions will be advised.

- THSDs will be equipped with turtle exclusion devices (TEDs) to limit fauna entrapment. If these are active (jetting) systems, they will be switched on before engaging the dredge pumps. When the dredging operation stops, the dredging pumps will be switched off before switching off the jetting system.
- Slow starts to all equipment such as dredge heads and vessel movements to enable marine fauna in the vicinity to move away from the zone of influence or interaction
- Any incidents that occur during dredging or disposal operations that result in the injury or death of turtles will be documented. Details of the incident, including time and date, cause of injury/mortality and the species (if known) will be recorded and reported to the EPA. If vessel-fauna interactions are occurring at unacceptable levels, the Dredging EMP will be reviewed in collaboration with EPA, and new risk mitigation measures implemented.

1.4.5.6 Level of Risk

The potential for collisions between fauna and vessels is regarded as slight, as most of these species would display behavioural and avoidance responses to the stationary or slow-moving dredging vessels. The greatest risk of collision would be for vessels steaming between dredging and reclamation areas. However, a high level of traffic management and the use of crew trained in marine fauna surveillance means that the expected risk of vessel collision is low.

The risk of entrainment in the active dredge head of operating dredges is expected to be low. The majority of dredging will be performed by grab (BHD) or cutter suction dredges, which operate from a stationary position and work slowly along a cutting face. For portions of the channel targeted by a TSHD (likely to be less than 25 % of QCLNG Project dredging), a combination of fauna mobility, avoidance behaviour, operational controls such as TEDs and slow start-ups to dredging operations will allow most nearby marine fauna to avoid injury. The anticipated risk of entrainment of marine fauna is therefore low.

Turtle capture data was collected in 1999 from dredging campaigns by the TSHD Sir Thomas Hiley in Weipa, Cairns, Townsville and Gladstone[55]. This followed fitting of 'tickler chain' TEDs to alert turtles before they could be sucked into active drag heads. Two juvenile green turtles were captured in a period of 2,235 hours of dredging. If this capture rate were maintained over

55 Morton, R and P Nella (2000). Capture of Sea Turtles by the Sir Thomas Hiley – Opportunities to Minimise Impacts. Prepared by The Port of Brisbane Corporation.

approximately four months of TSHD dredging for the QCLNG Project, two turtles would be captured. This contrasts with approximately 8,000 turtle deaths in Australia per year from other anthropogenic causes[56].

Entanglement of marine fauna in mooring systems and temporary structures is possible though uncommon. Entanglement typically occurs in areas where there is a large tidal range but slow currents which can result in mooring lines becoming slack, thus creating loops and snags for passing fauna. Due to the shallow water depths, high currents and constant maintenance routines expected for temporary structures, fauna entanglements are not expected to be common. This risk is therefore deemed to be low.

1.4.5.7 *Fauna Interactions Cumulative Impact Scenario*

As fauna interactions are directly correlated with the level of vessel and construction activity, the likely implications of the cumulative scenario is a relative increase in the likelihood of such interactions taking place. An increase in direct impacts such as vessel strikes and entanglement in temporary structures could potentially cause short term impacts to local population dynamics, especially for resident species such as turtles and dugongs. In addition, it is likely that increases in indirect impacts to dugongs and turtles might also be expected. Dugongs and turtles may both exhibit avoidance behaviour in relation to increased noise levels created by vessel and dredging activity[57] which in turn may exclude individuals or subgroups from locally important feeding or breeding locations. However, small vessel movements have been shown to have little impact on dugong feeding behaviour[58]. This observation, coupled with the availability of similarly suitable habitats in areas of the harbour where no dredging activity is planned should ensure that any effects to local populations of dugongs and turtle species are relatively short termed.

It is likely that highly mobile cetaceans, with greater range in their echo-location senses will exhibit more effective avoidance behaviour. These species are known to exhibit avoidance behaviour to vessel and industrial activity[59,60,61]. and the risk of direct impacts to these species may therefore decrease with increased activity. The indirect impact created by the temporary exclusion of cetaceans is likely to be short term and localised due

56 Ibid.

57 McCauley, R. D. and Cato, D. H. 2001. The underwater noise of vessels in the Hervey Bay (Queensland) whale watch fleet and its impact on humpback whales. J. Acoust. Soc. Am. 109: 2455

58 Hodgson, A., and Marsha, H. 2007. Response of dugongs to boat traffic: The risk of disturbance and displacement. *Journal of Experimental Marine Biology and Ecology* Volume 340, Issue 1, 2 January 2007, Pages 50-61.

59 Beasley, I. and Jefferson, T.A. 2000. Behavior and social organization of finless porpoises in Hong Kong's coastal waters. In: *Conservation Biology of the Finless Porpoise (Neophocaena phocaenoides) in Hong Kong Waters* (Ed. T.A. Jefferson), pp. 5.1-5.30. Hong Kong: Ocean Park Conservation Foundation.

60 Borggaard, D., Lien, J. and Stevick, P. 1999. Assessing the effects of industrial activity on large cetaceans in Trinity Bay, Newfoundland (1992-1995). *Aquatic Mammals* 25: 149-161.

61 Richardson, W.J., Fraker, M.A., Würsig, B. and Wells, R.S. 1985. Behavior of bowhead whales, *Balaena mysticetus*, summering in the Beaufort Sea: reactions to industrial activities. *Biological Conservation* 32: 195-230

to the temporary nature of the impact and the wide natural range of these species.

1.4.6 Noise, Vibration and Visual Amenity

1.4.6.1 Sources and Characteristics

Dredging generates sounds above and beyond general vessel noise. The sound produced from dredging activities might be detectable above background levels for a considerable distance from the source. The frequency and level of sound produced during dredging activities will depend on the type of dredge used. As with ship noise, most of the sound energy is at low frequencies, below 500 Hz, but mid-frequency (1 000 Hz) tones might be generated by the operating machinery, and sound emissions might extend up to 10 kHz[62,63]. Operating dredges will emit sound at their maximum source levels, which are in the 180 dB to 190 dB range at 1 m from source[64,65].

Table 6.1.10 provides examples of sound levels and frequencies produced by various dredge types. *Table 5.8.3* of *Volume 5 Chapter 8* summarises sound levels for a range of non-dredging vessels. Frequency ranges emitted by recreational craft and tugs towing loaded and empty barges extend into or exceed the upper frequency range for dredges. Source noise levels for tugs pulling loaded barges extend to 180 dB, which is comparable to many of the noise characteristics of dredges.

Specific information on the levels of underwater noise that will be emitted from dredging activity is unavailable. However, the Port of Gladstone receives more than 1 200 vessel visits each year[66] and exceeded 1 400 vessel visits in 2008 (*Volume 5 Chapter 15*) for vessels up to 220 000 dead weight tonnes (DWT). These numbers exclude recreational vessel movements, do not include tug movements associated with each vessel, do not include movements of locally operated ferries or barges, and do not include the dual movements associated with vessel entry and departure. If most large commercial vessels were accompanied by two tugs on each transit and both transits were counted, total vessel movements within Port Curtis would be several times greater than the 1 400 large ship visits identified in *Volume 5 Chapter 15*. In this context, and particularly the context of a large number of tug movements each day, dredge-related noises are considered to be within the range of daily exposures for local fauna.

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62 Richardson W J, Würsig B and Greene, C R (1990) Reactions of Bowhead Whales, Balaena mysticetus, to drilling and dredging noise in the Canadian Beaufort Sea. Marine Environmental Research, 29: 135-160

63 Richardson W J, Greene, C R, Malme, C I and Thomson, D H. 1995. Marine Mammals and Noise. Academic Press, San Diego

64 Richardson W J, Greene, C R, Malme, C I and Thomson, D H. 1995. Marine Mammals and Noise. Academic Press, San Diego

65 Simmonds, M.P., Dolman, S. and Weilgart, L. (eds). 2004. Oceans of Noise: A WDCS Science Report. Whale and Dolphin Conservation Society. Available from http://www.wdcs.org/submissions_bin/OceansofNoise.pdf

66 http://www.gpcl.com.au/shipping.html, 2009

A Loading Jetty will be constructed to provide berthing for LNG tankers and butane ships, with facilities for loading LNG and unloading butane. The Jetty is expected to consist of a driven-pile trestle structure. An MOF will be installed for transfer of supplies from the mainland to Curtis Island during the construction phase. The MOF may also require pile-driving for installation. In addition, pile-driving may be required for installation of supports for the bridge crossing.

Where pile driving is used to install Jetty/MOF facilities, the hammering sounds produced will generate underwater sound pulses. Sound pulses from pile driving have been reported with received levels to 135 dB re 1µPa at a distance of 1 km from the source, with peak frequencies in the 50-200 Hz band and an audible range extending to 10–15 km . A 2002 study of pile-driving operations (to construct a new Australian Defence Force wharfing area in Twofold Bay, Eden, NSW) recorded an average mean-squared pressure of 167 dB re 1 µPa (at 300 m from the operation), falling to 145 dB and 136 dB re 1 µPa at 1.8 and 4.6 km respectively . Curve-fitting of nine sets of measurements indicated that average signal strength fell from 150 dB to 140 dB re 1 µPa between 1 km and 3.1 km from the operation.

Table 6.1.10 Typical Sound Levels Produced by Dredges[67,68]

Dredge Type	Frequency Range (Hz)	Distance from source (m)	Peak Sound Level (dB)	Approximate Frequency of Peak (Hz)	Comment
Cutter Suction	Broadband	1	180	100	
	Broadband	1	177	80-200	
	20-1000	190	133		
	20-1000	200	140		
Cutter Head	70-1000		100-110		Inaudible at 500m
Hopper	Broadband	1	188	10	
	20-1000	430	138		Loading
	20-1000	930	142-177		
	20-1000	1500	131		Dumping
	10-2000	2000	127		
	10-2000	5000	120		
	10-2000	9000	110		

The presence of large dredges and the potential development of reclaim areas will have localised effects on visual amenity.

The development of new reclaim areas north of Fisherman's Landing will change the visual landscape of the area. While landscaping and revegetation will soften the potential impacts on visual amenity, the future development of this land may ultimately significantly change the local landscape.

67 Richardson W J, Greene, C R, Malme, C I and Thomson, D H. 1995. Marine Mammals and Noise. Academic Press, San Diego

68 Simmonds, M.P., Dolman, S. and Weilgart, L. (eds). 2004. Oceans of Noise: A WDCS Science Report. Whale and Dolphin Conservation Society. Available from www.wdcs.org/submissions_bin/OceansofNoise.pdf

Drill and Blast Operations

Investigations to date have targeted several small patches where high reflectivity seismic targets have intersected the intended dredge profile. Geotechnical investigations conducted in these areas (ongoing) have found no evidence of competent rock beyond the dredgeable limits for large CSDs. Notwithstanding this, it is not yet possible to conclusively eliminate the need for small amounts of blasting.

The largest CSDs in the world can dredge rock to UCS hardness 25 MPA to 50 MPA. Seismic velocity profiling tends to use 2,500 m/s as the cut-off discriminating low strength rock from medium strength rock (again, about UCS 25MPA). This boundary is often interpreted as the limit beyond which CSDs cannot work, and which require blasting. It is important to note that even good seismic coverage should be followed up by proper geotechnical assessment before concluding that a soil is not dredgeable.

Underwater blasting is done from a dedicated jack-up barge. The barge will drill a series of regularly spaced blasting holes, filling each with explosive material, and stemming holes to confine blasts before moving a short way off the blast site and initiating the blast. Fractured rocks are removed by BHD. Once recovered, the material can usually be used for a wider range of purposes than the softer overlying materials. This may include use in bund walls. Blasted material would be placed into a hopper barge and unloaded within the reclamation site.

Any blasting activities will be subject to Notice to Mariners and a local awareness campaign, giving locals the opportunity to move away. Safety Zones and Faunal Exclusion Zones will be policed by observers and attendant vessels.

1.4.6.2 *Extent of Impacts*

The key factors relating to the extent of noise impacts during dredging activates include but are not limited to the number and type of dredges active at any one time, their proximity to one another during operations, and their proximity to areas which contain important habitats for sensitive receptors.

Vessel types and movements will increase the extent of impact and Maunsell[69] suggests that approximately one percent of the materials in the Targinie and China Bay channels (i.e. perhaps 200 000 m^3) may have a UCS hardness > 25MPA and may pose difficulties dredging. Further investigations are required to better define these areas in terms of hardness and dredgeability. However, if blasting is required, it is likely to be confined to small areas and volumes of hard rock, and can be scheduled flexibly within the program.

Impacts on visual amenity will arise primarily from design of the reclamation area. All planning for this is currently being performed by GPC for its FL153

69 Maunsell, *Port of Gladstone Strategic Channel Development*, Unplublished Report for Central Queensland Ports Authority by Maunsell Australia Pty Ltd, 11 December 2007

and WBSDD Project EISs.

1.4.6.3 *Description of Impacts*

Impacts associated with noise primarily relate to behavioural responses in sensitive receptors.

Underwater sound is used by cetaceans for effective navigation, communication and foraging. Observed disturbance responses to anthropogenic sound in marine mammals include: altered swimming direction; increased swimming speed including pronounced startle reactions; changes to surfacing, breathing and diving patterns; avoidance of the sound source area, and other behavioural changes[70]. The occurrence and intensity of such responses are highly variable and depend on a range of factors relating to the organism and situation[71].

Injury and death can result following drilling and blasting if marine mammals or fauna are in close proximity to the blast area at the time of ignition.

1.4.6.4 *Receptors Affected*

Research has indicated that toothed whales, including dolphins, are most sensitive to sounds above approximately 10 kHz[72]. Bottlenose dolphins might detect sounds at frequencies as low as 40 Hz to 125 Hz. However, below ~10 kHz sensitivity deteriorates with decreasing frequency and below 1 kHz, sensitivity appears to be poor. This frequency range is higher than the frequency range of noise from dredging activities (20 Hz to 500 Hz with tones to 1000 Hz)[73]. Noise from dredging is therefore not expected to have a significant impact on dolphins in the port area.

No recognised shorebird feeding or roosting sites of importance have been identified on QGC's Curtis Island site or in the immediate vicinity of the QCLNG Project dredging area. Feeding and roosting sites have been identified more broadly within the Western Basin, on the basis of field surveys, literature review and consultation with relevant experts. These studies and the identified areas are indicated within *Volume 5 Chapter 8 Figure 5.8.11* and *Appendix 5.8 Figure 6b* of *Volume 5*. The most significant shorebird sites are those to the north of Fisherman's Landing, which include feeding and roosting areas. Reclamation of the southern portion of Fisherman's Landing may therefore cause temporary behavioural changes and displacement however

70 NRC, 2003. Ocean Noise and Marine Mammals. Summary Review for the National Academies National Research Council

71 NRC, 2003. Ocean Noise and Marine Mammals. Summary Review for the National Academies National Research Council

72 NRC, 2003. Ocean Noise and Marine Mammals. Summary Review for the National Academies National Research Council

73 Simmonds, M.P., Dolman, S. and Weilgart, L. (eds). 2004. Oceans of Noise: A WDCS Science Report. Whale and Dolphin Conservation Society. Available from www.wdcs.org/submissions_bin/OceansofNoise.pdf

this impact is likely to be minor, temporal in nature and highly localised. Impacts would be greater and permanent if reclamation occurred to the entire Fisherman's Landing area.

There is little information available in relation to noise impacts on turtles. Turtles have been shown to respond to low-frequency sound, with indications that they have the highest hearing sensitivity in the frequency range 100 Hz to 700 Hz[74]. This range corresponds with the frequency range of noise from dredging activities (20 Hz to 500 Hz with tones to 1 000 Hz)[75]. Reported responses of turtles to high levels of man-made noise include increased swimming activity and erratic swimming patterns.

Given the short-term continuous nature of the dredging program and the distance from known turtle nesting beaches, the likelihood is that turtles will exhibit avoidance behaviour in relation to the dredge vessels, and therefore impacts from noise are expected to be low.

Similarly, very little research has been undertaken to investigate the sensitivity of dugong to noise. Dugong are reported to have relatively low-level underwater vocalisations[76]. Dugong produce sounds (described as whistles, chirps and chirp-squeaks) in the middle frequencies (1 KHz to 8 kHz)[77]. This range is higher than the frequency range of noise from dredging activities (20 Hz to 500 Hz with tones to 1 000 Hz)[78]. Noise from dredging is therefore not expected to have a significant incremental impact on dugong in the area, given the existing noise environment, particularly as it relates to a large number of tug movements.

Sensitive receptors for visual impacts will primarily be boat-based observers, particularly recreational fishers, transiting the Western Basin waterways.

1.4.6.5 Management and Mitigation Measures

The most significant potential noise and vibration impacts from the development of the Swing Basin and Channel will occur from the reclamation works associated with management and placement of the dredge material. These reclamation works will involve heavy earthmoving equipment, pumps and some vessels which will generate localised noise profiles. However, as the reclamation areas most likely to be used for placement of the dredge material excavated are FL 153 and the proposed Western Basin Reclaim, which are located in industrial areas and well away from residential receptors,

74 Bartol SM, Musick JA. Sensory biology of sea turtles. In: Lutz PL, Musick JA,Wyneken J, editors. The biology of sea turtles, volume II. Boca Raton, FL: CRC Press; 2003. pp 79–102

75 Simmonds, M.P., Dolman, S. and Weilgart, L. (eds). 2004. Oceans of Noise: A WDCS Science Report. Whale and Dolphin Conservation Society. Available from www.wdcs.org/submissions_bin/OceansofNoise.pdf

76 NRC, 2003. Ocean Noise and Marine Mammals. Summary Review for the National Academies National Research Council

77 Richardson, W.J., Greene, C.R., Malme, C.I. and Thomson, D.H. 1995. Marine Mammals and Noise. Academic Press, San Diego

78 Simmonds, M.P., Dolman, S. and Weilgart, L. (eds). 2004. Oceans of Noise: A WDCS Science Report. Whale and Dolphin Conservation Society. Available from www.wdcs.org/submissions_bin/OceansofNoise.pdf

the impact has been assessed as negligible.

Management and mitigation measures to minimise the impacts of noise and vibrations from dredging activities might include the following:

- Dredging will be undertaken in as short a timeframe as practicable to minimise disturbance.
- Navigation permitting, dredging vessels will take the most direct routes and avoid approaching observed marine mammals or turtles.
- Dredging vessels will abide by Port of Gladstone speed restrictions.
- Dredging vessels will avoid or minimise the use of thrusters to maintain position where possible.
- Slow starts to dredging equipment and operations that might generate noise will be enforced to prevent potential injury to marine fauna as a result of the sound levels.

The presence of dredges in a working harbour for a relatively short duration will not change the visual amenity of the harbour , and requires no mitigation works. Proposed reclamation to the north of Fisherman's Landing lie within land zoned for industrial development, and already part of an industrial setting. These lands have already been identified with GPC's fifty year strategic plan as assuming an industrial nature, and therefore no specific mitigations are proposed.

Drill and Blast Operations

Blasting – unlikely to be required - will always be used as a method of last resort, following rotary drilling to confirm soil hardness. Explosives will be water-resistant, water-gel-based and must not require over-fuelling or a water ring for pumping. Millisecond delays will be used to stagger blast patterns so that maximum over- and under-pressure waves are reduced. All holes will be stemmed to a minimum of 1 m. Failing this, the blast site to be covered by a blast mattress. Environmental observers will be employed and will be tasked with identifying the possible presence of marine wildlife in the vicinity of the blasting operations. All blasts will be preceded by a 20 minute all-clear from dedicated 'Watch Program' observers, a 5 minute fish fright blast and a 1 minute fish fright blast.

1.4.6.6 Level of Risk

Given the high number of large vessel shipping movements within the Port of Gladstone and the usual program of maintenance dredging to maintain navigable channels, it is unlikely that the addition of noise from dredging of the Western Basin will result in a substantial change to marine animal behaviour within the vicinity of existing port infrastructure.

Given the number of shipping movements and other noise-generating activities within the Port of Gladstone, the increase in impacts from dredging-generated noise is expected to be incremental even with 24 hour-a-day operations.

1.4.6.7 Cumulative Impact Scenario

The anticipated schedule for the cumulative impact scenario will occur over a relatively compressed time frame. In order to meet the prescribed timelines there is an implied need to have multiple large dredges operating simultaneously during operations. This has implications for the propagation of noise not only at specific dredging locations, but also for the distribution and propagation of noise across the geographical extent of the port, as well as for the duration over which increased noise levels might be expected.

It is unlikely for reasons of practicality and safety that more than one large dredge vessel would operate in close proximity to another during the planned operations. Subsequently it is unlikely that noise amplification at a given location resulting from multiple sources could occur at levels that might cause permanent physical harm to marine fauna.

On this basis, it can be expected that should multiple large dredge vessels be employed simultaneously, they are likely to be deployed across a broad geographic range. Under such a scenario, the distance between the likely dredging locations combined the natural features within the port, such as soft sediments, convoluted shoreline and strong currents are likely to naturally mitigate any amplifying effect that might otherwise be expected.

The remaining risk under this scenario therefore is that the simultaneously operation of multiple dredges at a number locations could result in a reduction in available habitats (‘quiet refuges’) for sensitive receptors should the level of noise created by the active dredges be sufficient to trigger avoidance behaviours. It is feasible, though unlikely, that resident marine fauna such as dugong and turtles may be impacted through a cumulative loss of available ’quiet refuges’. Known feeding and breeding locations for these species are spread across the harbour and potential temporary refuges are likely to be available in Rodd’s Bay, The Narrows and along the southern and western shores of Curtis and Facing Islands, respectively. Additionally, dredges are likely to operate in a given area for only a relatively short duration before being moved to other locations either to deposit sediment in the case of the TSHD spread, or as operational requirements and constraints dictate.

1.4.7 Introduced Marine Species

1.4.7.1 Sources and Characteristics

Nine introduced species have been identified for the Port of Gladstone: five bryozoans, two ascidians, one hydrozoan and one isopod crustacean (refer *Volume 5, Chapter 8*). Introduced marine species can come from a range of foreign shipping ports and marine environs, with typical vectors being ship ballast and hull biofouling.

1.4.7.2 *Extent of Impacts*

Vessel hulls, ballast water, suction and marine water pumping equipment and anchors, chains and mooring ropes are typical parts of a vessel where invasive marine species and or their larvae are likely to be found. Invasive marine species may be introduced by ballast water and are likely to become first established in areas which are suitable for larval and juvenile development. Such habitats include seagrass beds, intertidal areas, mangroves and existing wharves and marine structures.

1.4.7.3 *Description of Impacts*

The impacts associated from invasive marine species vary from predation to competition and displacement. Invasive species typically are highly adaptable, exhibit naturally high fecundity and are typically aggressive predators or colonizers. These traits mean that native species can be severely impacted either due to increased predation or through displacement from their native ecological niche by the introduced species.

1.4.7.4 *Receptors Affected*

It is likely that many of the vessels to be used in dredging operations will travel to Gladstone from interstate and foreign ports, therefore presenting a potential risk of invasion. However, the Port of Gladstone is an international commodities port which receives large numbers of ocean-going, ballast-taking vessels (more than 1 400 visits in 2008). Vessels arriving in the port for dredging operations will be required to comply with Australian regulations, which require all ballast taken on in a foreign port to be discharged at sea and in waters greater than 200 m depth. On the basis of a minor incremental change in vessel visitation patterns and a requirement to comply with Australian regulations, dredging-related visitation is considered unlikely to pose any significant increased risk of an invasive marine species entering the port.

1.4.7.5 *Management and Mitigation Measures*

With QCLNG Project-related dredging likely to involve a maximum of three dredges (one each BHD, CSD, TSHD) plus a similar number of tender vessels, the incremental impact of this Project on vessel movements in the Port of Gladstone will be less than one percent. Management and mitigation for introduced marine species will therefore rely upon closely monitored compliance with existing national guidelines.

In May 2009 the Australian National System for the Prevention and Management of Marine Pest Incursions (herein referred to as the National System) was launched with the aim to prevent new marine pests arriving in Australia and minimise the risk of existing pests spreading to new areas.

Under the National System Non-trading vessels such as dredges are obliged to minimise the risk of invasive marine species incursions in three ways being:

- managing ballast water according to Australia's mandatory Ballast Water Management Requirements;
- minimising the amount of biofouling through a high standard of cleaning and maintenance; and,
- complying with any state/territory requirements.

Ballast water management

In July 2001, the Australian Quarantine Inspection Service (AQIS)[79] implemented mandatory ballast water management requirements for vessels engaged in international shipping. Where the potential risk is deemed to be high the three approved options for the management of ballast water are:

- full ballast water exchange at sea;
- tank to tank transfers; and
- no discharge of high risk ballast water is Australian waters.

A Ballast Water Management plan will require for sequential exchange of ballast water in deep ocean areas. Therefore in the event of grounding whilst transiting the GBRMP in ballast condition only clean, deep ballast water would be discharged to the marine environment. In the event of grounding in loaded condition, no ballast would be onboard.

Biofouling

Under The National System, a guidance document for the management of biofouling in non-trading vessels which includes barges and dredges has been produced to assist in the identification of risks and establishment of preventative measures for these types of vessels. This guidance document identifies a number of key aspects of dredge vessel employment which make them particularly susceptible to picking up potential pests species whilst operating in foreign ports. These include:

- long periods spent stationary or operating at low speeds in ports and coastal areas
- damage to and subsequent loss of antifouling coatings as a result of operational activities
- submerged surfaces not treated with antifouling due to operational requirements (e.g., drag heads)
- entrainment of sediment and mud into suction and dredge components
- regular transfers between coastal ports

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79 Department of Agriculture, Fisheries and Forestry (2008) Australian Ballast Water Management Requirements. Version 4 – March 2008. www.aqis.gov.au

To reduce the risk of introduction of an invasive marine species, all dredges and vessels entering the port from an interstate or international location will be inspected in accordance with the national guidance document, prior to entry into either Australian waters or the Port of Gladstone. Vessels will be vetted and approved for entry into the Port, in collaboration with the Port of Gladstone and / or Queensland State Government.

1.4.7.6 Level of Risk

The incremental impact of QCLNG Project-related shipping movements is less than one percent of existing shipping movements into and out of the Port of Gladstone.

The likelihood of survival of an introduced species is unpredictable however due to the low risk of introduction, the likelihood of any impact is minimal. The risk of new introduced species becoming fully established and becoming pests is low.

1.4.7.7 Cumulative Impact Scenario

With the most likely cumulative scenario involving sequential performance of various dredging projects using the same mobilised equipment, the number and type of vessels entering the port in association with the dredging operations is unlikely to differ significantly between the base case and cumulative scenario. As such the anticipated risk of an invasive marine species incursion resulting from the dredging operations is unlikely to change under the cumulative scenario.

Even if the cumulative scenario involved a full duplication of dredging equipment, the incremental increase in risk would be only one percent greater than the risks associated with a QCLNG-alone scenario.

1.4.8 Vessel (Collision) Management

1.4.8.1 Sources & Characteristics

The Port of Gladstone is an operating industrial port which experiences significant volumes of large vessel traffic throughout the year. Prevention of collision with shipping vessels and tugs will be an important consideration in the planning and scheduling of dredging operations. Conventional maritime notification processes (Notices to Mariners, lighting, visible marks, radio schedules) would be used as required by the Harbour Master so that visiting traffic is made aware of the location of any obstructions including dredges, moorings floating or submerged pipes and support vessels.

Significant volumes of marine diesel and associated fuels and lubricants are likely to be stored onboard by the various vessels during the dredging operations. The major impact associated with vessel collision therefore stems from the likelihood of a large hydrocarbon spill. Other impacts include solid wastes and artificial habitat creation from unrecovered vessels, equipment or vessel components.

1.4.8.2 Extent of Impacts

Most of the planned dredging is to occur in the new Curtis Spur Channel, where there is little present shipping traffic. Dredging operations, including non-dredging or support activities, are likely to occur on a 24 hour a day basis. Vessel collisions may occur under these conditions between small support craft moving around the operations area at night.

Shipping channels are currently configured to accommodate ships of 220,000 dead weight tonnes, and regularly receive Cape and Panamax size vessels for the coal trade. As active dredges move relatively slowly, the main risk of vessel collision in terms of consequence will be during operations associated with the widening and deepening of existing shipping channels around the Clinton Bypass, Wiggins Island Coal terminal and Targinie channel. In these areas there is a risk that a bulk carrier or container ship entering the port may collide with an active dredge.

Manoeuvrability varies for different types of dredge. Least manoeuvrable are spud-mounted grab or backhoe dredges. Cutter suction dredges and multi-point anchored BHDs are a little more manoeuvrable. Most manoeuvrable are the TSHDs which maintain full steerage while operating. As dredging methods become more precisely known, it may be necessary to accommodate shipping movements through active port zones (such as Clinton Bypass and the early part of the Targinie Channel) by selecting dredging methods which permit safe passage of entering and departing vessels.

1.4.8.3 Description of Impacts

The impacts associated with large hydrocarbon spills are well documented however in brief these include; toxicity in marine fauna via ingestion, smothering of sessile organisms and marine flora including mangrove root systems, immobilisation/incapacitation of sea birds.

1.4.8.4 Receptors Affected

Mangroves are highly susceptible to oil exposure; oiling can kill them within a few weeks to several months. Lighter oils such as diesel are more acutely toxic to mangroves than heavier oils. Although weathering generally lowers oil toxicity, mangroves can suffer long-term impacts at the cellular and population level. Fringing mangroves dominate the intertidal zones around Curtis Island and the mainland, and potential impacts from a spill are considered high around this area because of the sensitivity of mangroves to oiling and the difficulties with clean-up attempts.

1.4.8.5 *Management and Mitigation Measures*

The creation of the Swing Basin and Channel will result in additional shipping traffic in the Port of Gladstone and in the area adjacent Curtis Island. This additional traffic potentially increases risks to the coastal environment. However, risk assessment undertaken for shipping activities has indicated no significant increases in the risks from oil spills or release of hazardous materials in the port or adjacent areas of the GBRMP. The dredging activities involving large dredges and support vessels will also increase overall traffic in the harbour. However, as the Port of Gladstone is a high-volume shipping traffic area and the dredging activities will be only for a relatively short time, the potential impacts have been assessed as minor.

All bulk and container ships enter and leave the port under pilotage, and all dredge operations will be subject to publication of notices to mariners. These factors in conjunction with strict monitoring and controls regarding all dredging operations will significantly reduce the likelihood of a ship from colliding with a Dredge. All other vessel operations associated with the dredge program will be tightly monitored and controlled centrally to minimise the potential risk of vessel collisions between smaller craft. Management measures aimed to reduce the risk of collisions between shipping and dredge vessels may include:

- The dredging contractor will issue a Notice to Mariners to advise of dredging vessels movements and any significant changes to the dredging schedule.
- All transiting vessels will be advised of the location and operations of dredge and auxiliary vessels as well as any obstructions associated with the dredging works, including floating or submerged pipelines.
- All dredging vessels will maintain constant radio contact with the Port to ensure they are aware of any impending ship movements, any actions that might be required such as clearing existing channels of dredges, hopper or pipelines, and when planned movements are completed.

Dredging operations will also be planned and conducted, so as to minimise the impact on other port users. These may include:

- Coordination of all vessel operations between the Port and the dredge contractor including following the existing protocols and procedures, utilising long-term and day–to-day planning, and implementing an emergency response and cyclone management plan. These elements will be included in Project-specific EMPs, and will be consistent with Port of Gladstone’s existing cyclone plan).
- The contractor will advise on a daily basis the Port and local sailing, boating and fishing organisations of its planned dredging locations, sailing routes, anchoring locations, secondary activities (e.g. surveying) and the details of any ancillary equipment to be used (e.g. length of pipeline).
- Suitable navigation lights, radar and visual watches and radio monitoring on multiple channels will also be maintained to ensure vessel masters and

watchmen are aware of any movements of small recreational or commercial vessel in their vicinity.

In a tiered response plan, Project-related vessels will be equipped with hydrocarbon spill kits (including oil booms, absorbent pads and oil-dispersing detergents), and crew will be trained in the appropriate and effective use of these kits, to handle minor spills. Preparation for larger spills will involve QCLNG Project contractors participating with GPC in a review of the appropriate resourcing and training for potentially larger vessel spills.

1.4.8.6 Level of Risk

The likelihood of a vessel collision is anticipated to be rare. However, due to the size of some vessels involved in the operations and the volumes of fuels that may be released in the event of a spill, the possible consequence of a vessel collision is considered major. The risk of a vessel collision, leading to a hydrocarbon spill is therefore considered moderate. Strict management and mitigation measures detailed above will be included as a minimum in management planning for QCLNG Project dredging.

1.4.8.7 Cumulative Impact Scenario

Potential cumulative impacts associated with vessel collision are unlikely to be significantly greater than potential impacts under the QCLNG-only case. The likelihood of a vessel collision is unlikely to increase over the duration of the cumulative dredging scenario as strict management and operational controls will be applied throughout. As the likelihood of collision is considered to be low and most probably between small vessels, the expected consequence of a single collision is expected to be relatively minor, localised and potentially manageable through spill response procedures.

With all hydrocarbon spills in coastal areas, some damage to marine flora including mangroves can be expected but this is also likely to be relatively contained given the most probable scenario that might occur. Potentially cumulative impacts therefore might be associated with incremental loss of mangrove or intertidal seagrass habitat in spot locations around the port. Providing a vessel collision between two large vessels which results in a large hydrocarbon spill does not occur then any cumulative impacts are unlikely to cause significant or lasting effects in the Port.

QGC undertakes to work with GPC and other concurrent dredging project proponents to ensure that locally-based oil spill response equipment and supplies are adequate to handle plausible spill events resulting from co-occurring dredging operations.

1.5 SUMMARY OF MANAGEMENT AND MITIGATION MEASURES

This Summary captures key management and mitigation measures, identifies ongoing studies, and provides a Dredging Environmental Management Plan (EMP) framework within which potential environmental impacts of dredging can be minimised to levels that are as low as reasonably practicable.

1.5.1 Key Management and Mitigation Measures

Table 6.1.11 summarises the management and mitigation measures indicated throughout this Volume.

Table 6.1.11 Key Management and Mitigation Measures

Chapter	Mitigation
Hydrodynamics	• Relative timing of Fisherman's Landing reclamation and nearby channel development needs to be examined in detail to reduce a potential exacerbation of water level impacts in The Narrows
Sediments	• Sediments greater than 5 km from Fisherman's Landing require additional planning to confirm the most acceptable form of disposal • Further work is required to look at alternatives that would allow marine disposal, either within Port Curtis, or in deeper waters of the GBR • A detailed EMP is required to address issues of sediment plume generation, including overflow dredging within the Western Basin • Feasibility needs to be assessed for rehandling in a confined portion of the Fisherman's Landing bunded area. • Overflow dredging will use a 'green valve' or near-bottom discharge • BHD operating near the MOF and rehandling near Fisherman's Landing may need to have operational constraints around the period of an hour before or after low water • Further modelling is required to determine the maximum dredging intensity which will allow ecological thresholds to be consistently met • It may be necessary to reduce overflow dredging, rehandling, relocate dredges to different parts of the bay, use silts curtains (MOF nearshore areas only) or even temporarily pause works to manage plume formation. • A structured program of baseline studies, model development, and management planning is necessary to ensure than an effective EMP can be developed and implemented with confidence.
Habitat Loss	• Additional modelling is required to direct coastal works so that impacts to mangrove and seagrass communities from siltation or altered coastal process are minimized. • Modelling needs to be extended to turbidity and light attenuation so that impacts to benthic primary producers can be predicted. • With 30 % to 32 % of Halophila-dominated seagrass beds in the Port Curtis – Rodd's Bay region to be lost or 'at risk'

Chapter	Mitigation
	(respectively), the regional significance of this type of seagrass community needs further analysis. • It may be necessary to optimise reclamation layout and heights in order to minimize disturbance to regionally significant seagrass beds. Consideration should be given to offshore disposal (into areas where benthic communities have lower regional significance) so that volumes brought ashore can be minimised and protection of sensitive habitats can be increased. Rapid habitat assessment methods, capable of being requested, implemented, reported and interpreted within a few days, need to be developed for benthic primary producer communities, to support responsive management of dredging impacts.
Release of Contaminants	• SAP reporting to identify any exceedances of water quality guidelines based on BMT WBT initial dilutions • Management strategies will be developed to ensure that a) releases of ammonia are minimized where possible; and b) Initial Dilutions of ammonia-bearing materials are appropriate to limit ecological risks. • An Acid Sulfates EMP to manage the dredging and placement of high PASS materials into reclamation. • High operational standards for fuel management, including a commitment to work closely with GPC and the Harbour Master on fuel management and planning for spill mitigation.
Fauna Interactions	• Turtle Excluding Devices on all mobile dredges • Training of vessel crews in locally important marine megafauna, its habits and identification, and the encouragement of active surveillance and reporting by all crew members.
Noise and Vibration	• Modelling of underwater sound from a multiple-dredge spread • Slow starts on equipment • Drilling and blasting – if required – to be used as a method of last resort. If used, to follow best practice for blast control, including stemming, sequencing, warning and 'fish scare' blasts, and 'Watch Program' observers
Introduced Marine Species	• Observance of AQIS guidelines • Pre- and during- IMS surveys
Vessel (Collision) Management	• Coordination with GPC and the Harbour Master

1.5.2 *Summary of Required Studies*

Several types of study are required to complete demonstration of the efficacy of an EMP for large-scale dredging in Port Curtis. These include:

- Expanded ecological baselines
  - Method development
  - Field surveys
- Model development
- Management Systems

- Exposure Rules
- Management Procedures
- Contingency Planning
- Peer Review and Regulatory Sign-off

1.5.2.1 Expanded baselines

Method Development

Many of the techniques applied to traditional monitoring and management programs rely on resurvey intervals of several months to a year. Benthic primary producers can, under some circumstances, be affected by turbidity in periods of less than a week. This implies a need to develop two tiers of field methods, one that can operate on an ongoing basis and another when additional surveillance is warranted by an increasing risk profile.

Near-real-time data collection is required for a subset of indicators which will respond and reveal a 'warning threshold'. This may be as simple as turbidity and seabed light levels. Data can be collected by telemetry or relatively quickly by a boat crew. It would be customary for details such as reporting processes to be established well ahead of time to ensure that the rapid feedback loop is functional from the start of monitoring operations.

More detailed surveillance methods also need development for fast-response assessment of benthic community health. These tasks may include:

- Development and field verification of rapid assessment methods (such as, but not limited to, airborne multispectral scanning) that can be used to determine benthic primary producer health on an as-required basis during dredging operations
- Prior determination of sentinel species and/or morpho-species identification levels that allow rapid data analysis, without obscuring important ecological trends.

Field surveys

PCIMP has a comprehensive monitoring program in place for Port Curtis, but this focuses on matters other than dredging, and is based upon impact and reference site designations appropriate to other impact assessment hypotheses. While this leads to a good distribution of study sites on the western (mainland) side of Port Curtis, it means that sites relevant to Curtis Spur Channel dredging are under-represented. Additional baseline studies will be done before dredging commences to ensure a proper BACI design is achieved for the quantitative impact assessment process. Some of this can be accomplished by adding sites to the suite of PCIMP survey sites. Others require specially designed studies.

All surveys will attempt to employ survey techniques and target monitoring species employed under the existing PCIMP programs as this will enable the incorporation of available PCIMP data into the final assessment, which in turn will ensure that cyclic patterns and natural processes do not confound the assessment outcomes.

Baseline habitat mapping, including species composition and density, is required for benthic primary producers, mangrove, infauna and epi-benthic fauna.

Baseline water quality monitoring (turbidity [NTU], temperature, conductivity, dissolved oxygen, pH, light climate, potential dissolved contaminants, total suspended solids [TSS] and sedimentation), primarily comprising extension of existing programs into portions of the bay not adequately assessed to date. It is important that this work be intensive enough to cover tidal, daily, lunar, seasonal and weather-related variability.

Good practice would be to incorporate the following survey design considerations:

- BACI design with appropriate impact and control locations including adjacent to the proposed reclamation area and at key known benthic habitat areas within the harbour. Control locations might need to be identified outside the inner and western harbours of the port such as the Fitzroy River estuary, Keppel Bay, etc.
- individual sampling sites positioned along two axes: one in the direction of predominant tidal current, and; one that is across-current/shoreline at each survey location.
- replication levels to be determined on the basis of statistical power analysis
- sampling before, during and after dredging/reclamation operations. A sufficient baseline survey (usually at least one winter/dry season and one summer/wet season) completed before operations commence to capture seasonal variability. This type of survey would also typically continue at the same frequency over the duration of the project, and extend into the post-construction period sufficient to confirm predicted recovery.
- After identifying the zone of potential impacts, specify appropriate reference sites outside the potential zones of influence of dredging and reclamation operations.

1.5.2.2 *Model development*

The cornerstone of a dredge management plan is an ability to confidently predict ecological risks and the response of sensitive receptors to emerging conditions. While effective and efficacious models of Port Curtis already exist, they are not developed to a stage where they can be used with confidence to predict receptor responses. Several additional model development tasks are required:

- Complete the development of a 3-dimensional model across the study area, including wind forcing, particle introduction, advection and removal, and validation of the revised model.
- Progressively undertaken model enhancement and validation to verify efficacy for:
  - prediction of ambient sediment loads as a function of tidal and wind and wave forcing
  - dispersion and fate of particles smaller than the 'fine silts' modelled to date
  - relationships between total suspended solids, turbidity and seabed light in the photosynthetically active region (PAR) of the light spectrum
- Field-verify the accuracy of these predictive tools, perhaps by reference to a 'trial' dredging exercise, extreme events or other validation technique
- Perform a confirmatory round of predictions based on detailed construction scheduling, to identify sensitive receptor sites, and suitable reference sites. Some of these might be sites already utilised for historical monitoring within Port Curtis.
- Classify zones of impact (i.e., where habitat loss is predicted), stress (habitat loss can be avoided through effective management) and influence (impacts are predicted not to occur) of turbidity plumes and sediment deposition on benthic primary producers
- Develop the numerical model into a tool which can be rerun in near-real-time, permitting the assessment of alternative methodologies. This will require the development of interfaces to accommodate input of present turbidity conditions and planned dredge operations (areas, source strengths, source positioning in water column), and output formats that allow simple interpretation of trends at nominated key receptor sites, all within a turn-around timeframe of approximately 6 hours.

1.5.2.3 *Management Systems*

Management systems are required to give confidence and predictability to dredgers and regulators alike. For the purposes of this document, management systems development can be thought of as falling into four classes. 'Exposure Rules' are required to precisely define the ecological threshold (and recovery conditions in the event of an exceedance) in a manner relevant to dredging operations. Management Procedures are required, which are mutually acceptable to the broader range of stakeholders typically involved in a dredging EMP, and which offer unambiguous procedures to be followed for all plausible standard and exceedance conditions. Contingency Plans require the identification, verification and may even require the prior approval of regulators if their implementation has to be immediate upon response to an observed condition. Regulatory sign-off processes can also require a significant lead-time to plan, develop and agree.

Exposure Rules

- conduct a technical review of 'Best Practice' in managing dredging impacts to benthic primary producers. This document will guide the development of thresholds into dredging constraints.
- develop a detailed set of health-based criteria for the sensitive receptors, based on exceedance probability curves.
- verification based upon observed response to and recovery from actual challenges (trial dredging, shading studies, weather extremes)
- establish the environmental quality criteria (Ecological Thresholds) to protect social values in the long term
- Exposure rules must also include 'recovery rules' which define conditions under which dredging controls are relaxed after a period of higher risk has passed.

Management Procedures

- develop maps showing the predicted zones of impact, stress and influence arising from the dredging, dredged material relocation and reclamation activities on water quality and sensitive benthic receptors
- agree with regulators those management zones within which:
  - impacts are an accepted consequence of approval
  - protection is required from the effects of dredging and dredge material relocation
  - agreed reference areas, unaffected by the Project
- negotiation with regulators of a tiered response scheme which permits minimal intervention in dredging methodology providing that exceedance probability curves are not breached; and escalates progressively through increased surveillance to precautionary intervention and finally to mandatory intervention in the event that exceedance curves are breached.
- specify the management actions and contingency measures to be implemented in the event of exceedance of the levels
- define an upper limit for the intensity of fugitive sediment releases from dredging (the rate of discharges) at a level that allows ecological thresholds to be consistently met
- Management structure and methods for drawing together relevant experts and resource managers to make judgements in cases which are

borderline, or not contemplated in the EMP, or at pre-defined review points

- Ensure that permits are structured to reflect the operation of the EMP, and in particular, to accommodate a need to rapidly return to unhindered dredging operations when a period of heightened risk has passed.

Contingency Planning

Studies and/or modelling to define:

- Detailed investigations of options for creating a confinement basin within a portion of the Fisherman's Landing reclamation area, such that spoil rehandling can be achieved in an area protected from excessive currents and dispersion.
- Dredge management strategies involving modification to dredge methods, including overflow strategies, location of a dredge to an area where dispersion can be reduced or enhanced, scheduling of down-time etc.

Regulatory Sign-off

The Dredging EMP is likely to require formal execution by one or more State and Commonwealth Ministers because it will contain mechanisms to delegate authority for permit-related decisions made in the course of executing the EMP. This task will require a significant lead time.

1.5.3 Outline of Dredging EMP

The development of the Swing Basin and Channel may pose a hazard to marine species and the ecology of Gladstone Harbour. However, a detailed Dredge Management Plan designed to minimise harm to the marine ecology, in particular sensitive species, will be developed for the dredging activities. This plan will require approval from Queensland and Commonwealth environmental regulators prior to any dredging activities commencing.

The potential cumulative impact of dredging and dredge material placement from the contemporaneous development of WICT Project, GLNG Project and Stage 1b of the WBSDD Project with the QCLNG Project has been assessed. Impacts from dredging activities may be minimised by implementation of individual Dredge Management Plans and, if required, a more comprehensive and integrated management plan for multiple dredging activities.

1.5.3.1 Objectives

The objective of the Port Curtis Dredging EMP is to:

- protect sensitive marine environmental values and receptors from the effects of sediment deposition, deterioration in light attenuation, contamination and other impacts associated with dredging and reclamation
- protect the long-term social, socio-economic and human health values of

Port Curtis marine environments.

When its development is completed, this EMP will:

- address monitoring requirements and management measures to protect sensitive marine environmental values and receptors and social values consistent with the operational requirements of the port, and any other areas within the potential zone of influence of the environmental effects of dredging and reclamation
- identify and spatially define appropriate environmental quality objectives to be met during dredging and relocation of dredged material
- set out the procedures for monitoring water quality at appropriate reference sites and potential impact sites
- set out the procedures for the deployment of in situ data loggers throughout the dredging period inshore impact sites, calibrated to provide an estimate of suspended sediment or sedimentation for continuous monitoring
- specify reporting procedures.

1.5.3.2 Responsibilities

Recent monitoring programs for large scale dredging programs have adopted the following:

- The dredging Proponent is the party bearing overall responsibility.
- The dredging Proponent convenes a Dredging Technical Advisory and Consultative Committee, comprising representative members of the port authority, the port user community, the local community and specialists in public consultation, engineering and environmental management.
- monitoring and management plans are to be subject to independent technical review before final acceptance of methodologies, and before final acceptance of conclusions.
- The dredging Proponent would commit to a structured program of engagement with the community to identify perceptions and issues and for dissemination of EMP results to the broader community.

1.5.3.3 Contact Details

The dredging Proponent would establish a primary liaison role for co-ordinating communications across stakeholder groups.

1.5.3.4 Scope

- This EMP has been developed to serve several purposes, including to:
- confirm the nature and intensity of impacts, allowing comparisons to be

drawn to the impact predictions of the EIS

- meet the conditions of any conditional approval granted
- create a "monitor and manage" culture, to ensure that impacts are managed and mitigated to acceptable levels
- to limit adverse impacts associated with:
  - water quality and sediment characteristics
  - stress or death to areas of seagrass, macroalgae and corals closest to the dredging activities
  - accidental introduction of marine pest species from vessel hulls and ballast water
  - accidental hydrocarbon spills e.g. during refuelling
  - waste management
  - injury or death of fauna due to vessel/dredging interactions.

1.5.3.5 Monitoring Programs

In addition to the fast-response style of monitoring and management identified as the theme of *Section 1.5.2.1* the following longer term monitoring programs would typically be required:

Operational Monitoring

- water quality monitoring (NTU, temperature, conductivity, dissolved oxygen, pH, light climate, potential dissolved contaminants, TSS and sedimentation)
- sediment quality monitoring at proposed reclamation area
- light attenuation studies (NTU, TSS and light)
- coral and seagrass health assessments
- introduced marine pests on dredging equipment
- mangrove health assessments
- marine fauna surveys
- aerial photography for dispersion of sediment plumes.

Introduced Marine Species Monitoring

Any QCLNG project dredging vessels found to contain evidence of material from previous dredging or non-indigenous marine species will be immediately sent offshore (to water depth of at least 200 m) and be directed to take appropriate action in accordance with state and federal regulatory requirements. All relevant state and federal bodies, including GPC, Australian Quarantine Inspection Service, and the dredging contractor will be notified and a consultation process commenced to address any potential issues or additional management/compliance requirements. Any species identified from the Consultative Committee on Introduced Marine Pest Emergencies (CCIMPE) trigger list (refer *Table 6.1.12*) might induce the need for an invasive species emergency response as detailed in the Australian Emergency Marine Pest Plan 2005.

If the non-indigenous marine species were successfully removed and there is sufficient Proof of Freedom then the dredge might return directly to port and commence dredging without the need for an arrival inspection or subsequent inspections until departure. If Proof of Freedom cannot be reasonably ensured then upon the dredge's return to port it must be reinspected within 48 hours, in relation to criteria established during the consultation process.

The consultation process should follow that required by the Queensland Government and the CCIMPE, which has been established by the Commonwealth Government to provide a national communication and advisory support role.

Quarterly inspections will be carried out for the duration of the dredging program. Should infestations be detected during subsequent dredge inspections, surveys will be extended on the basis of a rapid risk assessment to cover priority zones within the area of dredging and disposal operations.

A departure inspection might be required if the dredge is being transferred to another area in Australian territorial waters and an inspection report then be submitted to the both the Queensland and receiving state government agencies and the Commonwealth Government.

1.5.3.6 Compliance Auditing

QGC will work with GPC to implement appropriate compliance and review processes for monitoring programs.

1.5.3.7 Long-term Monitoring Programs

QGC is a full member of the PCIMP and is actively participating in the broad range of environmental studies conducted under this initiative.

When the Responsive Monitoring Program is developed a review will be undertaken to establish whether any elements of the program ought to be picked up in the PCIMP program.

Table 6.1.12 CCIMPE Trigger List Species

CONSULTATIVE COMMITTEE ON INTRODUCED MARINE PEST EMERGENCIES

CCIMPE TRIGGER LIST SPECIES

	Scientific Name/s	Common Name/s
Species Still Exotic to Australia		
1 *	*Eriocheir* spp.	Chinese Mitten Crab
2	*Hemigrapsus sanguineus*	Japanese/Asian Shore Crab
3	*Crepidula fornicata*	American Slipper Limpet
4 *	*Mytilopsis sallei*	Black Striped Mussel
5	*Perna viridis*	Asian Green Mussel
6	*Perna perna*	Brown Mussel
7 *	*Corbula (Potamocorbula) amurensis*	Asian Clam, Brackish-Water Corbula
8 *	*Rapana venosa* (syn *Rapana thomasiana*)	Rapa Whelk
9 *	*Mnemiopsis leidyi*	Comb Jelly
10 *	*Caulerpa taxifolia* (exotic strains only)	Green Macroalga
11	*Didemnum* spp. (exotic invasive strains only)	Colonial Sea Squirt
12 *	*Sargassum muticum*	Asian Seaweed
13	*Neogobius melanostomus* (marine/estuarine incursions only)	Round Goby
14	*Marenzelleria* spp. (invasive species and marine/estuarine incursions only)	Red Gilled Mudworm
15	*Balanus improvisus*	Barnacle
16	*Siganus rivulatus*	Marbled Spinefoot, Rabbit Fish
17	*Mya arenaria*	Soft Shell Clam
18	*Ensis directus*	Jack-Knife Clam
19	*Hemigrapsus takanoi/penicillatus*	Pacific Crab
20	*Charybdis japonica*	Lady Crab
Species Established in Australia, but not Widespread		
21 *	*Asterias amurensis*	Northern Pacific Seastar
22	*Carcinus maenas*	European Green Crab
23	*Varicorbula gibba*	European Clam
24 *	*Musculista senhousia*	Asian Bag Mussel, Asian Date Mussel
25	*Sabella spallanzanii*	European Fan Worm
26 *	*Undaria pinnatifida*	Japanese Seaweed
27 *	*Codium fragile* spp. *tomentosoides*	Green Macroalga
28	*Grateloupia turuturu*	Red Macroalga
29	*Maoricolpus roseus*	New Zealand Screwshell
Holoplankton Alert Species * For notification purposes, eradication response from CCIMPE is highly unlikely		
30 *	*Pfiesteria piscicida*	Toxic Dinoflagellate
31	*Pseudo-nitzschia seriata*	Pennate Diatom
32	*Dinophysis norvegica*	Toxic Dinoflagellate
33	*Alexandrium monilatum*	Toxic Dinoflagellate
34	*Chaetoceros concavicornis*	Centric Diatom
35	*Chaetoceros convolutus*	Centric Diatom

* species on Interim CCIMPE Trigger List

Note: Endorsed by National Introduced Marine Pest Coordinating Group (NIMPCG) in 2006

1.6 SUMMARY

1.6.1 Findings

Based on the hydrodynamic and coastal assessments the proposed dredging:

- will not result in direct impact on the ability of the site or adjoining land to function as a barrier protecting lands from coastal waters

- is not expected to directly impact on natural coastal processes that supply sand to beaches
- will maintain the stability of the dredging area, noting the possibility of direct impact from sedimentation at the Swing Basin and MOF over the long term
- will maintain water quality, excepting short-term impacts from dredging that are within the bounds of natural variability of the system and localised within the Swing Basin and channel areas
- will not cause unacceptable risk to existing land uses from coastal hazards.
- The hydrodynamic impacts of the proposed works were found to have a negative minor direct impact, with the exception of in the immediate vicinity of the proposed dredged Swing Basin, where dredging will change velocities, with a negative moderate direct impact.
- There are negligible direct impacts on tidal flushing behaviour with and without the Project.
- In the case of Swing Basin dredging, greater suspended concentrations were realised during neap tides, where dispersion was less as a result of reduced tidal velocities. An immediate impact zone of the order of several hundred metres in scale was identified during these times and, outside this area, maximum additional TSS concentrations of approximately 25 mg/L were predicted (over ambient). These values are in the order of the natural variability of TSS concentrations across the site. Concentration increases during spring tides were generally less than during neap tides.
- Similar behaviour was observed in the model results for the proposed bridge and pipeline construction scenarios. The immediate impact zones were again in the order of hundreds of metres in dimension during neap tides (and considerably smaller during spring tides), with maximum additional TSS concentrations outside this zone of 15 to 17 mg/L.
- Several pieces of work are ongoing, including the interpretation of the above plume predictions in the context of light attenuation to benthic primary producers.
- Fisherman's Landing Reclamation scenarios are similar for the QCLNG Project and for the works proposed in GPC's FL153 and WBSDD Projects. On this basis, there is no incremental loss of habitat associated with QCLNG Project reclamation. If QCLNG Project reclamation were to occur in isolation of any other mooted projects, and were to occupy only the southern half of the Fisherman's Landing area, it would represent a loss of approximately 3 % of regional seagrass communities. These impacts would be permanent and significant and in the case of seagrasses, would involve the removal of a significant proportion of the relatively uncommon Halophila-dominated seagrass beds. 'At risk' seagrasses, requiring careful implementation of a Dredging EMP to ensure their protection, represent a further 14 % of regional seagrasses.
- Mangrove losses, totalling approximately 47.5 ha or 1.6 % of local

mangroves, are almost entirely related to reclamation at Fisherman's Landing. These impacts will be permanent and significant. A further 11.0% of local mangroves may be at risk of short term impacts due to sedimentation related to dredging.

- Up to 45 ha of high density scallop/rubble reefs (6.1 % of those in the Western Basin) and 122 ha of low density open substrate benthic communities (39.6 % of those in the Western Basin) may be lost within dredging footprints. In practice, these communities will be resilient to high turbidity and may be pre-adapted due to shipping-related turbidity, and impacts are therefore likely to be much smaller than otherwise implied. Most of these impacts are independent of the QCLNG Project, as they would occur in an identical manner for dredging associated with WICT, GLNG or GPC Stage 1b projects.
- Contaminant releases are expected to be minor and manageable with conventional controls. The Dredging EMP will be required to identify specific operational measures to ensure that small pockets of sediments containing ammonia in their pore-water are dredged in a manner that prevents short term exposure of marine fauna to elevated ammonia concentrations.
- Faunal interactions are expected to pose a low risk, but it will be necessary to model underwater noises from operational scenarios involving multiple dredges. It will also be necessary to use Turtle Excluding Devices on drag heads of mobile (TSHD) dredges. Drilling and blasting, if required, must be used as a method of last resort, and will require a special EMP to limit faunal impacts.
- Introduced Marine Species risks are low, but potential consequences are high. Existing AQIS standards will be adhered to, and additional surveillance will be performed to confirm the presence or absence of new introductions.
- Other than coordination with GPC and the Harbour Master and a commitment to follow existing communication practices within Port Curtis, no additional measures are believed necessary to manage collision risks.
- Based on these findings, the impacts to hydrodynamics and marine water quality from the Project are characterised as being short-term (related to construction stages), with major local impacts from the dredging works with increased TSS. These increases are within the bounds of natural variability of the system and are not expected to have any significant long term direct impacts on marine environmental values of water. With appropriate management of turbid plumes and their potential impact on benthic primary producers, the environmental values of the Project area can be protected from QCLNG Project-related dredging.

A summary of the impacts outlined in this Chapter are provided in *Table 6.1.13.*

Table 6.1.13 Summary of Impacts for QCLNG Project-related Dredging

Impact assessment criteria	Assessment outcome
Impact assessment	Negative
Impact type	Direct and secondary
Impact duration	Short-term for impacts to hydrodynamics, marine water quality, benthic communities lying beyond 200m from the dredging footprint, and marine fauna of Port Curtis. Long term for some of the benthic communities within new channel footprints. Long term impacts to mangroves and seagrass communities in and around Fisherman's Landing.
Impact extent	Local
Impact likelihood	High

Overall assessment of impact significance: minor. The proposed dredging can be performed within the framework of an EMP, which is regarded as having the potential to successfully manage temporary impacts to acceptable levels.

1.6.2 Mitigations and Offsets

QGC is committed to working with GPC and other WBSDD Project proponents to identify appropriate mitigations and offsets.

Other less obvious but important benefits arising from the QCLNG Project include:

- Flow-on benefits to the scientific, Port and broader community from the QGC Marine Sediments Study
- Improved techniques for managing the marine environment to flow from the development of rapid survey methods, seagrass exposure rules and updated habitat surveys.
- Contribution to costs of maintaining the Curtis Island environmental precinct.

1.6.3 Matters of National Environmental Significance

Matters of National Environmental Significance (MNES) that may potentially be affected by dredging and reclamation activities include the following:

- World Heritage Properties
- National Heritage Places
- Listed threatened species and communities
- Commonwealth Marine Environment

MNES relevant to channel construction and reclamation are discussed in the QCLNG EIS at:

- Vol 1 Ch 5 s5.8.3 – Sea Dumping. QGC is continuing its assessment of the potential for sea dumping as a possible mitigation for sediment-related risks associated with rehandling sediments into the proposed Fisherman's Landing reclamation.
- Vol 2
  - *Ch 4 s.4.3.* This section describes the LNG facilities in general and identifies the features of State and National Environmental Significance. With respect to Matters of National Environmental Significance, this section identifies the Great Barrier Reef World Heritage Area and the Directory of Important Wetlands of Australia.
  - *Ch 10.* This section describes swing basin and shipping channel operations, with the relevant synopsis being that GPC, under the provisions of the Transport Infrastructure Act 1994 (Qld) is the statutory operator of the Port and will manage its operation and maintenance. Shipping operations within the Port of Gladstone, including within any in the proposed Curtis Spur Channel, are managed by the Gladstone Harbourmaster, principally under the provisions of the Maritime Safety (Queensland) Act 2002. Volume 6 addresses maintenance dredging requirements, which are predicted to be very low, only briefly.
  - *Ch 14 s 14.1 – 14.8. Volume 2 Chapter 14* describes the QCLNG Project and matters related to construction of swing basins and channels. It identifies methods and alternatives, identifies the cumulative impact scenario pertinent to the QCLNG Project, and identifies other relevant statutory approvals required. Impact assessment of the works described in *Volume 2 Chapter 14* occurs in *Volume 6*.
- *Vol 5*
  - *Ch 7 s.7.2 – 7.10*. This section addresses terrestrial ecology of the LNG site, and concludes that no terrestrial plants, amphibians, reptiles or mammals of state or national conservation significance are expected to occur within the study area.
  - *Ch 8 s 8.2 - 8.6.* This section addresses marine ecology associated with the QCLNG site, with *Chapter 8 s 8.3.3* specifically discussing Matters of National Environmental Significance. Given the geographic overlap of the QCLNG study site and the swing basin and channel construction area, the findings of *Volume 5 Chapter 8* are directly relevant to Volume 6, and have been utilized within *Volume 6*. Section 8.4.6 deals with the impact assessment of MNES involving marine ecology. This section concludes that there are 12 threatened marine species, 24 migratory marine species and 72 listed marine species that may be present in the Port of Gladstone area. *Annex 5.3* provides a full list of EPBC Act listed species. The assessment concluded that the Project would not have a significant impact on EPBC Act listed species, due to the small number

of individuals that utilise the subject site, and the likelihood that small numbers of marine fauna would continue to utilise parts of the site during the construction and operational phases of the Project.

  - *Ch 11 s 11.2 – 11.8.* This Chapter addresses the coastal environment, and relevant material has been utilized in *Volume 6*. Please refer to *Volume 5 Chapter 11 s 11.2 – 11.8* for a broader-ranging discussion of matters associated with water movement and coastal processes.

- *Vol 6.* The current Volume addresses matters specifically pertaining to the marine environment affected by construction of swing basins and channels. *Section 1.3.2* identifies the presence of cetaceans, shorebirds and seabirds, some of which are significant species listed under various agreements. However, this section also notes that, although these species occur in the area, no portions of Port Curtis have warranted listing under these agreements.
- *Vol 13.* This Volume specifically summarises Matters of National Environmental Significance. *Sections Chapter 2 s.2.5.9* addresses MNES with respect to swing basin and channel dredging. The summarised findings are consistent with the conclusions of this *Volume 6*. *Annex 13.3* provides a more comprehensive report than the summary provided in *Volume 13*.

1.6.4 Commitments List

QGC undertakes to:

- work with GPC on further engineering design and planning for dredging, reclamation and disposal methods
- work cooperatively with any other proponents undertaking contemporaneous dredging within the WBSDD Project framework, to ensure that cumulative impacts are effectively managed, and
- develop (with GPC if required) a plan for further investigations leading to a Dredging EMP, typical requirements of which are tabulated below:
  - Final layouts and design of shoreline facilities to take into consideration the loss of important habitats to ensure clearing and direct permanent impacts are minimised.
  - Management and mitigation controls will be developed, verified and implemented in relation to dredging activities and reclamation pond overflows.
  - Close monitoring of sediment mobilisation and dredge plume dispersion to ensure any increases in turbidity do not exceed levels which might have an adverse impact on resident benthic communities in the harbour.
  - Further modelling and predictive work on the final configuration and scheduling of dredging to determine the maximum intensity and scheduling so that long term or permanent habitats losses are

adequately managed.

- Sediment sampling program at the reclamation area to confirm effective treatment and containment of any contaminated sediments.
- Develop an Acid Sulfate Soils EMP that will, amongst other matters, identify dredge scheduling to place PASS materials into reclamation ponds at their deepest level.
- Develop a common Fuel Management EMP which will include clear guidelines for refuelling operations to ensure the potential risk of a loss of containment is minimised.
- The development of HSSE induction and training materials for marine crews to enhance everyday surveillance / avoidance procedures.
- The use of Turtle Excluding Devices on mobile dredges.
- Blasting to be used as a method of last resort, following rotary drilling to confirm soil hardness.
- Consult with the Harbour Master on measures to reduce collision risk.
- Consult with the Port on hydrocarbon spill management including crew training, review of locally available equipment and supplies.

BMT WBM

Internal Memorandum

From:	Tony McAlister	To:	BG – Attention Dr Brett Kettle
Date:	16th July 2009	CC:	
Subject:	Initial Dilution Assessments		

Dear Brett

Following from our earlier discussions and e-mail correspondence, we have now completed the initial dilution assessments associated with various potential dredging/tail water/spoil disposal cases at Gladstone. These assessments have evaluated the likely rates of dilution of pore waters liberated by dredging and spoil disposal practices, as well as the dilution of elutriate waters, which may be formed due to the mixing of spilled solids with ambient waters in Port Curtis.

In regard to these assessments, the following background and assumptions apply:

- We have used the well calibrated and most up-to-date TUFLOW-FV model of Port Curtis for these assessments;
- Four (4) potential locations of dredging and associated tail water/spoil discharge were considered, as follows;
  - A grab dredge of 150 m^3/hr capacity operating in the vicinity of the MOF;
  - A cutter suction dredge (CSD) of 1500 m^3/hr capacity operating in the vicinity of the proposed BG swing basin;
  - Discharges of CSD spoil material to a site 'within' the proposed FL153 impoundment area; and
  - Discharge/dumping of 12,000 m^3 capacity trailing suction hopper dredge (TSHD) material at the site of a potential unconfined 'pit' immediately to the north of the FL153 impoundment (note we have not simulated the pit in the model).
- Rates of spillage of sediment from these operations were derived based on sources such as Collins (1995) and John et al (2000). In summary, the following rates were adopted:
  - Grab dredge - 10 kg spillage/m^3 of excavation or 1,500 kg/hr spillage (25 kg/minute); and
  - CSD - 6 kg spillage/m^3 of excavation or 9,000 kg/hr spillage (150 kg/minute).
- In regard to 'pore water', we have assumed a bulk (wet) sediment density of 2 tonnes/m^3, which equates to a 40% voids ratio. This converts to 0.25 m^3 of water per 1 tonne of solids.
- In regard to 'elutriate', we have assumed a 10:1 ratio of spilled solids to the entrained water as defining the effective elutriate discharge rate. In the case of the CSD discharge, this rate was reduced to 5:1 based on advice from BG dredging specialists in regard to how much water will be used in the standard operation of a CSD.
- For the TSHD, we have assumed that dumping will occur as a 10 minute 'pulse' load on a three hourly cycle. Elutriate is calculated using the above quoted 10:1 ratio.
- Based of all of the above, eight (8) discharge cases can be derived as listed in Table 1.
- The TUFLOW-FV model was run for a two (2) week period to enable both some degree of model warmup, and also midfield accumulation of discharged material. The model results were then interrogated to identify the initial dilution characteristics of each discharge case under both neap and spring tide conditions

(see Figure 1). The model was started at a time coming out of neap tides. Typical local wind forcing data were applied to the model.

Table 1 Model Loading Assumptions

Source	Solids spillage	Pore water	Elutriate
Backhoe	1.5 t/hr	0.1 L/s	.0042 m^3/s
CSD	9 t/hr	0.62 L/s	.025 m^3/s
CSD Tail Water	3,000 t/hr	166 L/s	4.167 m^3/s
TSHD Dumping	2,400 t/min	8,000 L/s	400 m^3/s

- Model loadings were simulated as an effective 1 g/L discharge at the rates listed in Table 1 above (in fact, we combined the flowrate with this concentration to derive a 'loading', this was then applied to the model).
- Model results were then extracted at the locations of the proposed discharges in the TUFLOW-FV model to provide the **worst case** initial dilutions. Time series of concentration predictions were interrogated and are presented for each discharge case in the attached Figure 2 to Figure 5.
- In regard to the dilutions presented in Figure 2 to Figure 5, note that a dilution of 0 implies that the model location contains **only** discharge water and **no** ambient or background waters from Port Curtis. A dilution of 1 represents equal mixing of discharge water and ambient waters etc etc.

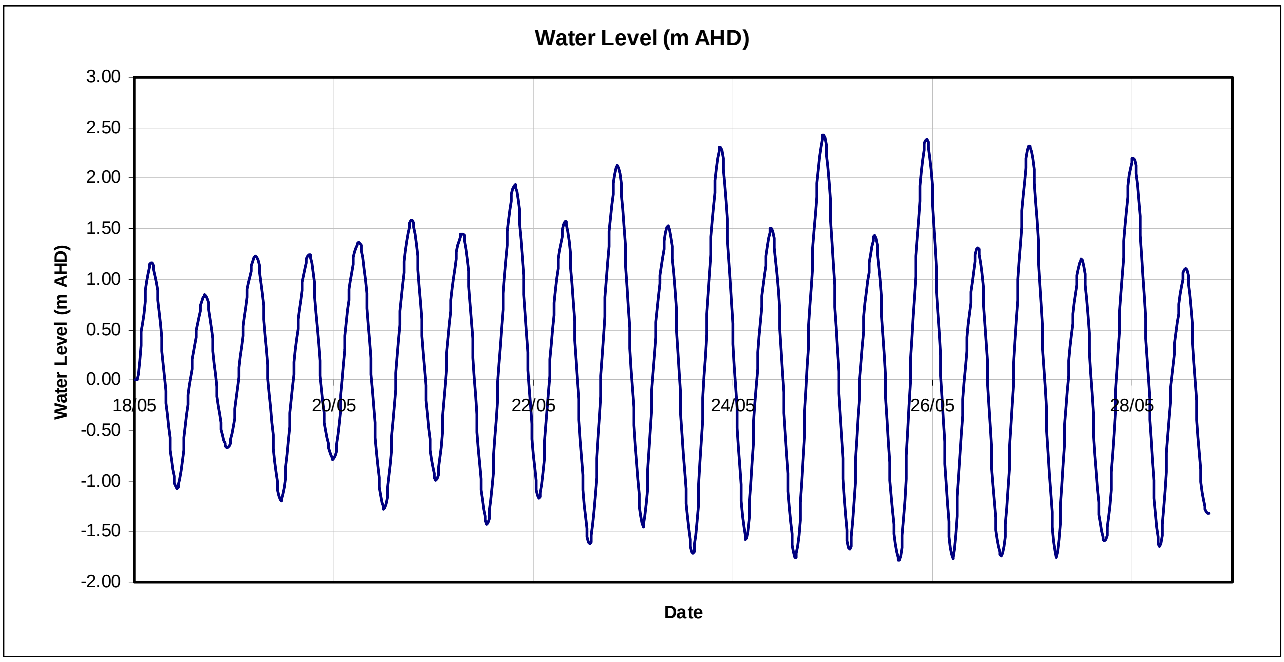
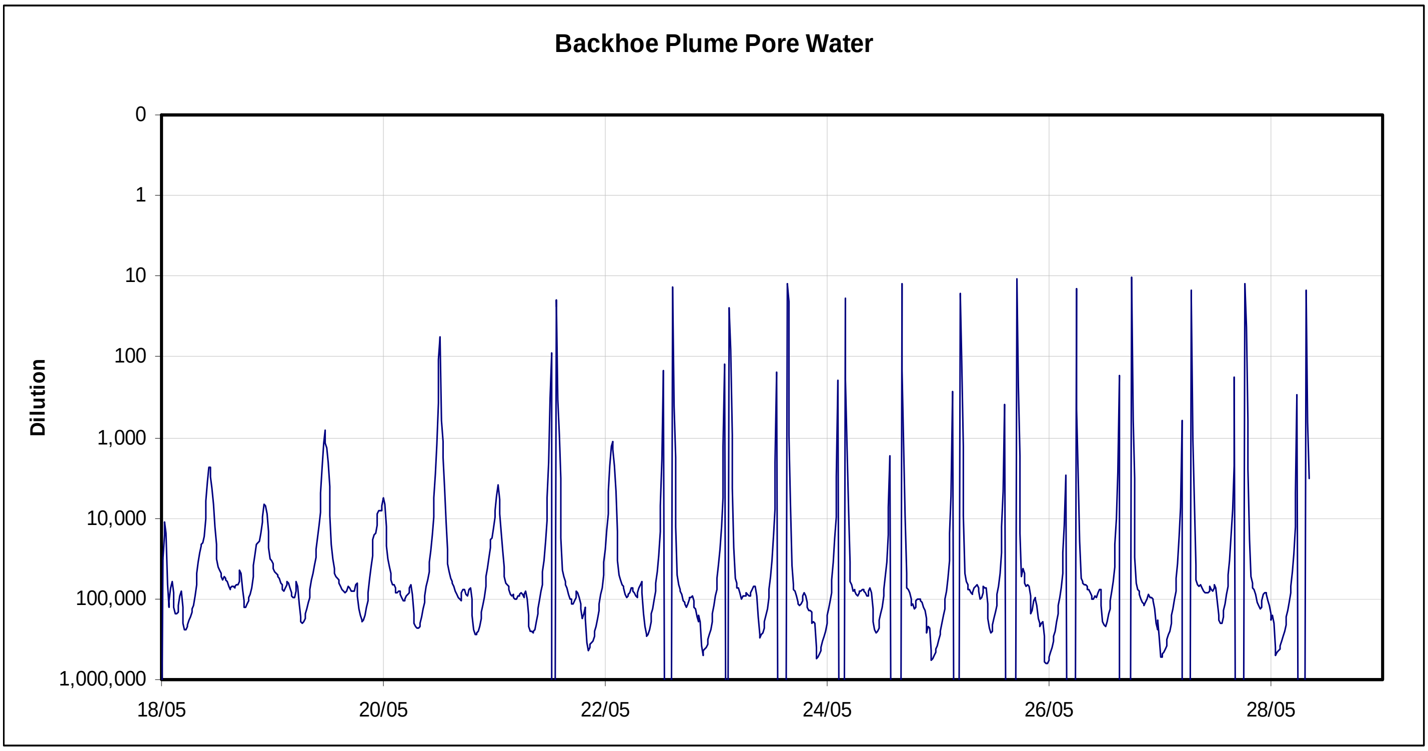


Figure 1 Tidal Data for Modelled Period



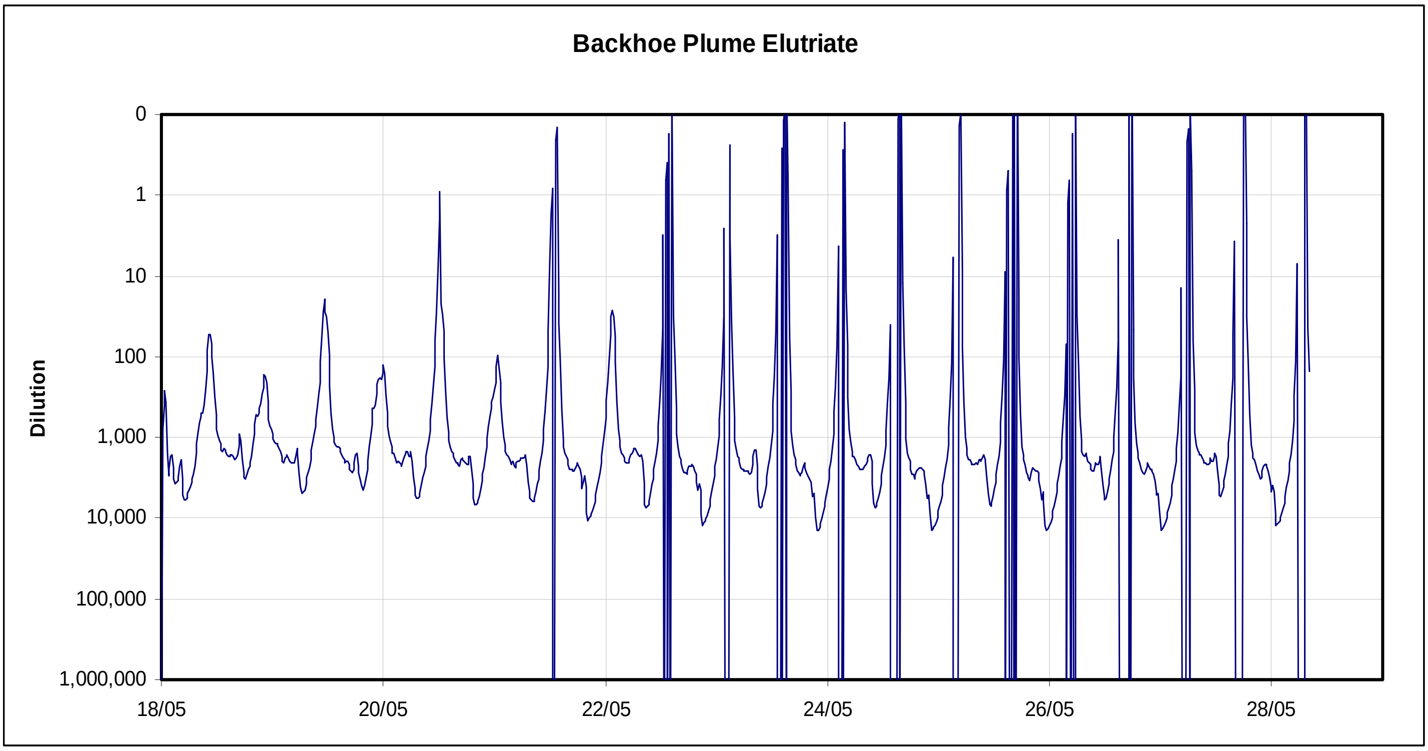
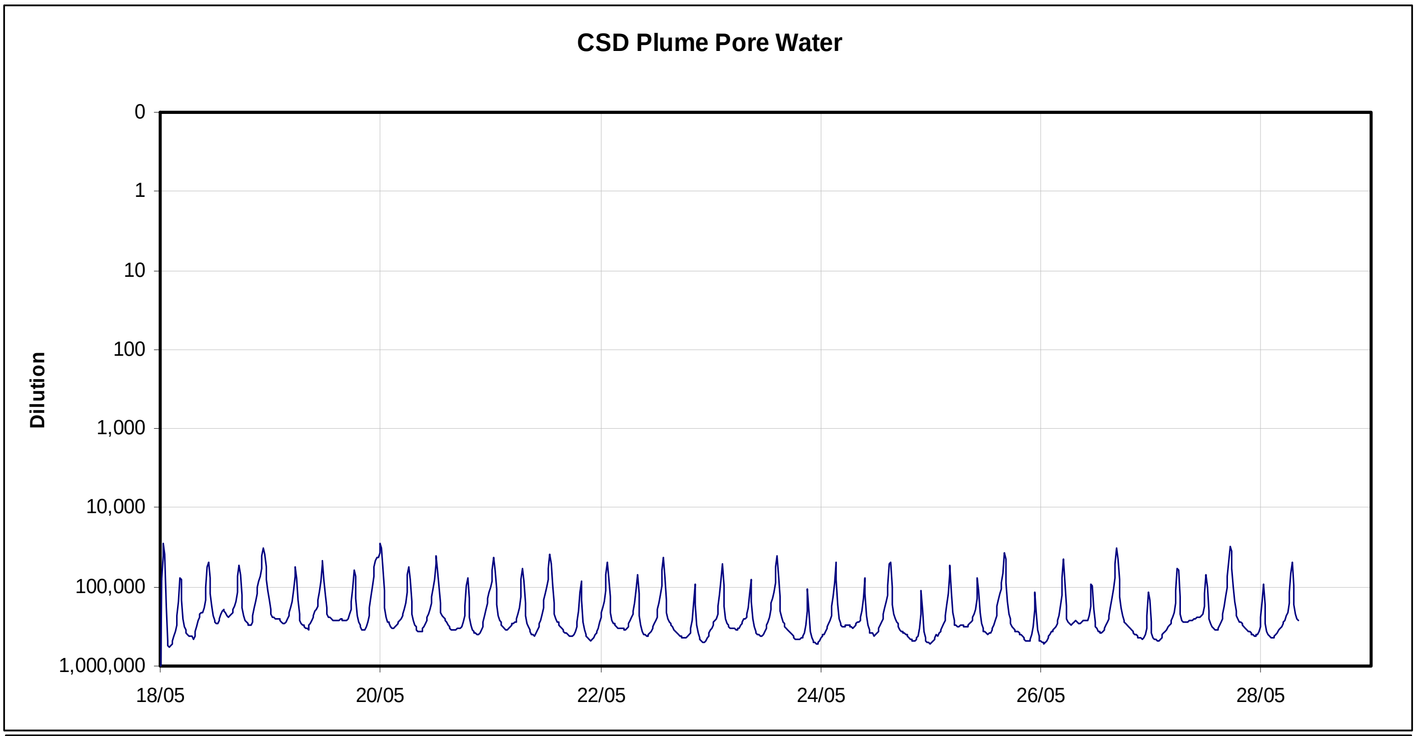


Figure 2 Backhoe Pore Water and Elutriate Dilutions



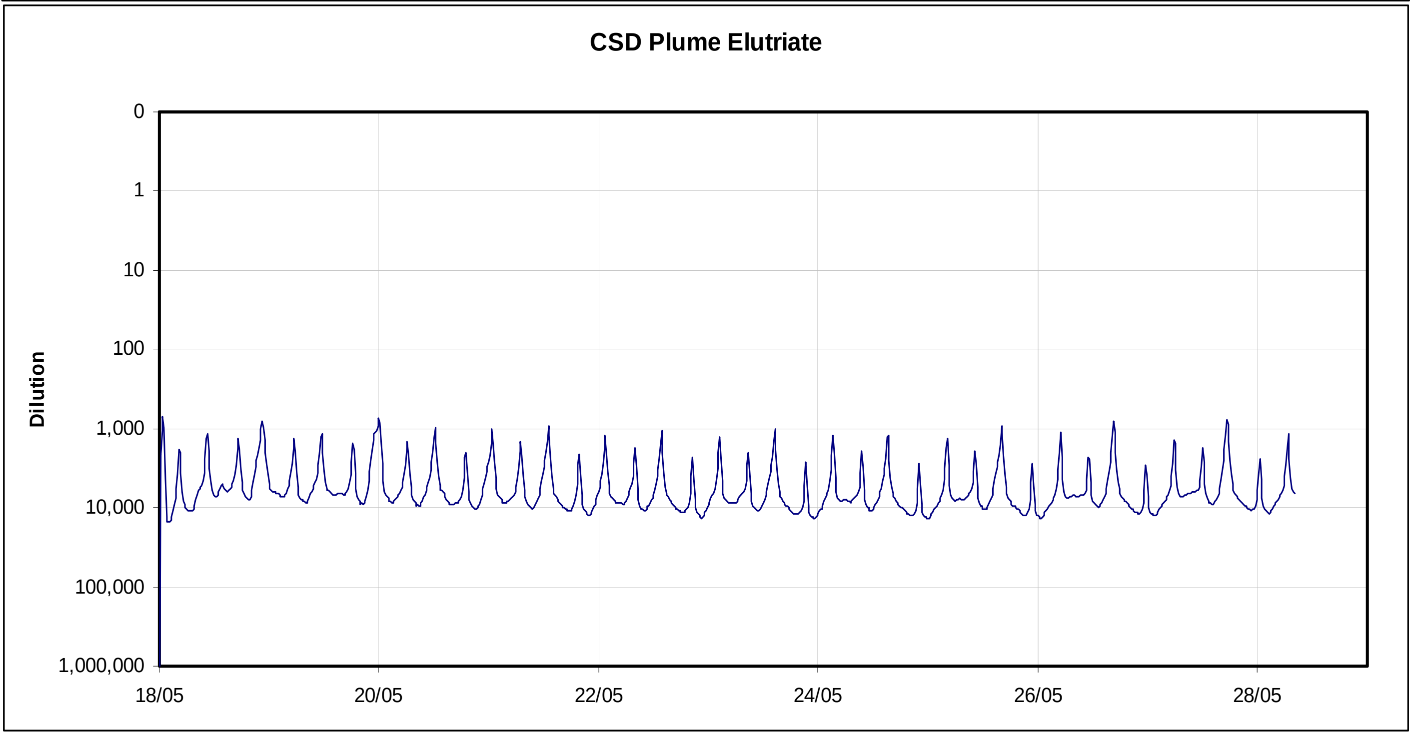
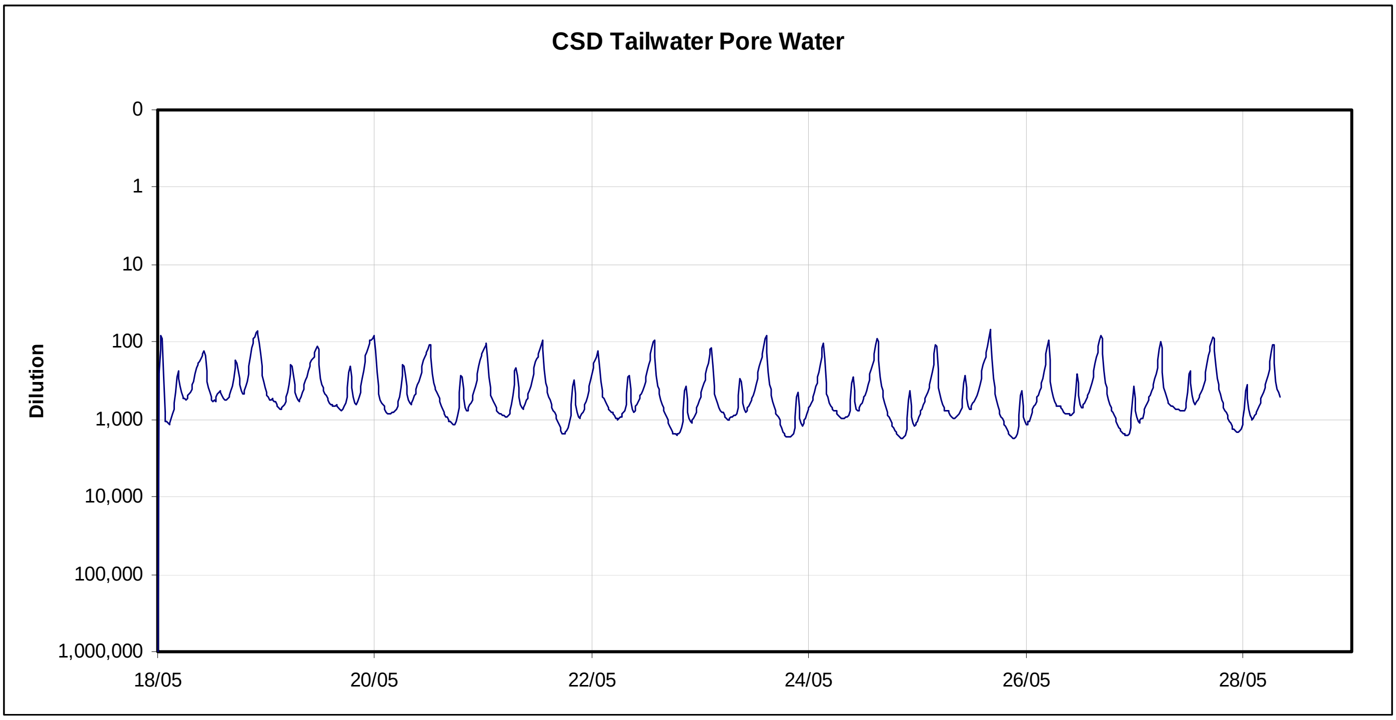


Figure 3 CSD Pore Water and Elutriate Dilutions



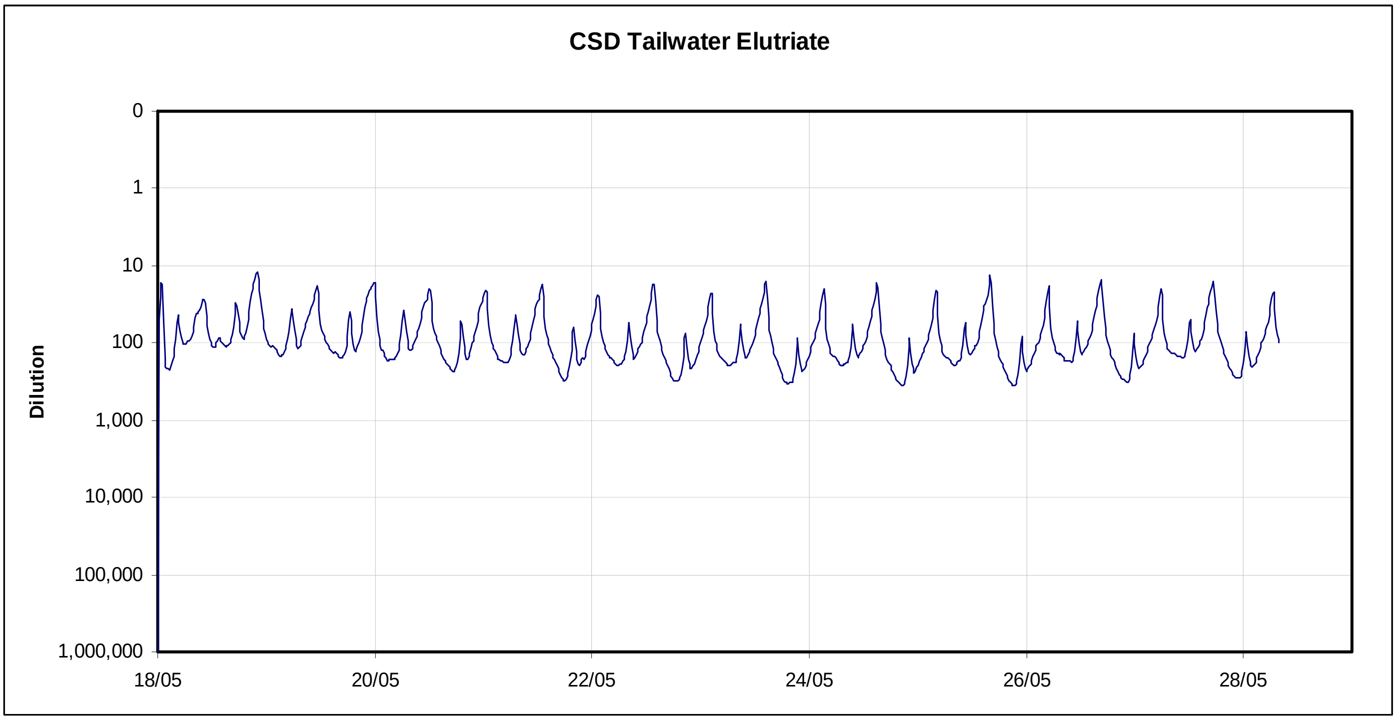
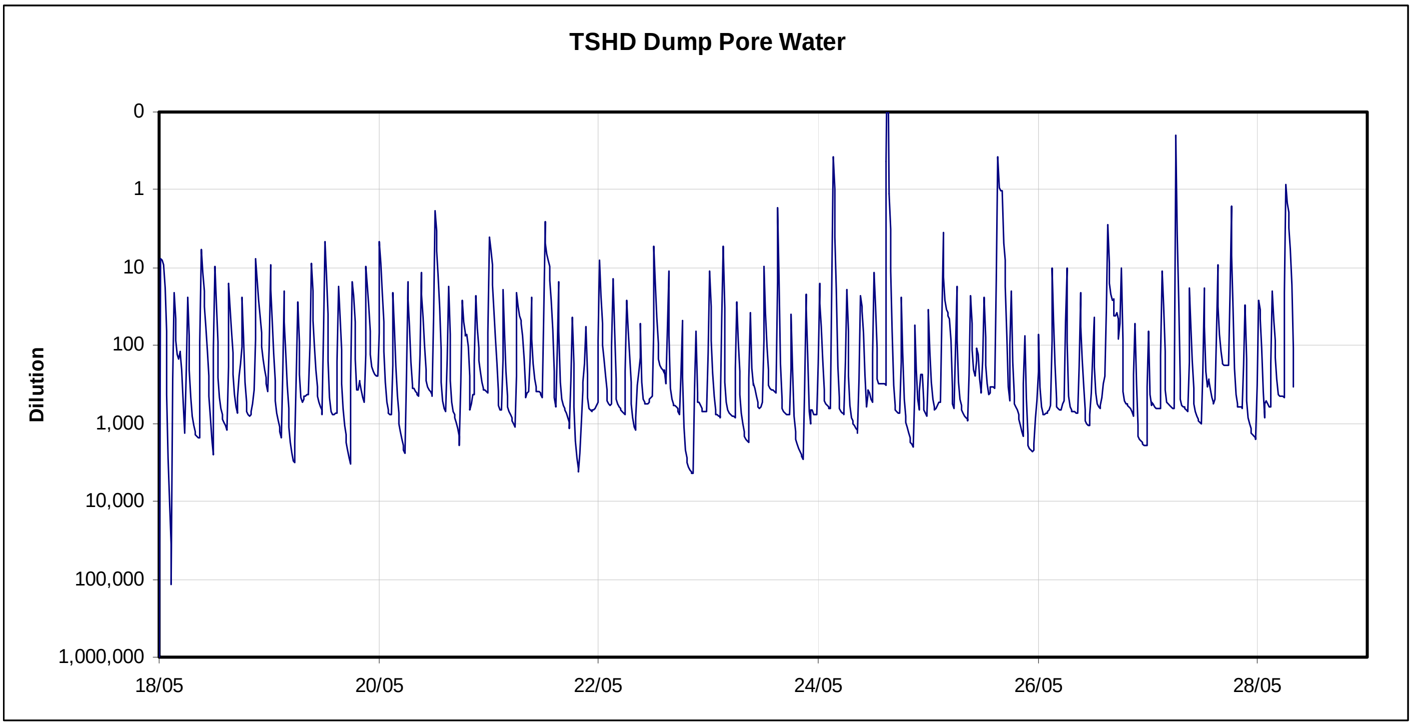


Figure 4 CSD Tailwater Pore Water and Elutriate Dilutions



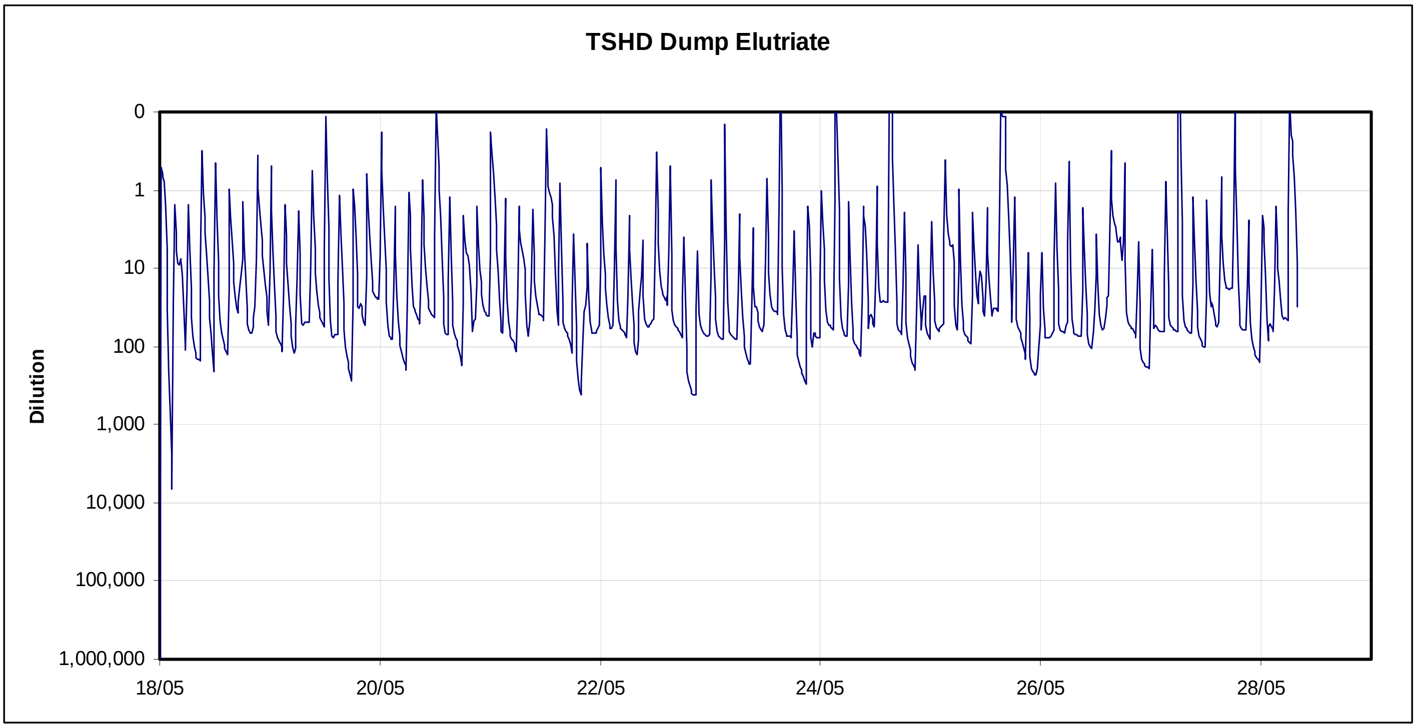


Figure 5 TSHD Dumping Pore Water and Elutriate Dilutions

The above analyses have focused on initial dilutions of pore water and sediment/water (or elutriate) mixtures at the point of discharge to the waters of Port Curtis. In the case of elutriate, what may be of more interest to regulatory bodies is the fate of the sediment/water mixture typically after four hours of advection and dispersion. This is a somewhat more difficult situation to simulate using the Port Curtis TUFLOW FV model as the patterns of transport and mixing of materials between the various sites is highly dynamic, obviously varying due to different flow patterns within and between tidal cycles. This makes selection of any one particular model extraction site with which to define additional dilution problematic.

In order to quantify this process however, the model was used with the following key assumptions:

- A time period when minimum initial dilutions were being predicted at all sites within the model domain was determined. As could be expected, this time period correlated with a low, neap tide condition;
- An ‘artificial’ discharge of two-hour duration bracketing the critical low tide was simulated at each site, and subsequently tracked in the model for a four-hour period as it advected and dispersed throughout the model domain;
- At the end of this four-hour period, the maximum concentration at the centroid of the simulated plume was extracted from the model;
- By comparing this value with the initial concentration that was predicted by the model at the discharge point, we can then derive the *additional* dilution associated with the four hours of transport and mixing within the model domain.

The results of these assessments for each potential discharge site are summarised in Table 2 below.

Table 2 Additional Dilution of Elutriate after Four Hours Transport/Mixing

Source	Additional Dilution
Backhoe	10:1
CSD	32:1
CSD Tail Water	10:1
TSHD Dumping	20:1

This process, in terms of how the concentration profiles change between the two sides, is illustrated in Figure 6. The predicted patterns of worst elutriate dilution for each discharge case combining the results presented in Figure 2 to Figure 5 (initial dilution) with the results of Table 2 (subsequent dilution over a 4 hr period) can now be derived, and are presented in Figure 7 and Figure 8.

Conclusions

Salient conclusions which can be drawn from this work are as follows:

a) In the case of backhoe operations in and around the MOF, even though the loads of both pore water and elutriate are quite low, there is some potential for short term, localised, water quality impacts. This is due to the low volumes of resident water and associated reduced tidal exchange rates in and around the MOF under low, spring tide, conditions. Figure 9 shows tidal water levels on the same graph as predicted MOF backhoe elutriate concentrations and it is apparent that maximum elutriate concentrations/minimum dilutions occur under low, spring tide conditions. Within 4 hours of discharge of materials at this location and the formation of an elutriate, additional dilutions of at least a further factor of 10 to those presented in Figure 2 should occur.

b) For the CSD operating in the vicinity of the proposed swing basin, dilutions are always high. This is due to the large volumes of water in this area and the higher tidal flow rates. There are unlikely to be any impacts associated with this operation from a pore water or elutriate related water quality perspective. Within 4 hours of discharge of materials at this location and the formation of an elutriate, additional dilutions of at least a further factor of 32 to those presented in Figure 3 should occur.

c) For the CSD tailwater case, dilutions are still quite acceptable, for similar reasons b) above. There is some long-term accumulation apparent in this location, at dilutions of the order of 500:1 for pore water and 100:1 for elutriate. There are unlikely to be any impacts associated with this operation from a pore water or elutriate related water quality perspective. Within 4 hours of discharge of materials at this location and the formation of an elutriate, additional dilutions of at least a further factor of 10 to those presented in Figure 4 should occur.

d) For TSHD dumping, the degree of potential impact is much greater than any of the other potential cases, obviously due to the quantum of material being dealt with. There is an obvious trend to increasing concentrations/reducing dilutions of material when dumping occurs on or around slack water, especially in the case of low spring tides. This trend is readily apparent in Figure 10. Within 4 hours of discharge of materials at this location and the formation of an elutriate, additional dilutions of at least a further factor of 20 to those presented in Figure 5 should occur.

Recommendations

Key recommendations that are apparent based on the findings of this investigation are as follows:

- For backhoe dredging in and around the MOF, consideration should be given to suspending works for a period of 1 to 2 hours either side of low water, spring tide, conditions. This will significantly reduce the potential for water quality and associated ecological impacts in the vicinity of the MOF; and
- For TSHD dumping, such works should ideally be scheduled so that they do not occur on or around any low tide, especially so in the case of spring tides.

References

John, S.A, Challinor, S.L., Simpson, M., Burt, T.N. and Spearman, J. (2000). Scoping the assessment of sediment plumes from dredging. CIRIA London

Collins, M.A. (1995). Dredging-Induced Near-Field Sediment Concentrations and Source Strengths. US Army Corps of Engineers.

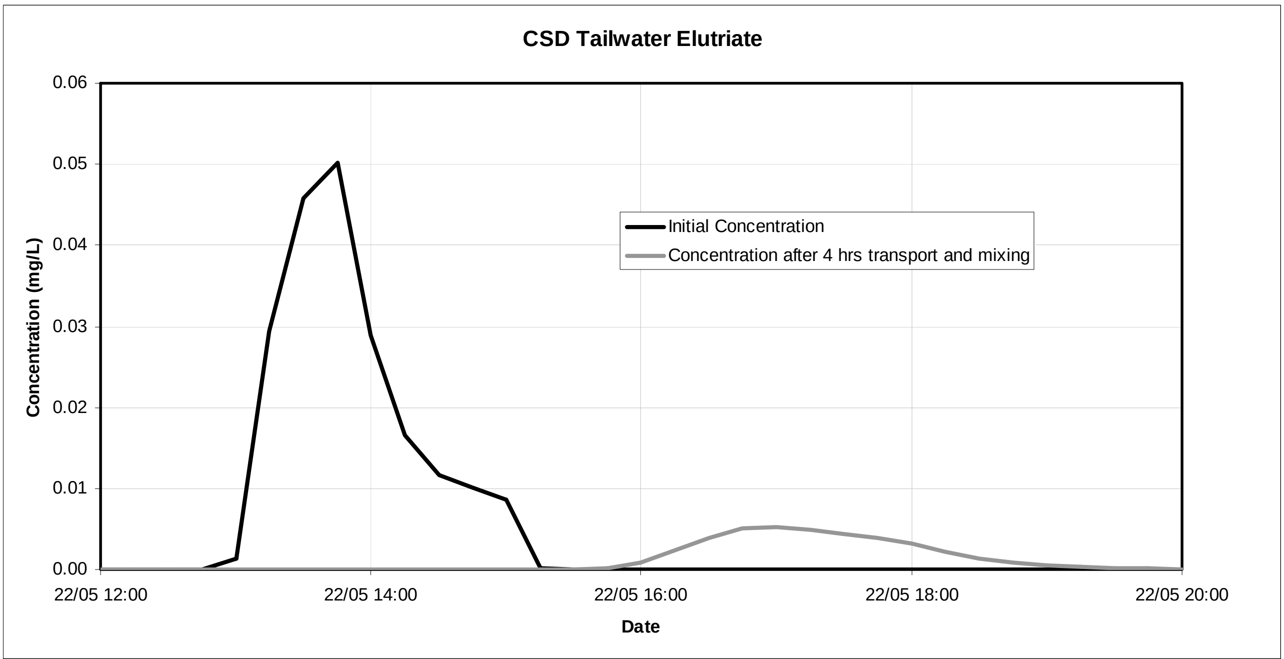
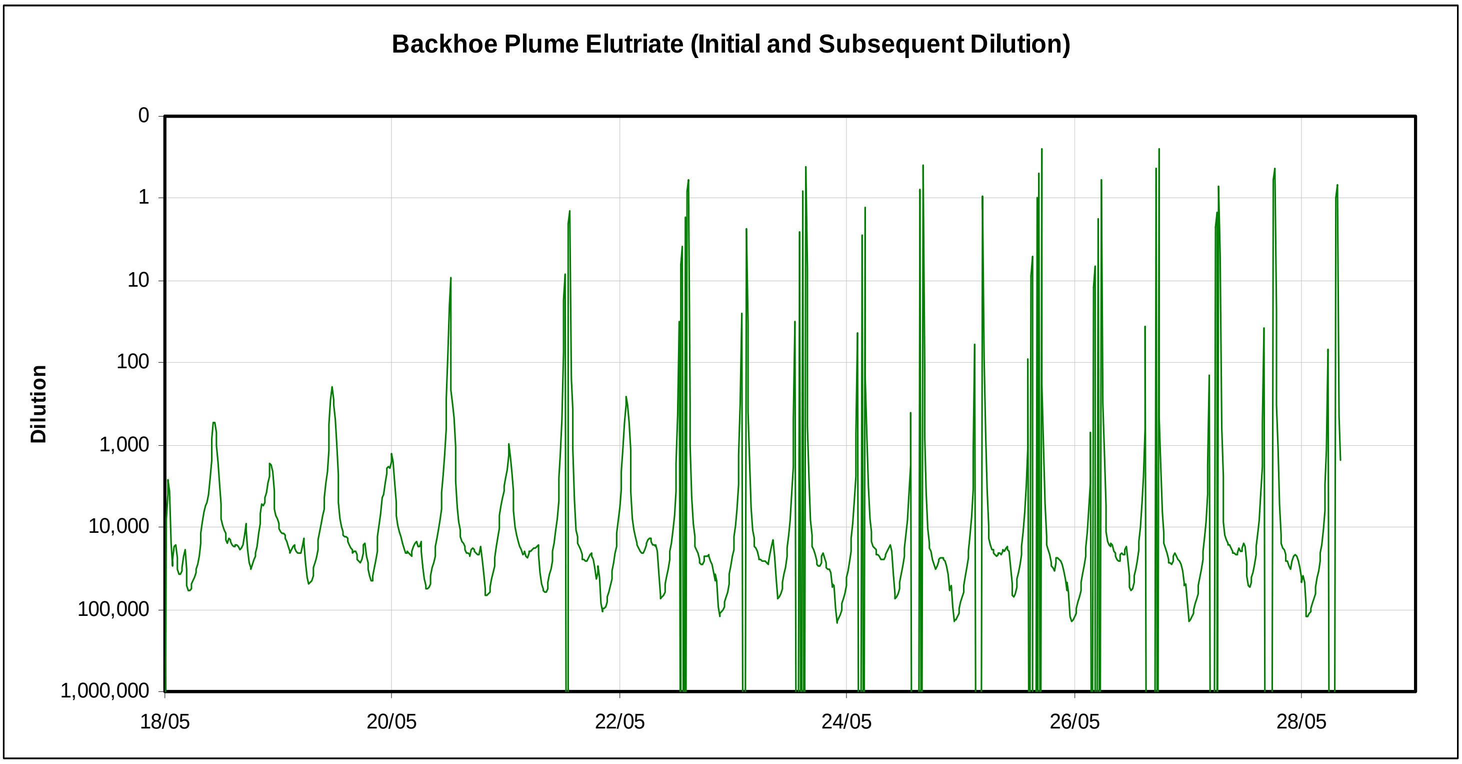


Figure 6 Example of Additional Dilution of Elutriate after Four Hours Transport/Mixing



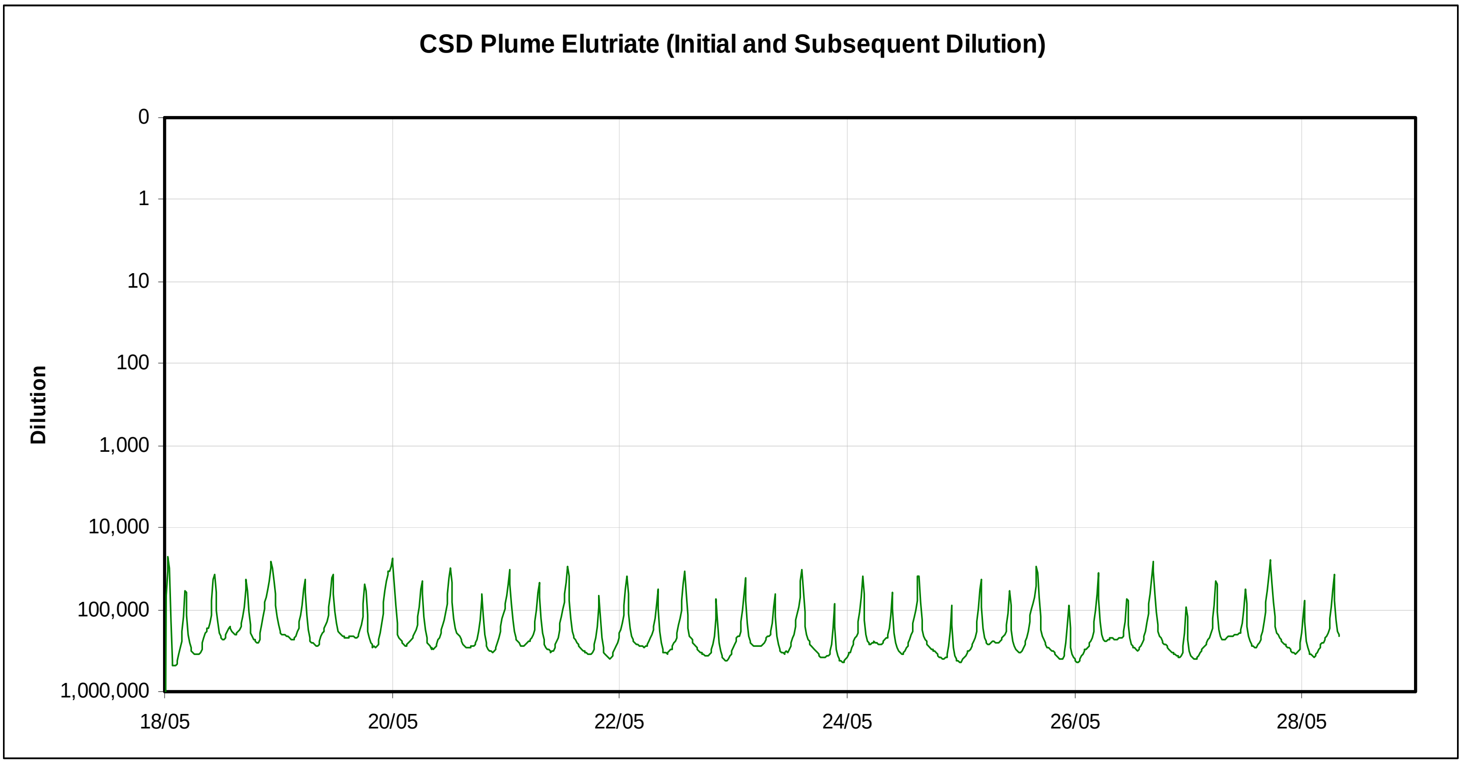
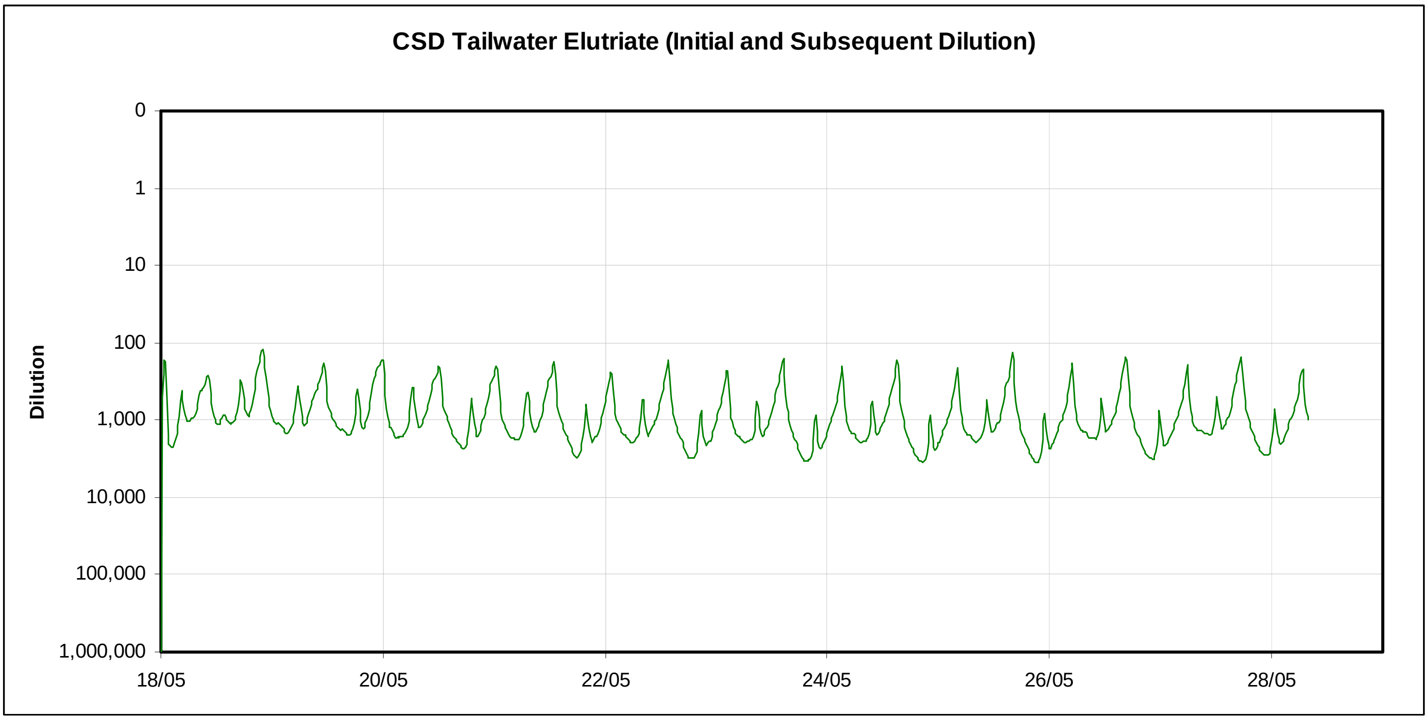


Figure 7 Backhoe and CSD Plume Elutriate Combined Initial and 4 Hr Dilutions



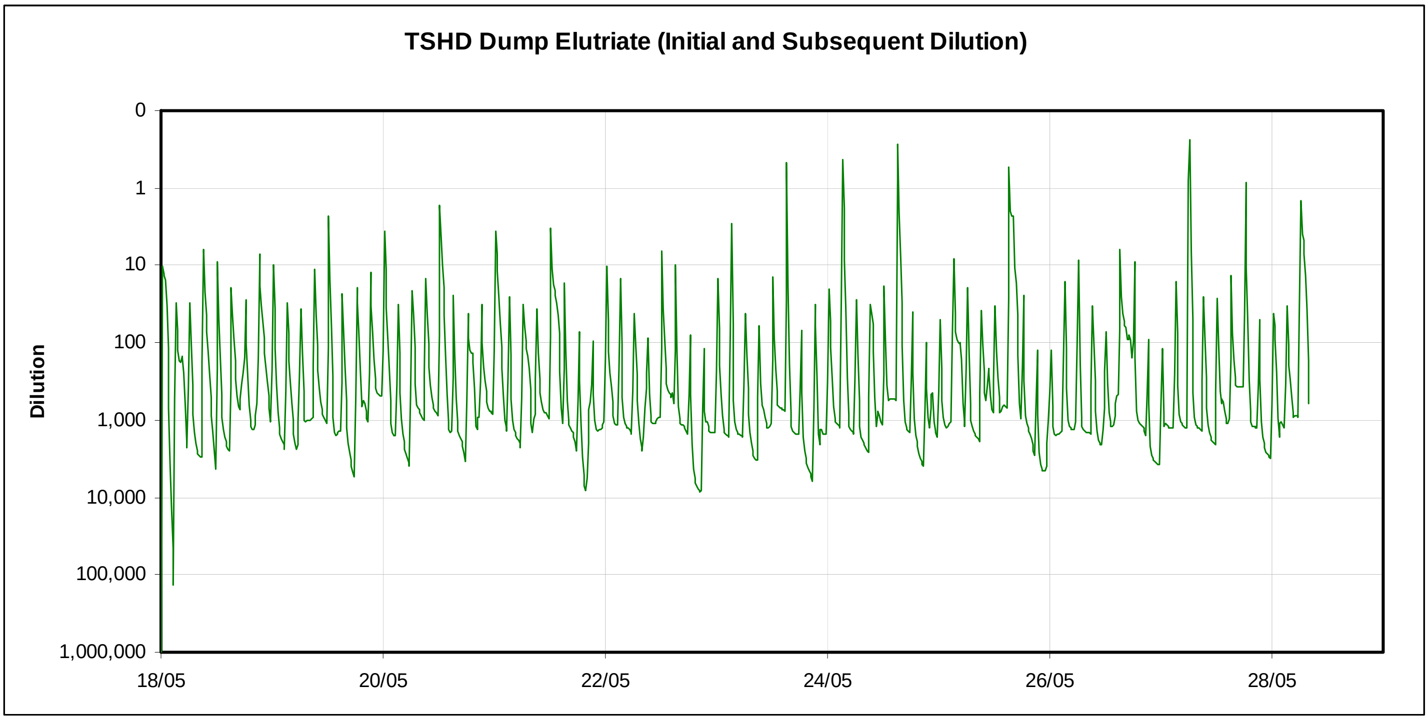


Figure 8 CSD Tailwater and TSHD Dumping Elutriate Combined Initial and 4 Hr Dilutions

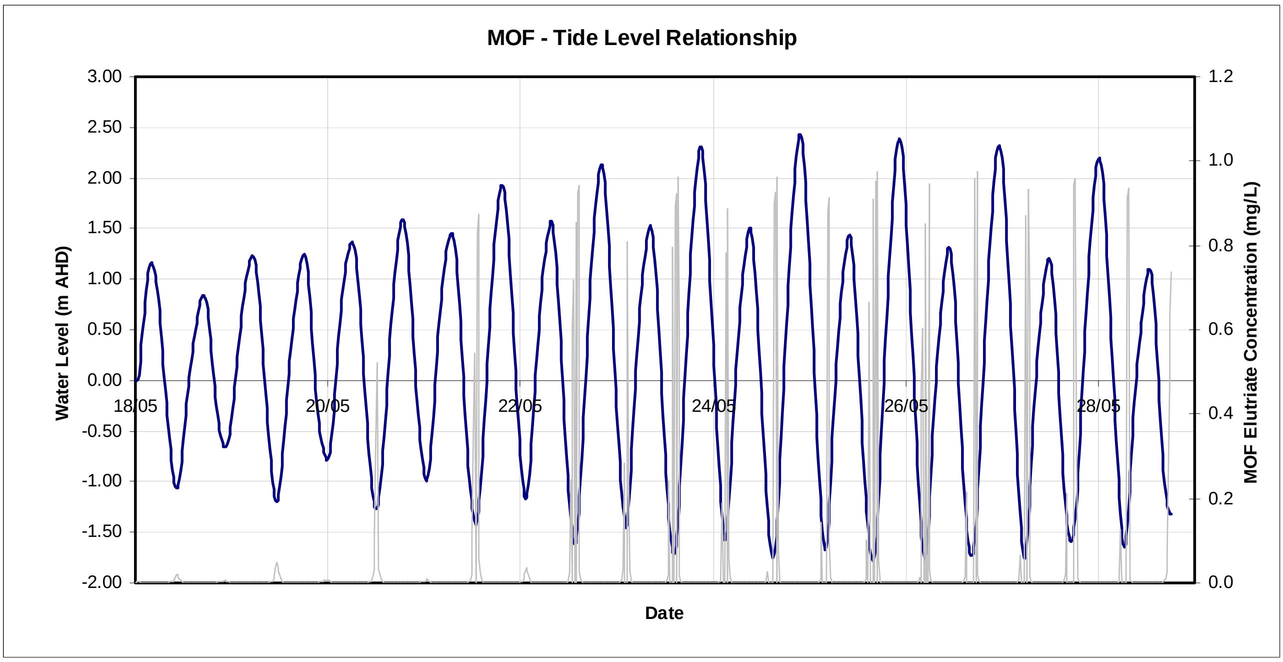


Figure 9 Backhoe Elutriate Concentration plotted with Tidal Water Levels

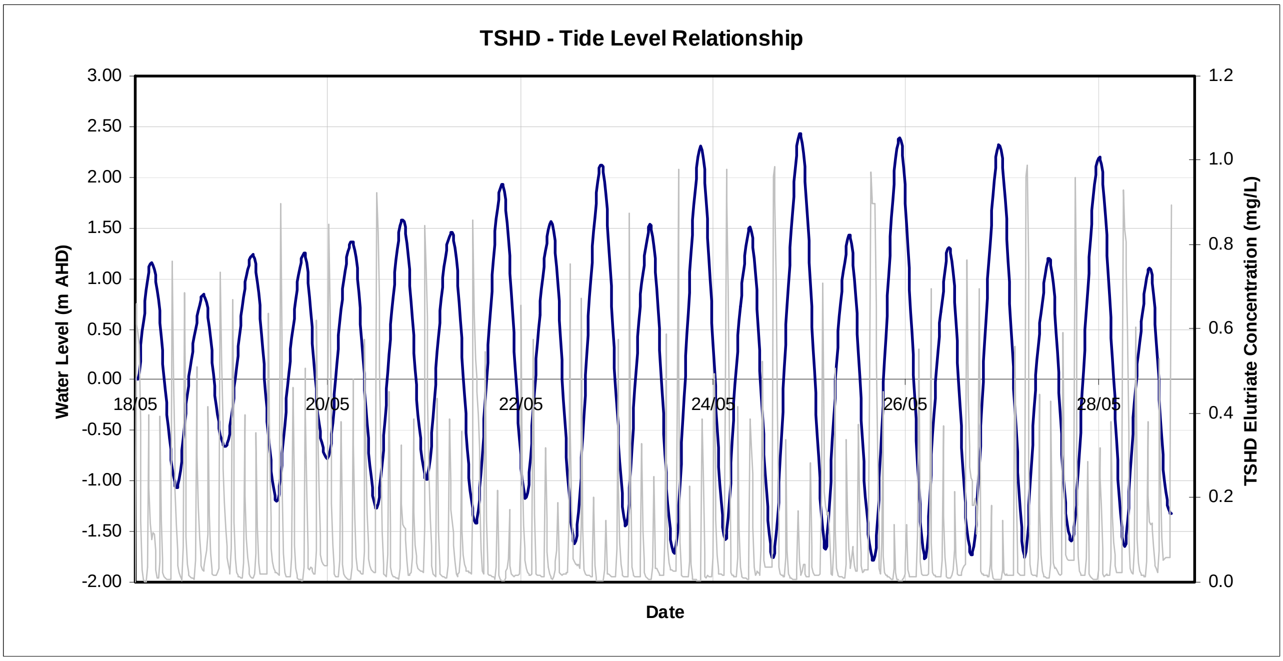


Figure 10 TSHD Dumping Elutriate Concentration plotted with Tidal Water Levels