



G5 | Water Quality



Report

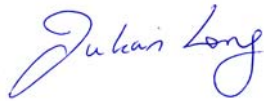
Port Curtis Marine Water Quality Studies

NOVEMBER 2009

Prepared for
Santos
32 Turbot Street
Brisbane, Qld 4000
42626452

URS

Project Manager:

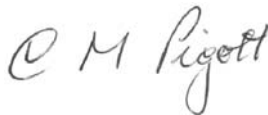


Julian Long
Principal Water Quality
Scientist

URS Australia Pty Ltd

**Level 16, 240 Queen Street
Brisbane, QLD 4000
GPO Box 302, QLD 4001
Australia
T: 61 7 3243 2111
F: 61 7 3243 2199**

Project Director:



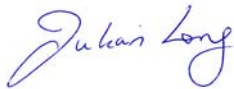
Chris Pigott
Senior Principal

Author:



Violette Edwards
Graduate Engineer

Reviewer:



Julian Long
Principal Water Quality
Scientist

Date: **November 2009**
Reference: 42626452/01/C
Status: FINAL

© Document copyright of URS Australia Pty Limited.

The contents of this report are and remain the intellectual property of URS and are not to be provided or disclosed to third parties without the prior written consent of URS. No use of the contents, concepts, designs, drawings, specifications, plans etc. included in this report is permitted. URS Australia accepts no liability of any kind for any unauthorised use of the contents of this report and URS reserves the right to seek compensation for any such unauthorised use.

Document delivery

URS Australia provides this document in either printed format, electronic format or both. URS considers the printed version to be binding. The electronic format is provided for the client's convenience and URS requests that the client ensures the integrity of this electronic information is maintained. Storage of this electronic information should at a minimum comply with the requirements of the Commonwealth Electronic Transactions Act (ETA) 2000.

Where an electronic only version is provided to the client, a signed hard copy of this document is held on file by URS and a copy will be provided if requested.



Table of Contents

	Executive Summary	vi
1	Introduction	1
1.1	Study Methodology.....	1
2	Project Description	2
2.1	Dredge Material Characteristics	4
2.2	Dredging Scenario and Plume Loadings.....	5
2.2.1	Dredging Scenario	5
2.2.2	Dredge Losses and Plume Loadings.....	5
2.2.3	Decant Assumptions	6
3	Legislative Context	7
4	Baseline Coastal Environmental Conditions	9
4.1	Sensitive Environments within Port Curtis	9
4.1.1	Sensitive Receptors.....	9
4.1.2	Seagrass and Coral Tolerances to Dredging Impacts	9
4.2	Background Turbidity and TSS Levels in Port Curtis	9
4.2.1	Scope	9
4.2.2	Water Quality Guidelines	9
4.2.3	Literature Review Data Sources.....	9
4.2.4	Field Survey.....	9
4.2.5	Results and Discussion	9
4.3	The Relationship between Turbidity and TSS Levels in Port Curtis.....	9
4.3.1	Scope	9
4.3.2	Literature Review Data Sources.....	9
4.3.3	Discussion.....	9
4.4	The relationship between PAR and Turbidity	9
4.4.1	Scope	9
4.4.2	Literature Review	9
4.4.3	Results	9
4.5	Baseline Sedimentation Rates.....	9
4.5.1	Scope	9
4.5.2	Literature Review	9

4.5.3	Field Investigation	9
4.5.4	Results	9
4.5.5	Discussion	9
5	Dredging Impact Assessment.....	9
5.1	Plume Dispersion and Deposition Modelling	9
5.1.1	Background	9
5.1.2	Modelling Methodology	9
5.1.3	Model Results and Discussions - TSS.....	9
5.1.4	Model Results and Discussions – Sediment Deposition	9
5.2	Other Water Quality Impacts from Dredging	9
5.2.1	Scope	9
5.2.2	Field Survey.....	9
5.2.3	Analysis	9
5.2.4	Results	9
6	Mitigation Measures and Recommendations	9
7	References.....	9
8	Limitations	9

Tables

Table 2-1	Dredge Material Volumes	4
Table 2-2	In-situ sediment and long-term plume suspended sediment composition.....	5
Table 2-3	Plume loading assumptions	6
Table 4-1	Selected seagrass communities	9
Table 4-2	Impacts of reclamation on seagrass and coral reef	9
Table 4-3	Queensland Water Quality Guidelines for enclosed coastal and estuarine waters.....	9
Table 4-4	Summary of Turbidity and TSS data for Eastern Port Curtis.....	9
Table 4-5	Summary Turbidity and TSS data.....	9
Table 4-6	Logger deployment	9
Table 4-7	Sediment Trap Deployment Locations.....	9
Table 4-8	Mean Sediment Accumulation Rates.....	9
Table 5-1	Simulation Method and Plume Loading details.....	9
Table 5-2	Model Sediment and Plume Characteristics.....	9
Table 5-3	Summary statistics for predicted TSS concentrations generated by the CSD at sensitive receptor locations.....	9
Table 5-4	Impact severity matrix for suspended sediment impact on Seagrass	9
Table 5-5	Impact severity matrix for suspended sediment impact on Coral	9
Table 5-6	Predicted deposition rates from CSD	9
Table 5-7	Impact severity matrix for sediment deposition impact on Seagrass	9
Table 5-8	Impact severity matrix for sedimentation impact on corals	9

Figures

Figure 2-1	Location Plan	3
Figure 2-2	Average Particle Size Distribution	4
Figure 4-1	Distribution of seagrass beds within Port Curtis area	9
Figure 4-2	Subtidal communities Locations	9
Figure 4-3	Percentage live cover at Subtidal community Sites	9
Figure 4-4	Turbidity Meter Deployment Locations	9
Figure 4-5	Turbidity measurements 7/8/09- 2/9/09	9
Figure 4-6	Turbidity–TSS Relationships from Both Natural and Dredge Plume Sampling	9
Figure 4-7	PAR and Turbidity Logger Deployment Locations	9
Figure 4-8	Turbidity, Wave Height (depth m) and Light at depth for Logger 4 Deployment 2.	9
Figure 4-9	Typical Sediment Trap Assemblage	9
Figure 4-10	Sediment Trap Locations	9
Figure 5-1	Sensitive Receptor Assessment Sites in Port Curtis	9
Figure 5-2	Plume Source Locations	9
Figure 5-3	CSD with 50mg/L decant discharge – maximum plume TSS concentration	9
Figure 5-4	CSD with 50mg/L decant discharge – 10% exceedabce TSS concentration	9
Figure 5-5	CSD with 50mg/L decant discharge – Plume snapshot at 01:00 on 18/02/2009 (Neap Tide)	9
Figure 5-6	CSD with 50mg/L decant discharge – Plume snapshot at 09:00 on 26/02/2009 (Spring Tide)	9
Figure 5-7	Simulated TSS Concentrations for the CSD with 50mg/L decant discharge (PT1)	9
Figure 5-8	Simulated TSS Concentrations for the CSD with 50mg/L decant discharge (PT6)	9
Figure 5-9	CSD with 50mg/L decant - average plume deposition rate	9
Figure 5-17	Sediment Sampling Locations	9

Appendices

Appendix A	Plume Dispersion Modelling and Data Review
Appendix B	Sedimentation Rates
Appendix C	Sedimentation Core Samples - Ellutriate and BOD

Abbreviations

Abbreviation	Description
ADCP	Acoustic Doppler Current Profiler
ALS	Australian Laboratory Services
ANZECC	Australia and New Zealand Environment and Conservation Council
AR	Aspect Ratio
BHD	Backhoe Hydraulic Dredger
BOD	Biological Oxygen Demand
CSD	Cutter Suction Dredger
DEH	Department of Environment and Heritage
DMP	Dredge Management Plan
DMPF	Dredge Material Placement Facility
DNR	Department of Natural Resources
DO	Dissolved Oxygen
DPA	Dugong Protection Area
DPI&F	Department of Primary Industries and Fisheries
EHSMS	Environmental Health and Safety Management System
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
EPBC	Environmental Protection and Biodiversity Act
GBRWHA	Great Barrier Reef World Heritage Area
GLNG	Gladstone Liquefied Natural Gas
GPC	Gladstone Port Corporation
GPS	Global Positioning System
IDAS	Integrated Development Assessment System (of the IPA)
IL	Investigation Levels
IPA	Integrated Planning Act 1997
JCU	James Cook University
LAT	Latitude
LNG	Liquefied Natural Gas
MAR	Mass Accumulation Rate
MGA	Map Grid of Australia
NAGD	National Assessment Guidelines for Dredging 2009
NLWRA	National Land and Water Resources Audit
NTU	Nephelometric Turbidity Units
PAR	Photosynthetically Active Radiation
PCIMP	Port Curtis Integrated Monitoring Programme
PSD	Particle Size Distribution
QWQG	Queensland Water Quality Guidelines
SCUBA	Self Contained Underwater Breathing Apparatus
SE	Standard Error
TSHD	Trailer Suction Hopper Dredge
TSS	Total Suspended Solids

Executive Summary

This report has been prepared as part of the Supplementary EIS to provide additional information on the potential impacts of capital dredging works proposed for the GLNG project on water quality and sensitive habitats within Port Curtis.

Three alternative dredging techniques have been considered for the capital dredging works with the most likely being a combination of Cutter Suction Dredger (CSD), Trailing Suction Hopper Dredger (TSHD) and a hydraulic backhoe dredger (BHD). Santos proposes to use a large CSD for the dredging works. The potential impacts of dredging were assessed through computer modelling of plume dispersion and deposition within Port Curtis and at sensitive receptor sites, and through an assessment of other potential water quality impacts.

A variety of habitats are present within the eastern side of Port Curtis. The sensitive receptors of most concern were identified in the EIS as seagrass meadows. In addition, since completion of the EIS, supplementary investigations have identified other sensitive receptors in the form of subtidal communities comprising a variety of soft corals surrounding Hamilton Point.

The impact assessment found that dredging activity using a CSD has the potential to have a slight impact on an area of seagrass surrounding South Passage Island, with impacts on other seagrass areas in Port Curtis being marginal if any. It is anticipated that the slight impacts on seagrass that may arise during dredging may be recoverable once the dredging has finished. The seagrass meadows in the affected area have been classified as aggregated patches of *Halophila Ovalis* with *Zostera Capricorni* seagrass, contain small biomass and represent only 0.8% of the total seagrass area within Port Curtis. The seagrass communities and low biomass present mean that this area is considered unlikely to be utilised by dugongs.

Modelling predictions also indicate that dredging has the potential to have marginal, if any, impacts on subtidal communities. However it should be noted that the modelling results are based on dredging within the swing basin. Whilst the vast majority of dredging activity (5.7 Mm³) will occur in this location, dredging will also be required for the approach channel (1.1 Mm³) which will require operation of the CSD in closer proximity to the intertidal communities for a period of approximately 8 weeks. During this period sub-tidal communities surrounding Hamilton Point may experience elevated TSS concentrations and minor to moderate impacts are considered possible. The potential for any adverse impacts to arise will be minimised by limiting periods of continuous dredging activity within the approach channel.

Introduction

This report has been prepared as part of the Supplementary EIS to provide additional information on the potential impacts of capital dredging works proposed for the GLNG project on water quality and sensitive habitats within Port Curtis. This report builds on information provided in the coastal environment assessment of the potential impacts of the capital dredging works presented in Section 8.7 and Appendix R2 of the EIS and its purpose is to:

- Provide further detail on baseline conditions within Port Curtis with regard to turbidity, Total Suspended Solids, Photosynthetically Active Radiation, and sediment deposition
- Refine the coastal environment impact assessment to the proposed dredging methodologies
- Discuss potential direct and indirect effects of the proposed dredging on sensitive habitats within Port Curtis
- Address comments that were raised in government agency and public submissions on the EIS

1.1 Study Methodology

This assessment has considered the potential project effects of capital dredging works on marine water quality, hydrodynamics and marine sediments of Port Curtis and supplements information presented in Section 8.7 of the EIS.

The methodology adopted for the assessment involved the following tasks:

- A review of the sensitive environments within Port Curtis
- A review of existing background data for turbidity, Total Suspended Solids (TSS) and Photosynthetically Active Radiation (PAR) within Port Curtis
- Deployment of Nephelometers to obtain background turbidity data in the vicinity of the proposed Dredge Material Placement Facility (DMPF) decant discharge
- A sediment deposition field survey program was undertaken to gather data on background deposition rates at sensitive habitat locations in the vicinity of the capital dredging works
- A revision of the source terms for sediment re-suspension and losses during dredging for the proposed dredging methods
- Assessment of the impacts of the proposed capital dredging activities on the coastal environment by comparison of predicted water quality and sediment deposition rates through hydrodynamic and sediment dispersion modelling with baseline conditions,
- Development of mitigation measures to minimise the potential dredging impacts

Introduction

This report has been prepared as part of the Supplementary EIS to provide additional information on the potential impacts of capital dredging works proposed for the GLNG project on water quality and sensitive habitats within Port Curtis. This report builds on information provided in the coastal environment assessment of the potential impacts of the capital dredging works presented in Section 8.7 and Appendix R2 of the EIS and its purpose is to:

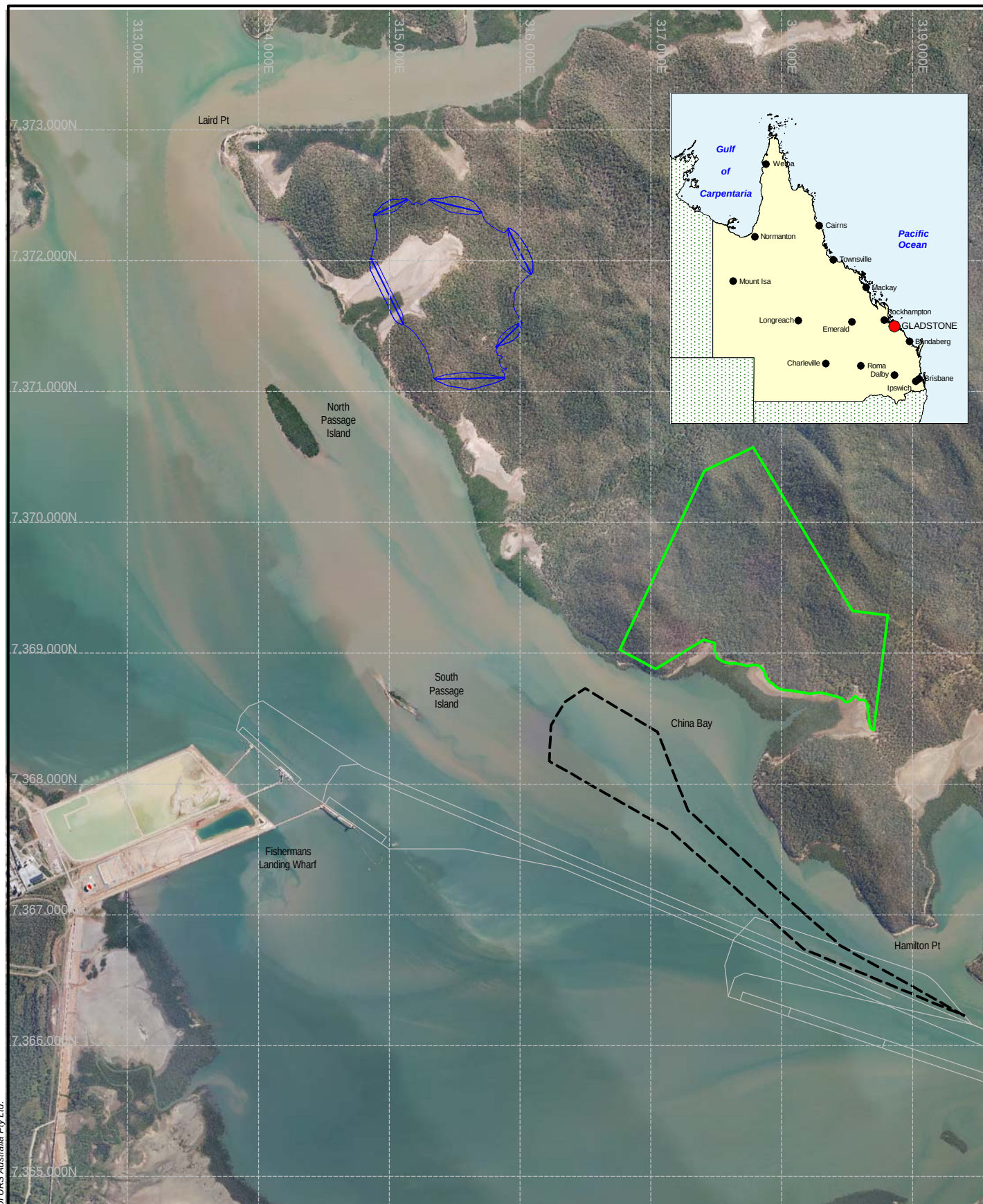
- Provide further detail on baseline conditions within Port Curtis with regard to turbidity, Total Suspended Solids, Photosynthetically Active Radiation, and sediment deposition
- Refine the coastal environment impact assessment to the proposed dredging methodologies
- Discuss potential direct and indirect effects of the proposed dredging on sensitive habitats within Port Curtis
- Address comments that were raised in government agency and public submissions on the EIS

1.1 Study Methodology

This assessment has considered the potential project effects of capital dredging works on marine water quality, hydrodynamics and marine sediments of Port Curtis and supplements information presented in Section 8.7 of the EIS.

The methodology adopted for the assessment involved the following tasks:

- A review of the sensitive environments within Port Curtis
- A review of existing background data for turbidity, Total Suspended Solids (TSS) and Photosynthetically Active Radiation (PAR) within Port Curtis
- Deployment of Nephelometers to obtain background turbidity data in the vicinity of the proposed Dredge Material Placement Facility (DMPF) decant discharge
- A sediment deposition field survey program was undertaken to gather data on background deposition rates at sensitive habitat locations in the vicinity of the capital dredging works
- A revision of the source terms for sediment re-suspension and losses during dredging for the proposed dredging methods
- Assessment of the impacts of the proposed capital dredging activities on the coastal environment by comparison of predicted water quality and sediment deposition rates through hydrodynamic and sediment dispersion modelling with baseline conditions,
- Development of mitigation measures to minimise the potential dredging impacts



0 750 1500m
Scale: 1:40,000 (A4)
Datum: GDA94



Existing Channels
Proposed Dredging Channel



Dredge Material Placement Facility
LNG Facility Indicative Site Boundary

Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Client 	Project GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT SUPPLEMENT MARINE WATER QUALITY		Title STUDY AREA	
	Drawn: RG	Approved: JB	Date: 09-12-2009	Figure: 2-1
	Job No: 4262 6440 /6220	File No: 42626440-g-2160.wor	Rev:B A4	

2 Project Description

2.1 Dredge Material Characteristics

There are broadly two types of material that will be dredged from within the capital dredging area, loose sandy silt and a small amount of rock. Table 2-1 shows the proportions of silty sand and rock to be removed from each of the dredge areas.

Table 2-1 Dredge Material Volumes

Dredge Area	Dredge volumes (m ³)		Total Volume (m ³)
	Silty Sand	Rock	
GLNG basin	5,482,000	193,000	5,675,000
North China Bay Approach Channel	1,079,000	0	1,079,000
Total volume (m ³)	6,561,000	193,000	6,754,000

The Particle Size Distribution (PSD) of the silty sand material to be dredged is provided in Figure 2-2 below.

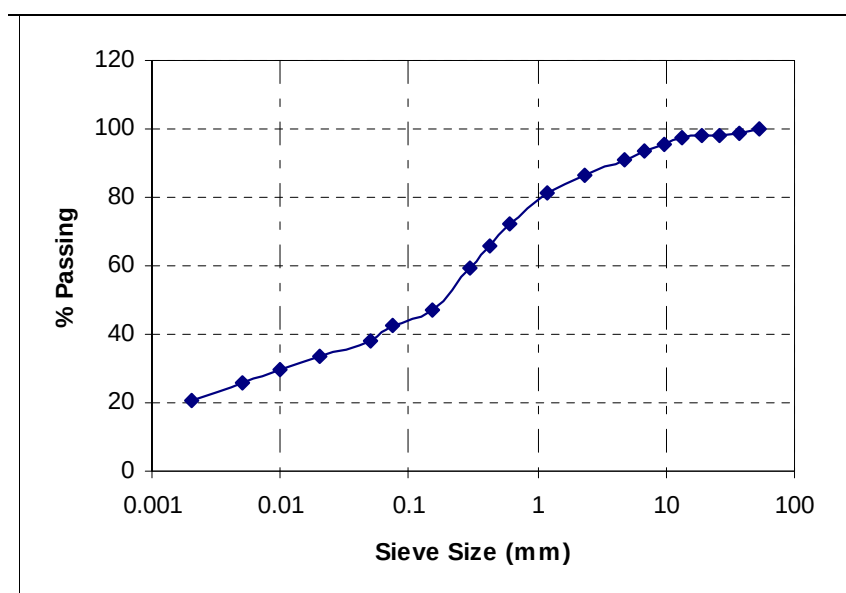


Figure 2-2 Average Particle Size Distribution

The average PSD indicates that approximately 57 % of the dredged materials are coarse grained and 43 % are fine grained.

2 Project Description

2.2 Dredging Scenario and Plume Loadings

2.2.1 Dredging Scenario

For the purposes of project planning and the EIS it has been assumed that dredging will be carried out within a period up to 58 weeks depending on which scenario is adopted. There are three different dredging techniques that have been considered for the project. Santos proposes to use a large CSD for the capital dredging works. At the time of preparing the EIS Supplement the following scenario was modelled.

The dredging scenario involves the use of a large stationary cutter suction dredger (CSD) to cut and pump all material up to 7km to the Laird Point DMPF. In order to pump material over these distances a booster station will be required. Dredging will take place for 140 hours per week with a weekly productivity for sand of 150,000 m³. For rock, the weekly productivity will be 42,000 m³. In this scenario dredging will be complete within 48.8 weeks (HR Wallingford 2009 attachment G9 of the EIS Supplement).

2.2.2 Dredge Losses and Plume Loadings

Dredging works cause additional re-suspension of bed material and the generation of plumes of suspended sediment through a number of potential sources/mechanisms. There is considerable uncertainty associated with the prediction of dredge plume source loadings.

Source plume loadings have been adopted which are consistent with the approach taken in the Gladstone Western Basin EIS. The accuracy of the estimates and the sensitivity to changes will be evaluated post EIS.

Information on the composition of the substrate material to be dredged along with information on the suspended sediment characteristics of the “Wombat” (CSD vessel) plume were used to derive the long term plume fraction and composition of the source long-term plume suspended sediment fractions. It has been assumed that 100 % of the entrained fine sand and silt remain suspended in the long term plume while 0 % of the gravels and coarse sand fractions remain in suspension. The relative fractions of both the in-situ sediment and the long-term plume source material are summarised in Table 2-2 and a summary of plume loadings provided in Table 2-3. A composition of 35 % silt and 65 % clay in the decant discharge has been assumed.

Further information on sediment compositions and plume loading assumptions used in TSS modelling in this study utilises data from Appendix A – Plume dispersion Modelling.

Table 2-2 In-situ sediment and long-term plume suspended sediment composition

	Gravel	Coarse Sand	Fine Sand	Silt	Clay	Total
In-situ sediment composition	18 %	40 %	4 %	14 %	24 %	100 %
Long-term plume composition	0 %	0 %	4 % (16 % of plume)	14 % (56 % of plume)	7 % (28 % of plume)	25 % (30 % of total minus gravel)

2 Project Description

Table 2-3 Plume loading assumptions

Source - Location	Total Loading
Large CSD – Santos Basin Decant @ 50 mg/l	4 kg/s for 20 hours each 24 hour period 2.8 m ³ /s continuous

2.2.3 Decant Assumptions

Dredge material will be pumped to the DMPF and into a series of internal ponds separated by bunds with strategically located weirs to allow the seawater to flow from one pond to the next. The dredged material will pass slowly through these structures, allowing the solid material (sand, silt etc) to settle out of the seawater. Following a period of controlled settlement and monitoring, the seawater will be discharged back into the marine environment. The performance of the proposed DMPF and characteristics of the proposed discharge are presented in Attachment G4 of the EIS Supplement.

The decant discharge operating and loading parameters adopted for modelling of potential impacts are as follows:

- Decant TSS: 50 mg/L (source: URS/Santos);
- Decant discharge rate 2.8 m³/s (source: URS/Santos);
- Source location E 314509, N 7371297 (MGA94 zone 56)

Legislative Context

The GLNG project is subject to both Commonwealth and State legislation as described in Appendix C of the EIS. The following pieces of legislation are of particular relevance to the dredging and protection of sensitive receptor areas:

Commonwealth legislation

- *Environment Protection and Biodiversity Conservation Act 1999* (EPBC)
- *Great Barrier Reef Marine Park Act 1975* includes further provisions to assess and manage environmental impact of coastal development activities such as dredging. General dredging and sea dumping permits are subject to conditions which may typically include restrictions to the size of the impacted zone, limitations to a certain period of the year, turbidity limits and tidal restrictions (EPA, 2001).
- *Australian Ballast Water Management Requirements 2001*
- *Environment Protection (Sea Dumping) Act 1981*

State Legislation

- *Coastal Protection and Management Act 1995* (Coastal Act). Development within the coastal zone is regulated by the Environmental Protection Agency (EPA). The removal of quarry material from State coastal land below high water mark in a coastal management district requires either a resource allocation or a dredge management plan.
- *Integrated Planning Act 1997* (IPA). Most of the powers of Coastal Act are administered through the Integrated Development Assessment System (IDAS) of the IPA. Spoil disposal associated with dredging may require approval under the *Integrated Planning Act 1997* with concurrence under the jurisdiction of the *Coastal Protection and Management Act 1995*, *Environmental Protection Act 1994* and/or the relevant planning scheme (if disposal is to occur on land), as well as approval under the *Marine Parks Act 2004*.
- *Marine Parks Act 2004*
- *Nature Conservation Act 2002*
- *Fisheries Act 1994*—under section 123, marine plants are protected against removal, destruction or damage, and their removal is only allowed under permit. The Act also includes provisions to issue restoration orders where non-approved removal occurs. Port authorities, extractive industries etc. require permits for dredging, sand mining and similar activities.
- *Environmental Protection Act 1994* governs dredging and disposal of dredged spoil in Australia
- *Environmental Protection (Water) Policy 2009*
- Dredging material from the bed of any waters is also defined as ERA 19 and the extraction of any rock is defined as ERA 20 under Schedule 1 of the *Environmental Protection Regulation 1998*.

The GLNG EIS Terms of Reference states that if all of the dredge material is proposed to be disposed of on land, then a detailed Dredge Management Plan (DMP) can be developed subsequent to the EIS. The DMP will describe in detail the activities to be undertaken and the mitigation measures to be implemented. This DMP will require approval prior to commencement of activities. A draft DMP has been provided as Attachment G9 of the EIS Supplement.

In addition to supporting the regulatory approval of the EIS the DMP must be separately approved by the Queensland Environmental Protection Agency (EPA) under the Coastal Act. Accordingly, the DMP has been developed in line with the EPA's guidance set out in the document "Approval of a Dredge Management Plan".

3 Legislative Context

Plans and Policies

There are also a number of Coastal Management Plan Policies that will apply to the dredging programme as follows

- Policy 2.1.1 – Areas of State significance (social and economic): (no such areas are thought to be affected by the dredging/placement aspects of the DMP)
- Policy 2.1.6/2.1.8 – Extractive industry/Dredging
- Policy 2.2.4 – Coastal hazards
- Policy 2.3.1 – Future need for access: (no significant loss of public use of amenity areas from the dredging activities).
- Policy 2.4.1 – Water quality management
- Policy 2.4.5 – Groundwater quality
- Policy 2.5.1 – Cultural resources
- Policy 2.8.1 – Areas of State significance (natural resources)
- Policy 2.8.2 – Coastal wetlands
- Policy 2.8.3 – Biodiversity

In addition to the State policies GLNG, as a responsible proponent, will also require the dredging and placement operations to be undertaken in accordance with their own environmental policy and Environmental Health and Safety Management System (EHSMS).

Baseline Coastal Environmental Conditions

Existing environmental values, baseline marine water quality, hydrodynamics and marine sediment conditions were discussed in Section 8.7 of the EIS. The information presented here provides further detail on baseline conditions within Port Curtis for the following:

- Sensitive Environments (Section 4.1)
- Turbidity and TSS Levels within Port Curtis (Section 4.2)
- The relationship between turbidity and TSS levels in Port Curtis (Section 4.3)
- The relationship between PAR and turbidity (Section 4.4)
- Sediment deposition rates at Sensitive Receptors (Section 4.5)

4.1 Sensitive Environments within Port Curtis

The Port Curtis area includes over 1000 km² of coastal hinterland, wetlands and estuarine waters with marine and coastal zone wetlands covering an area of over 300 km² (McKinnon *et al.*, 1995). Mangrove, seagrass, salt marsh, rocky and sandy shoreline, open water and subtidal benthic habitats support varied biological communities within Port Curtis and adjacent marine areas. Much of the estuarine nearshore is lined by dense stands of mangrove, mainly *Avicennia marina* and *Rhizophora stylosa*, while bare soft sediments cover most of the remaining bedforms (Currie & Small, 2005).

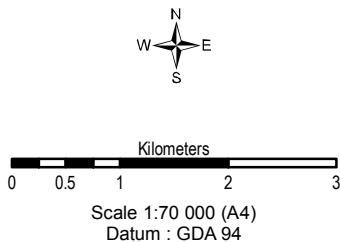
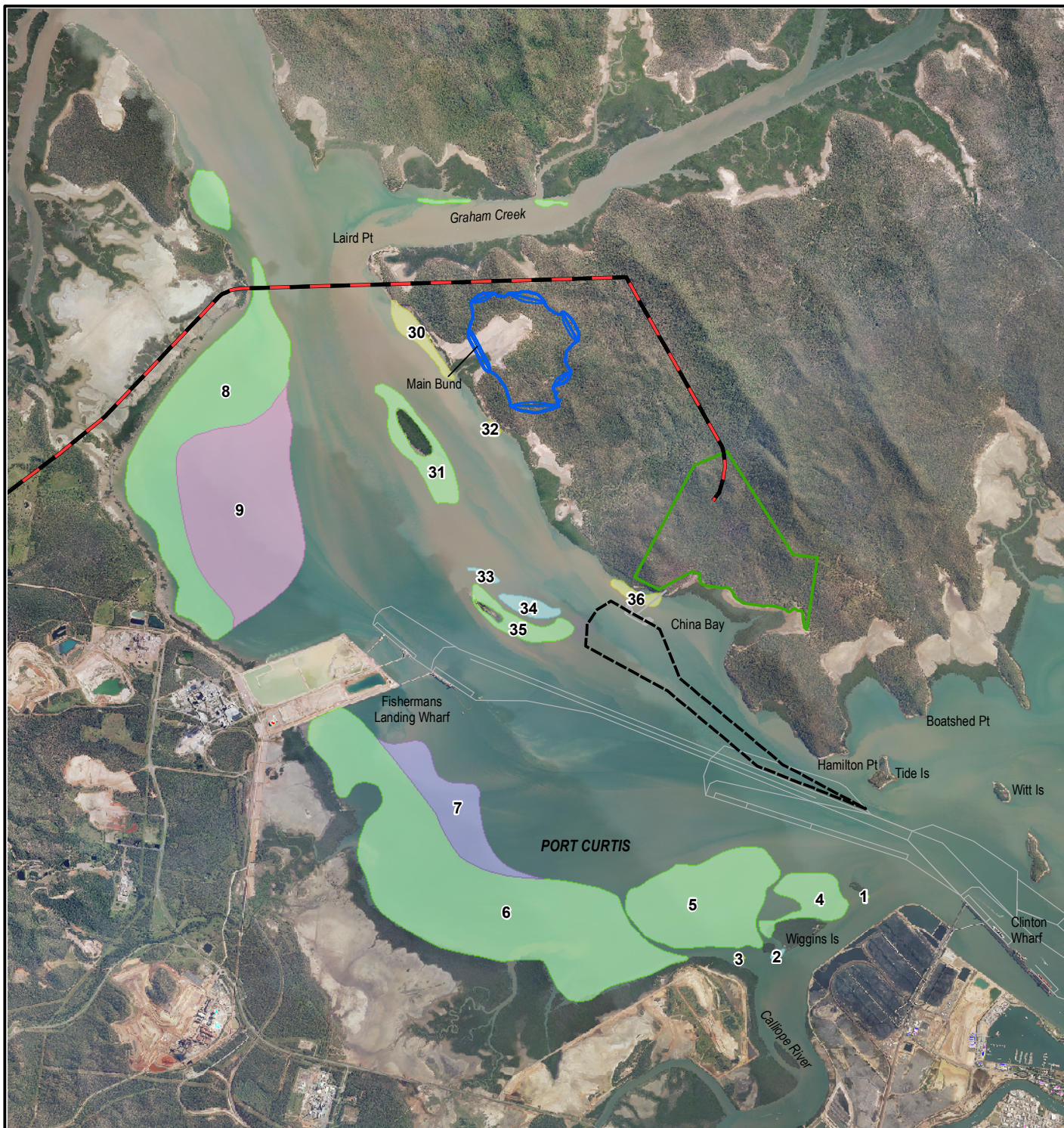
Intertidal and subtidal marine areas provide a variety of habitats for many species during different stages of their life cycle. The importance of marine habitats such as seagrass, mangroves, rocky outcrops and sand bars for the maintenance of marine communities has been well documented. Mangroves, saltmarsh and seagrass communities are known for their contribution to fisheries productivity particularly as nursery areas for juvenile fish species (Danaher *et al.*, 2005). Studies conducted by DPI&F indicate that mangroves and seagrass are critical to more than 75 % of commercial and recreational species during some stage of their life cycle.

The EIS identified a number of mechanisms by which the dredging activities and the discharge from placement operations could impact upon the sensitive environments of Port Curtis. The primary impacts of concern were the smothering of benthos due to the dispersion and subsequent deposition of sediment from dredging and placement activities and loss of light penetration due to increased suspended sediment concentrations in the water column.

This section describes the sensitive habitats that are present in the eastern side of Port Curtis and their current condition which can then be used as a basis to describe the potential impacts of the dredging activity.

4.1.1 Sensitive Receptors

A variety of habitats are present within the eastern side of Port Curtis. The receptors of most concern were identified in the EIS as seagrass meadows. In addition, since completion of the EIS, supplementary investigations have identified soft coral subtidal communities off Hamilton Point. The locations of the seagrass meadows and soft coral subtidal communities are presented in Figure 4-1 and Figure 4-2 respectively.



SEAGRASS

- Halophila decipiens
- Halophila decipiens with Halophila ovalis
- Halophila ovalis with Zostera Capricorni
- Zostera capricorni
- Zostera capricorni with Halophila ovalis

- GLNG Gas Transmission Pipeline (Sep. 2009)
- Existing Channels
- Proposed Dredging Channel
- Dredge Material Placement Facility
- LNG Facility Indicative Site Boundary

Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Client



URS

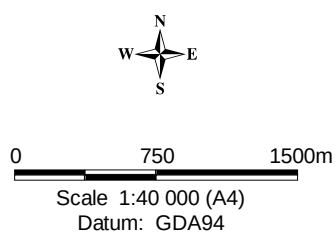
GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT SUPPLEMENT DREDGE MATERIAL PLACEMENT FACILITY

Drawn: MG Approved: JL Date: 03-11-2009
Job No.: 4262 6440 File No.: 42626440-g-2171.mxd

DISTRIBUTION OF SEAGRASS WITHIN PORT CURTIS REPRODUCED FROM RASHEED ET AL (2003)

Figure: 4-1

Rev. B
A4



- Existing Channels
- Proposed Dredging Channel
- Dredge Material Placement Facility Footprint
- LNG Facility Indicative Site Boundary

- Rocky Reef Survey Sites
- Rubble Slope
- Rocky Headland

Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Client 	Project GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT SUPPLEMENT MARINE WATER QUALITY		Title ROCKY REEF LOCATIONS	
	Drawn: LL	Approved: JB	Date: 03-11-2009	Figure: 4-2
	Job No: 4262 6440/6220	File No: 42626440-g-2172.wor	Rev:B A4	

4 Baseline Coastal Environmental Conditions

Seagrass Meadows

Seagrass meadows in Queensland are known to provide valuable nursery habitats for juvenile commercial and recreational fisheries species, as well as important food resources for endangered and threatened species such as dugong and turtles (Rasheed *et al.*, 2008). The value of seagrasses in the Port Curtis area to dugong has been recognised by the declaration of the Rodds Bay Dugong Protection Area (DPA). Seagrasses also show measurable responses to changes in water quality making them ideal candidates for monitoring the “health” of port environments. Results from long term monitoring programs conducted in other Queensland port locations have provided valuable information on the relationships between climatic changes, anthropogenic disturbance and seagrass abundance. They have also indicated that healthy and productive seagrass habitats can co-exist with appropriately managed port facilities (Chartrand *et al.*, 2008).

Seagrass was the dominant habitat feature of intertidal banks in Port Curtis (4496 ha) and the Rodds Bay (2750 ha) covering a total of 7,246 ha. Seagrass meadows were also found in deeper areas within the port limits covering an additional 6,332 ha. Seagrass communities in Port Curtis included meadows of species preferred as food by dugong as well as denser, high biomass meadows that are known to be important as juvenile prawn nursery grounds in other Queensland locations. The extensive areas of seagrass in Port Curtis and Rodds Bay are likely to be of regional significance as they are the only major area of seagrass between Hervey Bay (170 km south) and Shoalwater Bay (170 km north) that have been described.

Figure 4-1 above shows the seagrass communities within the eastern side of Port Curtis as belonging to the *Zostera Capricorni* or *Halophila Ovalis* species, with one species usually dominant in each area. Meadows in the vicinity of the dredging operations include areas 30 – 36. However, these areas are mostly isolated or aggregated patches of seagrass growth, and represent an area small in comparison to the more established meadows on the mainland side of the estuary. In total these areas occupy a combined area of 108 ha or 2.4 % of the total intertidal seagrass area in Port Curtis as summarised in Table 4-1.

Table 4-1 Selected seagrass communities

Meadow ID	Community Type	Cover	Mean Biomass (g dw m ⁻²)	Mean Area (ha)
30	Light <i>Zostera Capricorni</i>	Aggregated patches	2.9 ± 1.5	14.9 ± 1.3
31	Light <i>Zostera Capricorni</i> with <i>Halophila Ovalis</i>	Aggregated patches	0.9 ± 0.2	40.0 ± 2.6
32	<i>Zostera Capricorni</i>	Isolated patches	na	2.4 ± 0.3
33	Moderate <i>Halophila Ovalis</i> with <i>Zostera Capricorni</i>	Aggregated patches	2.0 ± 1.2	2.1 ± 0.4
34	Moderate <i>Halophila Ovalis</i> with <i>Zostera Capricorni</i>	Aggregated patches	1.0 ± 0.5	10.1 ± 0.8
35	Light <i>Zostera Capricorni</i> with <i>Halophila Ovalis</i>	Aggregated patches	0.7 ± 0.2	22.1 ± 2.0
36	Light <i>Zostera Capricorni</i>	Isolated patches	0.3 ± 0.3	6.5 ± 0.7

A study of interactions between dugongs and seagrasses in Moreton Bay found that dugongs favoured areas of higher biomass, dominated by *Halophila* species, and that almost all of the areas avoided were dominated by *Zostera capricorni*. Further, the mean biomass where dugongs were

4 Baseline Coastal Environmental Conditions

sighted and where tracking fixes occurred was 21.2 g dw m^{-2} and 15.3 g dw m^{-2} , respectively (Preen 1992).

When this information is considered in the context of the seagrass meadows in the vicinity of the dredging operations, community 36, would be expected to be totally avoided by dugongs, communities 31 and 35 are unlikely to be utilised, and communities 33 and 34 have such low biomass that it would be unlikely that they would provide important feeding grounds for dugongs.

The reported sightings of dugongs in Port Curtis (see Section 8.4.36 of the EIS) have been in areas dominated by *Halophila* and with higher biomass (ie between Fisherman's Landing and Wiggins Island, and on the Pelican Banks in the lee side of Facing Island). This is consistent with the above information.

Subtidal Communities

The significance of subtidal community habitats in Port Curtis is discussed in Attachment F5 of the EIS Supplement. This attachment presents the findings of a specific survey of subtidal communities habitats undertaken to provide quantitative data on the subtidal communities potentially impacted by dredging activities associated with the development of the GLNG facility. A summary of the survey methodology and results is discussed below.

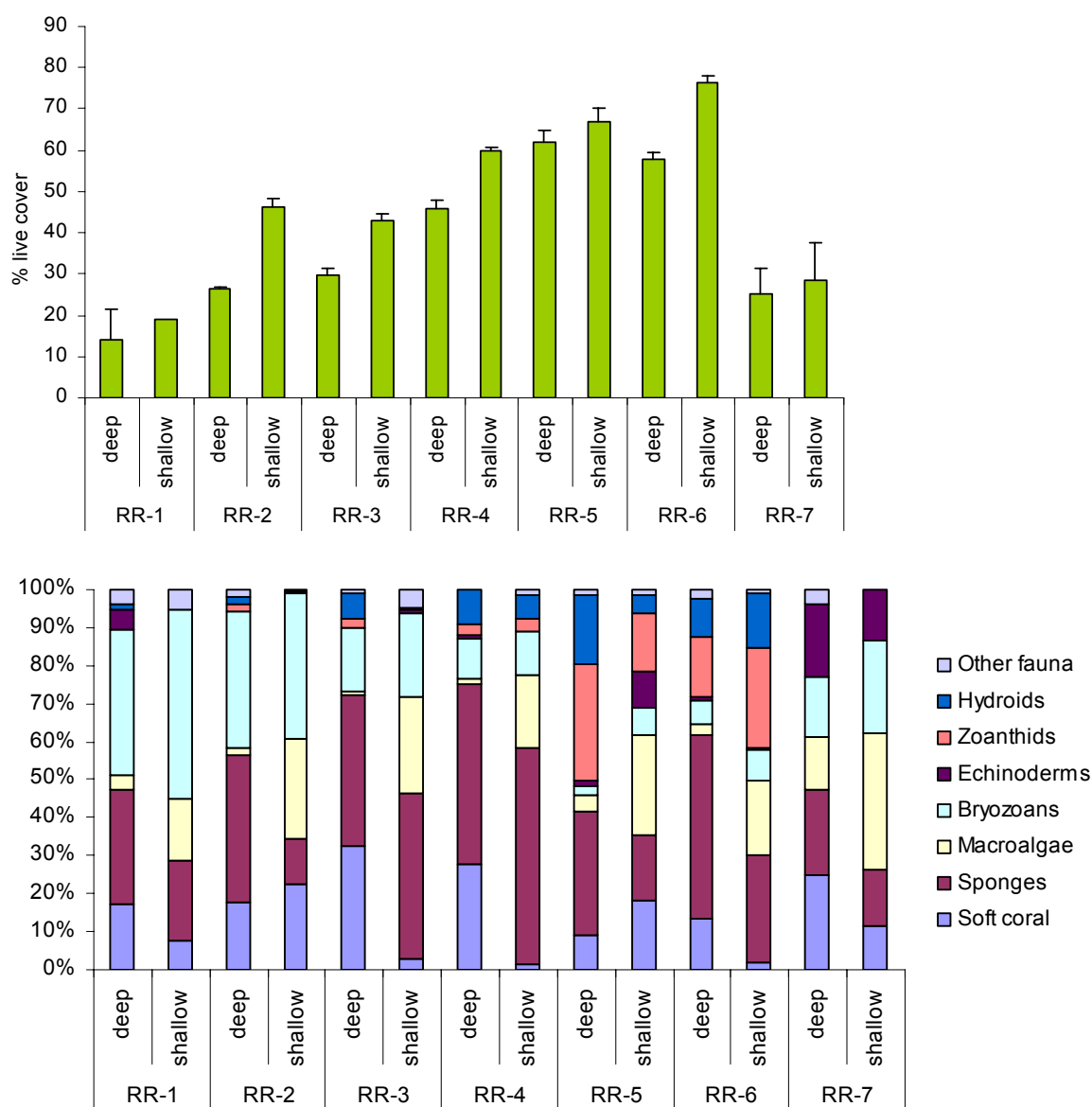
Seven subtidal community sites were selected for the survey based upon previous observations of the subtidal communities in the vicinity of the GLNG facility with the survey locations shown in Figure 4-2.

At each survey site a GPS position was taken and notes taken on weather conditions. Divers using self contained underwater breathing apparatus (SCUBA) surveyed the subtidal communities occurring along 50 m transect at seven monitoring sites. Four transects were surveyed at each site; two transects in approximately 7 – 8 m water depth, and two transects in approximately 3 – 4 m water depth.

The survey found that total live cover averaged over all sites and depths was $44 \pm 4 \%$ (mean $\pm$ Standard Error (SE)). Total live cover averaged over all shallow sites was $51 \pm 5 \%$, ranging from 19 % at Site RR-1¹ through to $77 \pm 2 \%$ at Site RR-6. Total live cover averaged over all deep sites was $37 \pm 5 \%$, ranging from $14 \pm 8 \%$ at Site RR-1 through to $62 \pm 3 \%$ at Site RR-5. Figure 4-3 shows the mean ($\pm$ SE) percentage cover for each depth at each site, and the composition of the major taxa.

¹ There is no SE associated with this number as only one transect was surveyed.

4 Baseline Coastal Environmental Conditions



**Figure 4-3 Percentage live cover at Subtidal community Sites
– Reproduced from Attachment F5 of EIS Supplement.**

Overall, soft coral cover was higher at the deeper transects than at shallow transects. Sponge cover was approximately the same at both depths on shallow transects, and on deep transects. There was significantly higher coverage of macroalgae and bryozoans on shallow transects than on deep transects. There was no significant difference in Zoanthid or hydroid cover between shallow and deep transects. The percentage live cover increases as the sites approach Hamilton Point near the southern tip of Curtis Island, where increased tidal velocities are present.

4 Baseline Coastal Environmental Conditions

4.1.2 Seagrass and Coral Tolerances to Dredging Impacts

Key impacts on seagrasses and subtidal communities from dredging are:

- increased turbidity and resultant reduction in light penetration;
- physical removal or burial of vegetation at the dredging/disposal site;
- increased sedimentation in adjacent seagrass meadows;
- temporarily reduced dissolved oxygen concentration;
- release of nutrients and pollutants from contaminated sediments; and
- hydrographic changes (Erfemeijer and Lewis, 2006).

Doorn-Groen and Foster (2007) developed the classification scale presented in Table 4-2, to assess the impacts of dredging activities on seagrass and coral reef areas.

Table 4-2 Impacts of reclamation on seagrass and coral reef

No impact:	Changes are significantly below physical detection level and below the reliability of numerical models, so that no change to the quality or functionality of the receptor will occur.
Slight impact:	Changes can be resolved by numerical sediment plume models, but are difficult to detect in the field as they are associated with changes that cause stress, not mortality, to marine ecosystems. Slight impacts may be recoverable once the stress factor has been removed.
Minor impact:	Changes can be resolved by the numerical models and are likely to be detected in the field as localized mortalities, but to a spatial scale that is unlikely to have any secondary consequences.
Moderate impact:	Changes can be resolved by the numerical models and are detectable in the field. Moderate impacts are expected to be locally significant.
Major impact:	Changes are detectable in the field and are likely to be related to complete habitat loss. Major impacts are likely to have secondary influences on other ecosystems.

4.2 Background Turbidity and TSS Levels in Port Curtis

4.2.1 Scope

The investigation of background turbidity and TSS levels involved two main components:

1. Literature Review - Collation and interpretation of all available information on turbidity and TSS for the Eastern Side of Port Curtis.
2. Field survey - Deployment of nephelometers at the proposed decant discharge location for the dredge material placement facility to gather information on natural turbidity levels in the receiving environment

The data sourced from the literature review was combined with turbidity data recorded during the field survey to provide a baseline against which hydrodynamic, sediment dispersion, advection dispersion modelled impacts of the proposed dredging activity could be assessed.

4 Baseline Coastal Environmental Conditions

Appendix A of this report includes all relevant data and information from previous studies, including those reviewed in the EIS and several supplementary studies, pertaining to background turbidity and TSS for the eastern side of Port Curtis.

4.2.2 Water Quality Guidelines

Queensland Water Quality Guidelines (EPA 2006) for enclosed coastal and mid-estuarine waters are listed in Table 4-3. The area of interest in Port Curtis is considered enclosed coastal.

Table 4-3 Queensland Water Quality Guidelines for enclosed coastal and estuarine waters

Parameter	Units	Water body type	
		Enclosed coastal	Mid Estuarine
Turbidity	NTU	6	8
Suspended Solids	mg/L	15	20

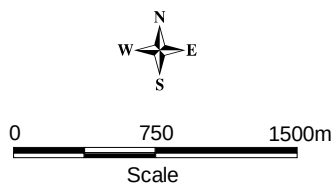
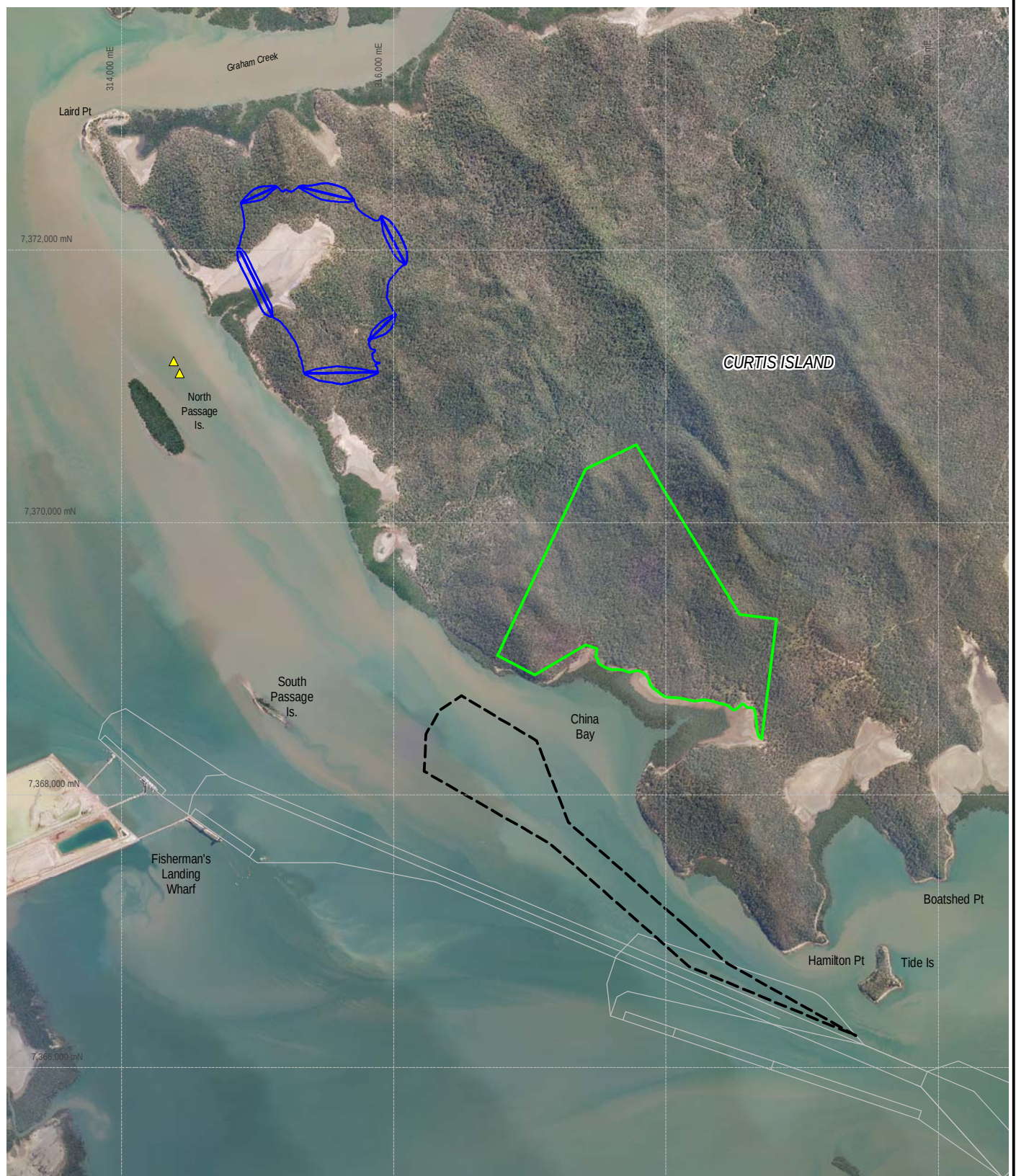
4.2.3 Literature Review Data Sources

The following data sources were reviewed and relevant data analysed to describe the background TSS and turbidity conditions within Port Curtis;

- Department of Environment and Heritage and the Department of Natural Resources (DEH/DNR) (1999)
- Queensland Environmental Protection Agency (EPA) (2002-2008);
- National Land and Water Resources Audit (NLWRA) condition assessment reports (1998 and 2001);
- Geoscience Australia Australian Ports Literature Review (1998);
- Port Curtis Integrated Monitoring Program (PCIMP) Ecosystem health report card and Biomonitoring (2005, 2006 and 2007);
- BMT WBM studies (1999, 2001, 2008, 2009).

4.2.4 Field Survey

Turbidity measurement instruments were deployed in the channel between North Passage Island and Curtis Island as shown below in Figure 4-4 to record turbidity data for the receiving environment of the proposed decant discharge from the dredge material placement facility.



- Existing Channels
- Proposed Dredging Channel
- Dredge Material Placement Facility
- LNG Facility Indicative Site Boundary

▲ URS Turbidity Meter

Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Client 	Project GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT SUPPLEMENT MARINE WATER QUALITY			Title TURBIDITY METER DEPLOYMENT LOCATIONS Draft	
	Drawn: RG	Approved: JB	Date: 03-11-2009	Figure: 4-4	
Job No: 4262 6440 /6220		File No: 42626440-g-2161.wor		Rev:B A4	

4 Baseline Coastal Environmental Conditions

Turbidity measurement instruments were deployed on 7th August 2009, and retrieved on the 2nd September 2009. At each measurement location, two turbidity instruments (one McVan Instrument and one Greenspan instrument) were mounted on a steel mooring frame, which was positioned on the seafloor approximately 2m below low water datum. In their deployment location, the turbidity instrument sensor faces were positioned approximately 0.25 m above the seabed. An additional tide recorder was positioned on the base of the steel mooring frame at Site 1. A calibrated YSI water quality measuring instrument was used to check the water turbidity shortly after deployment and following instrument retrieval, in order to calibrate the data from the McVan instruments sensors.

The McVan instrument turbidity data were post-calibrated (using a calibration factor derived from comparison of the profiling turbidity measurements from the YSI instrument). No post-calibration factor was applied to the Greenspan instruments data record since they were previously calibrated.

4.2.5 Results and Discussion

A full discussion of the data obtained during the literature review and the field assessment are provided in Appendix A of this report. A summary is provided below.

The turbidity data obtained from the field investigations is shown in Figure 4-5. The data gathered over the deployment period show a clear relationship between tide and turbidity levels. The turbidity at the measurement locations varies from between 2-4NTU during neap tides and 25-35NTU during spring tides.

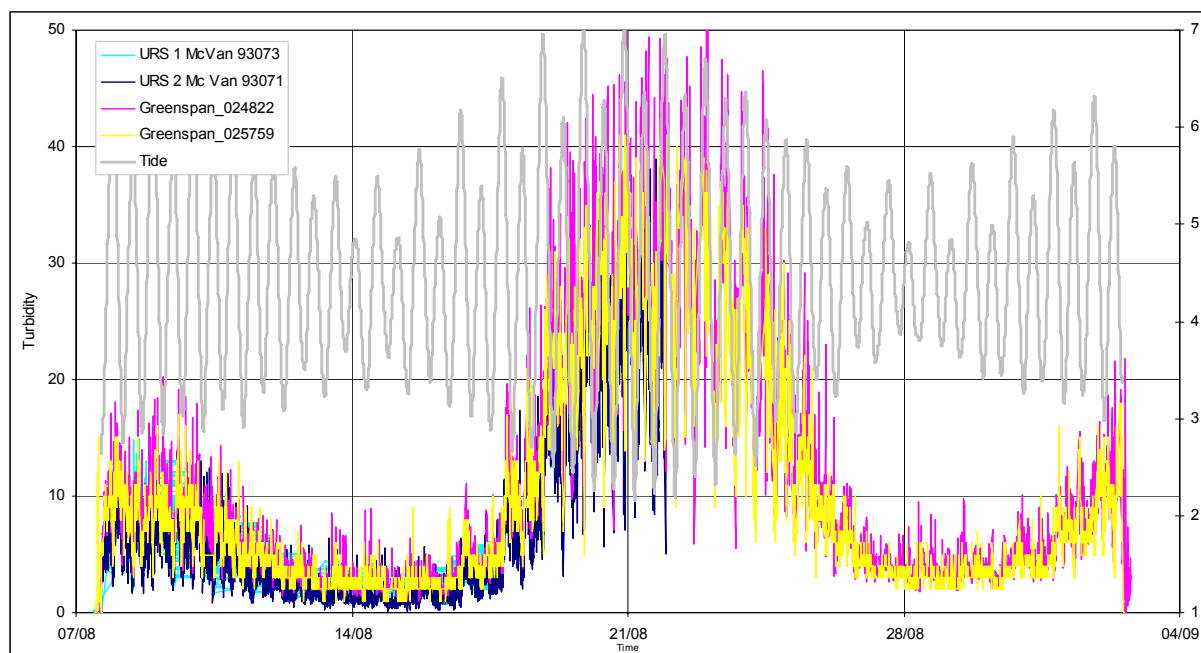


Figure 4-5 Turbidity measurements 7/8/09- 2/9/09

The field results are consistent with the results obtained from previous investigations of turbidity levels within Eastern Port Curtis.

A summary of the turbidity and TSS results obtained from the literature review is provided in Table 4-4.

4 Baseline Coastal Environmental Conditions

Table 4-4 Summary of Turbidity and TSS data for Eastern Port Curtis

Data Source	Location	Range	Median	Frequency
Turbidity (NTU)				
DEH/DNR (1999)	Calliope River mouth		<30	Monthly
EPA (2002-2008)	Calliope River mouth		10	Monthly
NLWRA (1988 and 2001)	Calliope River mouth		9	Discontinuous
GPA (1998)	Clinton and Boyne Island Wharves	1- 40		Continuous
PCIMP (2005)	'Site C2' (China Bay)		5.6	Annual
PCIMP (2005)	'Site P2' (Hamilton Point)		5.4	Annual
PCIMP (2006)	Inner Harbour/ Fishermans Landing		8.8	Annual
PCIMP (July 2007)	Inner Harbour/Fishermans Landing		5.7	Annual
PCIMP (Sept 2007)	Inner Harbour/Fishermans Landing		3.9	Annual
BMT WBM (2009)	North Passage Island channel	2-35		Continuous
BMT WBM (February 2008)	Eastern Port Curtis	4-14		Daily
BMT WBM (June 2008)	Eastern Port Curtis	4-26		Daily
WBM (2001)	Curtis Island (1)	4.4- 104.0	28.8	Bi-monthly + events
WBM (2001)	Curtis Island (2)	3.0- 168.8	29.9	Bi-monthly + events
WBM (1999)	Hamilton Point	7-10		Discontinuous
Total Suspended Solids (mg/L)				
BMT WBM (June 2008)	Eastern Port Curtis	5-45	30	Discontinuous
WBM (2001)	Curtis Island (1)	2- 113	46.7	Bi-monthly + events
WBM (2001)	Curtis Island (2)	9- 116	41.9	Bi-monthly + events
WBM (1999)	Hamilton Point	8-14		Discontinuous

It should be noted that few studies have involved continuous monitoring of turbidity and where this has occurred the monitoring duration is unlikely to reflect the full annual range. Only two studies, each conducted by WBM in 2001, provide data on the turbidity ranges experienced during wet weather events and in each of these cases continuous monitoring was not undertaken.

The following statements can be made about background turbidity and TSS levels in the eastern side of Port Curtis based on the results of field investigations and the literature review. These are as follows:

4 Baseline Coastal Environmental Conditions

- Turbidities and suspended solids concentrations are moderate, and also highly variable throughout the eastern side of Port Curtis;
- Turbidity increases with tidal velocity, and,
- Primary variations in the spatial distribution and nature of turbidity and TSS appear to be controlled by tidal stage
- There is anecdotal evidence that stream flow from major rivers into Port Curtis also influences turbidity and TSS concentrations.

4.3 The Relationship between Turbidity and TSS Levels in Port Curtis

4.3.1 Scope

The main purpose of establishing a relationship between turbidity and TSS levels is to enable an interpretation of the predicted TSS concentrations generated during dredging (presented as TSS) in terms of the turbidity that may arise at sensitive receptors. Turbidity measures the degree to which light is scattered in the water column whereas TSS is a measure of the mass of material present in the water column.

The investigation of the relationship between turbidity and TSS levels involved the collation and interpretation of available data comparing turbidity and TSS concentrations within the eastern side of Port Curtis.

4.3.2 Literature Review Data Sources

The literature review identified five previous studies where turbidity and TSS analysis had been simultaneously undertaken. The results from four of these studies are summarised in Table 4-5 whilst the results for the fifth study (the most recent) are discussed below.

Table 4-5 Summary Turbidity and TSS data.

Data Source	Location	Range	Median
Turbidity (NTU)			
BMT WBM (June 2008)	Eastern Port Curtis	4-26	
WBM (2001)	Curtis Island (1)	4.4- 104.0	28.8
WBM (2001)	Curtis Island (2)	3.0- 168.8	29.9
WBM (1999)	Hamilton Point	7-10	
Total Suspended Solids (mg/L)			
BMT WBM (June 2008)	Eastern Port Curtis	5-45	30
WBM (2001)	Curtis Island (1)	2- 113	46.7
WBM (2001)	Curtis Island (2)	9- 116	41.9
WBM (1999)	Hamilton Point	8-14	

BMT WBM Water quality profiling and sampling (April – June 2009)

BMT WBM undertook water quality profiling and sampling in conjunction with ADCP measurements of currents and acoustic backscatter for both neap tide conditions (April 2009) and spring tide conditions

4 Baseline Coastal Environmental Conditions

(June 2009). Over the two sampling periods, more than 100 concurrent measurements of turbidity (NTU) and TSS (mg/L) were collected in order to characterise the naturally re-suspended material within the Port Curtis Project Area. The results of the TSS and turbidity sampling are presented in Figure 4-6.

Sampling of turbidity and TSS within dredge plumes was also undertaken on two occasions; firstly during RG Tanna Berth Pocket maintenance dredging performed by the TSHD “Brisbane”, and secondly during capital dredging of the Fisherman’s Landing Berth 1/Swing Basin by the CSD “Wombat”. Two samples were also obtained from the Fisherman’s Landing reclamation pond decant discharge.

The concurrent turbidity/TSS measurements for the two dredge plume sampling exercises described are also plotted in Figure 4-6 and can be seen to systematically sit above the turbidity/TSS line fitted to the baseline samples.

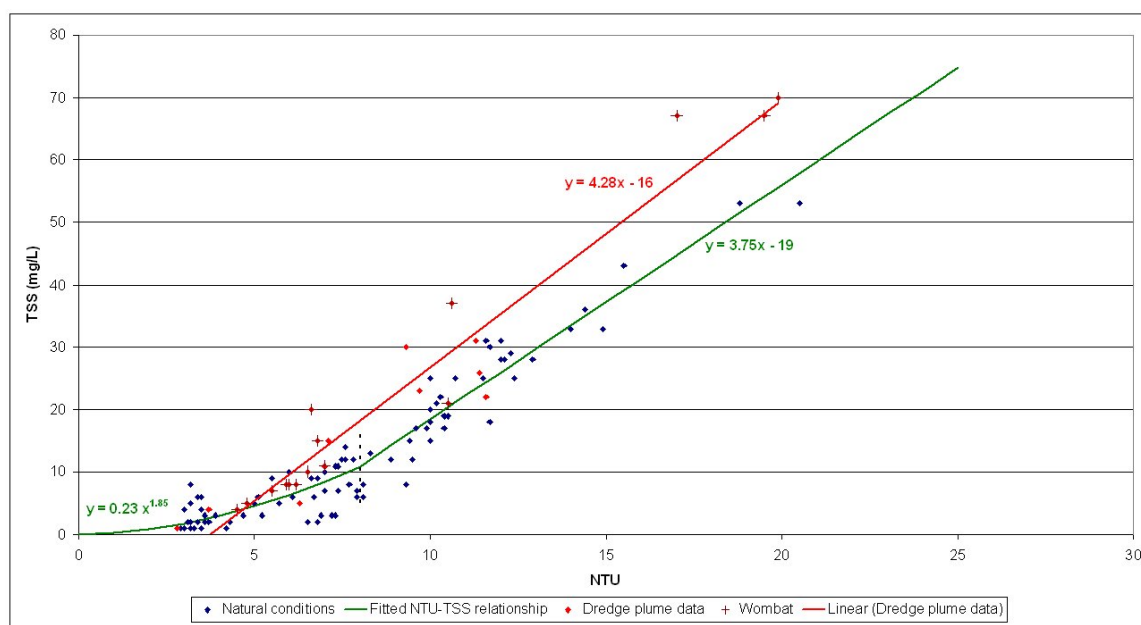


Figure 4-6 Turbidity–TSS Relationships from Both Natural and Dredge Plume Sampling

The BMT/WBM data shows that for TSS levels above 10mg/L the relationship between TSS and turbidity is given by the equation:

$$y = 3.75x - 19 \text{ where } y \text{ is TSS and } x \text{ is the turbidity.}$$

The results also show that during dredging works the relationship is expected to change and based on sampling undertaken during dredging activity that the relationship between TSS and turbidity becomes:

$$y = 4.28x - 16$$

It should be noted that whilst this is the best available data that could be obtained, on the relationship between TSS and turbidity in Port Curtis for the EIS Supplement, it is based on limited sampling.

4 Baseline Coastal Environmental Conditions

4.3.3 Discussion

Turbidity measures the degree to which light is scattered in the water column, and is affected by both the nature (size and shape) and quantity of material in the water column. Finer grained material per unit mass generally results in higher turbidity because of the larger number of particles present in the water column. Conversely, coarse material may result in elevated TSS values while causing little turbidity. Even though TSS does not directly reflect turbidity levels, it is a useful indicator for water clarity which is important for ecological processes associated with seagrass communities.

The results show that the relationship between TSS and turbidity is highly variable and varies with concentration. Lawson and Treloar (VCA, 1997) support this stating that large variations in sediment particle size in natural sediment suspensions causes suspended solids to be poorly correlated with turbidity.

4.4 The relationship between PAR and Turbidity

Suspended sediment plumes generated by dredging cause light intensity at the seabed to reduce through increases in turbidity. Reductions in light can negatively impact seagrass health as the amount of time that the seagrass receives enough light to photosynthesise is decreased. In order to establish whether capital dredging is likely to reduce the light intensity reaching the seabed in seagrass meadows it is necessary to firstly establish the baseline light intensity in seagrass beds which is available for photosynthesis (Photosynthetically Active Radiation (PAR)). As PAR is affected by turbidity it is also necessary to establish the relationship between PAR and turbidity to assess the impact of dredging.

4.4.1 Scope

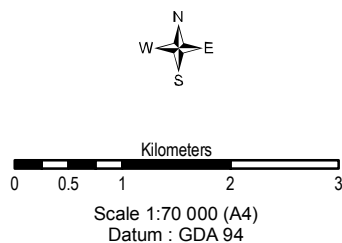
The main purpose of the investigation was to collate available data on PAR profiles at a variety of locations and under varying tidal conditions to establish baseline conditions as a basis for investigating the effects of increased turbidity in reducing PAR reaching seagrass communities.

4.4.2 Literature Review

There is very limited data available for PAR measurements within Port Curtis. The results for one study which was undertaken for Gladstone Port Corporation (GPC) for the Western Basin Dredging EIS were obtained for analysis.

Sampling Sites

Data loggers were deployed at ten locations within the Western Basin of Port Curtis as shown in Figure 4-7.



- GLNG Gas Transmission Pipeline (Sep. 2009)
- Existing Channels
- Proposed Dredging Channel
- Dredge Material Placement Facility
- LNG Facility Indicative Site Boundary

Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Client 	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT SUPPLEMENT DREDGE MATERIAL PLACEMENT FACILITY		PHOTOSYNTHETICALLY ACTIVE RADIATION AND TURBIDITY LOGGER LOCATIONS	
	Drawn: MG Job No.: 4262 6440	Approved: JL File No.: 42626440-g-2173.mxd	Date: 03-11-2009	Figure: 4-7 Rev. B A4

4 Baseline Coastal Environmental Conditions

Four deployments (each of approximately one month duration) were undertaken during the investigation. Table 4-6 below summarises the data collection dates and parameters recorded at each location. The numbers in brackets are the coordinates for the initial April deployment. Following the April deployment, Loggers 1, 3 and 4 were repositioned to better account for proximity to sensitive habitats and based on a review of preliminary hydrodynamic modelling.

Table 4-6 Logger deployment

	Deployment 1	Deployment 2	Deployment 3	Deployment 4
Deployment dates	20/04 – 19/05	19/05 – 25/06	23/06 – 28/07	27/07 – 19/08
Logger 1	T, L	-	-	T, L, D, W
Logger 2	T, L, D, W	-	T, L, D, W	T, L, D, W
Logger 3	T	T, L	T, L, D, W	T, L, D, W
Logger 4	T, L, D, W	T, L, D, W	T, L	T, L, D, W
Logger 5	-	T	T	-
Logger 6	-	-	T	-
Logger 7	-	T	T	-
Logger 8	-	T	T, L	-
Logger 9	-	T	T, L, D, W	-
Logger 10	-	-	T	-

T = Turbidity

L = Light D = Depth

W = Wave Height

Parameters Measured by Loggers

The loggers employed for the study recorded a maximum of five parameters. Not all deployments included measurements for all parameters. The following descriptions summarise the measurements made.

- Light: Measurements of PAR were made using an up-facing PAR sensor mounted on the logger. Measurements were made in units of $\mu\text{E} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ (where μE is a micro Einstein, a unit of irradiance).
- Turbidity: Turbidity was measured using a scatter sensor. The scatter angle is 180 degrees. The Turbidity is reported in Nephelometric Turbidity Units (NTU).
- Depth: A pressure transducer was used to measure water depth.

4.4.3 Results

Unfortunately the data loggers deployed for the PAR investigation undertaken for GPC experienced a variety of data collection problems. These problems ranged from periodic gaps in data collection through to almost complete failure of one or more loggers for the duration of each deployment. Consequently data collected for nine of the ten deployments where all four parameters of interest had been collected was discarded from further analysis.

Only one deployment (Deployment 4 at location 2) was successful in generating a complete data set for light, turbidity and depth. The results from this deployment are provided in Figure 4-8. The data presented shows that light intensity decreases as depth increases during spring tides. Light intensities reach a maximum of $72.41 \mu\text{E} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ during neap tides but only $18.20 \mu\text{E} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ during spring tides.

4 Baseline Coastal Environmental Conditions

The reduction in light intensity also coincides with an increase in turbidity. It is apparent from the data presented in Figure 4-8 that the reduction in light intensity is influenced by both depth and turbidity.

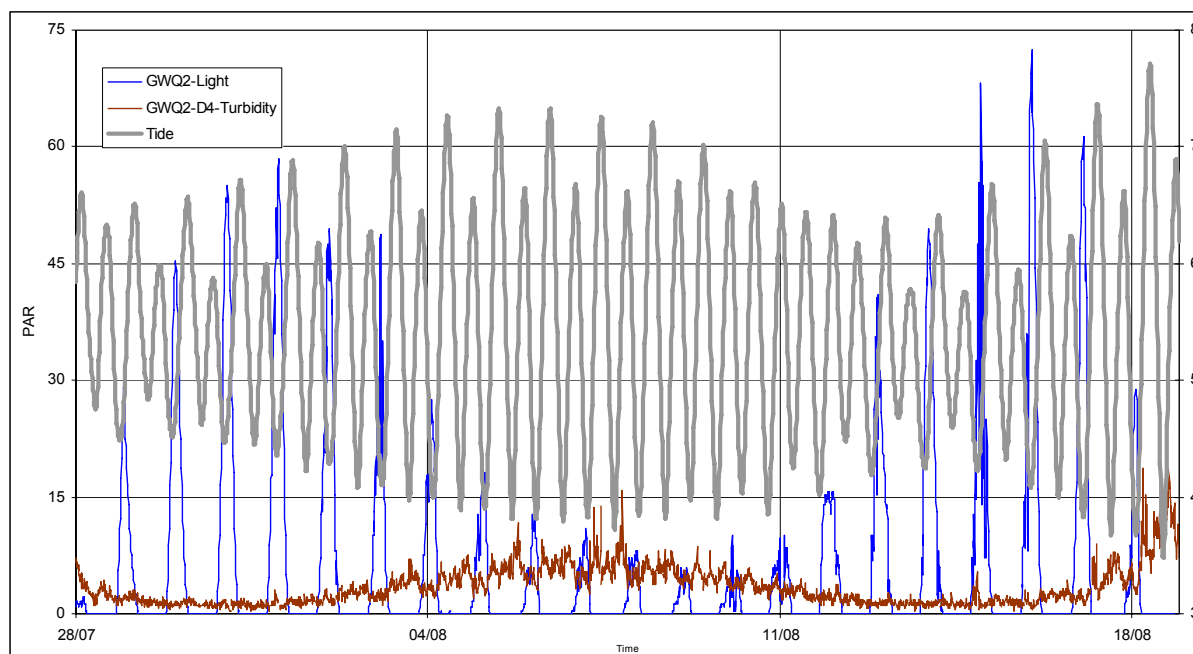


Figure 4-8 Turbidity, Wave Height (depth m) and Light at depth for Logger 4 Deployment 2.

The available data was insufficient to establish the relationship between turbidity and PAR.

4.5 Baseline Sedimentation Rates

As part of the GLNG Project EIS investigation, two-dimensional hydrodynamic and advection dispersion models were developed for Port Curtis and The Narrows to assess the impact of the proposed dredging programme. This modelling work had enabled the sediment plumes caused by the suspension of sediments during dredging to be assessed in terms of TSS but not in terms of the deposition of those sediments on sensitive habitats. In order to assess the impact of dredging activities on deposition rates an investigation was undertaken to gather baseline data on sedimentation rates within sensitive habitats.

4.5.1 Scope

The main purpose of the investigation was to measure potential baseline sedimentation rates within sensitive habitats close to the capital dredging works which could be compared with predicted deposition rates during dredging to assess potential impacts.

The investigation of baseline sedimentation rates involved two main components:

1. Literature Review - Collation of information on sedimentation measurement and sediment trap design.
2. Field investigation - Deployment of sediment traps at sensitive receptor locations to enable the measurement of baseline sedimentation rates.

4 Baseline Coastal Environmental Conditions

4.5.2 Literature Review

Sediment traps are commonly deployed in a variety of environments from deep ocean to coastal, lacustrine to estuarine, to measure sedimentation rates. However each of these environments presents a range of problems associated with the accurate measurement of the downward flux of suspended material. Consequently the design of many devices is specific to the application and location of its deployment. This situation is further compounded by the lack of any standard design criteria or commercially produced equipment.

All traps, in some way or another are going to affect the flow of water around the entrance to the collection vessel. It is suggested by White (1990) and Murdoch & MacKnight (1994) that straight-sided cylinders make the most effective trap shape. They are thought to collect sediment by both particles falling directly into the trap and through particles entering the trap by trap-induced turbulence.

The efficiency of sediment traps is influenced by three key parameters:

- The Trap Aspect Ratio
The trap aspect ratio (AR) = H/D_i , where H is the trap height and D_i is the internal diameter of the trap aperture. Murdoch & MacKnight (1994) have suggested that AR may ideally be the range of 5 to as high as 10 and Buesseler et al (2007) suggest that ARs over 5 will be required for good collection efficiencies under most ocean current conditions.
- The trap Reynolds number
The trap Reynolds number $R_t = uD_o/\nu$, where u is the velocity at the trap aperture, D_o is the outside diameter of the aperture; ν is the kinematic viscosity of the seawater. In order to ensure that there is no resuspension of the trapped material it is essential that the velocity profile caused by movement of water across the aperture does not extend to the bottom of the collection device (Hargrave & Burns, 1979). Studies quoted in White (1989) attempted to relate Reynolds number to washout. The results tend to suggest that for a fixed AR, increasing values of R_t will increase the depth of the turbulent profile within the tube and increase washout.
- The ratio of Current Speed to Particle Speed Velocity
The ratio of flow speed to particle fall velocity, $R_v = u/w$. As velocity increases and or particle size reduces the efficiency of collection is reduced.

4.5.3 Field Investigation

Sampling Techniques

Sediment traps were designed for the field investigation based on the findings of the literature review.

Each trap consisted of four 450 mm long, 50 mm diameter plastic tubes mounted on a steel frame and anchored to the seabed using star pickets, with each tube representing a sample replicate. Each tube was capped during installation on the seabed to prevent ingress of sediment stirred up by the divers. A typical trap assembly is shown in Figure 4-9. The collection tubes were sized to give an aspect ratio (height: diameter) of 9 which was calculated to be sufficient to prevent trap washout for a predicted possible maximum current velocity of 1.1 ms^{-1} . Traps were deployed for a total of 25 days and upon retrieval each tube was capped, chilled and dispatched for laboratory analysis of Total Suspended Sediment (TSS).

4 Baseline Coastal Environmental Conditions



Figure 4-9 Typical Sediment Trap Assemblage

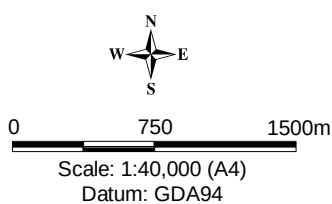
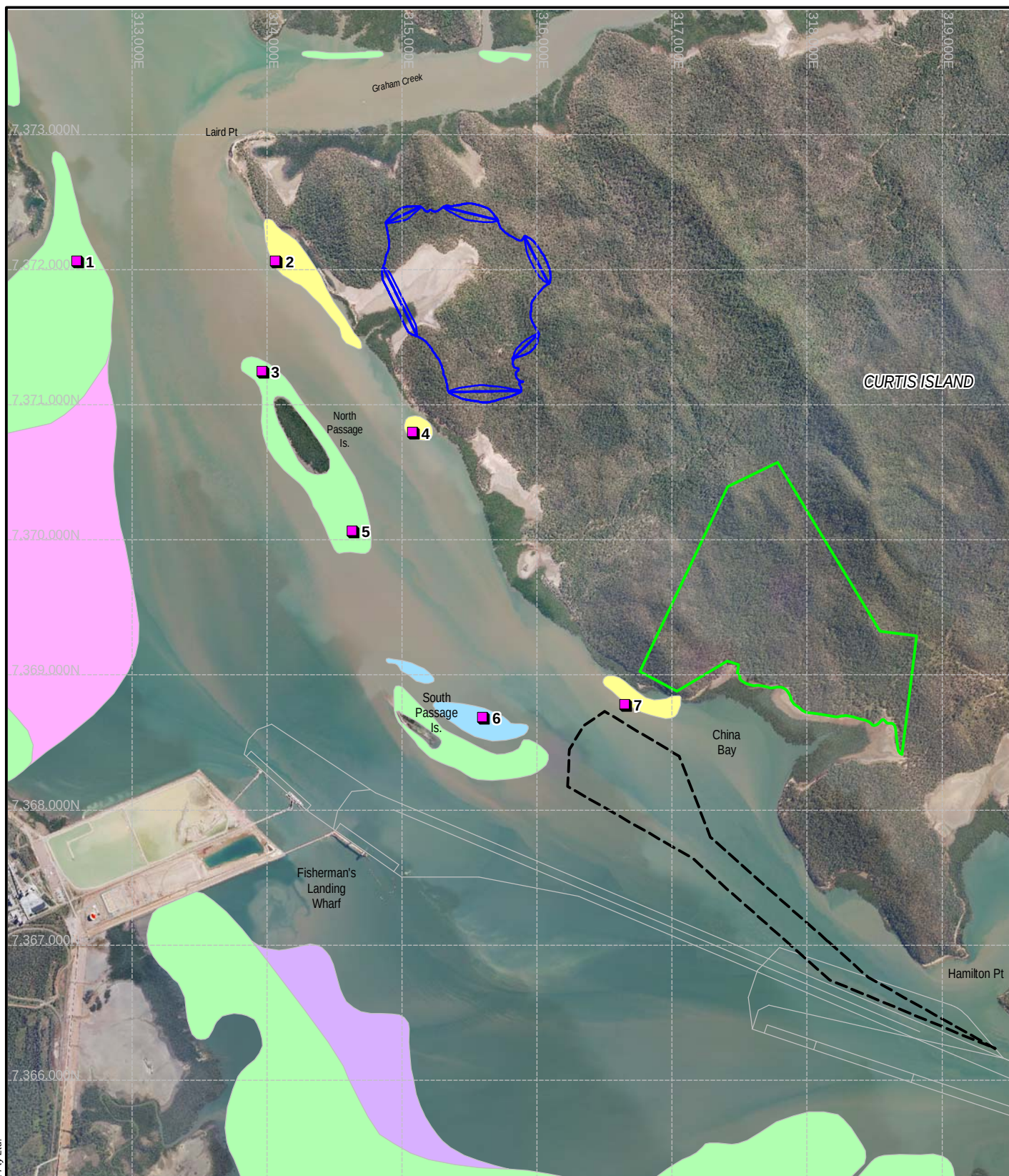
Sampling Sites

Sediment traps were deployed at seven sensitive receptor locations as shown in Figure 4-10. These sites were selected within seagrass meadows identified by Rasheed *et. al.*, (2003) and within relatively close proximity to the capital dredging works. The coordinates for the sampling locations are provided below in Table 4-7.

Table 4-7 Sediment Trap Deployment Locations

Sampling Location	Trap Location (Decimal Degrees)	
1	151.161231	-23.751638
2	151.175639	-23.751804
3	151.174564	-23.759169
4	151.185458	-23.763383
5	151.180984	-23.769924
6	151.190269	-23.782494
7	151.200643	-23.781767

This drawing is subject to COPYRIGHT. It remains the property of URS Australia Pty Ltd.



SEAGRASS

-  Halophila decipiens
-  Halophila decipiens with Halophila ovalis
-  Halophila ovalis with Zostera Capricorni
-  Zostera capricorni
-  Zostera capricorni with Halophila ovalis

-  Sediment Trap Location
-  Existing Channels
-  Proposed Dredging Channel
-  Dredge Material Placement Facility
-  LNG Facility Indicative Site Boundary

Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Client



URS

Project

GLADSTONE LNG PROJECT
ENVIRONMENTAL IMPACT STATEMENT
SUPPLEMENT
MARINE WATER QUALITY

Title

**SEDIMENT TRAP
LOCATIONS**
Draft

Drawn: RG	Approved: JB	Date: 03-11-2009
Job No: 4262 6440 /6220 File No: 42626440-g-2163.wor		

Figure: 4-10

Rev:B
A4

4 Baseline Coastal Environmental Conditions

4.5.4 Results

In coastal waterways, sedimentation rates refer to the amount of material (organic and mineral) deposited from the water column over a given interval of time. Sedimentation is measured in terms of vertical accumulation (mm yr^{-1}) over time or mass accumulation ($\text{g cm}^2 \text{yr}^{-1}$).

The TSS results for each sediment trap are shown in Table 4-8.

Table 4-8 Mean Sediment Accumulation Rates

Trap Site	Site Replicate	TSS (mg/L)	Deployment Length (d)	Trap Volume (L)	Trap Gross Sediment Mass (mg)	Trap Baseline Sedimentation MAR ($\text{mg/cm}^2/\text{d}$)	Mean Site Baseline Sediment MAR ($\text{mg dry wt/cm}^2/\text{d}$)	Mean Site Linear Sediment Vertical Accumulation rate (mm/day)
1	A	10400	25	0.884	9189	18.72	17.55	0.39
	B	11200	25	0.884	9896	20.16		
	C	9400	25	0.884	8306	16.92		
	D	8000	25	0.884	7069	14.40		
2	A	10100	25	0.884	8924	18.18	20.93	0.47
	B	8020	25	0.884	7086	14.44		
	C	14600	25	0.884	12900	26.28		
	D	13800	25	0.884	12193	24.84		
3	A	12200	25	0.884	10780	21.96	20.12	0.45
	B	12400	25	0.884	10956	22.32		
	C	10800	25	0.884	9543	19.44		
	D	9320	25	0.884	8235	16.78		
4	A	16100	25	0.884	14226	28.98	25.52	0.57
	B	13400	25	0.884	11840	24.12		
	C	13200	25	0.884	11663	23.76		
	D	14000	25	0.884	12370	25.20		
5	A	14000	25	0.884	12370	25.20	22.94	0.51
	B	13900	25	0.884	12282	25.02		
	C	15200	25	0.884	13430	27.36		
	D	7880	25	0.884	6963	14.18		
6	A	9080	25	0.884	8023	16.34	24.25	0.54
	B	13800	25	0.884	12193	24.84		
	C	12300	25	0.884	10868	22.14		
	D	18700	25	0.884	16523	33.66		
7	A	9550	25	0.884	8438	17.19	16.07	0.36
	B	10600	25	0.884	9366	19.08		
	C	7520	25	0.884	6644	13.54		
	D	8050	25	0.884	7113	14.49		

TSS results were converted to sedimentation mass accumulation rates (MAR) using the following formula:

4 Baseline Coastal Environmental Conditions

$$\text{Sedimentation MAR} = \text{TSS} * \text{TrapVolume} / \text{TrapArea} / \text{DeploymentLength}$$

A mean sedimentation MAR was then calculated for each sampling location by taking the average of the sedimentation MAR for each replicate as shown in Table 4-8. . Laboratory Results are provided in Appendix B.

4.5.5 Discussion

A review of similar published research (Hopley *et. al.*, 1990) has shown that the mean sedimentation MAR measured at each site are comparable with values for similar locations. From the results it can be seen that the rate of sediment deposition varies from approximately $16 \text{ mgcm}^{-2}\text{d}^{-1}$ at site 7 to $25.5 \text{ mgcm}^{-2}\text{d}^{-1}$ at site 4, with no discernable relationship between deposition rate and location.

It should be noted that the sediment trap deployment occurred during a period of prolonged dry weather and as such the measured sedimentation rate is not affected by recent wet weather events.

Dredging Impact Assessment

This section of the report seeks to present the impacts of the proposed capital dredging activities on the coastal environment by comparison of predicted water quality and sediment deposition rates with baseline conditions. This assessment has involved the following components:

- Plume Dispersion and Deposition modelling of the predicted TSS concentrations and sedimentation rates generated by the proposed capital dredging activities, and comparison of the modelled results against baseline conditions.
- Testing of dredge sediments for Oxygen Demand and Metals to identify potential water quality impacts that may arise due to the potential presence of contaminants in the dredge material and their introduction into the water column during dredging activities.

5.1 Plume Dispersion and Deposition Modelling

5.1.1 Background

The “dredge plume” is defined as the quantity of Total Suspended Solids (TSS) which is in the water column due to dredging, and is above the natural background levels for that location and time. The increased turbidity associated with the dredge plume and the additional sediment deposition associated with settling of the dredge plume material are two of the primary sources of potential environmental impacts caused by dredging activities.

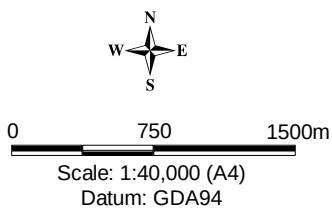
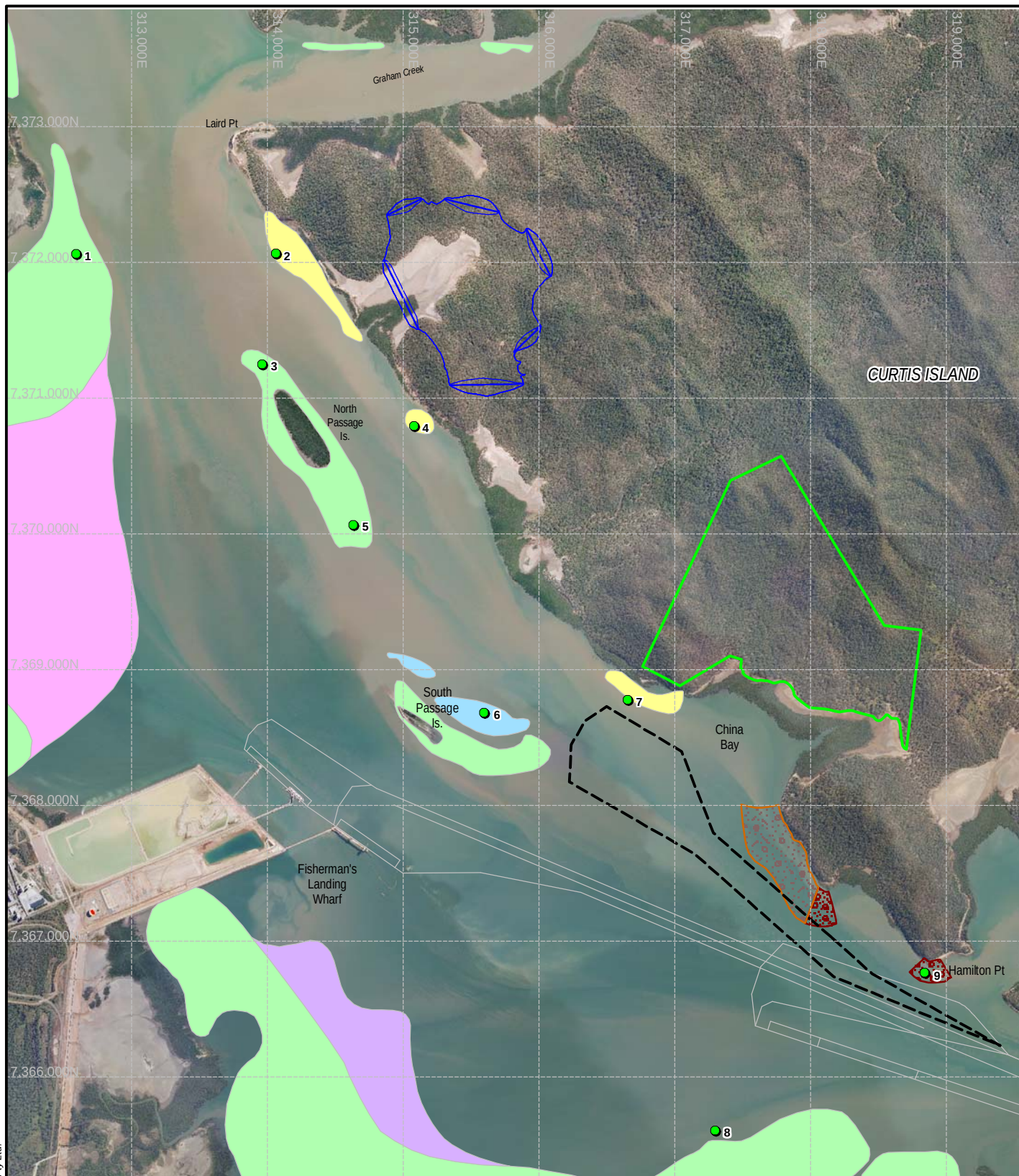
TSS concentrations and plume sediment deposition rates were modelled to predict the maximum and 10 % exceedance levels that would be produced during dredging activities. The maximum levels represent the potential maximum values during dredging operations but do not represent the duration of impact. The 10 % exceedance predictions attempt to provide information on the duration of impact as they represent the levels that are expected to be exceeded for at least 10 % of the time during dredging operations. These predictions were supplemented by snapshot in time representations of levels that would be anticipated during neap tide slack water and during spring rising tide to illustrate the range of values that could be experienced at any particular time during dredging operations. Time series plots of the predicted TSS concentrations and deposition rates were also produced at nine sensitive receptor sites to assess the potential dredging impacts. These sites were chosen to represent the nearest sensitive receptors to the capital dredging and comprise both seagrass meadows and subtidal communities. The locations of the sensitive receptor sites are shown in Figure 5-1.

5.1.2 Modelling Methodology

The proposed dredging scenario is described in Section 2.2. Santos proposed the use of a large CSD for the capital dredging works. The plume modelling assumptions and plume loading rate applied for the proposed dredging scenario are discussed in detail in Appendix A of this report and are summarised in Table 5-1 below.

Table 5-1 Simulation Method and Plume Loading details

Source - Location	Total Loading
Large CSD – Santos Basin Decant @ 50 mg/l	4 kg/s for 20 hours each 24 hour period 2.8 m ³ /s continuous



SEAGRASS

- Halophila decipiens
- Halophila decipiens with Halophila ovalis
- Halophila ovalis with Zostera Capricorni
- Zostera capricorni
- Zostera capricorni with Halophila ovalis

- Rubble Slope
- Rocky Headland
- Sensitive Receptor Assessment Site
- Existing Channels
- Proposed Dredging Channel
- Dredge Material Placement Facility
- LNG Facility Indicative Site Boundary

Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Client



URS

Project

GLADSTONE LNG PROJECT
ENVIRONMENTAL IMPACT STATEMENT
SUPPLEMENT
MARINE WATER QUALITY

Title

**SENSITIVE RECEPTOR
ASSESSMENT SITES**

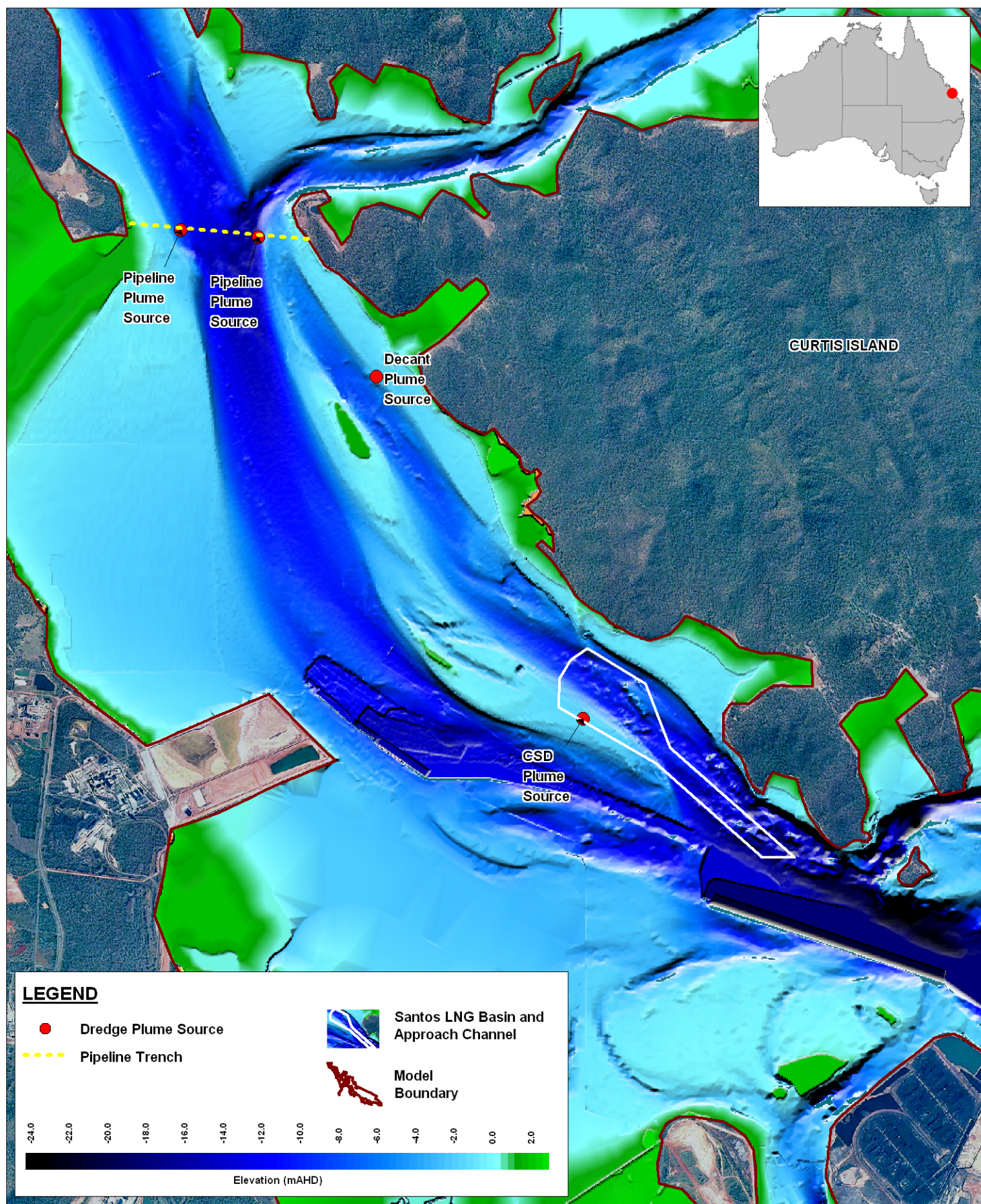
Drawn: RG Approved: JB Date: 04-11-2009
Job No: **4262 6440** /6220 File No: 42626440-g-2166.wor

Figure: **5-1**

Rev:C
A4

5 Dredging Impact Assessment

The source generation locations for the plume dispersion and deposition modelling are shown below in Figure 5-2. The CSD was modelled as a stationary point source within the swing basin area where the majority of the dredging (84 %) will be undertaken. The decant discharge from the DMPF was also modelled as a point source plume.



Title:
Sediment Plume Source Locations

Figure:
2-3

Rev:
A

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



0 2 4km
Approx. Scale



Filepath : I:\B17608.L\at_GladstoneSantos\DRG\COA_001_091020_Dredge_Plume_Cells.wor

5 Dredging Impact Assessment

The dredging scenario was modelled for a one (1) month period from the 4/2/2009 to the 4/3/2009 using measured tidal and wind boundary conditions.

The composition of the dredge plume suspended sediment load was considered to be similar to the naturally suspended material. The modelled sediment and plume characteristics are summarised in Table 5-2 below.

Table 5-2 Model Sediment and Plume Characteristics

Particle	Fine Sand	Silt	Clay
Still Water Fall Velocity, w_{s0} (m/s)	1.0E-02	2.0E-04	2.0E-05
Equivalent Stokes Diameter, d_{s0} (μ m)	110	15	4.8
Critical Shear Stress Deposition, τ_{cd} (N/m ²)	0.5	0.5	0.5
Sediment particle density, ρ_s (kg/m ³)	2650	2650	2650
% Dredge Plume	16	56	28
% Discharge (Decant) Plume	0	35	65

The dredge plume assessment did not model the resuspension of already deposited plume material which means that the estimates of deposition due to dredging are conservative and therefore an overestimate. The reason for the exclusion of re-suspension from the computer modelling was based on the premise that whilst there is the potential for re-suspension of the fine suspended load which does settle out, it will generally become mixed with and hence indistinguishable from resuspension of the natural bed material. Settling will occur when and in areas that currents and waves (and hence bed shear stresses) are lower. These are areas of naturally occurring fine bed sediments and the amount of resuspension will be a function of the prevailing conditions and the nature of the material, rather than the origin of the material. Accordingly, the amount of resuspension will be dominated by the natural bed material which will not be affected by the project.

5.1.3 Model Results and Discussions - TSS

The maximum TSS concentrations and the 10 % exceedance results are shown in Figure 5-3 & Figure 5-4 respectively. Snapshot representations of TSS concentrations predictions during neap tide and spring tide are shown in Figure 5-5 & Figure 5-6 respectively.

5 Dredging Impact Assessment

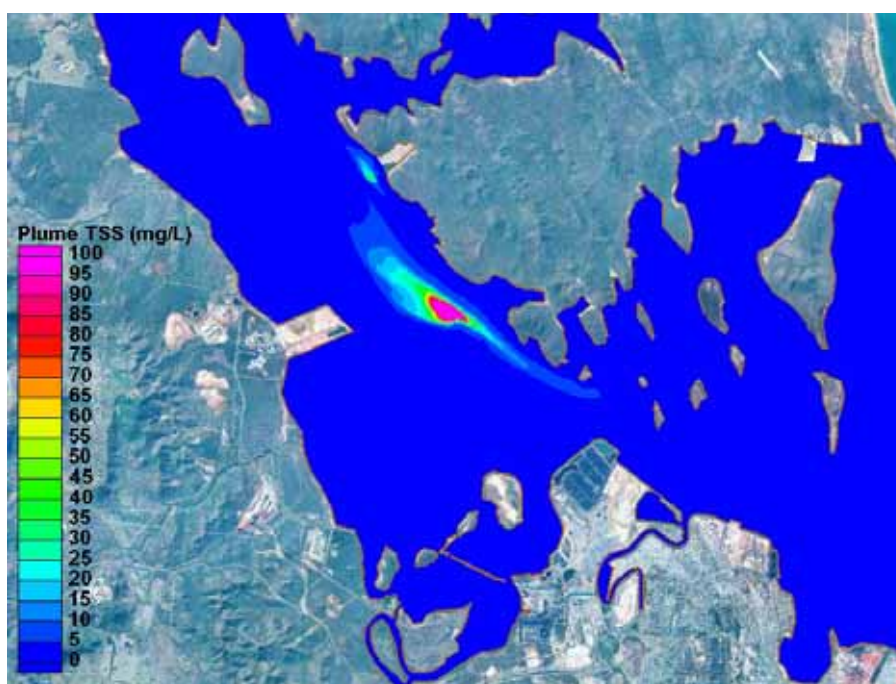


Figure 5-3 CSD with 50mg/L decant discharge – maximum plume TSS concentration

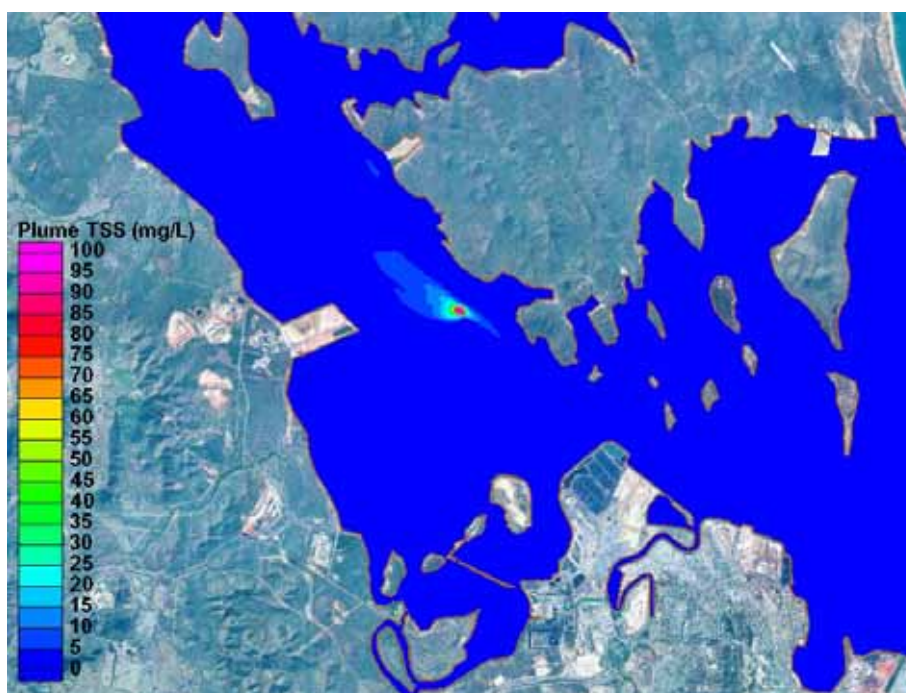


Figure 5-4 CSD with 50mg/L decant discharge – 10% exceedance TSS concentration

5 Dredging Impact Assessment



Figure 5-5 CSD with 50mg/L decant discharge – Plume snapshot at 01:00 on 18/02/2009 (Neap Tide)



Figure 5-6 CSD with 50mg/L decant discharge – Plume snapshot at 09:00 on 26/02/2009 (Spring Tide)

shows the predicted maximum TSS concentrations for the proposed dredging operations. As discussed earlier these values represent the potential maximum values and do not represent the duration of impact. They should therefore be interpreted as an envelope for potential dredging impact. The 10% exceedance predictions for TSS concentration shown in provides more information on the potential duration of impact. The data shown in this figure indicates that for 10 % of the time TSS

5 Dredging Impact Assessment

concentrations will exceed 100mg/L at the dredger head and are predicted be in the order of 30 mg/L in the immediate vicinity of the dredger. These concentrations decrease to approximately 5 mg/L within the channel between South Passage Island and Curtis Island. The results shown in Figure 5-5 indicate that during Neap Tide the concentration TSS concentrations may exceed 100mg/L at the dredge head but that the predicted dredge plume will be confined to the immediate vicinity of the dredger. The results shown in Figure 5-6 indicate that during Spring tide TSS concentrations are unlikely to exceed 20 mg/L in area surrounding the dredger.

Sensitive Receptor locations

Simulated time series graphs of TSS concentrations during dredging were produced for the nine sensitive receptor locations shown in Figure 5-1 to provide greater detail for the assessment of impacts from dredging activity. These graphs are presented in Appendix A. Graphs showing the range of TSS concentrations at sensitive receptor locations are provided in Figure 5-7 and Figure 5-8.

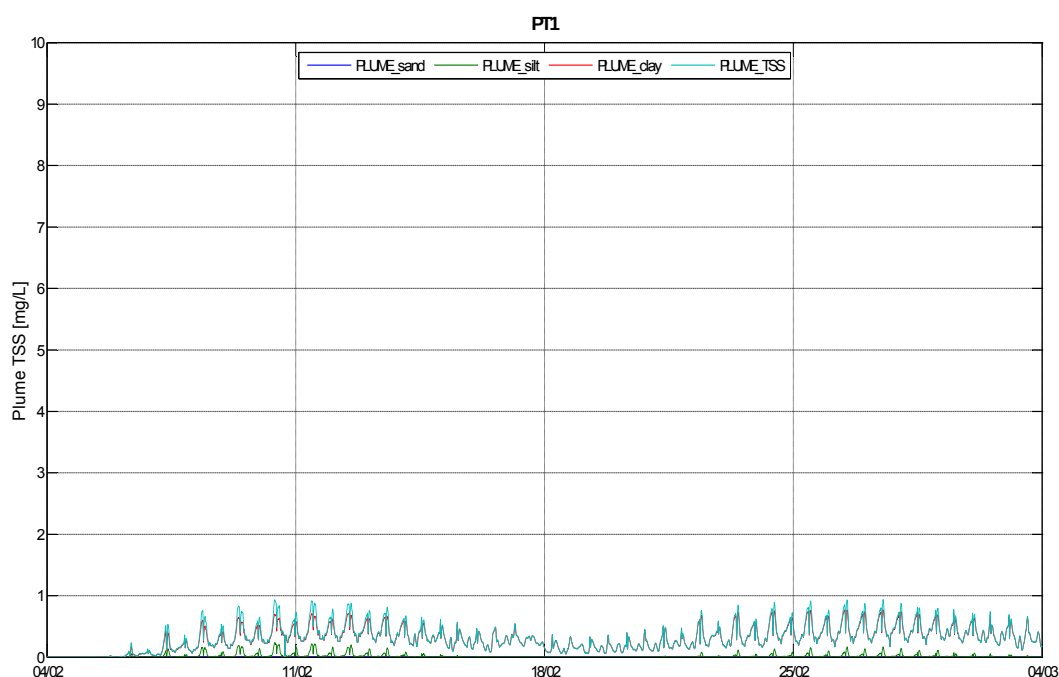


Figure 5-7 Simulated TSS Concentrations for the CSD with 50mg/L decant discharge (PT1)

5 Dredging Impact Assessment

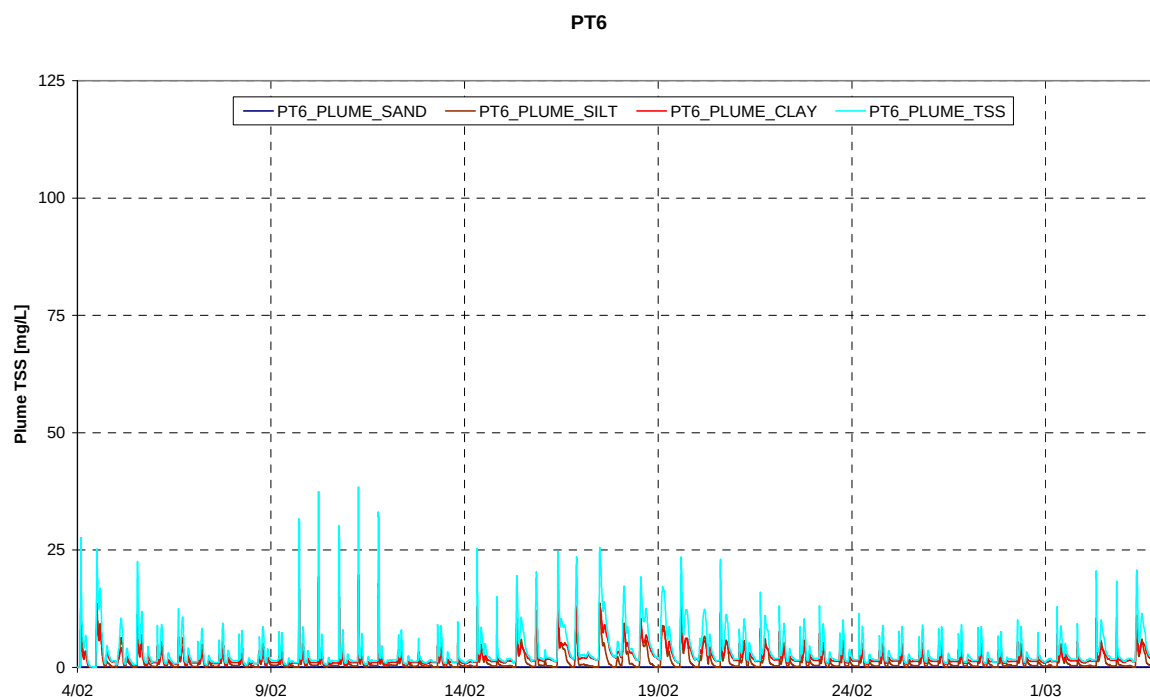


Figure 5-8 Simulated TSS Concentrations for the CSD with 50mg/L decant discharge (PT6)

Summary statistics for the TSS concentrations produced by the CSD at the sensitive receptor locations are provided in Table 5-3.

Table 5-3 Summary statistics for predicted TSS concentrations generated by the CSD at sensitive receptor locations

		Sensitive Receptor Locations								
	TSS (mg/L)	PT1	PT2	PT3	PT4	PT5	PT6	PT7	PT8	PT9
CSD	50 th Percentile	0	2	1	1	2	2	1	1	1
	80 th Percentile	0	3	2	2	2	5	2	1	2
	90 th Percentile	1	3	2	2	3	8	2	1	2
	95 th Percentile	1	4	2	2	3	11	2	1	3
	Maximum	1	5	3	3	6	38	3	2	4

The summary data provided in Table 5-3 shows that predicted 95th percentile TSS concentration increases generated by the CSD range from 1 – 4 mg/L for the majority of sensitive receptors on the eastern side of Port Curtis, while the increase is predicted to be 11mg/L for PT6.

5 Dredging Impact Assessment

Impacts of predicted TSS concentrations on Sensitive receptors

TSS concentrations recorded in Port Curtis as summarised in Table 4.4 have mean values of between 30-45 mg/L, with peak natural TSS values of approximately 110 mg/L. The predicted TSS concentrations arising from the dredging activity are increases above background levels.

Seagrass Meadows

Increases in TSS concentrations represent an increase in the concentration of suspended sediment in the water column. The presence of suspended sediment changes the optical properties of the water and in so doing increases turbidity levels and decreases light transmission.

Reductions in light due to turbidity have been identified as a major cause of loss of seagrasses worldwide (Shepherd *et al.*, 1989; Green and Short, 2003). High turbidity reduces photosynthesis and will reduce plant growth. Prolonged high turbidity will cause plant mortality in seagrass meadows. Seagrass requires higher light levels than most macroscopic algae, and they often occur in fine sediments which cause more persistent turbidity when dredged (EPA, 2001).

Studies in Moreton Bay, Australia compiled by Erftemeijer and Lewis (2006) have investigated the light requirements for *Zostera capricorni* seagrass, also common to Port Curtis. These studies determined the critical threshold of seagrasses (i.e. 'minimum light requirements') to be 30 % of surface irradiance.

Unfortunately it was not possible to establish the percentage reduction of surface irradiance that would result from the predicted TSS concentrations during dredging based on the datasets available for this assessment.

Whilst minimum light requirements are important, it is an oversimplification to assume that light attenuation alone determines plant response to increased turbidity. Also of importance is the length of time that different species can survive at low light levels. Temporary fluctuations in turbidity may be accommodated by the plant depending on the nature of the species and the period of sub-optimal light (Westphalen *et al.*, 2004).

Doorn-Groen and Foster (2007) prepared an impact severity matrix for seagrass meadows based on monitoring experience from the SE Asia region which is provided in Table 5-4.

5 Dredging Impact Assessment

Table 5-4 Impact severity matrix for suspended sediment impact on Seagrass

Severity	Location of study
No Impact	Excess Suspended Sediment Concentration > 5mg/l for less than 20% of the time
Slight impact	- Excess Suspended Sediment Concentration > 5mg/l for more than 20% of the time - Excess Suspended Sediment Concentration > 10mg/l for less than 20% of the time
Minor Impact	Excess Suspended Sediment Concentration > 25mg/l for less than 5% of the time
Moderate Impact	- Excess Suspended Sediment Concentration > 25mg/l for more than 20% of the time - Excess Suspended Sediment Concentration > 75mg/l for less than 1% of the time
Major Impact	Excess Suspended Sediment Concentration > 75mg/l for more than 20% of the time

The summary data for TSS concentrations, which would be exceeded 20 % of the time (80th percentile) during dredging operations, shows that predicted TSS concentration increases generated by the CSD range from 0 – 3 mg/L for the majority of sensitive receptors on the eastern side of Port Curtis, while the maximum 80th percentile increase is expected to be 5 mg/L for PT6. A comparison of the predicted 80th percentile TSS concentrations with the impact severity matrix presented in Table 5-4 shows that the TSS levels arising from dredging operations are below the impact threshold for the majority of sensitive receptor locations within seagrass communities. The exception is PT6 where predicted TSS levels are within the 'Slight Impact' range.

The area of seagrass in the immediate vicinity of PT6, where slight impacts may arise from dredging, surrounds South Passage Island and represents an area of approximately 34 ha which equates to approximately 0.8 % of the seagrass area in Port Curtis. It is anticipated that the slight impacts on seagrass may be recoverable once the dredging has finished. The seagrass meadows in the affected area have been classified as aggregated patches of *Halophila Ovalis* with *Zostera Capricorni* seagrass, and contain small biomass and areas compared with other seagrass meadows within the Port Curtis area. The seagrass communities and low biomass present mean that this area is considered to be unlikely to be utilised by dugongs.

Subtidal Communities

Very few studies have been conducted on the potential impacts of dredging on subtidal communities. Most previous work has focussed on zooxanthellate hard corals, whereas the species found during the subtidal community survey were azooxanthellate (ie not dependent on light), and with the exception of *Tubastrea faulkneri*, all were soft corals.

5 Dredging Impact Assessment

It has been well documented that healthy coral communities may exist in chronically turbid water (van Woesik, 1994 and Postorok & Bilyard, 1985), especially where strong currents prevent the build up of sediment (Postorok & Bilyard, 1985), however the communities are generally less diverse and abundant than those in clear water (van Woesik, 1994). Changes in trophic mode, such as increased feeding on suspended particulate matter may offset the stress in high particulate loads (Anthony and Fabricius, 2000).

Doorn-Groen and Foster (2007) established a severity matrix for suspended sediment impact on coral based on monitoring data from multiple projects in Singapore which is provided Table 5-5 below.

Table 5-5 Impact severity matrix for suspended sediment impact on Coral

Severity	Location of study
<i>No Impact</i>	Excess Suspended Sediment Concentration > 5 mg/l for less than 5 % of the time
<i>Slight impact</i>	- Excess Suspended Sediment Concentration > 5 mg/l for less than 20 % of the time - Excess Suspended Sediment Concentration > 10 mg/l for less than 5 % of the time
<i>Minor Impact</i>	- Excess Suspended Sediment Concentration > 5 mg/l for more than 20 % of the time - Excess Suspended Sediment Concentration > 10 mg/l for less than 20 % of the time
<i>Moderate Impact</i>	- Excess Suspended Sediment Concentration > 10 mg/l for more than 20 % of the time - Excess Suspended Sediment Concentration > 25 mg/l for more than 5 % of the time
<i>Major Impact</i>	- Excess Suspended Sediment Concentration > 25 mg/l for more than 20 % of the time - Excess Suspended Sediment Concentration > 100 mg/l for more than 1 % of the time

The predicted 95th percentile TSS concentration at PT9 is 3 mg/L. A comparison of this result with the impact severity matrix presented above indicates that this concentration is below the impact threshold and consequently impacts of subtidal communities around Hamilton Point are anticipated to be marginal if any. However it should be noted that the modelling results are based on dredging within the swing basin. Whilst the vast majority of dredging activity (5.7 Mm^3) will occur in this location, dredging will also be required for the approach channel (1.1 Mm^3) which will require operation of the CSD in closer proximity to the intertidal communities for a period of approximately 8 weeks. During this period intertidal communities surrounding Hamilton Point may experience TSS concentrations similar to or exceeding those predicted for PT6 and thus minor to moderate impacts are considered possible.

5 Dredging Impact Assessment

5.1.4 Model Results and Discussions – Sediment Deposition

Predicted potential sediment deposition rates arising from the CSD is presented as a spatial plot of average plume material deposition rates in Figure 5-9. It should be noted that these estimates represent potential sedimentation since deposition modelling did not account for resuspension.

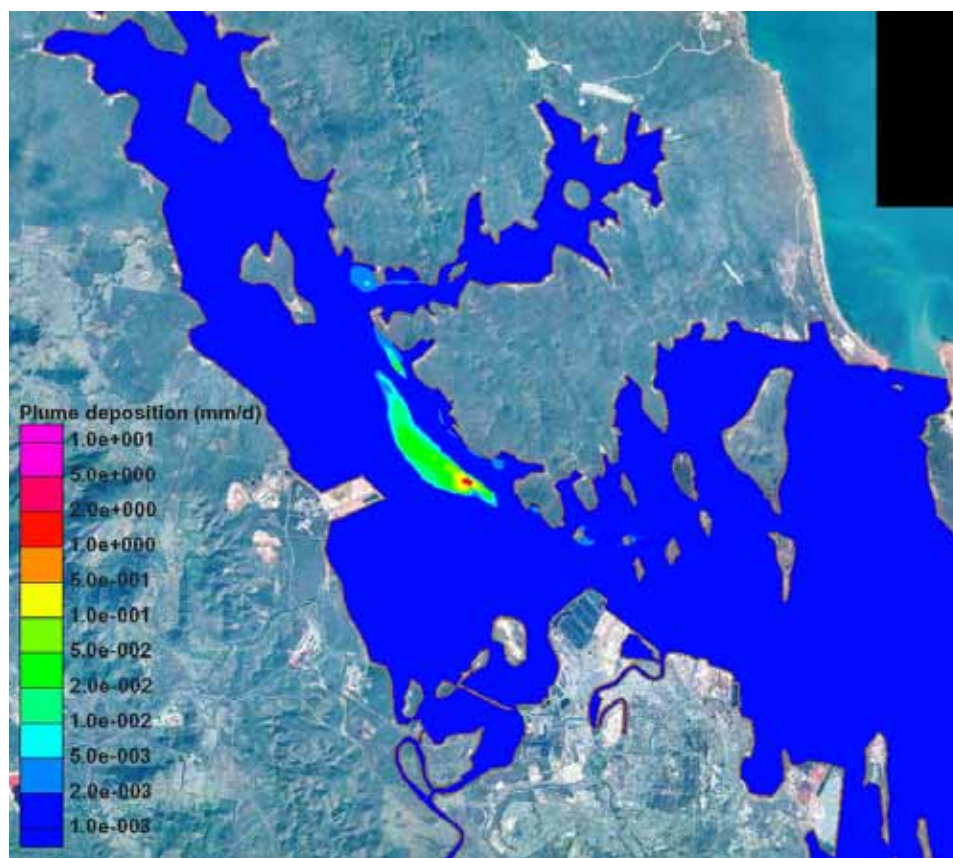


Figure 5-9 CSD with 50mg/L decant - average plume deposition rate

The deposition modelling results indicate that dredging activity has the potential to contribute to increased deposition rates in the eastern side of Port Curtis. Increased rates in the order of 1mm/d are anticipated at the dredge head and 0.1 mm/d in close proximity to the dredger (Figure 5-9). Increased rates in the order of 0.02 mm/d are predicted in the channel between the Passage Islands and Curtis Island which represents a 4% increase on background deposition rates (Table 4-8).

In order to assess the depositional impacts of the proposed dredging activity on sensitive receptors time series graphs of plume deposition were produced for each receptor site. These graphs are provided in Appendix B of Appendix A of this report. Average sediment deposition rates were derived at each site based on the final 2 weeks of the 1 month simulation, when suspended sediment mass levels were seen to have reached a dynamic saturation level. The average deposition rates predicted at each sensitive receptor location for the CSD are provided in Table 5-6.

5 Dredging Impact Assessment

Table 5-6 Predicted deposition rates from CSD

Sensitive Receptor Site	PT1	PT2	PT3	PT4	PT5	PT6	PT7	PT8	PT9
Deposition (mm/day)	0.00	0.0089	0.0037	0.00071	0.0175	0.0560	0.0012	0.00014	0.00
Mass Accumulation Rate (g/cm ² /d)	0.0	0.0004	0.00017	0.000032	0.00079	0.0025	0.000053	0.000006	0.00
mass accumulation (mg/cm ² /d)	0.0	0.399	0.167	0.032	0.789	2.52	0.053	0.0065	0.00
Mass Accumulation Rate (g/cm ² /yr)	0.0	0.146	0.061	0.012	0.288	0.92	0.020	0.0024	0.00

Seagrass Meadows

The seagrass communities in and around Gladstone are under a status of high threat according to the Great Barrier Reef World Heritage Area (GBR WHA) due to coastal, port and urban/industrial development. The Gladstone region (Map 2) contains significant areas of high value seagrass including extensive meadows of species important for dugong as well as high fisheries value nursery meadows (Rasheed *et al.* 2003).

Several studies have documented deterioration of seagrass meadows by smothering due to excessive sedimentation. The consequences of enhanced sedimentation for seagrass plants depend on several factors such as depth of burial and life history of the species involved (Duarte *et al.*, 1997). Seagrasses are also likely to be affected by the nature of the sediments that are deposited, which may bring with them pollutants or a high nutrient load. Furthermore, the redox state of sediments may be altered if there is a high organic load.

Doorn-Groen and Foster (2007) established a severity matrix for sediment deposition impacts for seagrass based on experience in the SE Asia region which is provided below in Table 5-7.

Table 5-7 Impact severity matrix for sediment deposition impact on Seagrass

Severity	Location of study
No Impact	• Sedimentation < 0.1kg/m ² /day (<0.25mm/day)
Slight impact	• Sedimentation < 0.25kg/m ² /day (<0.63mm/day)
Minor Impact	• Sedimentation < 0.5kg/m ² /day (<1.25mm/day)
Moderate Impact	• Sedimentation < 1.0kg/m ² /day (<2.5mm/day)
Major Impact	• Sedimentation > 1.0kg/m ² /day (>2.5mm/day)

The potential sedimentation rate arising from the CSD is predicted to range from 0.0012 to 0.056 mm/day within seagrass communities on the eastern side of Port Curtis, with lower levels being predicted elsewhere. A comparison of these results with the impact matrix provided above indicates that the potential increase in deposition due to dredging is below the impact threshold for seagrasses.

5 Dredging Impact Assessment

It is therefore anticipated that the depositional impacts on seagrasses due to dredging would be marginal if any.

Subtidal Communities

Very few studies have been conducted on the potential impacts of sedimentation on the subtidal communities within Port Curtis. While all the coral species found within the subtidal communities during the surveys conducted for the EIS Supplement (see Attachment F5 of the EIS Supplement) have some ability to remove sediments using their polyps, there is no data available on the rates of removal or the amount of sediment deposition likely to cause partial or total mortality.

A wide range of responses to sedimentation impacts have been reported for corals and other taxa. Most of the experimental approaches have been limited by the relatively short time corals have been exposed to sedimentation. This short time frame is suitable to detect acute effects, but doesn't provide much information on the chronic effects, which may be expected if dredging is to continue over many months.

Monitoring of background levels of sediment deposition was not carried out for site 9 and its location near Hamilton Point is in a high flow rate area compared to the other monitoring sites so the data collected for these sites cannot be directly applied.

Doorn-Groen and Foster (2007) derived tolerance limits for corals to sedimentation impacts based on monitoring undertaken in Singapore which can be viewed in Table 5-8 below.

Table 5-8 Impact severity matrix for sedimentation impact on corals

Severity	Location of study
No Impact	• Sedimentation < 0.1 kg/m ² /day (<0.25 mm/day)
Slight impact	• Sedimentation < 0.25 kg/m ² /day (<0.63 mm/day)
Minor Impact	• Sedimentation < 0.5 kg/m ² /day (<1.25 mm/day)
Moderate Impact	• Sedimentation < 1.0 kg/m ² /day (<2.5 mm/day)
Major Impact	• Sedimentation > 1.0 kg/m ² /day (>2.5 mm/day)

The time series graph of potential sediment deposition at the subtidal community sensitive receptor site (PT9) provided in Appendix B of Appendix A of this report indicates that the increase in average sedimentation rate during dredging operations using a CSD would be 0.00 mm/d. This sedimentation rate does not exceed the thresholds presented in Table 5-8. However, as discussed previously the modelled deposition rates reflect dredging within the proposed swing basin. In actuality dredging will occur in close proximity to subtidal communities for a period of approximately 8 weeks and it is anticipated the during this period subtidal communities will be exposed to deposition rates more akin to that experienced at PT6 or higher. However, even if deposition rates increased to that predicted for PT6 in these communities during dredging, the depositional impacts would be expected to be marginal if any.

5 Dredging Impact Assessment

5.2 Other Water Quality Impacts from Dredging

Dredging operations involve the disturbance of bed material which may release pollutants bound within bottom sediments into the water column. A contaminant assessment of the materials to be dredged was undertaken during the preparation of the EIS and presented in Appendix R3 of the EIS. The report found that concentrations of heavy metals such as antimony, arsenic, chromium, copper, manganese, mercury and nickel, exceeded the Investigation Levels (ILs) established in some of the guidelines. Also, whilst no guidelines have been established for either iron or aluminium, both metals were present in notable concentrations.

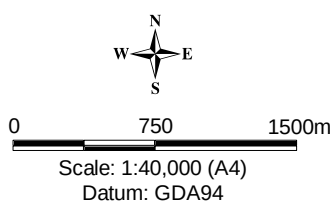
In addition it is well established that the disturbance of dredge material during dredging activities may cause a local depletion of dissolved oxygen levels in the surrounding water column due to the release of substances that have a high biological oxygen demand. The potential for capital dredging to cause a depletion of dissolved oxygen levels was not assessed during the preparation of the EIS and is addressed in this EIS supplement.

5.2.1 Scope

The assessment of the potential for dredging to give rise to water quality impacts other than TSS and sedimentation involved the collection of samples of material from the capital dredging area which were submitted for laboratory analysis for BOD and Metals.

5.2.2 Field Survey

Intact sediment cores were collected using a vibracorer from eight locations within the capital dredging area. Sampling locations were selected based on proximity to sites that had previously been sampled during the EIS as discussed in Appendix R3. The sampling locations are shown in Figure 5-10.



- Existing Channels
- Proposed Dredging Channel
- Dredge Material Placement Facility
- LNG Facility Indicative Site Boundary

◆ Sediment Cores

Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Client		Project			Title		
		GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT SUPPLEMENT MARINE WATER QUALITY			SEDIMENT SAMPLING LOCATIONS		
		Drawn: RG	Approved: JB	Date: 16-11-2009	Figure: 5-10		Rev.C
		Job No: 4262 6440 /6220		File No: 42626440-g-2164.wor			A4

5 Dredging Impact Assessment

5.2.3 Analysis

Sediment samples were submitted to ALS laboratories for Elutriate Testing for Biological Oxygen Demand and Metals (laboratory results provided as Appendix C). Elutriate testing was undertaken in accordance with methods established in National assessment guidelines for dredging 2009 (NAGD, 2009) to assess the potential impact of dredge material disturbance on water quality in the vicinity of the dredging.

Elutriate testing assesses the potential for contaminants of concern to be mobilised and impact marine water quality. Test results are normally compared to the relevant Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ 2000a,b) trigger values for 95 percent protection.

The elutriate test uses a dilution of 1:4, wet sediment: added seawater, and will greatly overestimate water quality impacts given that, within the four-hour period, dilutions of the order of a hundred times or more (and often much more) would normally be expected. The test data are therefore corrected for the calculated dilution factor after the four-hour mixing period (after taking account of the test dilution of 1:4) to assess whether or not the water quality guidelines will be exceeded.

5 Dredging Impact Assessment

5.2.4 Results

Biological Oxygen Demand (BOD)

The BOD results are presented in Table 5-1 Elutriate BOD results

Table 5-1 Elutriate BOD results

Borehole	Depth (m)	BOD (mg/L)
BH01A	0-1.0	<2
BH01A	1.0-2.1	<2
BH01A	2.1-2.8	<2
BH02A	0-1.0	<2
BH02A	2.0-2.75	<2
BH02A	2.75-3.1	<2
BH04A	0.2-0.5	<2
BH04A	0.5-1.0	<2
BH04A	0-0.2	<2
BH07A	0-1.0	<2
BH07A	2.0-2.8	<2
BH07A	3.0-4.0	<2
BH08C	0-1.0	<2
BH08C	3.0-4.0	<2
BH08C	4.75-5.6	<2
BH13A	0-1.0	<2
BH13A	11.5-12.0	<2
BH13A	6.0-7.0	<2
BH13A	COMP	<2
BH14A	0-1.0	<2
BH14A	2.5-3.5	<2
BH14A	6.0-7.0	<2
BH17A	0.3-1.2	<2
BH17A	0-0.3	4
BH18A	10.0-11.0	<2
BH18A	11.1-11.5	<2
BH18A	2.0-3.0	<2

The results show the BOD was below the limit of detection for all samples except BH17A 0-0.3 which was low at 4 mg/L. The results indicate that the dredge material is unlikely to pose a risk to dissolved oxygen levels within the water column surrounding capital dredging works.

Metals

The elutriate and leachate testing results are presented in Appendix C.

5 Dredging Impact Assessment

Elutriate testing found elevated concentrations of Manganese in samples from all locations. Concentrations ranged from a low of 63 µg/L to a high of 2520 µg/L with average concentrations across all samples being approximately 1100 µg/L. No specific guideline levels for manganese are specified in the ANZECC guidelines for Fresh and Marine Water Quality due to insufficient data. Manganese is a naturally occurring element that is found in rock, soil and water. It is ubiquitous in the environment and comprises about 0.1 % of the Earth's crust. Given the absence of specific guideline levels and the high levels present in sediment it is likely that manganese is naturally occurring in the area and will not pose a significant risk to the receiving environment.

Low concentrations of arsenic and nickel were found in samples from all locations. Low concentrations of iron and aluminium were also detected in elutriate samples from locations 4 and 5 respectively.

The elutriate testing results suggest that there is a low potential for dredge materials to pose a risk to ambient water quality through the release of metals during mixing with seawater either in the vicinity of the dredging or through the release of decant water from the DMPF.

Mitigation Measures and Recommendations

Mitigation measures to control the impacts of dredging are presented in the Draft Dredge Management Plan which is provided as Attachment G9 of the EIS Supplement. The potential for any adverse impacts to arise on subtidal communities will be minimised by limiting periods of continuous dredging activity within the approach channel.

A water quality monitoring programme will be implemented which will involve the monitoring of water quality at sensitive receptor locations during dredging activity.

Real-time water quality monitors will be established at sensitive receptor sites within Port Curtis. These monitors will collect real-time data on suspended solids and other standard parameters including salinity, temperature and pH levels. A period of baseline monitoring should be carried out prior to the commencement of dredging to adequately characterise baseline conditions. The water quality monitoring will continue for four weeks after the dredging is completed to provide evidence that there are no ongoing effects on the Port Curtis environment.

It is further recommended that additional baseline monitoring programmes be undertaken to provide better information on the sensitivity of seagrass and subtidal communities to dredging impacts. Specifically it is recommended that the following additional investigations be undertaken:

- Establish the relationship between TSS, turbidity, and PAR through a specific monitoring programme.
- Establish baseline deposition rates in subtidal communities through specific monitoring.
- Further review the sensitivity of seagrass and subtidal communities to TSS and sediment deposition including field investigations if required.
- Review the sensitivity of the predicted impact to the dredging input parameters used for the hydrodynamic and dispersion modelling.
- Monitoring during and post dredging.

References

- Anthony, K.R.N. and Fabricius, K.E. (2000) *Shifting roles of heterotrophic and autotrophy in coral energetics under varying turbidity*. Journal of Experimental Marine Biology and Ecology 252, 221-253.
- Australian and New Zealand Environment and Conservation Council (ANZECC) (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality.
- Buesseler, K. O., Antia, A. N., Chen, M., Fowler, S. W., Gardner, W. D., Gustafsson, O., Harada, K., Michaels, A. F., Loeff, M. R., Sarin, M., Steinberg, D. K. and Trull, T. (2007), "*An assessment of the use of sediment traps for estimating upper ocean particle fluxes*". Journal of Marine Research, 65, 345-416, 2007.
- Chartrand, K., Rasheed, M., and Unsworth R (2008). *Long term seagrass monitoring in Port Curtis and Rodds Bay, Gladstone – November 2008*.
- Currie, D. R., Small, K. J. (2005) "*Macrobenthic community responses to long-term environmental change in an east Australian sub-tropical estuary*" Estuarine, Coastal and Shelf Science 63: 315-331
- Danaher KF, Rasheed MA & Thomas R (2005) *The intertidal wetlands of Port Curtis*. Information Series QI05031. Department of Primary Industries and Fisheries, Queensland, 55 pp.
- Doorn-Groen, SM & Foster, TM (2007). *Environmental Monitoring and Management of Reclamation Works Close to Sensitive Habitats*. Paper presented at the XVIII World Dredging Congress, Orlando, USA.
- Duarte C.M. (1991) *Seagrass depth limits*. Aquatic Botany 40: 363-377.
- Environmental Protection Agency (EPA) (2006) Queensland Water Quality Guidelines
- Environmental Protection Agency (EPA) (2004) *Approval of a Dredge Management Plan*, Coastal Development Guideline.
- Environmental Protection Authority (EPA) (2001). *Best Practice Environmental Management: Guidelines for Dredging*, Victoria, Australia.
- Erftemeijer P.L.A. and Lewis R.R.R (2006) *Environmental impacts of dredging on seagrasses: A review*. Marine Pollution Bulletin 52: 1553–1572
- Hargrave, B. T. and Burns, N. M. (1979), "*Assessment of sediment trap collection efficiency*". Limnol. Oceanographer, 24(6), 1979, 1124-1136
- Hopley, D., Van Woesik, R., Hoyal, D. C., Rasmussen, C. E., and Steven, A. D. (1990), *Sedimentation resulting from Road Development, Cape Tribulation Area*. Sir George Fisher Centre for Tropical Marine Studies, James Cook University of North Queensland.
- McKinnon SJ, Lupton CJ & Long PE (1995) *A fisheries resource assessment of the Calliope River system in Central Queensland 1994*. Information Series QI95001. Department of Primary Industries, Brisbane, 153 pp.
- Murdoch, A. and MacKnight S. D. (Eds), (1994) "*Handbook of techniques for aquatic sediment sampling*", Second ed. CRC Press Inc, Boca Raton, Florida, USA.
- National Assessment Guidelines for Dredging (NAGD) (2009) Commonwealth of Australia Canberra
- Postorok. R. A. and G. R Bilyard. (1985). *Effects of sewage pollution on coral reef communities*. Mar. Ecol. Prog. Ser. 21: 175. - 189.
- Preen AR Thesis, James Cook University.

7 References

Preen AR Thesis, James Cook University.

Shepherd S.A., McComb A.J., Bulthuis D.A., Neverauskas V.P., Steffensen D.A. and West R. (1989) Decline of seagrasses. In: Larkum A.W.D., McComb A.J. and Shepherd S.A. Eds. *Biology of seagrasses*. Elsevier, Amsterdam, pp. 346-388.

Rasheed, M.A., Thomas, R., Roelofs, A.J. Neil, K.M. and Kerville, S.P. (2003) Port Curtis and Rodds Bay seagrass and benthic macro-invertebrate community baseline survey, November/December 2002. DPI Information Series QI03058 (DPI, Cairns), 47 pp.

Rasheed, M.A., McKenna, S.A., Taylor, H.A. and Sankey, T.L. (2008). Long term seagrass monitoring in Port Curtis and Rodds Bay, Gladstone – October 2007. DPI&F Publication PR07- 3271 (DPI&F, Cairns), 32 pp.

Van Woosik, R. (1994) Natural disturbances to coral communities. *Journal of Coastal Research* 7, 551-558.

VCA 1997, Corio Bay Channel Improvement Program Baseline Monitoring of Turbidity, Final report, Report #J5044/R1700, Lawson and Treloar, Melbourne.

Westphalen, G., Collings, G., Wear, R., Fernandes, M., Bryars, S., Chesire, A., (2004). A review of seagrass loss on the Adelaide metropolitan coastline. Adelaide Coastal Waters Study, technical report No. 2, August 2004.

White, J, (1990), "The use of sediment traps in high-energy environments", *Marine Geophysical Researches*, 12: 145-152, 1990 (1992). Interactions between dugongs and seagrasses in a subtropical environment. PhD

Limitations

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 15 July 2009.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between 5 October 2009 and the 26 October 2009 is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Appendix A Plume Dispersion Modelling and Data Review

Plume Dispersion Modelling and Data Review Port Curtis GLNG Supplementary EIS

R.B17608.002.02.Plume_sims.doc
November 2009



Plume Dispersion Modelling and Data Review Port Curtis GLNG Supplementary EIS

Prepared For: URS

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

Offices

*Brisbane
Denver
Mackay
Melbourne
Newcastle
Perth
Sydney
Vancouver*

DOCUMENT CONTROL SHEET

BMT WBM Pty Ltd BMT WBM Pty Ltd Level 11, 490 Upper Edward Street Brisbane 4000 Queensland Australia PO Box 203 Spring Hill 4004 Tel: +61 7 3831 6744 Fax: + 61 7 3832 3627 ABN 54 010 830 421 www.wbmpl.com.au	<table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 35%;">Document :</td> <td>R.B17608.002.02.Plume_sims.doc</td> </tr> <tr> <td>Project Manager :</td> <td>Tony McAlister</td> </tr> </table> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 35%;">Client :</td> <td>URS</td> </tr> <tr> <td>Client Contact:</td> <td>Julian Long</td> </tr> <tr> <td>Client Reference</td> <td></td> </tr> </table>	Document :	R.B17608.002.02.Plume_sims.doc	Project Manager :	Tony McAlister	Client :	URS	Client Contact:	Julian Long	Client Reference	
Document :	R.B17608.002.02.Plume_sims.doc										
Project Manager :	Tony McAlister										
Client :	URS										
Client Contact:	Julian Long										
Client Reference											

Title :	Plume Dispersion Modelling in Port Curtis: GLNG Supplementary EIS
Author :	Tony McAlister, Paul Guard
Synopsis :	Hydrodynamic modelling of TSS levels in Port Curtis under a particular dredging scenario, modelling of impacts associated with pipeline laying activities and modelling of a combined treated wastewater and brine outfall. Review of baseline turbidity and TSS data.

REVISION/CHECKING HISTORY

REVISION NUMBER	DATE OF ISSUE	CHECKED BY		ISSUED BY	
0	20 th October 2009	ABM		PG	
1	29 th October 2009	ABM		PG	
2	13 th November 2009	ABM		PG	

DISTRIBUTION

DESTINATION	REVISION			
	0	1	2	3
Santos/URS	PDF	PDF	PDF	
BMT WBM File	PDF	PDF	PDF	
BMT WBM Library	PDF	PDF	PDF	

CONTENTS

Contents	i
List of Figures	ii
List of Tables	iv
1 INTRODUCTION	1-1
1.1 Scope	1-1
1.2 Brief Project Description	1-1
1.3 Model Description	1-1
2 DREDGE PLUME DISPERSION	2-1
2.1 General Considerations	2-1
2.1.1 Bed Sediment Characteristics	2-2
2.1.2 Suspended Sediment Characteristics	2-3
2.2 Methodology	2-5
2.2.1 Dredging Scenarios	2-5
2.2.2 Pipeline Construction Impacts	2-5
2.2.3 Plume Source Loadings	2-5
2.2.4 Dispersion Parameters	2-7
2.2.5 Particle Size/Settling Velocity Parameters	2-9
2.3 Potential Dredge Plume Impacts	2-10
2.4 Discussion of Potential Impacts	2-13
2.4.1 Scenario 1 – CSD with 50mg/L decant discharge	2-13
2.4.2 Scenario 2 – Pipeline laying – western side of channel	2-15
2.4.3 Scenario 3 – Pipeline laying – eastern side of channel	2-15
3 OUTFALL MODELLING	3-1
3.1 Preamble/Background	3-1
3.1.1 Near Field Assessments	3-1
3.1.2 Far Field Assessments	3-5
3.1.2.1 Scenario 1: Wastewater Discharge	3-5
3.1.2.2 Scenario 2: Combined Wastewater and Brine Discharge	3-5

4	BASELINE TURBIDITY AND TSS DATA REVIEW	4-1
4.1	Introduction	4-1
4.1.1	Scope	4-1
4.1.2	Data Sources	4-1
4.1.3	Water Quality Guidelines	4-1
4.1.4	Seagrass and Coral Tolerances	4-2
4.2	Total Suspended Solids, Turbidity and Sedimentation in Eastern Port Curtis	4-3
4.2.1	Turbidity and TSS	4-3
4.2.1.1	DEH/DNR (1999)	4-3
4.2.1.2	EPA Water Quality Monitoring (2002-2008)	4-3
4.2.1.3	National Land and Water Resources audit (1998 and 2001)	4-4
4.2.1.4	Australian Ports environmental data and risk analysis literature review (1998)	4-4
4.2.1.5	Port Curtis Integrated Monitoring Program (2005-2007)	4-6
4.2.1.6	BMT WBM turbidity logger data (2009)	4-8
4.2.1.7	BMT WBM baseline data collection (2008)	4-10
4.2.1.8	WBM Port Curtis water quality monitoring program (2001)	4-19
4.2.1.9	WBM marine water quality review (1999)	4-22
4.2.2	Sediment Deposition	4-24
4.2.3	Remote Sensing	4-26
4.2.3.1	CRC Port Curtis remote sensing task (2005)	4-26
4.2.3.2	BMT ARGOS 1km resolution mean TSM spatial maps (2008)	4-26
4.2.3.3	MODIS 250m resolution spatial maps (2009)	4-29
4.3	Summary of Baseline Turbidity and TSS Levels in Eastern Port Curtis	4-32
5	REFERENCES	5-1
	APPENDIX A: PLUME TSS CONCENTRATION TIME SERIES	A-1
	APPENDIX B: PLUME DEPOSITION TIME SERIES	B-1

LIST OF FIGURES

Figure 1-1	Study site location	1-2
Figure 2-1	Turbidity time series collected by BMT WBM	2-2
Figure 2-2	Turbidity–TSS Relationships from Both Natural and Dredge Plume Sampling	2-4

Figure 2-3	Sediment Plume Source Locations	2-8
Figure 2-4	Sediment settling velocity calibration comparison	2-10
Figure 2-5	Simulation period water levels – Auckland Point	2-11
Figure 2-6	Simulation period wind speed and direction	2-11
Figure 2-7	URS Sensitive Receptor Sites in Port Curtis	2-12
Figure 2-8	Scenario 1: CSD with 50mg/L decant - maximum plume TSS concentration	2-15
Figure 2-9	Scenario 1: CSD with 50mg/L decant - TSS concentration exceeded 10% of the time	2-16
Figure 2-10	Scenario 1: CSD with 50mg/L decant - Plume snapshot at 01:00 on 18/02/2009	2-16
Figure 2-11	Scenario 1: CSD with 50mg/L decant - Plume snapshot at 09:00 on 26/02/2009	2-17
Figure 2-12	Scenario 2: Pipeline laying - western side - maximum plume TSS concentration	2-17
Figure 2-13	Scenario 2: Pipeline laying - western side - TSS concentration exceeded 10% of the time	2-18
Figure 2-14	Scenario 3: Pipeline laying - eastern side - maximum plume TSS concentration	2-18
Figure 2-15	Scenario 3: Pipeline laying - eastern side - TSS concentration exceeded 10% of the time	2-19
Figure 2-16	Scenario 1: CSD with 50mg/L decant - average plume deposition rate	2-19
Figure 2-17	Scenario 2: Pipeline laying - western side - average plume deposition rate	2-20
Figure 2-18	Scenario 3: Pipeline laying - eastern side - average plume deposition rate	2-20
Figure 3-1	Near Field Dilution With Distance Down Current From Outfall – Outfall Scenario 1	3-3
Figure 3-2	Near Field Dilution With Height Above Outfall – Outfall Scenario 1	3-3
Figure 3-3	Near Field Dilution With Distance Down Current From Outfall – Outfall Scenario 2	3-4
Figure 3-4	Near Field Dilution With Depth Below Outfall – Outfall Scenario 2	3-4
Figure 3-5	Wastewater discharge - maximum plume concentration	3-5
Figure 3-6	Brine discharge - maximum above-background salinity	3-6
Figure 3-7	Brine discharge - above-background salinity exceeded 10% of the time	3-6
Figure 4-1	DEH/DNR water quality monitoring sites, Calliope River (DEH/DNR, 1999)	4-3
Figure 4-2	EPA water quality monitoring sites on the Calliope River	4-5
Figure 4-3	2005 PCIMP monitoring sites (Anderson et al., 2006)	4-6
Figure 4-4	2006 and 2007 PCIMP monitoring sites (Anderson et al., 2007)	4-7
Figure 4-5	Location of turbidity loggers	4-8
Figure 4-6	Turbidity measurements 7/8/09- 2/9/09	4-9
Figure 4-7	YSI cast locations- Campaign 1	4-11
Figure 4-8	YSI cast locations- Campaign 2	4-12

Figure 4-9	YSI cast times- Campaign 1	4-13
Figure 4-10	YSI cast times- Campaign 2	4-13
Figure 4-11	Northern sites turbidity- Campaign 1	4-14
Figure 4-12	Mid sites turbidity- Campaign 1	4-14
Figure 4-13	Southern sites turbidity- Campaign 1	4-15
Figure 4-14	YSI turbidity profiles at a single location during the onset of a flood tide- Campaign 1	4-16
Figure 4-15	Interface of Calliope River turbid freshwater outflow during campaign 1	4-16
Figure 4-16	YSI turbidity profiles - Campaign 2 High Water	4-17
Figure 4-17	YSI turbidity profiles - Campaign 2 Low Water	4-17
Figure 4-18	Turbidity timeseries at southern S4 site- campaign 2	4-18
Figure 4-19	WBM water quality monitoring sites (WBM, 2001)	4-20
Figure 4-20	Box and whisker plot for turbidity (1998-2000) (BMT WBM, 2001)	4-21
Figure 4-21	Previous water quality sampling locations (WBM, 1999)	4-23
Figure 4-22	URS sediment trap sites	4-24
Figure 4-23	Port Curtis sample sites (Dekker and Phinn, 2005)	4-26

LIST OF TABLES

Table 2-1	Particle Size Distribution (PSD) of Materials to be Dredged (%)	2-2
Table 2-2	Particle Size Characteristics of Both Natural and Dredge Plume Suspended Sediments	2-4
Table 2-3	In-situ sediment and long-term plume suspended sediment composition	2-6
Table 2-4	Plume loading assumptions	2-7
Table 2-5	Plume model sediment fractions and settling parameters	2-10
Table 2-6	Regional Summary of Plume Concentration Exceedance for Scenario 1	2-15
Table 3-1	Expected WWTP Effluent Quality	3-1
Table 3-2	Near Field Modelling - Interrogated Velocity Data	3-2
Table 4-1	Queensland Water Quality Guidelines for enclosed coastal and estuarine waters	4-1
Table 4-2	Duration of time that seagrass species can survive in light intensities below their minimum light requirements (Source: Erfemeijer and Lewis 2006)	4-2
Table 4-3	Critical thresholds of seagrasses for sedimentation (Source: Erfemeijer and Lewis 2006)	4-2
Table 4-4	Suspended sediment and settlement rate limits for corals (Source: Hopley et al., 1991)	4-2
Table 4-5	Physicochemical monitoring results (DEH/DNR, 1999)	4-3
Table 4-6	EPA turbidity results for the Calliope River	4-4

Table 4-7	Median turbidity values (NLWRA, 1998 & 2001)	4-4
Table 4-8	Gladstone Port Authority turbidity logger results	4-4
Table 4-9	Mean turbidity levels recorded by PCIMP in 2005 (Anderson et al., 2006)	4-6
Table 4-10	Mean 2006 and 2007 PCIMP turbidity levels (Anderson et al., 2007)	4-8
Table 4-11	TSS grab sample results	4-19
Table 4-12	Mean, standard deviation and range of turbidity and TSS (1998- 2000) (BMT WBM, 2001)	4-21
Table 4-13	Range of turbidity and suspended solids data compiled from previous reports (WBM, 1999)	4-24
Table 4-14	Sedimentation rate results from URS sediment traps (URS, 2009)	4-25
Table 4-15	TSM concentrations for Port Curtis sites sampled in January and June 2002 (Dekker and Phinn, 2005)	4-26
Table 4-16	Summary of turbidity, TSS and sedimentation data in Eastern Port Curtis	4-32

1 INTRODUCTION

1.1 Scope

This report presents the results of modelling carried out by BMT WBM to assist and support URS in regard to the supplementary EIS for the Santos Liquefied Natural Gas (LNG) facility at Port Curtis. A review of baseline turbidity and TSS data is also included.

The scope includes modelling of TSS levels in Port Curtis for a particular dredging scenario, modelling of impacts associated with pipeline laying activities and modelling of treated wastewater and brine outfalls. The data review includes all available field collected and remotely sensed turbidity and TSS data for the eastern side of Port Curtis.

The dredge plume modelling methodology used in this study is based on the methodology developed for the Gladstone Western Basin EIS.

1.2 Brief Project Description

Santos Ltd. proposes to develop an LNG export facility in Gladstone in Central Queensland Australia, on the eastern side of Port Curtis. Figure 1-1 shows the location of the study site.

1.3 Model Description

The hydrodynamic modelling presented in this report was undertaken using the software package TUFLOW-FV. The TUFLOW-FV numerical scheme solves the conservative integral form of the Nonlinear Shallow Water Equations (NLSWE) (i.e. assuming that pressure varies hydrostatically with depth), including viscous flux terms and source terms for Coriolis force, bottom-friction and various surface and volume stresses. The scheme is also capable of simulating the advection and dispersion of multiple scalar constituents within the model domain.

Details of the modelling software, establishment, calibration and validation are provided in a separate report (BMT WBM, 2009).



Title:
Study Site Location

Figure:
1-1

Rev:
A

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



0 10 20km
Approx. Scale



Filepath : I:\B16752_I_BRH_GLNG\DRG\WQU_030_080317_Locality.wor

2 DREDGE PLUME DISPERSION

2.1 General Considerations

The Port Curtis Project Area seabed and intertidal areas are made up of mixed sediments comprising varying proportions of gravels, sands and fine silt/clay materials. These materials can become re-suspended by tidal currents and the action of locally-generated wind-waves on shallow areas. Continuous measurements of turbidity variations over periods in excess of a fortnight indicate that the spring-neap tidal cycle is a dominant signal in the suspended sediment timeseries as seen in Figure 2-1 for data collected by BMT WBM adjacent to Fisherman's Landing in August/September 2008. Any direct correlation between wave height and suspended sediment levels are much less clearly discerned from the available measurements, which indicates that tidal currents are the dominant natural re-suspension mechanism within the Port Curtis Project Area.

Dredging works cause additional re-suspension of bed material and the generation of plumes of suspended sediment through a number of potential sources/mechanisms. The nature and extent of these plume sources will be dependent on the characteristics of the sediment as well as the type and operational characteristics of the dredging operations such as:

- Dredge head re-suspension during dredging – Cutter Suction Dredge (CSD);
- Decant pond discharge – from dredge material placement area.

The “dredge plume” is defined as the quantity of Total Suspended Solids (TSS) which is in the water column due to dredging, and is above the natural background levels for that location and time. The increased turbidity associated with the dredge plume and the additional sediment deposition associated with settling of the dredge plume material are two of the primary sources of potential environmental impacts caused by dredging activities.

Prediction of dredge plume impacts involves a number of components, namely:

- Source strength definition, i.e. mass load and characteristics of sediment entrained by the dredging activities;
- Prediction of plume advection/dispersion;
- Prediction of plume settling.

The first of these is the most variable, and depends heavily on the type of dredging activities (e.g. type and size of dredge) as well as the material being excavated. As such, this component of the dredge plume impact assessment is also the most subject to variation. The prediction of plume advection/dispersion has been undertaken in the current study using the calibrated and validated TUFLOW-FV model of Port Curtis. The rate and cumulative extent of plume settling has been predicted within the TUFLOW-FV cohesive sediment module, using best-estimates of the plume suspended-sediment size and settling characteristics.

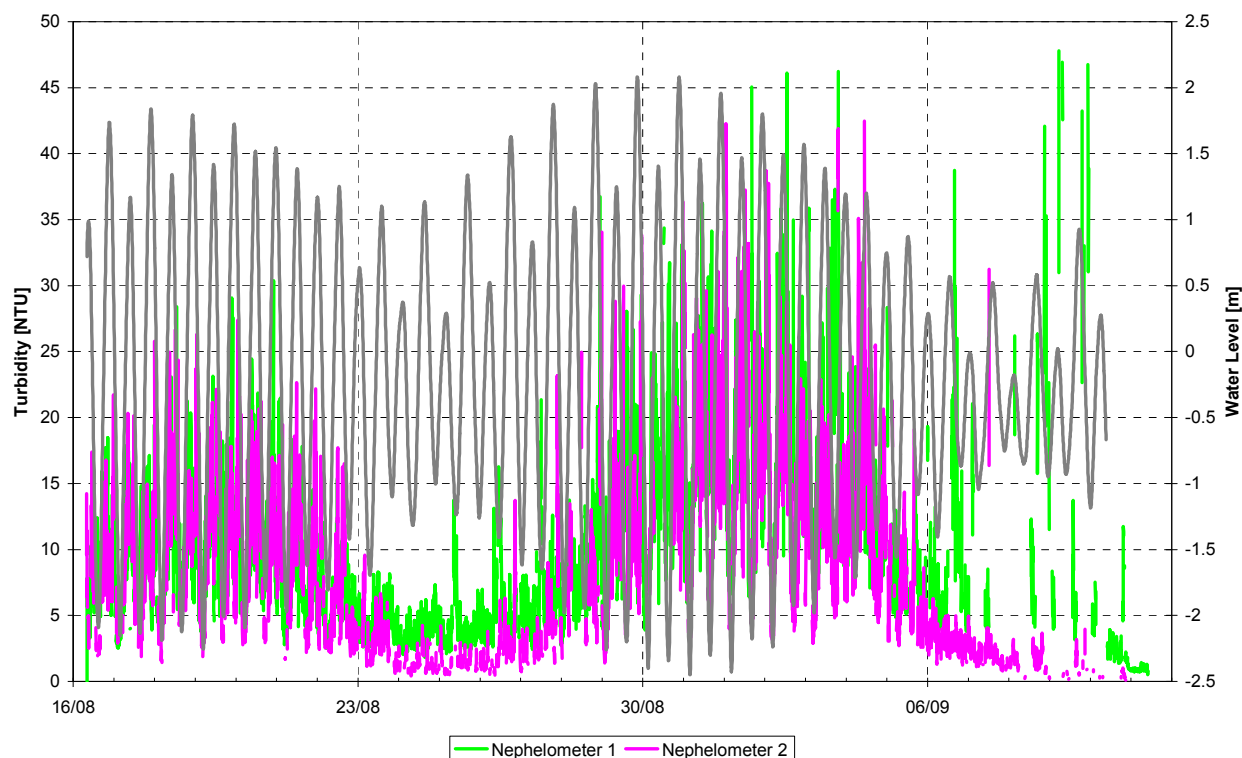


Figure 2-1 Turbidity time series collected by BMT WBM

2.1.1 Bed Sediment Characteristics

Table 2-1 provides an overview of the different substrate sediment compositions (expressed as percentage composition) at the Santos LNG dredge basin site based on information provided by URS (HR Wallingford, 2009).

Table 2-1 Particle Size Distribution (PSD) of Materials to be Dredged (%)

Particle Size (μm)	PSD 1 (loose material)	PSD 2 (cut rock)
< 20	27	20
20 - 60	18	16
60 - 80	7	12
80 - 100	4	8
100 - 150	7	14
150 - 200	9	12
200 - 300	9	8
300 - 400	5	4
400 - 600	5	2
600 - 1000	4	2
1000 - 2000	2	1
2000 - 4000	2	1
> 4000	1	0
Total	100	100

2.1.2 Suspended Sediment Characteristics

A number of different sources of field measurements have been compiled in order to characterise the levels and composition of naturally re-suspended solids, as well as the likely characteristics of dredge plumes.

BMT WBM undertook water quality profiling and sampling in conjunction with ADCP measurements of currents and acoustic backscatter for both neap tide conditions (April 2009) and spring tide conditions (June 2009). Over the two sampling periods, more than 100 concurrent measurements of turbidity (NTU) and TSS (mg/L) were collected in order to characterise the naturally re-suspended material within the Port Curtis Project Area. These data and a fitted relationship are shown in Figure 2-2. Particle size analysis was performed on 10 of these natural TSS samples and the results are summarised in Table 2-2. The average particle size composition of naturally re-suspended material was 3% sand ($d > 159\mu\text{m}$), 68% silt ($5\mu\text{m} < d < 159\mu\text{m}$) and 29% clay ($d < 5\mu\text{m}$).

Sampling of turbidity and TSS within dredge plumes was also undertaken on two occasions; firstly during RG Tanna Berth Pocket maintenance dredging performed by the TSHD "Brisbane", and secondly during capital dredging of the Fisherman's Landing Berth 1/Swing Basin by the CSD "Wombat". The concurrent turbidity/TSS measurements for the two dredge plume sampling exercises are also plotted in Figure 2-2 and can be seen to systematically sit above the turbidity/TSS line fitted to the natural samples. Particle size analysis was performed on 12 of the "Wombat" dredge plume samples (3 of these samples were identified to have been obtained outside the plume). The results of the particle size analysis indicate that the average particle size composition of the dredge plume samples was 7% sand, 68% silt and 25% clay.

Two samples were obtained from the Fisherman's Landing reclamation pond decant discharge. These samples had no sand content and a higher clay proportion than other samples. The average particle size composition of these two samples was 0% sand, 46% silt and 54% clay.

Table 2-2 Particle Size Characteristics of Both Natural and Dredge Plume Suspended Sediments

Description	Depth (m)	TSS (mg/L)	Turbidity (NTU)	d10 μm	d50 μm	d90 μm	% Med Sand >159 μm	% Fine Sand <159 μm >71 μm	% Silt <71 μm >5 μm	% Clay <5 μm
U/S of dredger	5	8	6.2	2.5	7.6	25	0.03	1.65	71.7	26.6
Dredge plume close to dredge head	6	8	6	2.8	8.6	32	0.00	1.55	75.9	22.6
25-30m D/S dredge head	10	67	17	2.4	12.0	60	0.35	8.67	68.2	22.8
Dredge plume	7	11	7	2.3	7.0	25	0.01	2.79	67.4	29.8
Dredge plume	10	70	19.9	2.4	10.0	60	1.04	7.97	66.0	25.0
Dredge plume	10	21	10.5	2.5	8.9	40	0.06	4.19	70.8	25.0
D/S of dredger	10	67	19.5	2.4	12.7	58	0.03	8.20	68.7	23.1
D/S of dredger	5	20	6.6	2.3	10.3	77	1.45	12.52	59.9	26.1
D/S of dredger (outside of plume)	10	5	4.8	2.2	8.1	24	0.00	0.35	71.2	28.5
U/S of dredger	3	8	5.9	2.1	6.1	16.2	0.00	0.00	64.7	35.3
D/S of dredger	10	15	6.8	2.8	10.0	49	0.00	5.72	72.6	21.7
Dredge plume	12.5	37	10.6	2.3	11.0	62	0.49	9.19	65.2	25.1
Pond outlet	-	9	-	1.6	3.5	7.5	0.00	0.00	34.7	65.3
Pond outlet	-	10	-	2.8	8.6	32	0.00	0.00	57.9	42.1
Passage Transect - West	5	53	18.8	2.5	8.5	40	0.78	4.62	69.5	25.1
Passage Transect - East	5	53	20.5	2.4	9.1	53	3.37	5.09	66.7	24.8
Targinnie Transect - Centre. 10 m deep.	5	12	7.5	2.1	6.3	16.4	0.00	0.00	66.0	34.0
Targinnie Transect - Centre. 15 m deep.	10	29	12.3	2.6	8.2	19.7	0.97	4.35	69.6	25.0
Targinnie Transect - East. 6.8 m deep.	5	20	10	2.0	6.6	22	0.00	0.21	67.1	32.7
Targinnie Transect - Centre. 14 m deep.	5	36	14.4	2.2	8.6	38.9	0.48	4.25	68.8	26.5
Targinnie Transect - Centre. 14 m deep.	10	43	15.5	2.5	9.3	60	1.89	6.89	67.0	24.2
Targinnie Transect - Centre.	10	6	6.1	2.1	5.9	14.2	0.00	0.00	64.3	35.7
Laird Transect - East. 6.8 m deep.	3	22	11.6	2.6	8.3	39	0.65	4.23	70.2	25.0
Laird Transect - Centre. 13 m deep.	10	9	6.8	2.2	6.0	19	0.00	0.69	64.1	35.2
Dredge Plume - Mean		35.1	11.5	2.5	10.1	51.4	0.4	6.8	68.3	24.6
Dredge Plume - Stdev		26.0	5.7	0.2	1.8	16.5	0.5	3.5	4.6	2.5
Dredge Plume - Median		21.0	10.5	2.4	10.0	58.0	0.1	8.0	68.2	25.0
Decant - Mean		9.5	-	2.2	6.1	19.8	0.0	0.0	46.3	53.7
Decant - Stdev		9.5	-	2.2	6.1	19.8	0.0	0.0	46.3	53.7
Decant - Median		9.5	-	2.2	6.1	19.8	0.0	0.0	46.3	53.7
Natural - Mean		23.4	10.8	2.3	7.6	29.8	0.6	2.5	67.8	29.1
Natural - Stdev		17.8	5.2	0.2	1.2	14.9	1.0	2.5	2.6	4.7
Natural - Median		20.0	10.0	2.2	8.1	24.0	0.0	1.7	67.1	26.6

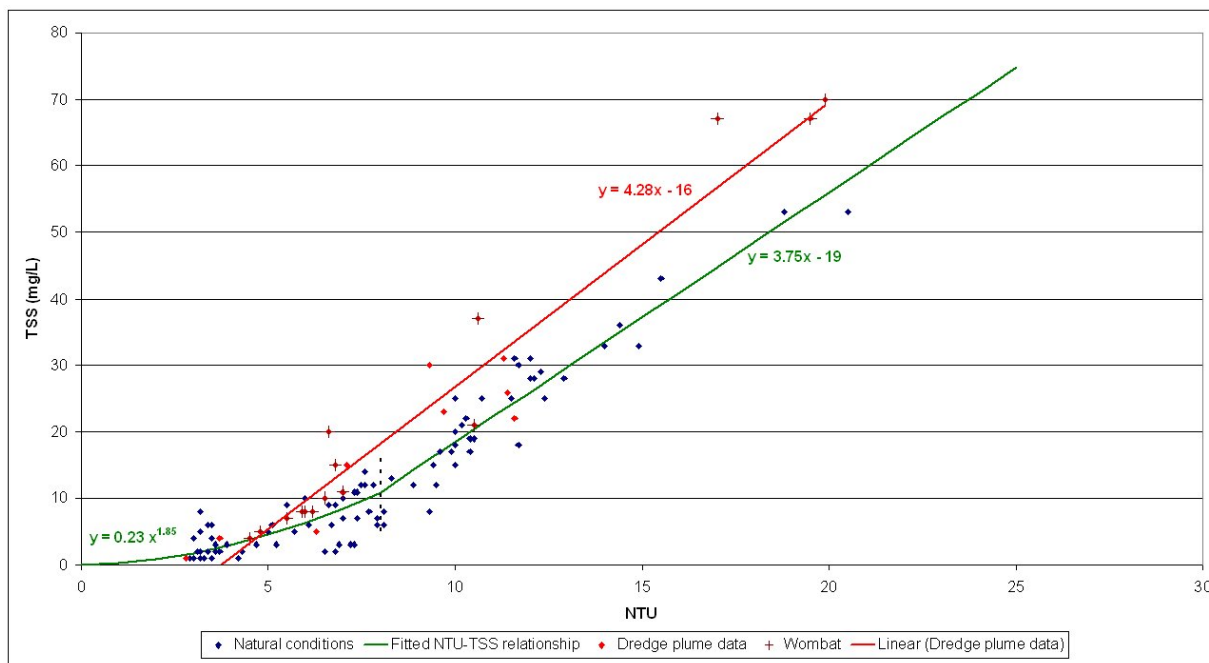


Figure 2-2 Turbidity–TSS Relationships from Both Natural and Dredge Plume Sampling

2.2 Methodology

2.2.1 Dredging Scenario

A single dredging scenario were assessed for this study.

- Cutter Suction Dredge (CSD) operating 20 hours in each 24 hour period

Under this dredging scenario, it is proposed to pipe the slurry from the operating dredge directly to a placement facility near Laird Point. The discharge of decant from the placement facility would be at $2.8\text{m}^3/\text{s}$ at an assumed TSS concentration of $50\text{mg}/\text{L}$.

The model used the existing Port Curtis bathymetry with the approved Wiggins Island Coal Terminal (WICT) dredging and Fisherman's Landing Berth 1 completed (as per the Base Case of the Western Basin EIS).

2.2.2 Pipeline Construction Impacts

The potential water quality impacts associated with pipeline laying across Port Curtis were also assessed. Based on an assumed productivity of $150\text{m}^3/\text{h}$ and a spillage rate of $10\text{kg}/\text{m}^3$, we have adopted an entrainment rate of $1500\text{kg}/\text{h}$ due to backhoe operation.

2.2.3 Plume Source Loadings

There is considerable uncertainty associated with the prediction of dredge plume source loadings. In the current assessment, the derivation of the source plume loadings has been undertaken using a systematic approach using available estimates of source plume loadings in a realistic but conservative manner consistent with the approach taken in the Gladstone Western Basin EIS.

Some terminology used in expressing the key assumptions made in deriving the plume loadings used in the assessment are defined as follows:

- **In-situ production rate** – volumetric rate of in-situ material excavation;
- **Turbidity generating units** – dry sediment mass rate per unit volume of in-situ material that is entrained during dredge operations. This includes a combination of sands, silts and clay materials. A proportion of this material, in particular the coarser sands and a proportion of the clay fraction as “clumps”, settles immediately to the bed;
- **Long term plume fraction** – dry mass percentage of the turbidity generating units/bulk overflow rate which has a sufficiently low settling velocity to remain in suspension as the “long term plume”.

Information on the composition of the substrate material to be dredged (Table 2-1) along with information on the suspended sediment characteristics of the “Wombat” plume (Table 2-2) have been used to derive the long term plume fraction and composition of the source long-term plume suspended sediment fractions. It has been assumed that 100% of the entrained fine sand and silt remain suspended in the long term plume while 0% of the gravels and coarse sand fractions remain in suspension. The relative proportion of the clay component is reduced due to the rapid settling of clay clumps that are not broken up during the dredging process. In Table 2-2, the clay-sized fraction

typically accounts for about 25% of the suspended sediment plume; accordingly the relative proportion of clay in the long-term plume composition has been reduced relative to the in-situ sediment composition such that it comprises 28% of the long term plume total. Based on these assumptions, the long term plume fraction is 30% of the initially entrained bed sediments (excluding gravel). The relative fractions of both the in-situ sediment and the long-term plume source material are detailed in Table 2-3.

Table 2-3 In-situ sediment and long-term plume suspended sediment composition

	Gravel	Coarse Sand	Fine Sand	Silt	Clay	Total
In-situ sediment composition	18%	40%	4%	14%	24%	100%
Long-term plume composition	0%	0%	4% (16% of plume)	14% (56% of plume)	7% (28% of plume)	25% (30% of total minus gravel)

A composition of 35% silt and 65% clay in the decant discharge has been assumed based on the relevant particle size distributions in Table 2-2.

The key plume loading assumptions for each class of dredging operation were based on those adopted for the Western Basin EIS and are detailed below:

Large Cutter Suction Dredge – cutter-head source:

- In-situ production rate: 1000 m³/hour;
- Cutter-head Turbidity Generating Units: 48 kg/m³;
- Cutter-head Long term plume fraction: 30%;
- Plume Source Rate: 4 kg/s;
- Operating 20 hours in each 24 hour period;
- Source location E 316460, N 7368070 (MGA94 zone 56)

Decant discharge:

- Decant turbidity: 58 NTU;
- Decant TSS: 50 mg/L (source: URS/Santos);
- Decant discharge rate 2.8 m³/s (source: URS/Santos);
- Source location E 314509, N 7371297 (MGA94 zone 56)

Pipeline laying:

- Backhoe production rate of 150 m³/h, with 10kg/m³ spillage, giving a plume source rate of 1500kg/h (0.42kg/s)
- Plume composition as per CSD;
- Two representative operating locations, one on each side of the channel between Laird and Friend Points.

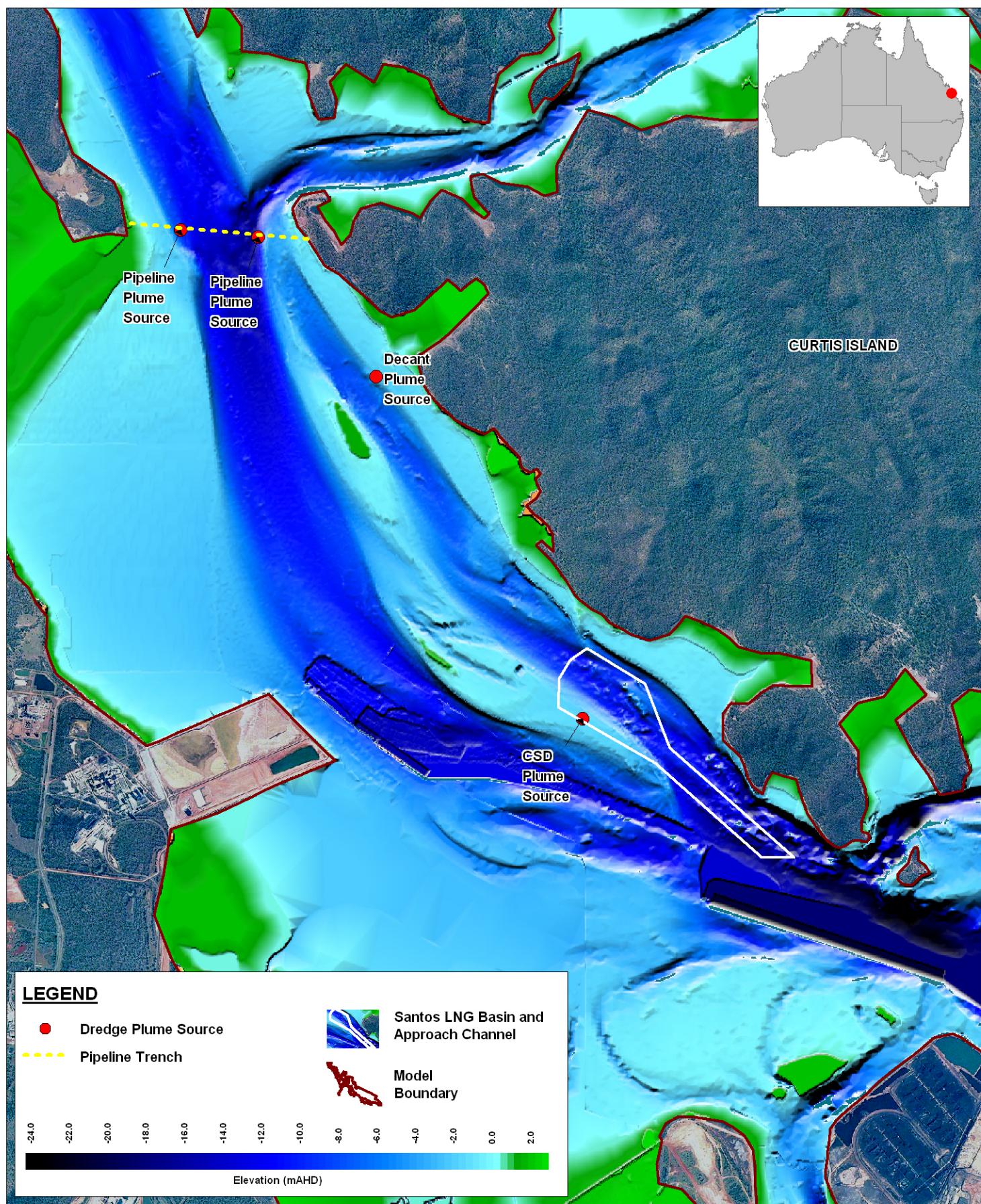
The plume source locations are shown in Figure 2-3. Based on these assumptions plume source loadings have been derived for each plume simulation and are summarised in Table 2-4.

Table 2-4 Plume loading assumptions

Simulation	Source - Location	Total Loading
1	Large CSD – Santos Basin Decant @ 50mg/l	4kg/s for 20 hours each 24 hour period 2.8m ³ /s continuous
2	Backhoe operating on western side of Laird Point – Friend Point channel	0.42kg/s continuous
3	Backhoe operating on eastern side of Laird Point – Friend Point channel	0.42kg/s continuous

2.2.4 Dispersion Parameters

The same dispersion parameters have been used in the dredge plume assessments as for the Gladstone Western Basin EIS. Please refer to the calibration and validation report (BMT WBM, 2009).



Title:
Sediment Plume Source Locations

Figure:
2-3

Rev:
A

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



0 2 4km
Approx. Scale



Filepath : I:\B17608.L\at_GladstoneSantos\DRG\COA_001_091020_Dredge_Plume_Cells.wor

2.2.5 Particle Size/Settling Velocity Parameters

In this assessment, dredge plumes have been modelled using 3 suspended sediment classes; fine sand, silt and clay. The relative composition of the dredge plume source loads in terms of these 3-fractions, the assumed still-water fall velocities and equivalent Stokes diameter are summarised in Table 2-5.

The modelled rate of sediment settling is a function of the depth-averaged sediment concentration, the still-water fall velocity (w_{s0}) and the bed shear stress (τ_b), according to the relationship:

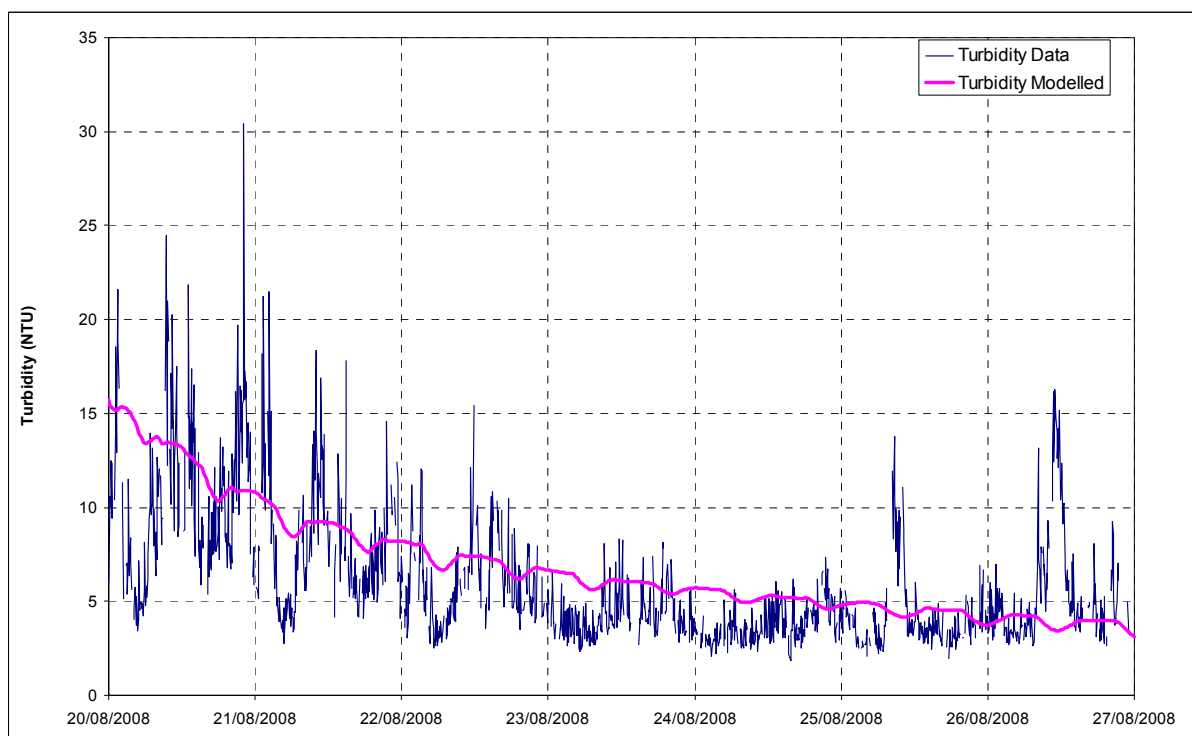
$$Q_{sd} = w_{s0} * \max(0, (1 - \tau_b / \tau_{cd}))$$

where τ_{cd} is a model parameter defining the critical shear stress for deposition. As such, sediment settling is reduced below its still water value by the action of bed shear stress and associated vertical mixing in the water column. A critical shear stress for deposition of 0.5 N/m^2 was adopted following calibration of the settling parameters to the measured reduction in turbidity during the transition from spring-tides to neap-tides, as shown in Figure 2-4. The calibration assessment was undertaken by dosing the model with an initial TSS concentration of 40 mg/L (approximately equivalent to 16 NTU using the relationship in Figure 2-2), comprising 3% fine-sand, 68% silt and 29% clay based on the natural suspended sediment measurements in Table 2-2. In Figure 2-4, it can be seen that the measured general trend in turbidity decay is reproduced in this assessment, however the strong semi-diurnal variations in turbidity during the spring tides at the beginning are not reproduced. These strong variations in the measurements may be due to a combination of spatial gradients which were advected past the turbidity sensor and/or active re-suspension/deposition over the timescale of a tidal cycle. The former process would not be accurately represented due to the artificial initial condition of this model calibration assessment while erosion processes were not included in the sediment plume assessments as discussed below.

There was no provision for re-suspension of already deposited plume material in the dredge plume assessments. While there is the potential for re-suspension of the fine suspended load which does settle out, it will generally become mixed with and hence indistinguishable from re-suspension of the natural bed material. Settling will occur when and in areas where currents and waves (and hence bed shear stresses) are lower. These are areas of naturally occurring fine bed sediments and the amount of re-suspension will be a function of the prevailing conditions and the nature of the material, rather than the origin of the material. Accordingly, the amount of re-suspension will be dominated by the natural bed material which will not be affected by the project. The sediment composition of the dredge plume suspended load is likely to be similar to the naturally suspended material, as evidenced by the comparative particle size distributions in Table 2-2.

Table 2-5 Plume model sediment fractions and settling parameters

Particle	Fine Sand	Silt	Clay
Still Water Fall Velocity, w_{s0} (m/s)	1.0E-02	2.0E-04	2.0E-05
Equivalent Stokes Diameter, d_{s0} (nm)	110	15	4.8
Critical Shear Stress Deposition, τ_{cd} (N/m ²)	0.5	0.5	0.5
Sediment particle density, ρ_s (kg/m ³)	2650	2650	2650
% Dredge Plume	16	56	28
% Dump Plume	16	56	28
% Decant Plume	0	35	65

**Figure 2-4 Sediment settling velocity calibration comparison**

2.3 Potential Dredge Plume Impacts

All dredge plume simulations were modelled for a 1 month period from the 4/2/2009 to the 4/3/2009 using measured tidal and wind boundary condition forcing. The tidal variation at Auckland Point during this period is shown in Figure 2-5 and wind speed and direction used for forcing the model is shown in Figure 2-6.

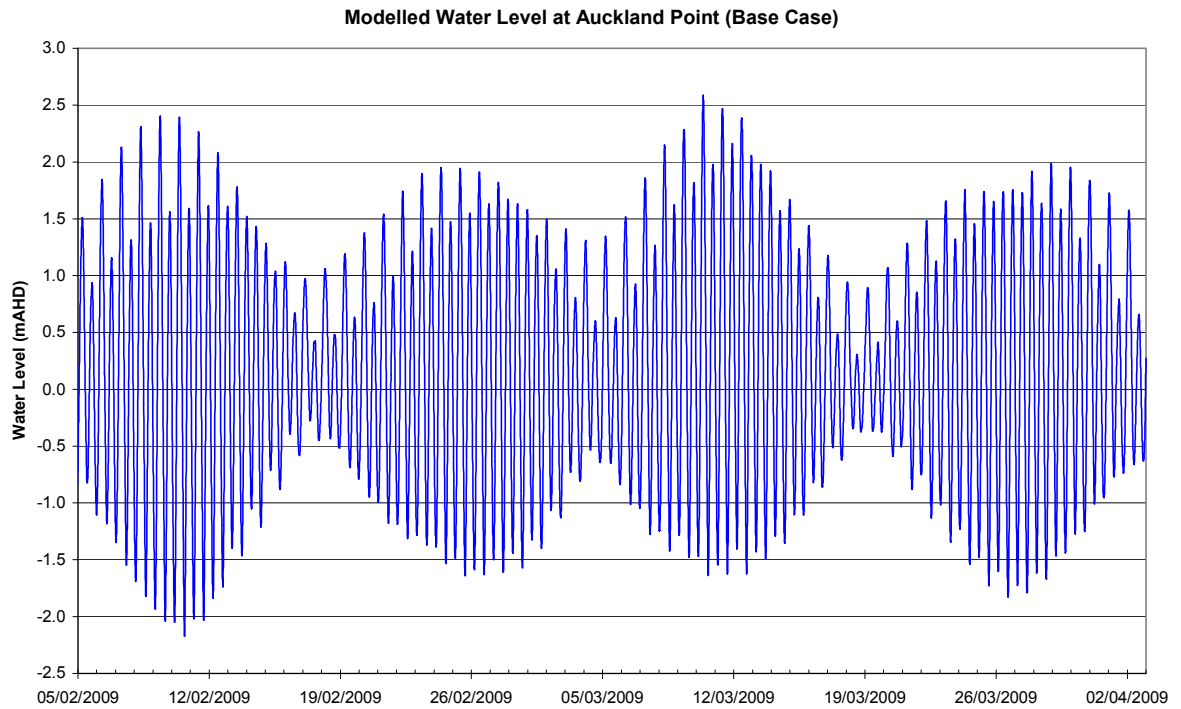


Figure 2-5 Simulation period water levels – Auckland Point

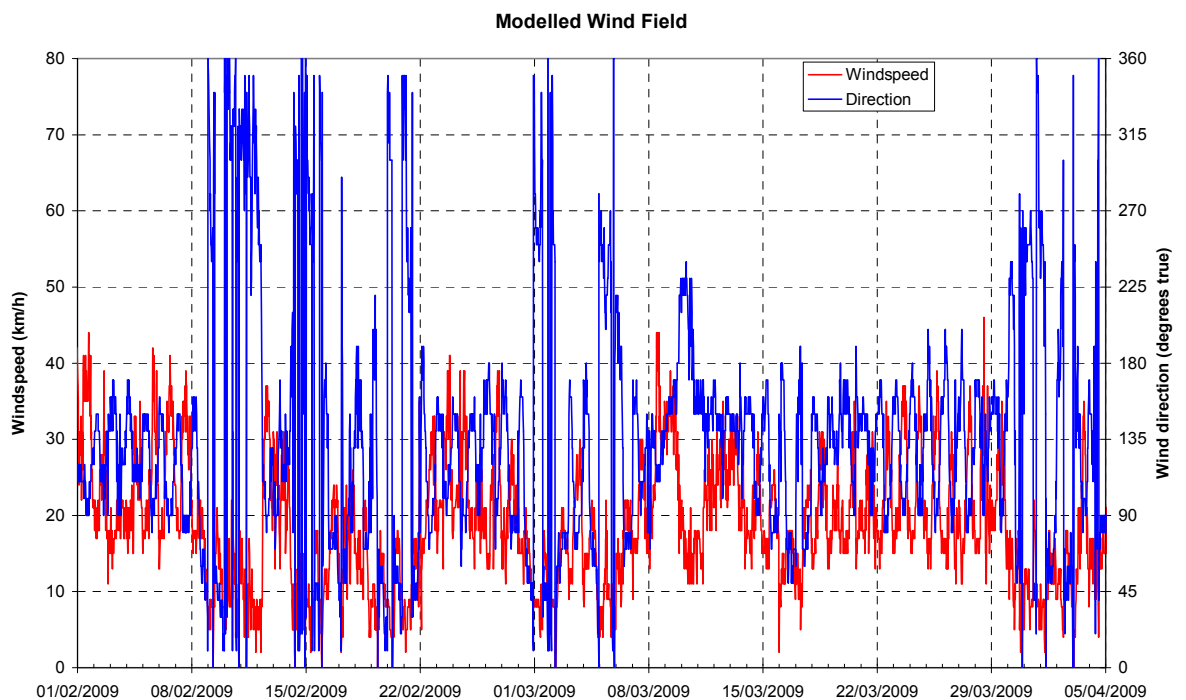


Figure 2-6 Simulation period wind speed and direction

TSS concentrations and plume sediment deposition rates were assessed at nine sensitive receptor sites provided by URS. These locations are shown in Figure 2-7.



Figure 2-7 URS Sensitive Receptor Sites in Port Curtis

Dredge plume impacts are presented for each scenario as:

- Timeseries of plume TSS concentration at each of the URS receptor sites in Appendix A.
- Spatial plots of maximum plume TSS concentration (Figure 2-8, Figure 2-12, Figure 2-14);
- Spatial plots of 10% exceedance plume TSS concentration (Figure 2-9, Figure 2-13, Figure 2-15);
- Timeseries of plume material deposition in Appendix B;
- Spatial plots of average plume material deposition rates (Figure 2-16, Figure 2-17, Figure 2-18).

The percentile measures of plume TSS concentration and average sediment deposition rates were derived from the final 2-weeks of the 1 month simulation, where suspended sediment mass levels were seen to have reached a dynamic saturation level.

All results presented below are for the plume TSS level above ambient conditions. A threshold plume TSS concentration of 5 mg/L has been adopted for illustration of the plume spatial extent. Such a level is comparable to natural water column TSS concentrations in the Project Area during neap tides and is a factor 4-10 less than typical natural water column TSS concentrations in the Project Area channels during spring tides (refer Figure 2-1 and Figure 2-2).

Despite simulating TSS concentrations in excess of 100 mg/L in proximity to the CSD source location/s, this value was adopted as the maximum TSS contour in the spatial plume extent figures in

order to retain adequate resolution of small/moderate impacts. Plume TSS concentrations in excess of 100mg/L would be approximately double the natural background TSS level during spring tide conditions and more than 10-times the natural background TSS during neap tide conditions.

The mesh cells that the plume was injected into have approximate side dimensions ranging between 30-110m in size, which will introduce some artificial dilution into the near-field predictions of plume concentration. The model results represent plume concentrations averaged over the extent of the entire element area, whereas in reality near its source the plume will not necessarily be uniformly mixed over an entire element. Therefore higher maximum concentrations than predicted by the model are likely to be intermittently experienced in the near-field vicinity of the source for the prescribed plume loading. In the medium to far-field, the model inaccuracies due to this initial dilution will become small due to the natural flow dispersion and turbulent diffusion processes that result in horizontal mixing of the plume.

2.4 Discussion of Potential Impacts

In general, the time series plots included in Appendix A illustrate that suspended sediment concentrations build up over about the first two weeks of the simulation and then reach a dynamic equilibrium varying on a semi-diurnal time-scale and with the magnitude of the tidal range through the spring – neap cycles. In areas close to the sediment sources, concentrations are highest during neap tides when velocities and dispersion rates are lowest. In far field areas, concentrations are typically highest during spring tides when the tidal excursion is great enough to advect the suspended sediment to those locations.

Maximum and 10% exceedance TSS concentrations are generally high (> 100mg/L above background) at the plume source/s and decrease with distance from these locations. In general, the highest plume concentrations tend to be confined to the main flow channels.

Deposition of plume material continues gradually, with varying rates again dependent on location and tidal state. These have been converted into an average long term deposition rate for ease of comparison and shown in Figures 2-16 to 2-19. The potential areal extent of the sediment deposition from the dredging operations can be estimated from these plots. The relatively high deposition rates in close proximity to the dredging sources are predominantly due to the fine sand component of the plume material settling out quickly. Much of this will be picked up by the ongoing dredging works in those areas, and hence is not of concern.

2.4.1 Scenario 1 – CSD with 50mg /L decant discharge

- The plume impact footprint shown in Figure 2-8 and Figure 2-9 is relatively compact and is confined to the Santos swing basin itself and the adjacent channel.
- Maximum and 10% exceedance plume concentrations above background TSS levels are shown in Figure 2-8 and Figure 2-9 and summarised for receptor locations in

Table 2-6;

- Snapshots of the plume are shown in Figure 2-10 (neap tide low water condition) and Figure 2-11 (spring tide flood condition) as examples of instantaneous areal extent
- Average plume TSS deposition rates are shown in Figure 2-16 and are less than 1mm per day outside the immediate vicinity of the dredge.

Table 2-6 Regional Summary of Plume Concentration Exceedance for Scenario 1

URS Receptor Site	Maximum plume TSS (mg/L)	10% exceedance plume TSS (mg/L)
PT 1	1	1
PT 2	5	3
PT 3	3	2
PT 4	3	2
PT 5	6	3
PT 6	34	9
PT 7	3	2
PT 8	2	1
PT 9	4	2

2.4.2 Scenario 2 – Pipeline laying – western side of channel

- Maximum and 10% exceedance plume concentrations above background TSS levels are shown in Figure 2-12 and Figure 2-13 and drop to less than 5mg/L away from the excavation site.
- The only one of the URS receptor sites to receive an impact of more than 1mg/L maximum above-background TSS was PT 1 (1.5mg/L)

2.4.3 Scenario 3 – Pipeline laying – eastern side of channel

- Maximum and 10% exceedance plume concentrations above background TSS levels are shown in Figure 2-14 and Figure 2-15 and drop to less than 5mg/L away from the excavation site.
- The only one of the URS receptor sites to receive an impact of more than 1mg/L maximum above-background TSS was PT 3 (1.2mg/L)

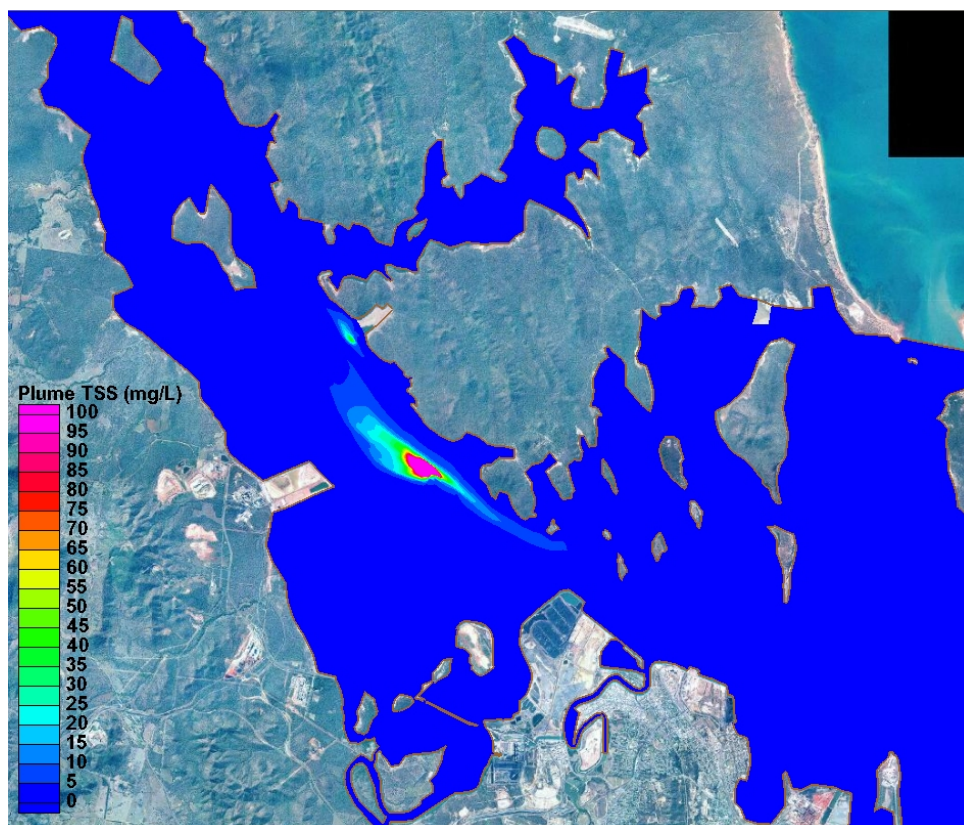
**Figure 2-8 Scenario 1: CSD with 50mg/L decant - maximum plume TSS concentration**



Figure 2-9 Scenario 1: CSD with 50mg/L decant - TSS concentration exceeded 10% of the time



Figure 2-10 Scenario 1: CSD with 50mg/L decant - Plume snapshot at 01:00 on 18/02/2009

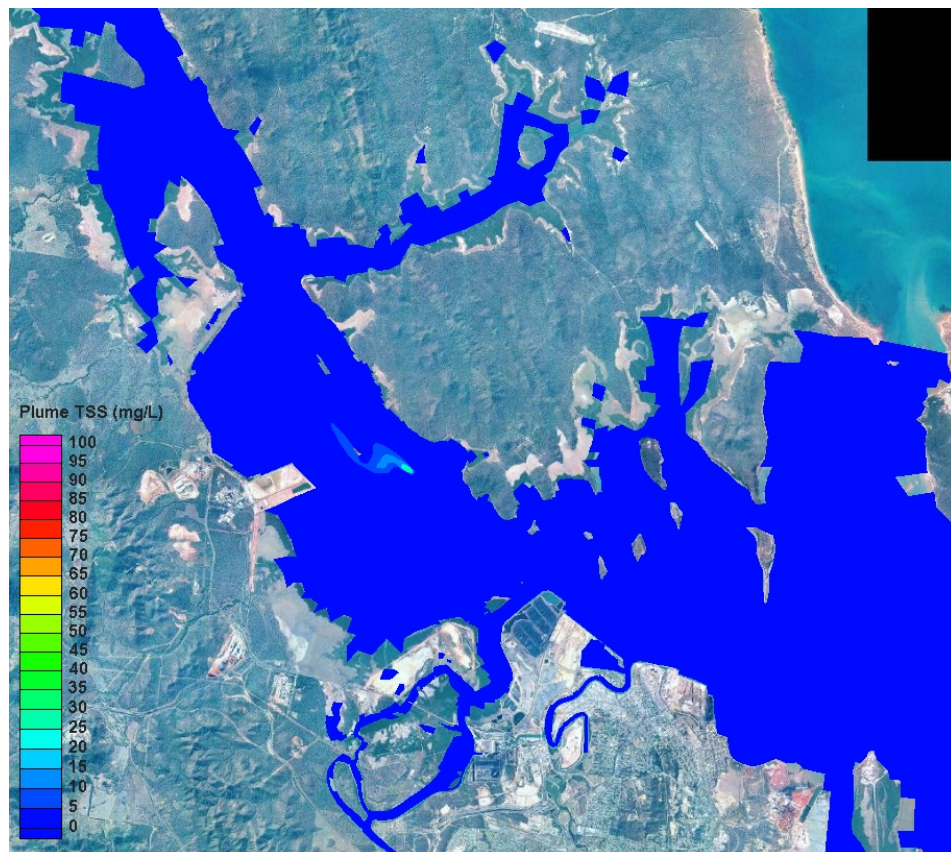


Figure 2-11 Scenario 1: CSD with 50mg/L decant - Plume snapshot at 09:00 on 26/02/2009

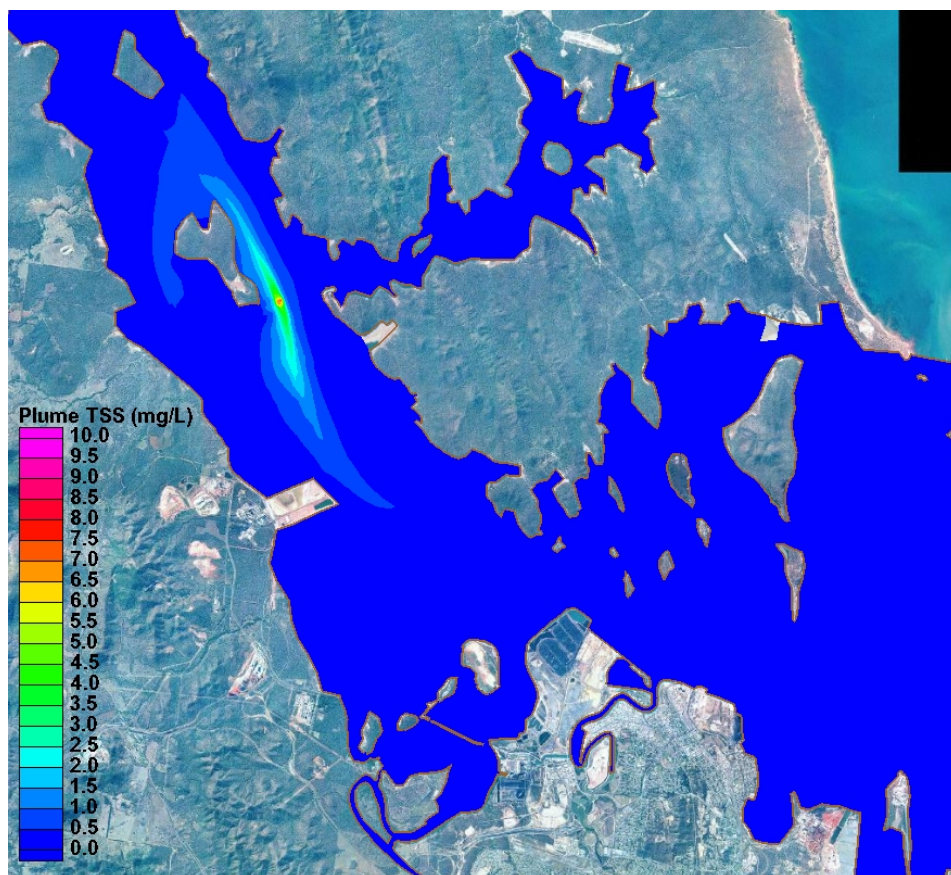


Figure 2-12 Scenario 2: Pipeline laying - western side - maximum plume TSS concentration

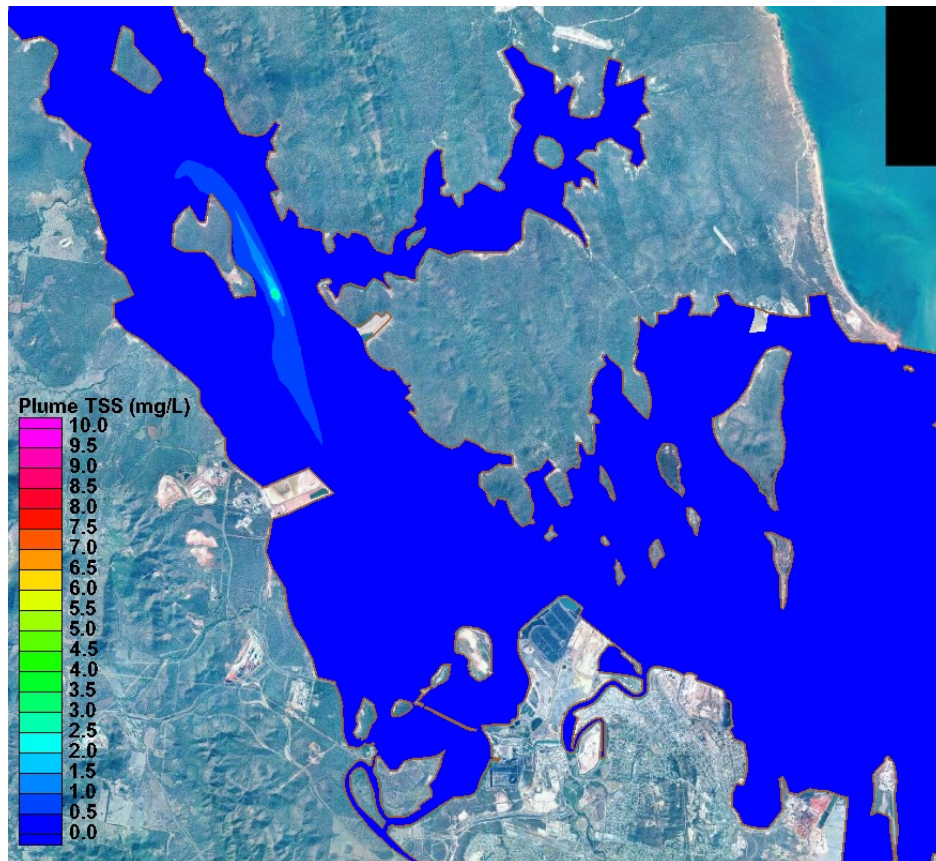


Figure 2-13 Scenario 2: Pipeline laying - western side - TSS concentration exceeded 10% of the time

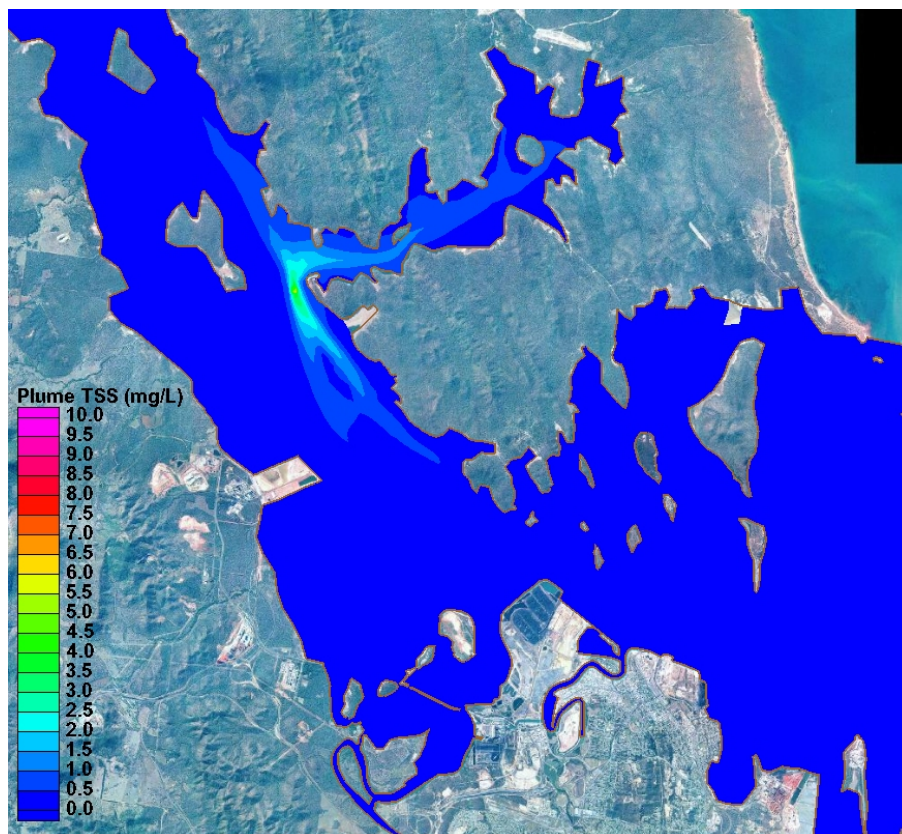


Figure 2-14 Scenario 3: Pipeline laying - eastern side - maximum plume TSS concentration

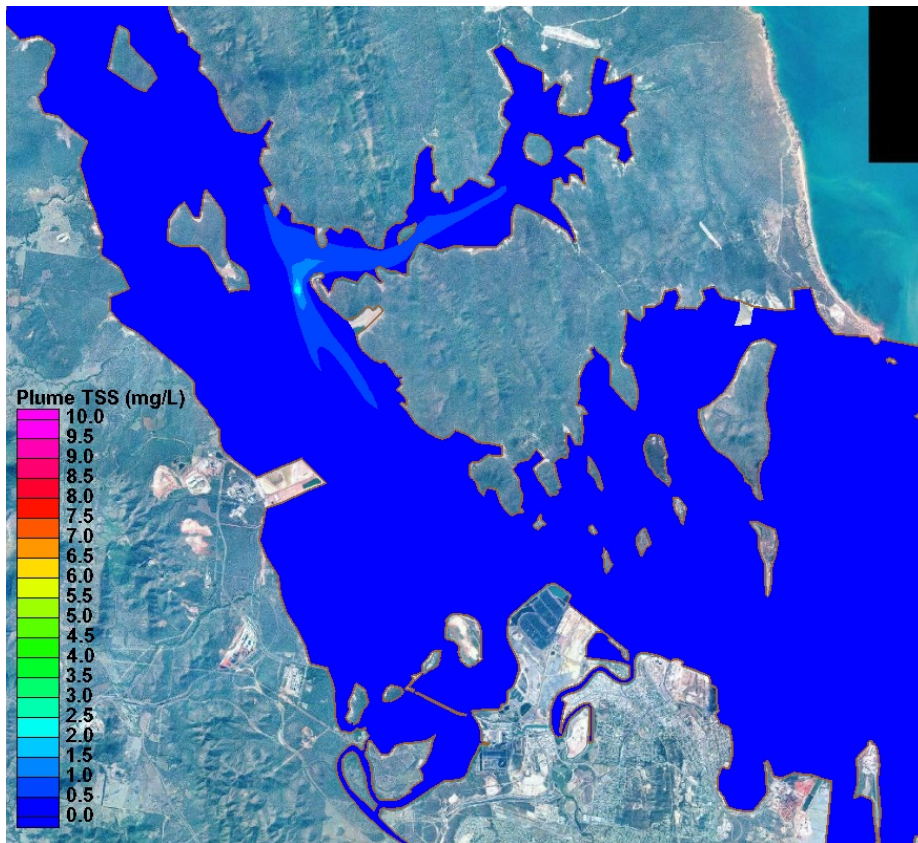


Figure 2-15 Scenario 3: Pipeline laying - eastern side - TSS concentration exceeded 10% of the time

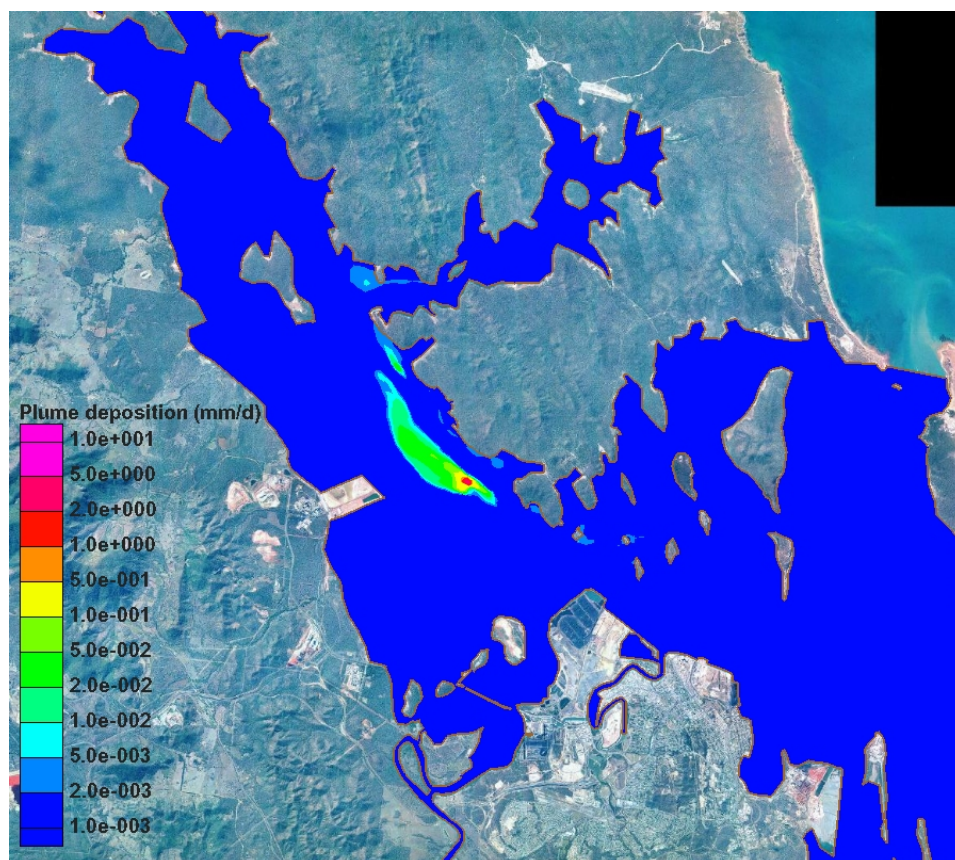


Figure 2-16 Scenario 1: CSD with 50mg/L decant - average plume deposition rate

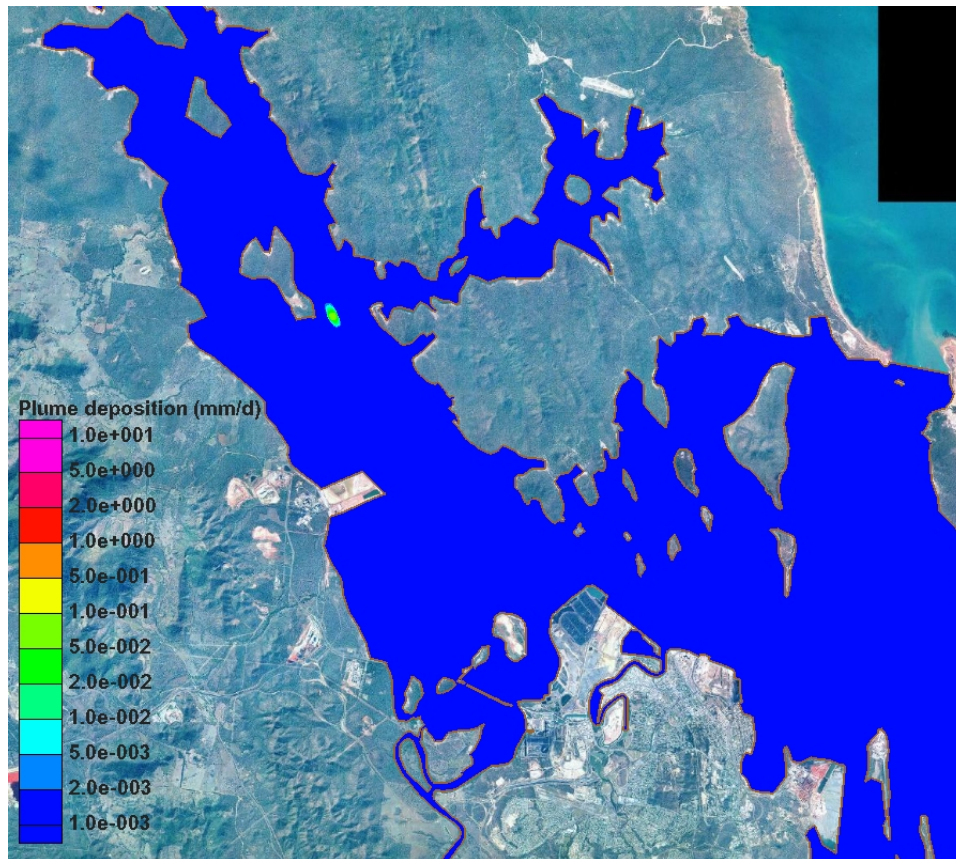


Figure 2-17 Scenario 2: Pipeline laying - western side - average plume deposition rate

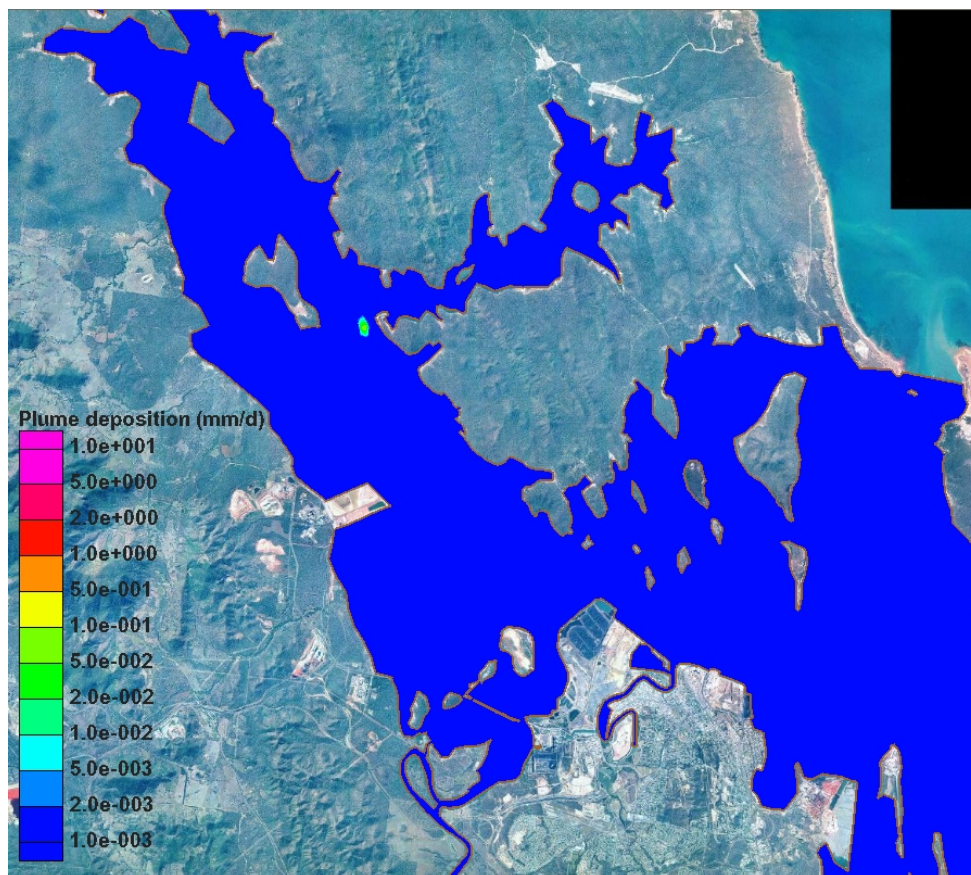


Figure 2-18 Scenario 3: Pipeline laying - eastern side - average plume deposition rate

3 OUTFALL MODELLING

3.1 Preamble / Background

A wastewater treatment plant (WWTP) and a reverse osmosis (RO) plant are proposed for installation in association with the LNG facility operation with an outfall located at E 317800 N 7367916 (MGA94 zone 56). The WWTP will have a typical discharge rate of 34 m³/hr (10 L/s), while the RO plant will produce a brine, or reverse osmosis concentrate (ROC), stream of approximately 54 m³/hr (15 L/s) with a commensurate salinity level of 63.5 g/L. Effluent quality from the WWTP is given in Table 3-1.

Table 3-1 Expected WWTP Effluent Quality

Parameter	Daily Average
BOD ₅	20mg/L
TSS	20mg/L
TN	20mg/L
TP	10mg/L

As a component of this study, near and far field modelling was conducted of the proposed WWTP and ROC discharges. Assumptions made in regard to this discharge were as follows:

- The WWTP effluent and ROC will be discharged as a constant wastewater stream at the stated respective flow rates of 10 L/s and 15 L/s;
- The ROC will have a constant salinity of 63.5 g/L. In regard to the near field modelling, where receiving water density is important, we have assumed ambient water will have a salinity of 35 g/L;
- The WWTP effluent and ROC temperature will be the same as that of the adjacent receiving waters. For the near field modelling, we have assumed that this temperature was 24° C;
- Scenario 1 will address WWTP effluent discharge only whereas Scenario 2 will address a combined discharge of both WWTP effluent and ROC; and
- We have assumed that there are no 'exotic' pollutants in the WWTP effluent/ROC streams that would warrant detailed assessment.

3.1.1 Near Field Assessments

Near field, or initial mixing, assessments were conducted using the accepted industry standard model for such applications, CORMIX. A CORMIX model was established of the proposed outfall, with this model being parameterised using the key assumptions outlined above. Additional specific considerations associated with the near field modelling were as follows:

- Several outfall configurations were assessed, and the recommended configurations were as follows
 - Scenario 1 - a 5m long diffuser, with 0.05m diameter orifices located 0.5m in from each end of the diffuser and every 1m along the diffuser (i.e. 5 parts in total), facing in alternate directions. This configuration will have an exit velocity from each outfall port of the order of 1.0 m/s, which will encourage maximum initial mixing; and

- Scenario 2 - a 12m long diffuser, with 0.05m diameter orifices located 0.5m in from each end of the diffuser and every 1m along the diffuser (i.e. 12 parts in total), facing in alternate directions.
- It was assumed that each diffuser option was oriented perpendicular to the prevailing current direction, that the minimum water depth below the diffuser at this site was 6m (this being important for the negatively buoyant plume case in Scenario 2) and that the diffuser was at all times covered by at least 4m of water (this being important for the positively buoyant plume case in Scenario 1); and
- Spring-neap tide model duration velocity time series data were extracted from the far field hydrodynamic model to inform the near field modelling. To be conservative, the lower 10th percentile velocity value from this data record was adopted for modelling. For information, the analysed velocity data as extracted from the model are summarised in Table 3-2.

Table 3-2 Near Field Modelling - Interrogated Velocity Data

Percentile	Velocity (m/s)
10	0.030
25	0.076
50	0.154
75	0.228
90	0.293

Based on this set of assumptions, relevant CORMIX models were developed and simulations of near field mixing were performed. The findings of these simulations were as follows:

- Scenario 1
 - the discharge receives 30:1 dilution within 2 m of the end of the outfall;
 - by the time the buoyant discharge plume reaches the water surface, dilution rates are of the order of 75:1; and
 - the patterns of plume dilution are further illustrated in Figure 3-1 and Figure 3-2.
- Scenario 2
 - the discharge receives greater than 30:1 dilution within 3.5 m of the end of the outfall;
 - by the time the negatively buoyant discharge plume reaches the sea bed, dilution rates exceed 125:1; and
 - the patterns of plume dilution are further illustrated in Figure 3-3 and Figure 3-4.

Further CORMIX modelling was also conducted under mean velocity conditions, and predicted surface and bottom contact dilutions for the two scenarios were respectively more than 530:1 (Scenario 1) and 720:1 (Scenario 2).

From these assessments it can safely be concluded that there will no detectable changes in local water quality patterns due to these small discharges. Typical nearfield nutrient concentration changes will be less than 0.04 mg/L for TN and 0.02 mg/L for TP for Scenario 1. Scenario 2 will see even greater dilutions (0.01 mg/L TN and 0.006 mg/L TP) and due to the negatively buoyant plume, is the preferred option.

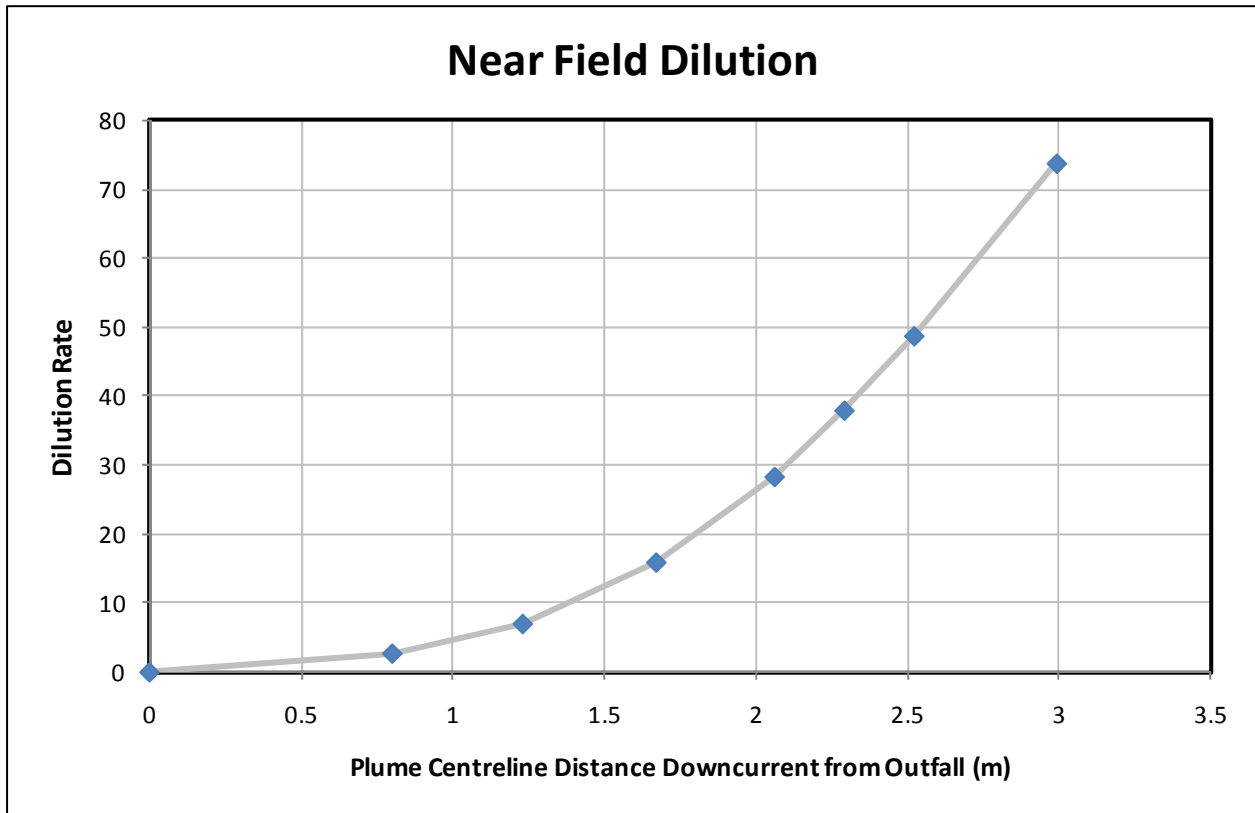


Figure 3-1 Near Field Dilution With Distance Down Current From Outfall – Outfall Scenario 1

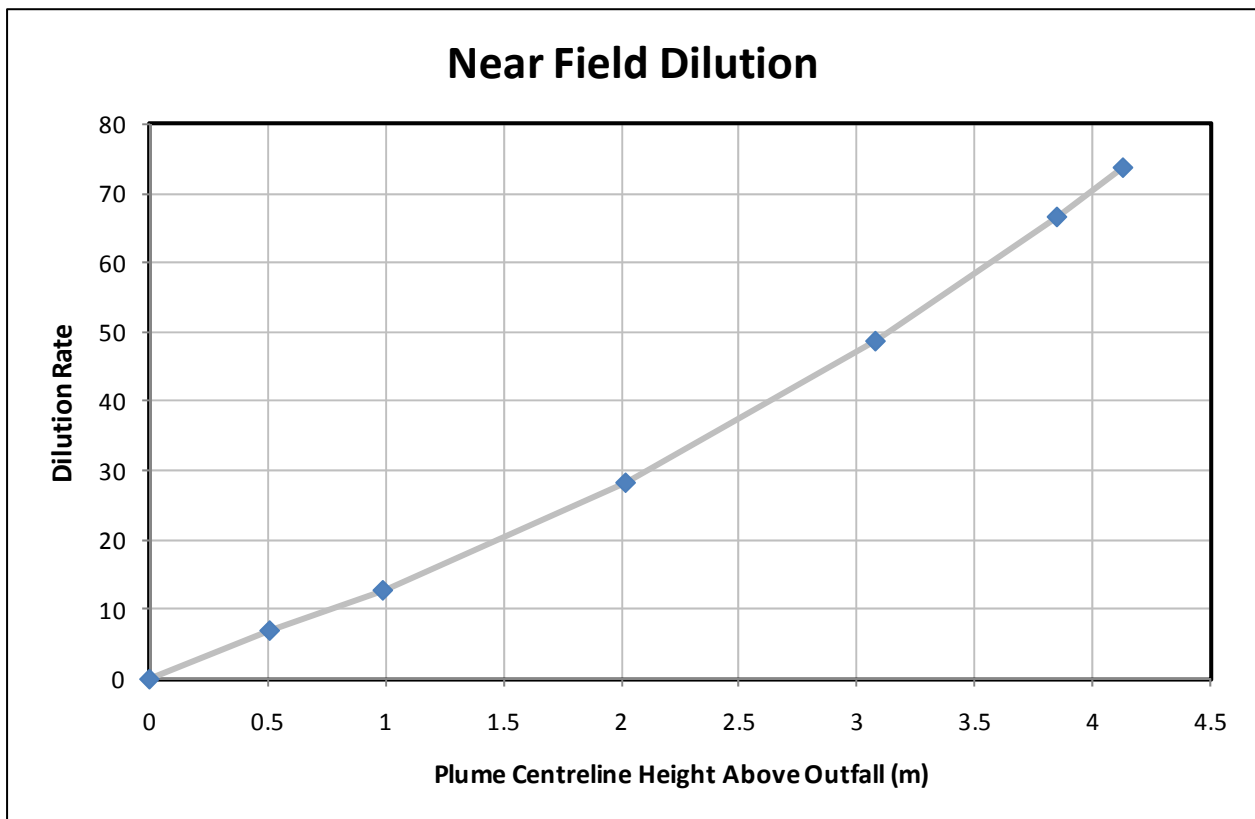


Figure 3-2 Near Field Dilution With Height Above Outfall – Outfall Scenario 1

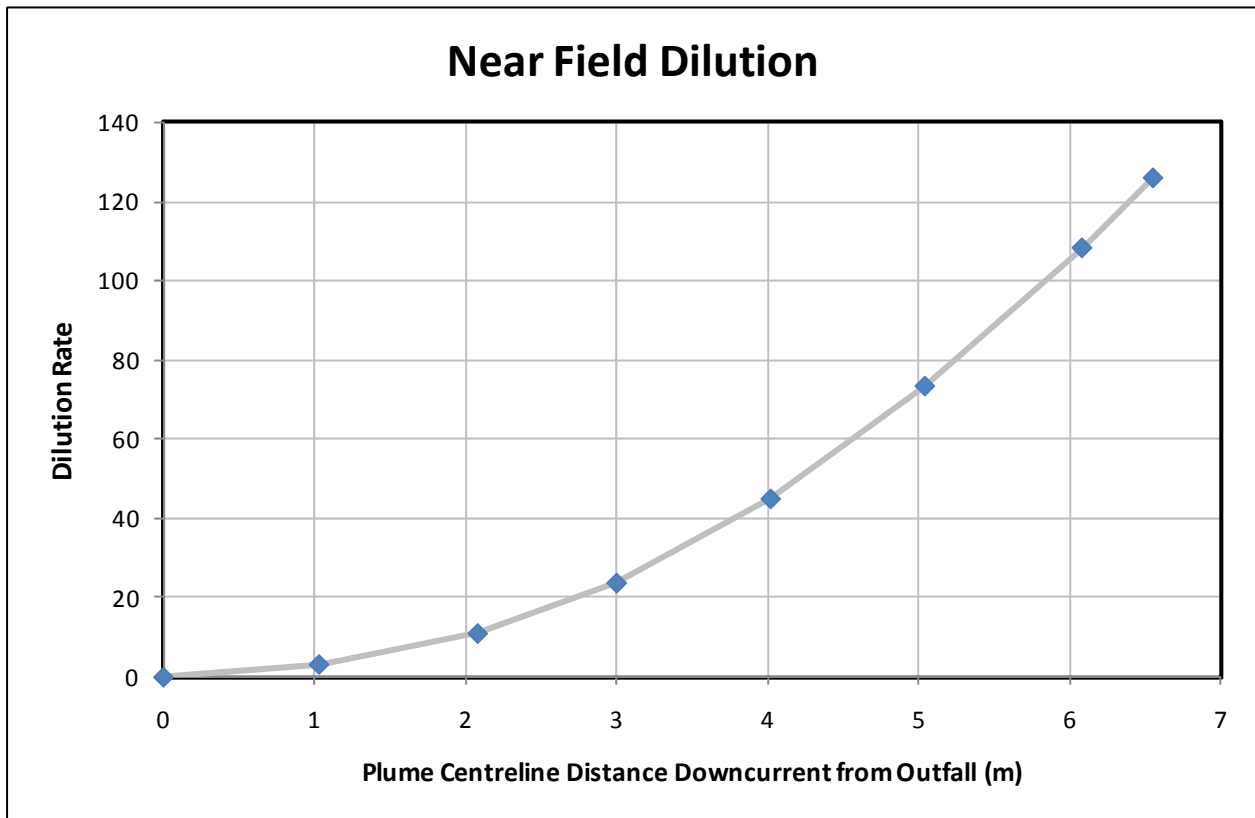


Figure 3-3 Near Field Dilution With Distance Down Current From Outfall – Outfall Scenario 2

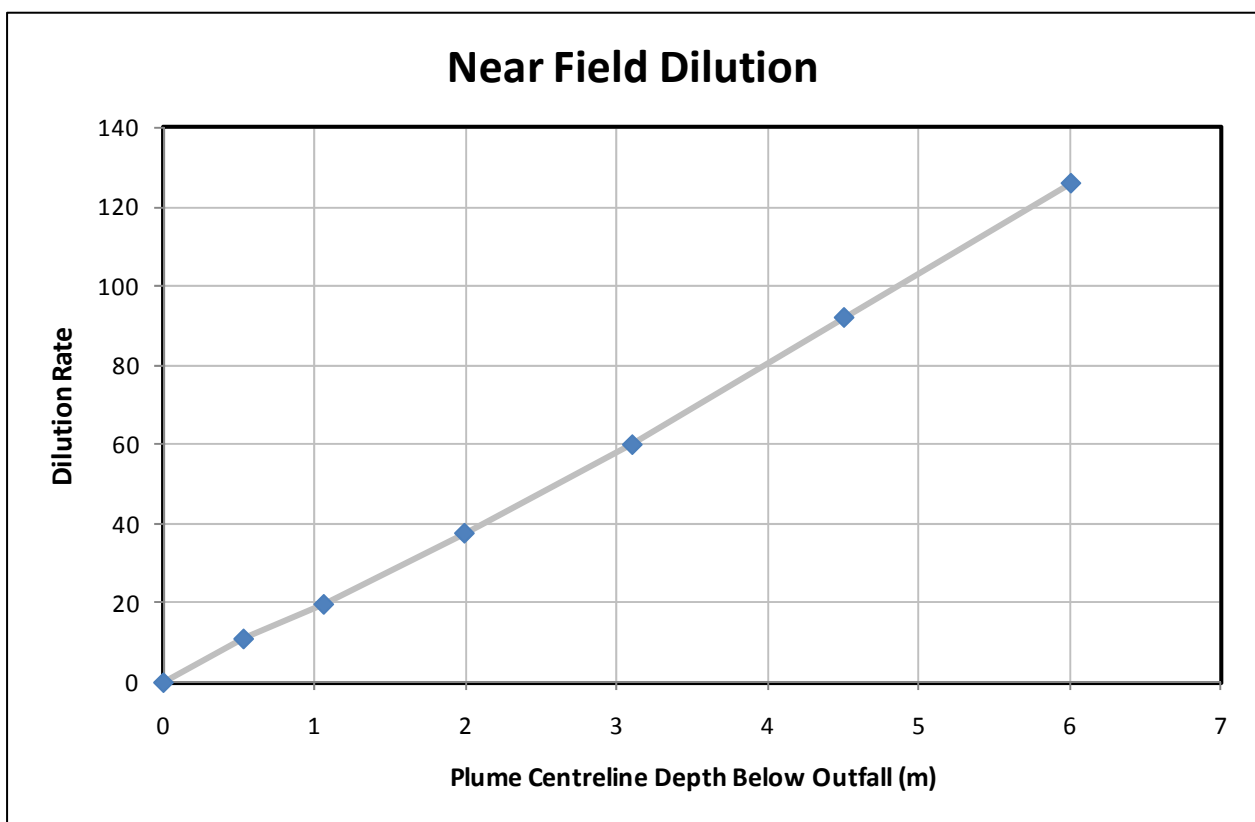


Figure 3-4 Near Field Dilution With Depth Below Outfall – Outfall Scenario 2

3.1.2 Far Field Assessments

3.1.2.1 Scenario 1: Wastewater Discharge

The TUFLOW-FV model was run for the same modelling period as the dredge plume simulations (4/2/09 to 4/3/09) with a discharge of 34m³/hr at a concentration of 20mg/L of a representative pollutant. The maximum concentration over the one month period in the surrounding waters is shown in Figure 3-5. This maximum concentration could represent any one of BOD, TSS or TN, while the maximum TP level expected would be half of that shown in Figure 3-5. In accordance with the near-field modelling results, the maximum concentration falls to below 0.2mg/L (dilution factor of 100) within a few metres of the outfall location.

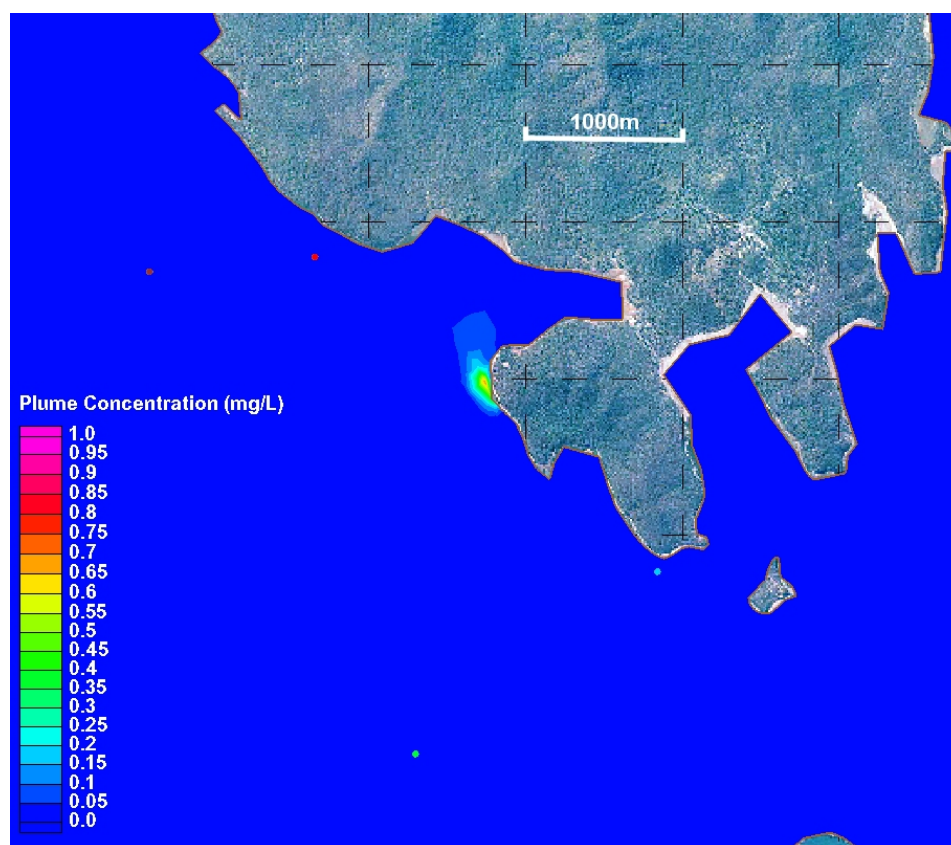


Figure 3-5 Wastewater discharge - maximum plume concentration

3.1.2.2 Scenario 2: Combined Wastewater and Brine Discharge

TUFLOW-FV model was run for the same modelling period as the dredge plume simulations (4/2/09 to 4/3/09) with a discharge of 88m³/hr (34m³/hr plus 54m³/hr) at a concentration of 39g/L (the brine concentration of 63.5g/L is expected to be diluted by the addition of the non-saline wastewater stream). The maximum additional salinity (above the background level) over the one month period in the surrounding waters is shown in Figure 3-6. The above-background salinity level exceeded 10% of the time during the one month modelling period is shown in Figure 3-7. It is seen that dilution factors of greater than 100 (ie above-background salinity less than 0.64g/L) are achieved at the outfall location over 90% of the time. The maximum wastewater pollutant concentrations for this scenario are the same as for Scenario 1.

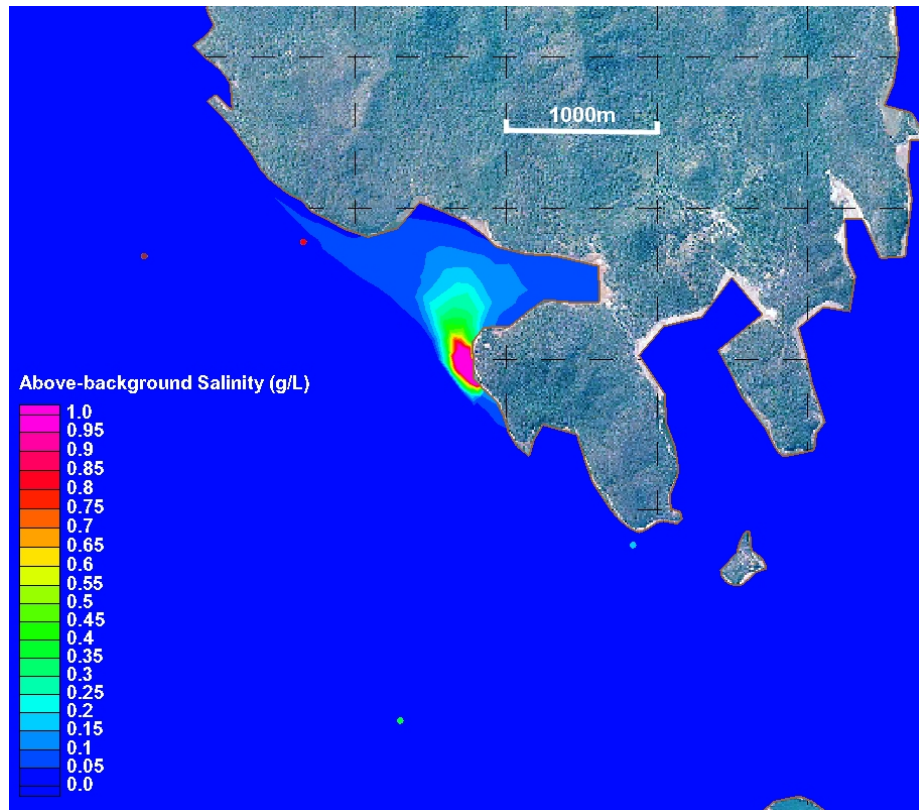


Figure 3-6 Brine discharge - maximum above-background salinity

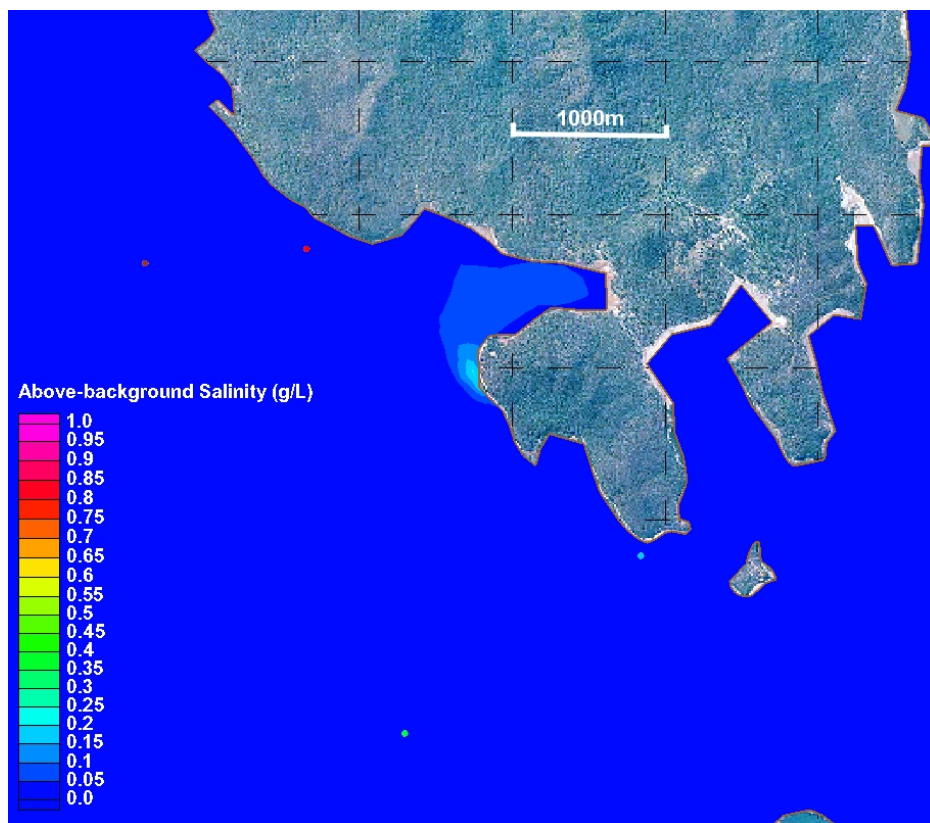


Figure 3-7 Brine discharge - above-background salinity exceeded 10% of the time

4 BASELINE TURBIDITY AND TSS DATA REVIEW

4.1 Introduction

4.1.1 Scope

This section of the report includes the collation and review of all available field collected and remotely sensed turbidity and TSS data for the eastern side of Port Curtis. Sediment deposition data collected by URS have also been reviewed. All of these data have been combined into an overall appraisal of turbidity and TSS levels in the area of potential impact as a baseline against which hydrodynamic, sediment dispersion, advection dispersion and sediment deposition modelled impacts may be assessed.

4.1.2 Data Sources

The following data sources were reviewed and relevant data analysed to provide an account of the condition of water quality in Port Curtis;

- Department of Environment and Heritage and the Department of Natural Resources (DEH/DNR) (1999)
- Queensland Environmental Protection Agency (EPA) (2002-2008);
- National Land and Water Resources Audit (NLWRA) condition assessment reports (1998 and 2001);
- Geoscience Australia Australian Ports Literature Review (1998);
- Port Curtis Integrated Monitoring Program (PCIMP) Ecosystem health report card and Biomonitoring (2005, 2006 and 2007);
- URS sediment deposition data; and
- BMT WBM studies (1999, 2001, 2008, 2009).

4.1.3 Water Quality Guidelines

Queensland Water Quality Guidelines for enclosed coastal and mid-estuarine waters are listed in Table 4-1. The area of interest in Port Curtis is considered enclosed coastal. It is noted that the baseline monitoring data presented in this report indicate that existing background levels regularly exceed these figures.

Table 4-1 Queensland Water Quality Guidelines for enclosed coastal and estuarine waters

Parameter	Units	Water body type	
		Enclosed coastal	Mid Estuarine
Turbidity	NTU	6	8
Suspended Solids	mg/L	15	20

4.1.4 Seagrass and Coral Tolerances

Key impacts on seagrasses from dredging include physical removal or burial of vegetation at the dredging/disposal site, increased turbidity and increased sedimentation in adjacent sea-grass meadows, temporarily reduced dissolved oxygen concentration, release of nutrients and pollutants from contaminated sediments and hydrographic changes (Erfemeijer and Lewis 2006).

While the minimum light requirement of seagrasses in the area is important, the duration of the period of sub-optimal light is also of importance (Erfemeijer and Lewis 2006). Table 4-2 shows that the survival period for the seagrasses found in the study area is approximately one month at sub-minimal light conditions. *Halophila ovalis* has been documented to cope with sub-optimal light for the shortest period of the seagrasses found in the study area (Erfemeijer and Lewis 2006). Therefore the survival period for this species should be used as a minimum conservative value. While dredging operations will increase light attenuation, the effects are expected to be transient in most areas according to modelling results.

Table 4-2 Duration of time that seagrass species can survive in light intensities below their minimum light requirements (Source: Erfemeijer and Lewis 2006)

Species	Light availability	Period survived (months)	Reference
<i>Halophila ovalis</i>	0	1	Longstaff et al. (1999)
<i>Zostera capricornii</i>	5% SI	1	Grice et al. (1996)

Table 4-3 Critical thresholds of seagrasses for sedimentation (Source: Erfemeijer and Lewis 2006)

Species	Location of study	Sedimentation (cm/yr)	Reference
<i>Cymodocea serrulata</i>	Philippines	13	Vermaat et al. (1997)
<i>Halophila ovalis</i>	Philippines	2	Vermaat et al. (1997)

It has been well documented that healthy coral communities may exist in chronically turbid water (van Woelk, 1994 and Postorok and Bilyard, 1985), especially where strong currents prevent the build up of sediment (Postorok and Bilyard, 1985), however the communities are generally less diverse and abundant than those in clear water (van Woelk, 1994). Changes in trophic mode, such as increased feeding on suspended particulate matter may offset the stress in high particulate loads (Anthony and Fabricius, 2000).

The relationship between turbidity and coral health is therefore not simple, though Hopley and Van Woelk (1991) proposed limits for suspended sediments and settlement rates (Table 4-3). Cooper et al. (2008) report that long-term turbidity >3 NTU leads to sublethal stress, whereas long-term turbidity >5 NTU corresponds to severe stress effects on corals at shallow depths. It is noted however that these should not be used as 'thresholds of concern' due to the varying factors of depth, species and duration of exposure to turbidity.

Table 4-4 Suspended sediment and settlement rate limits for corals (Source: Hopley et al., 1991)

	Time period	Rate of sediment settlement (mg/L)	Suspended sediment limit (mg/cm ² /day)
Absolute	-	1500	200
Short term	Up to 2 tidal cycles	1000	150
Medium term	Up to 20 days	120	120
Long term	Beyond 20 days	75	80

4.2 Total Suspended Solids, Turbidity and Sedimentation in Eastern Port Curtis

4.2.1 Turbidity and TSS

4.2.1.1 DEH/DNR (1999)

Broad scale physicochemical data for the Calliope River (Figure 4-1) was collected by DEH and DNR water quality monitoring programs between 1992 and 1996, and compiled in the 1999 'Testing the Waters' report on the quality of Queensland's waters. DEH sites were monitored monthly while DNR sites were monitored quarterly.



Figure 4-1 DEH/DNR water quality monitoring sites, Calliope River (DEH/DNR, 1999)

Median range guideline values for each water quality parameter were calculated and defined in terms of a category 1, 2 and 3; good, moderate and poor respectively. If a median value from a monitoring site falls within this range of values, it is categorised as such. All sites in the Calliope River were classified as 'estuarine' and fell within the 'good' category for all parameters monitored.

Table 4-5 Physicochemical monitoring results (DEH/DNR, 1999)

Parameter	QWQG	Site			
		1320801	1320804	1320808	1320810
Turbidity (NTU)	8	<30	<30	<30	<30

From this monitoring it can be seen that the water quality in the Calliope River is generally 'good'. The relevancy of this data to this particular study is mostly concerned with the site at the mouth of the Calliope River, as this site is within Port Curtis.

4.2.1.2 EPA Water Quality Monitoring (2002-2008)

Available water quality information at the nearest Environmental Protection Agency (EPA) monitoring sites in the Calliope River (Figure 4-1) was sourced from the EPA. A summary of turbidity data has

been provided in Table 4-6. Table 4-6 shows that turbidity exceeds the estuarine QWQG of 8 NTU at all sites.

Table 4-6 EPA turbidity results for the Calliope River

Distance from mouth of river	Number of samples collected	Median turbidity (NTU)	QWQG
0km	69	10.0	8
1.6km	69	9.0	8
3.2km	68	11.5	8
4.8km	68	12.0	8
6.4km	68	12.0	8
11.3km	68	10.0	8
12.9km	68	10.0	8
14.5km	67	12.0	8
16.1km	67	14.0	8
Ananbranch (2.8km from mouth of river)	69	16.0	8

4.2.1.3 National Land and Water Resources audit (1998 and 2001)

The following data were gathered as part of the National Land and Water Resources Audit (NLWRA; 1998) and were sourced through the Ozcoast and OzEstuaries search facility.

Table 4-7 Median turbidity values (NLWRA, 1998 & 2001)

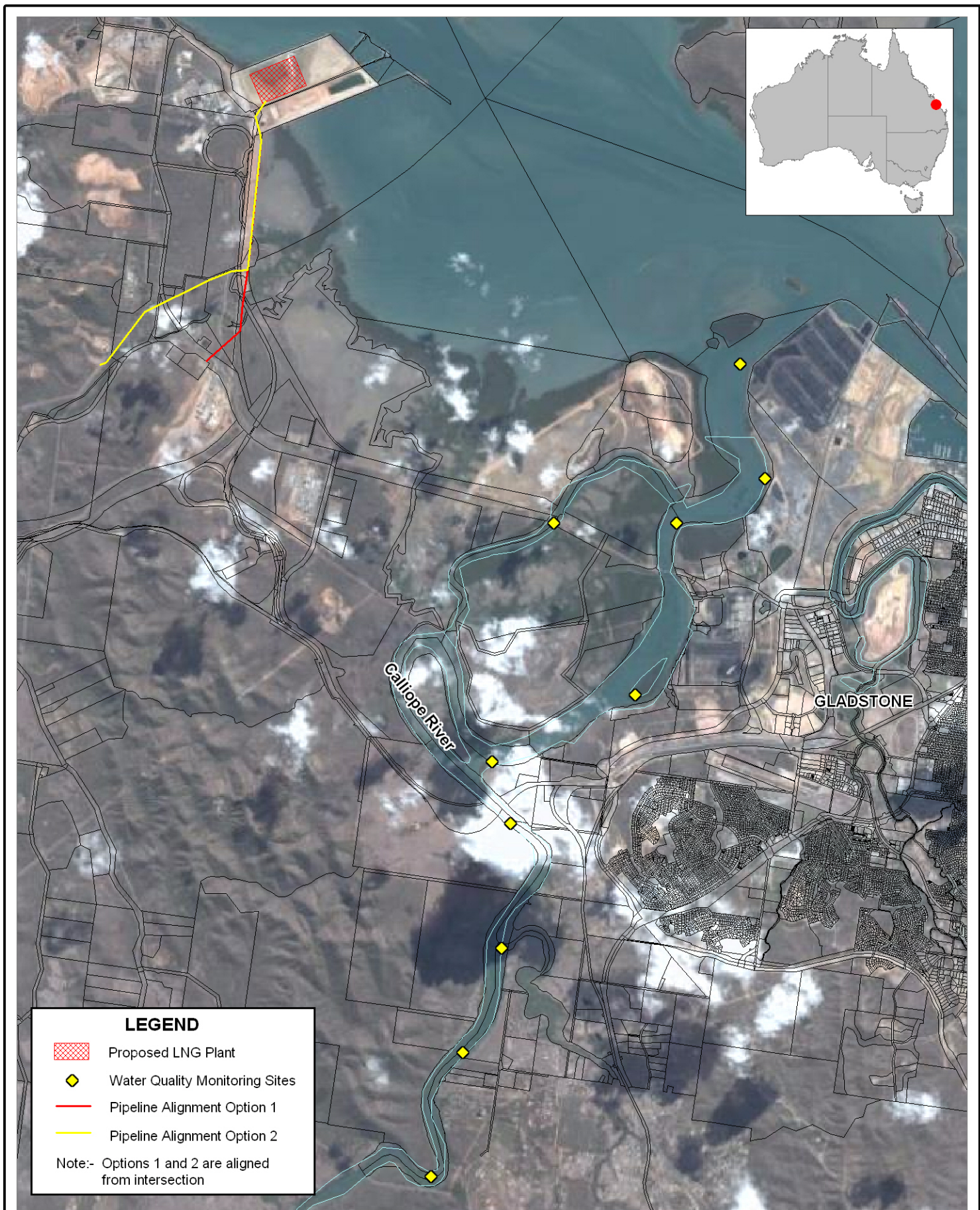
	Calliope River			Fitzroy River			Boyne River		
	Head	Middle	Mouth	Head	Middle	Mouth	Head	Middle	Mouth
Turbidity (NTU)	9	14	12	27	39	119	5	2	3

4.2.1.4 Australian Ports environmental data and risk analysis literature review (1998)

Gladstone Port Authority continuous monitoring systems were deployed in Gladstone Harbour at Clinton and Boyne Island Wharves. The range of turbidity values recorded is shown in Table 4-8.

Table 4-8 Gladstone Port Authority turbidity logger results

	Turbidity (NTU)	
	Minimum	Maximum
Spring tide	30	40
Neap tide	1	5



Title:
EPA Water Quality Monitoring Sites on the Calliope River

Figure:
4-2

Rev:
A

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



0 1 2km
Approx. Scale

4.2.1.5 Port Curtis Integrated Monitoring Program (2005-2007)

Depth averaged turbidity levels from the Port Curtis Integrated Monitoring Program are given in Table 4-9 and Table 4-10. The monitoring locations are shown in Figure 4-3 and Figure 4-4.

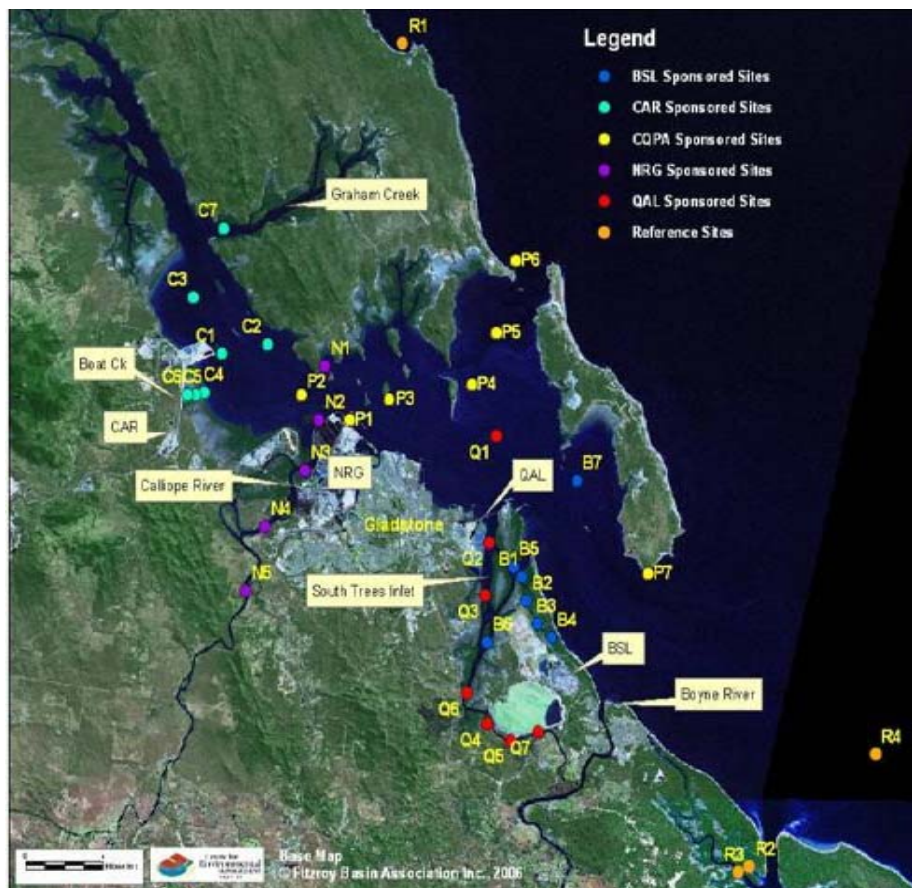


Figure 4-3 2005 PCIMP monitoring sites (Anderson et al., 2006)

Table 4-9 Mean turbidity levels recorded by PCIMP in 2005 (Anderson et al., 2006)

Site	Mean turbidity (NTU) $\pm$ standard deviation
R1	3.5 $\pm$ 0.5
R2	5.2 $\pm$ 2.3
R3	3.6 $\pm$ 1.0
R4	3.7 $\pm$ 1.1
P1	4.0 $\pm$ 0.2
P2	5.4 $\pm$ 0.5
P3	10.3 $\pm$ 5.3
P4	8.3 $\pm$ 2.3
P5	4.1 $\pm$ 0.2
P6	2.7 $\pm$ 0.6
P7	3.4 $\pm$ 0.2
C2	5.6 $\pm$ 1.1
C3	5.3 $\pm$ 0.6
N2	4.9 $\pm$ 0.4
B7	10.0 $\pm$ 5.2
Q1	5.2 $\pm$ 1.0

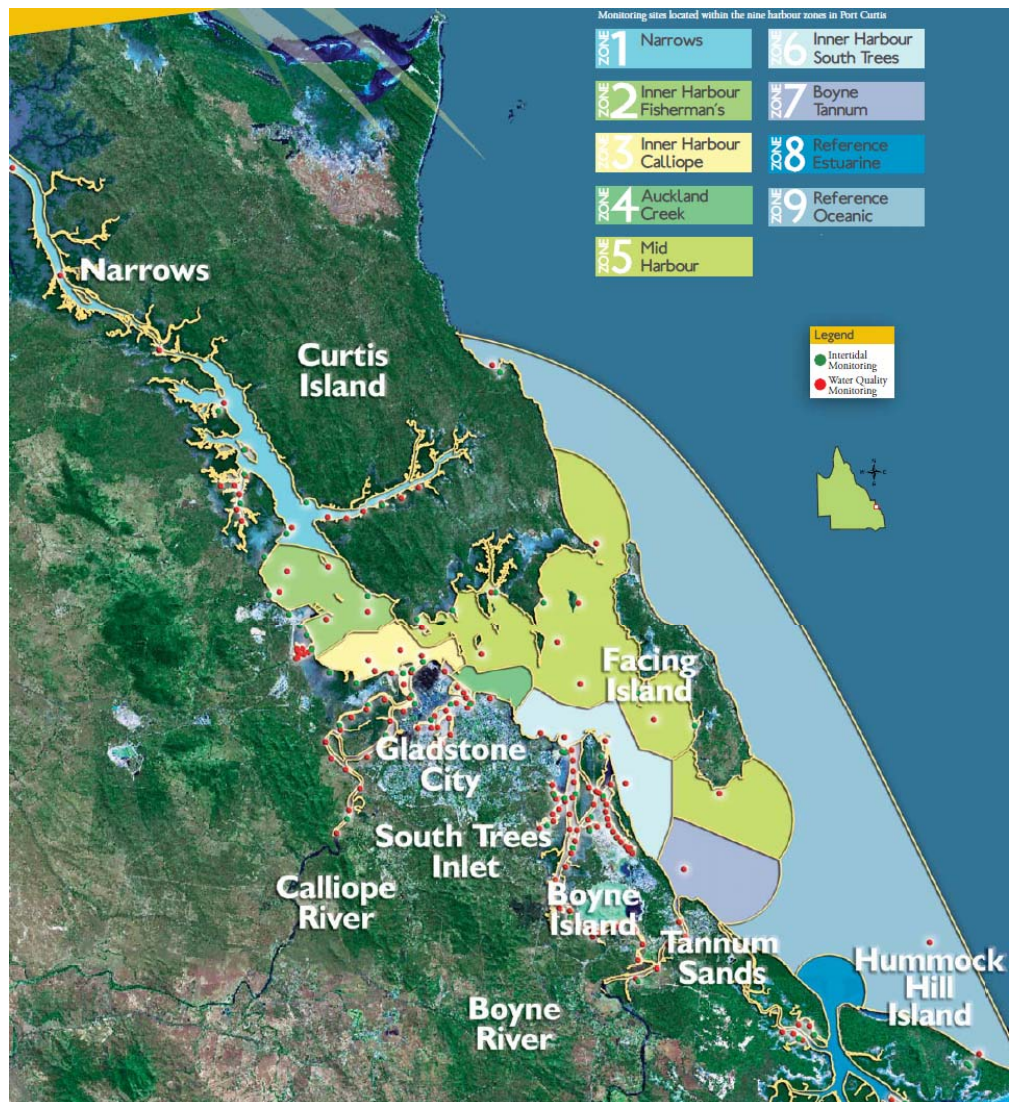


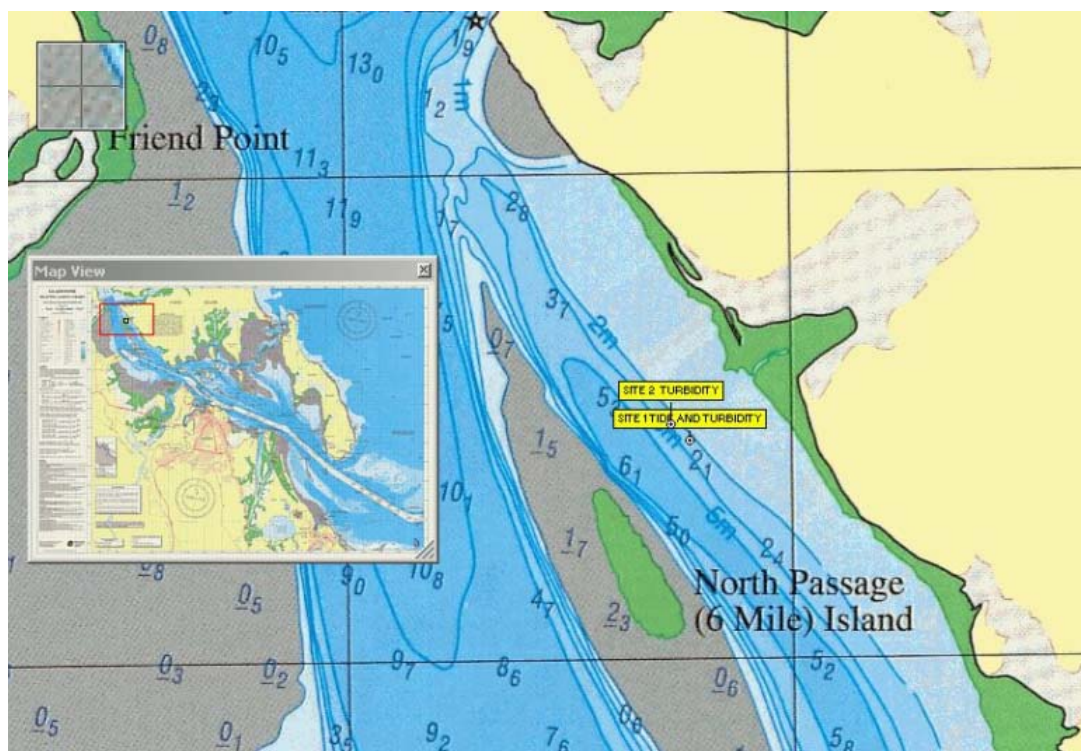
Figure 4-4 2006 and 2007 PCIMP monitoring sites (Anderson et al., 2007)

Table 4-10 Mean 2006 and 2007 PCIMP turbidity levels (Anderson et al., 2007)

Site	Mean turbidity (NTU) $\pm$ standard deviation		
	2006	Jul 2007	Sept 2007
Narrows	8.2 $\pm$ 0.5	6.2 $\pm$ 2.1	4.8 $\pm$ 1.4
Grahams Creek		3.6 $\pm$ 0.7	4.0 $\pm$ 0.9
Fishermans Landing	8.8 $\pm$ 1.2	5.7 $\pm$ 1.4	3.9 $\pm$ 1.6
Boat Creek		5.8 $\pm$ 1.0	5.8 $\pm$ 1.5
Wiggins Island	12.7 $\pm$ 2.3	4.4 $\pm$ 1.4	2.9 $\pm$ 0.7
Anabranh	14.5 $\pm$ 1.9	7.6 $\pm$ 2.9	12.9 $\pm$ 1.4
Calliope	20.7 $\pm$ 3.9	6.3 $\pm$ 1.5	4.4 $\pm$ 0.6
Auckland Creek	15.1 $\pm$ 5.8	3.8 $\pm$ 0.6	4.8 $\pm$ 0.7
Mid Harbour	8.0 $\pm$ 1.0	3.0 $\pm$ 0.6	3.5 $\pm$ 1.4
Inner Harbour/South Trees	9.5 $\pm$ 2.0		
Outer harbour	5.0 $\pm$ 2.5	0.4 $\pm$ 0.3	2.0 $\pm$ 0.4
Reference- Estuarine	5.9 $\pm$ 0.4	1.5 $\pm$ 0.4	0.6 $\pm$ 0.1
Reference- Oceanic	2.6 $\pm$ 0.2	0.2 $\pm$ 0.1	0.8 $\pm$ 0.5
AWQG trigger- Estuarine	1	1	1
AWQG trigger- Oceanic	20	20	20

4.2.1.6 BMT WBM turbidity logger data (2009)

On behalf of the Santos project and URS, BMT WBM deployed four turbidity logger instruments and one tide logger instrument on 7th August 2009, and retrieved the instruments on the 2nd September 2009. The instruments were deployed in the channel between North Passage Island and Curtis Island as shown below in Figure 4-5.

**Figure 4-5 Location of turbidity loggers**

At each measurement location, two turbidity instruments (one McVan Instrument and one Greenspan turbidity measuring instrument) were mounted on a steel mooring frame, which was positioned on the seafloor approximately 2m below low water datum. In their deployment location, the turbidity instrument sensor faces were positioned approximately 0.25 m above the seabed. An additional tide recorder was positioned on the base of the steel mooring at Site 1. A calibrated YSI water quality measuring instrument was used to check the water turbidity shortly after deployment and following instrument retrieval, in order to calibrate the data from the McVan instruments sensors.

The McVan Instrument turbidity data were post-calibrated (using a calibration factor derived from comparison of the profiling turbidity measurements from the YSI instrument). No post-calibration factor was applied to the Greenspan instruments data record since they were previously calibrated.

No other corrections have been applied to the dataset. A temporary obscuration of the turbidity sensor face on most instruments is visible in the dataset, particularly in the latter part of the deployment record arising from biofouling and/or due to drift seaweed, which was caught up on the steel mooring frames.

The turbidity data close to the seabed gathered over the deployment period show a variation in water turbidity at the measurement locations from typically 2-4NTU during neap tides, up to approximately 25-35NTU during the spring tides (Figure 4-6). Most of the intermittently higher turbidity readings are expected to be due to the influence of occasional biofouling.

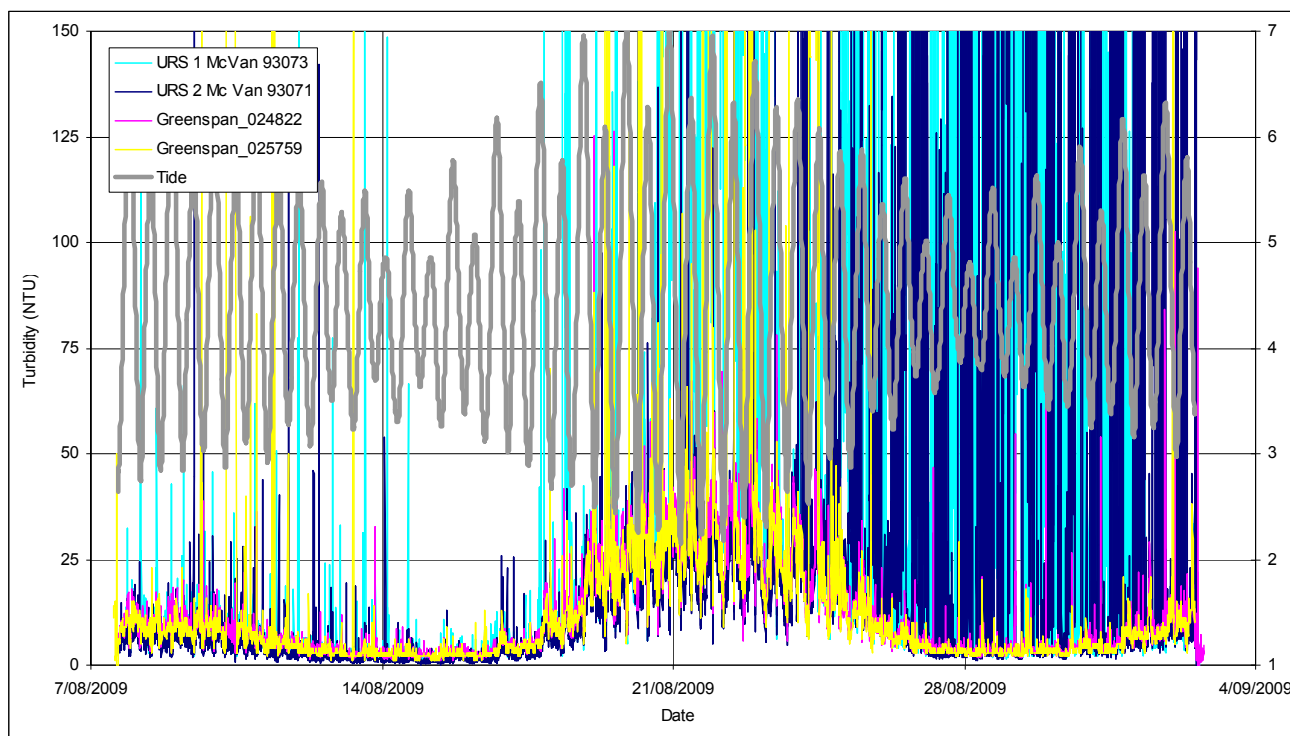
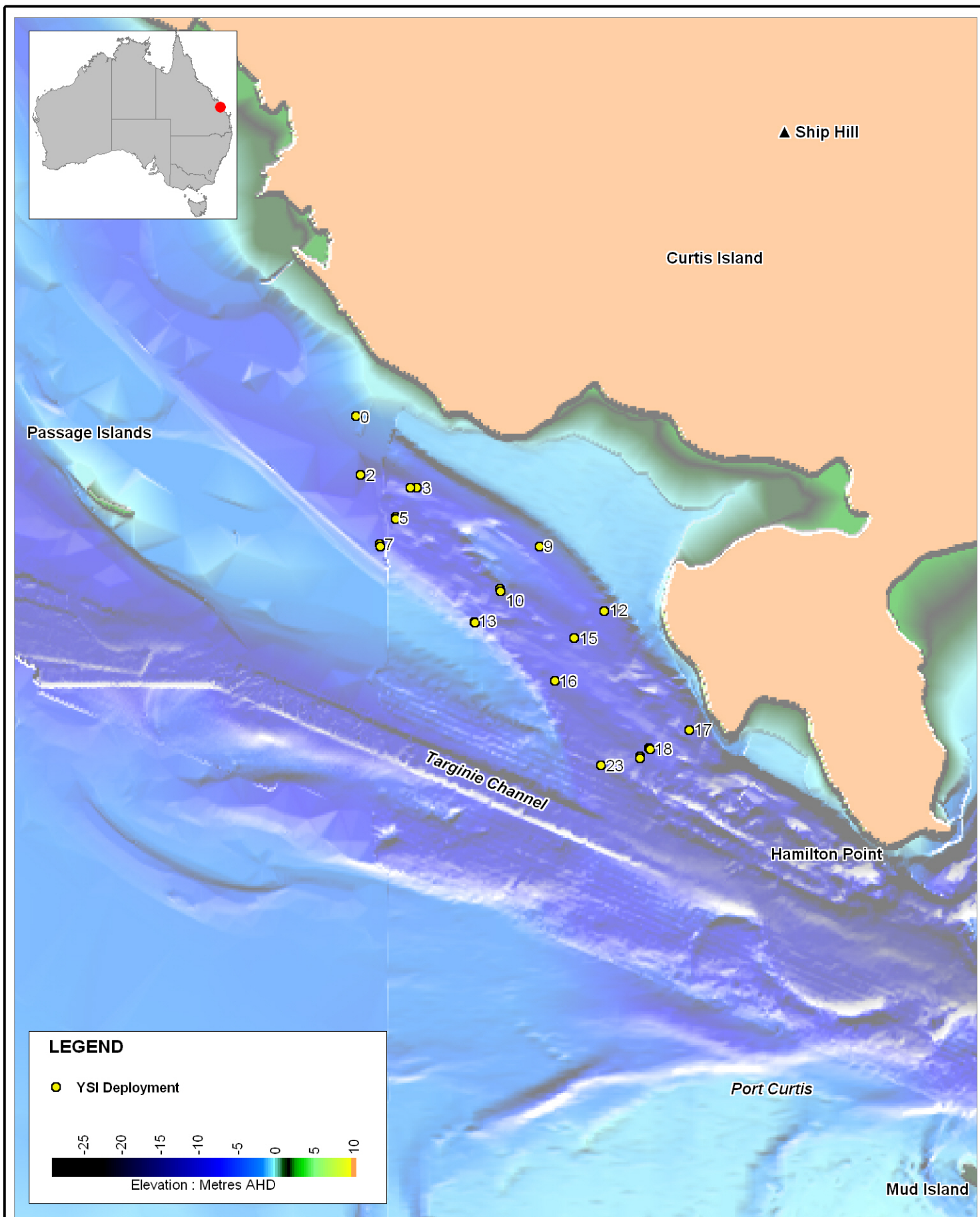


Figure 4-6 Turbidity measurements 7/8/09- 2/9/09

4.2.1.7 BMT WBM baseline data collection (2008)

A YSI water quality data logger instrument was cast at the locations shown Figure 4-7 and Figure 4-8. The timings of all casts relative to each tide are shown in Figure 4-9 and Figure 4-10. For Campaign 1 (3rd-7th February 2008), these casts were largely at, or near, the bottom of the tide, with the exception of the last 4 measurements, which were taken as a flood tide commenced. As such, any tidal influence on YSI measurements is small for that campaign. There was a greater temporal spread of YSI casts in Campaign 2 (4th-8th June 2008), due in part to the need to collect coincident water quality grab samples. Given this difference, the casts from both campaigns are described separately below.



Title:

YSI Deployment Locations- Campaign 1

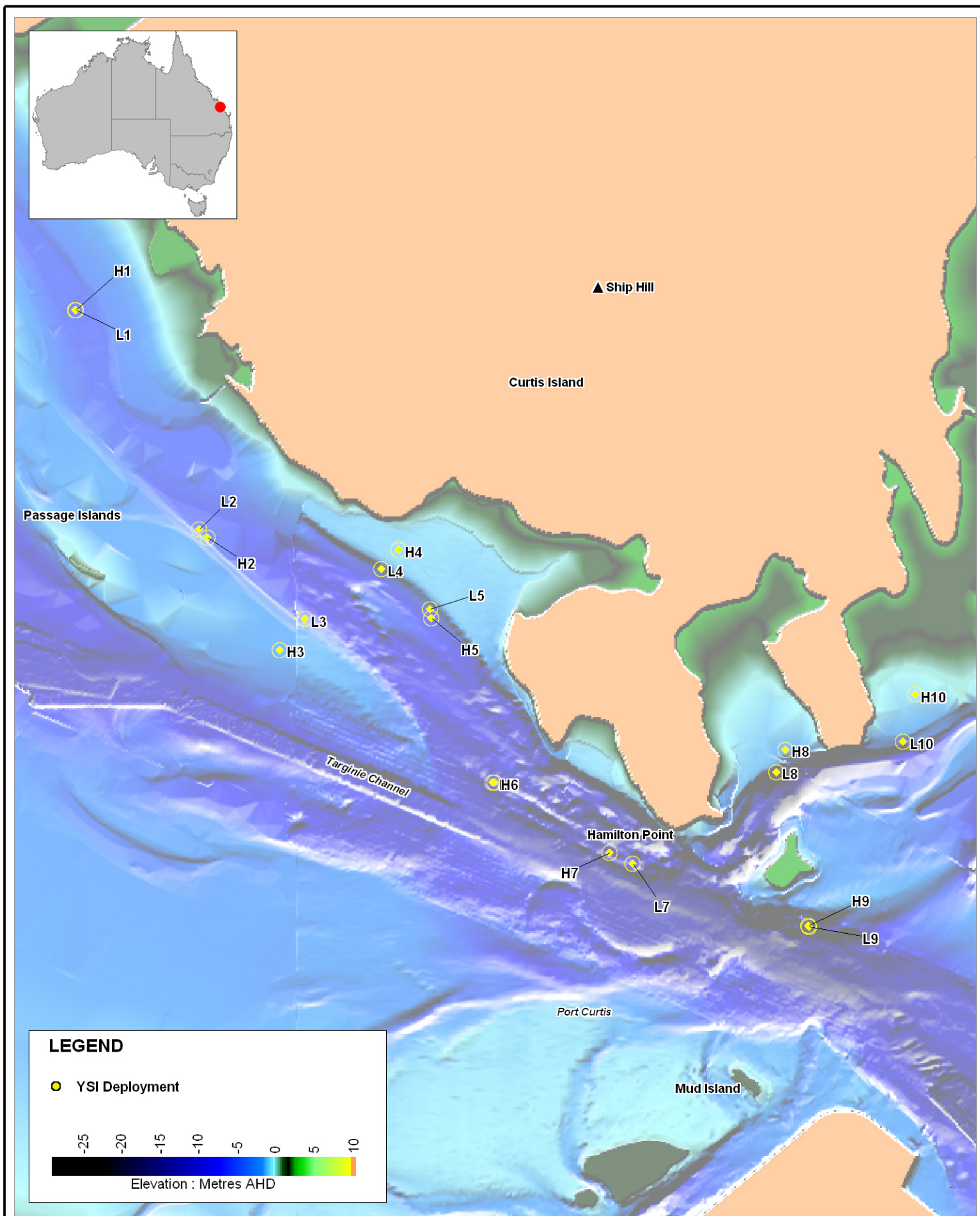
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.



0 0.5 1km

Approx. Scale

Filepath : I:\B16752_I_BRH_GLNG\DRGWQU_003_080225_WQLocations.wor



Title:
YSI Cast Locations - Deployment 2

Figure:
4-8

Rev:
A

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



0 0.5 1km
Approx. Scale



Filepath : I:\B16752_I_BRH_GLNG\DRGWQU_033_080816_WQLocations_June.wor

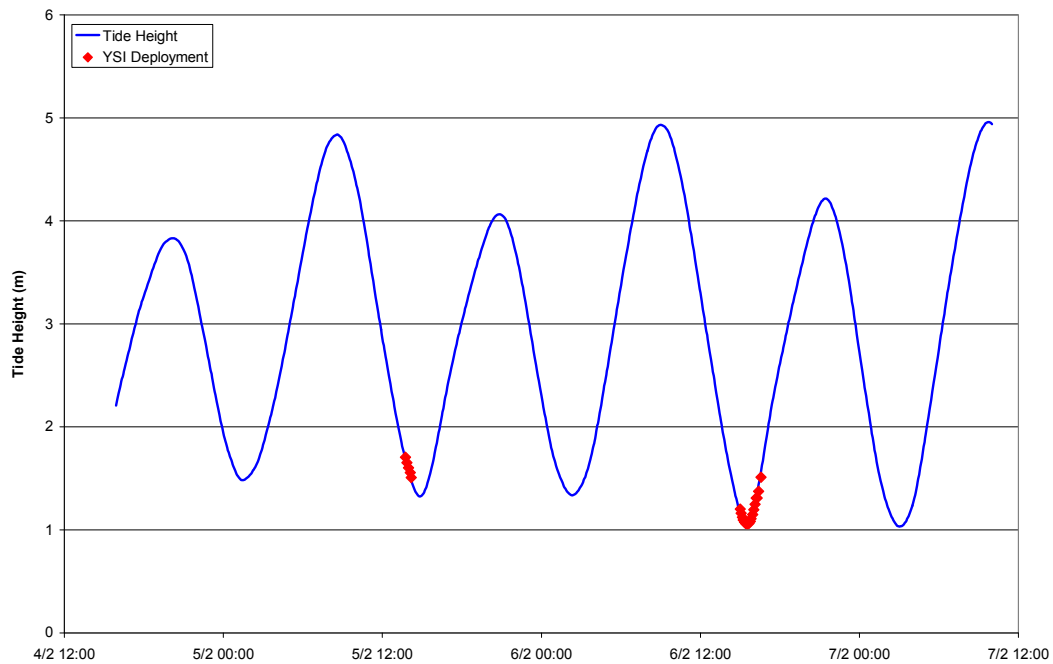


Figure 4-9 YSI cast times- Campaign 1

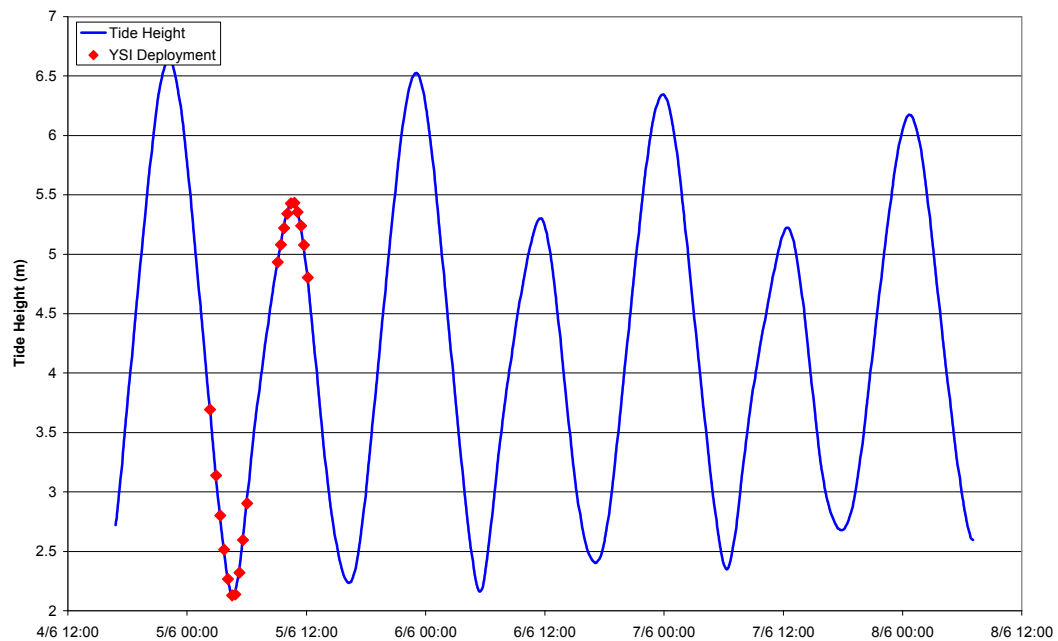


Figure 4-10 YSI cast times- Campaign 2

Campaign 1 (February)

Given the small tidal influence for Campaign 1, turbidity data have been spatially analysed. To this end, the profiles have been grouped into three areas: northern (profiles 1 to 8), mid (profiles 9 to 16) and southern (profiles 17 to 20). Profiles 20 to 23 are essentially replicates collected as the flood tide began, and as such they are presented separately. Results under these spatial groupings are presented below.

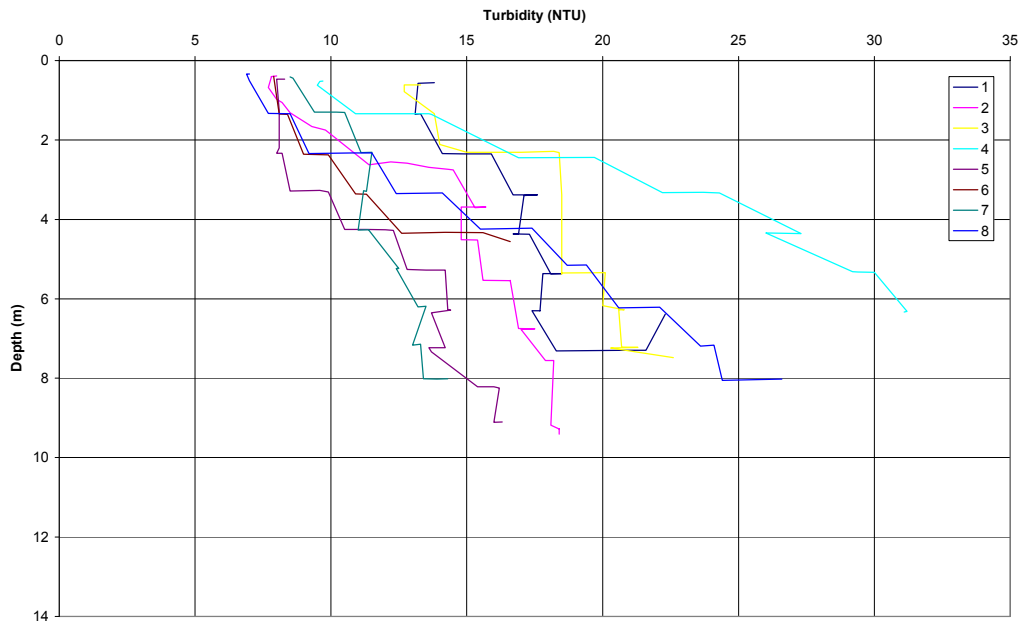


Figure 4-11 Northern sites turbidity- Campaign 1

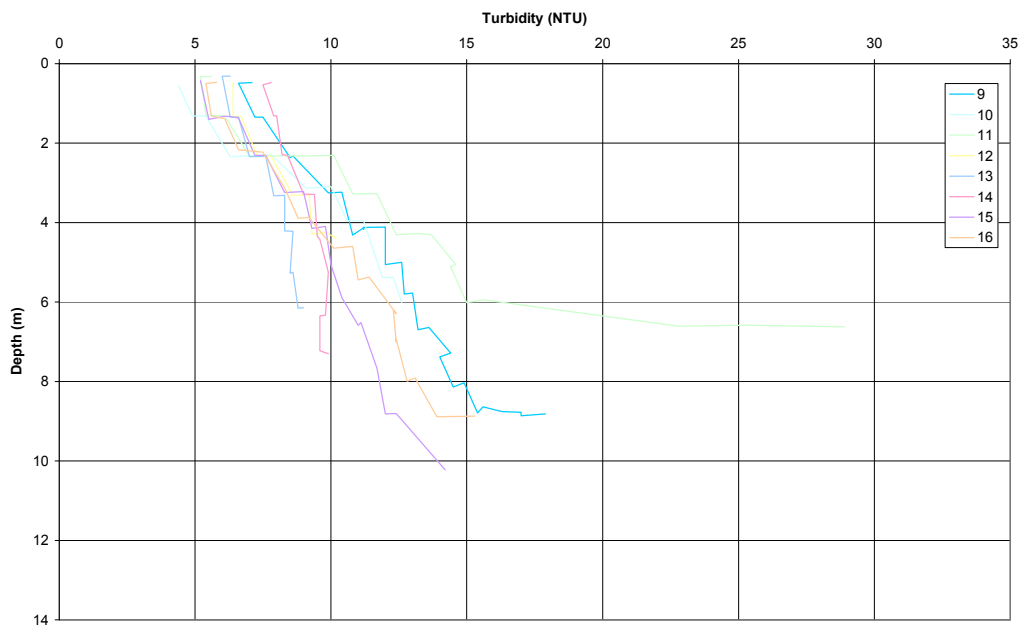


Figure 4-12 Mid sites turbidity- Campaign 1

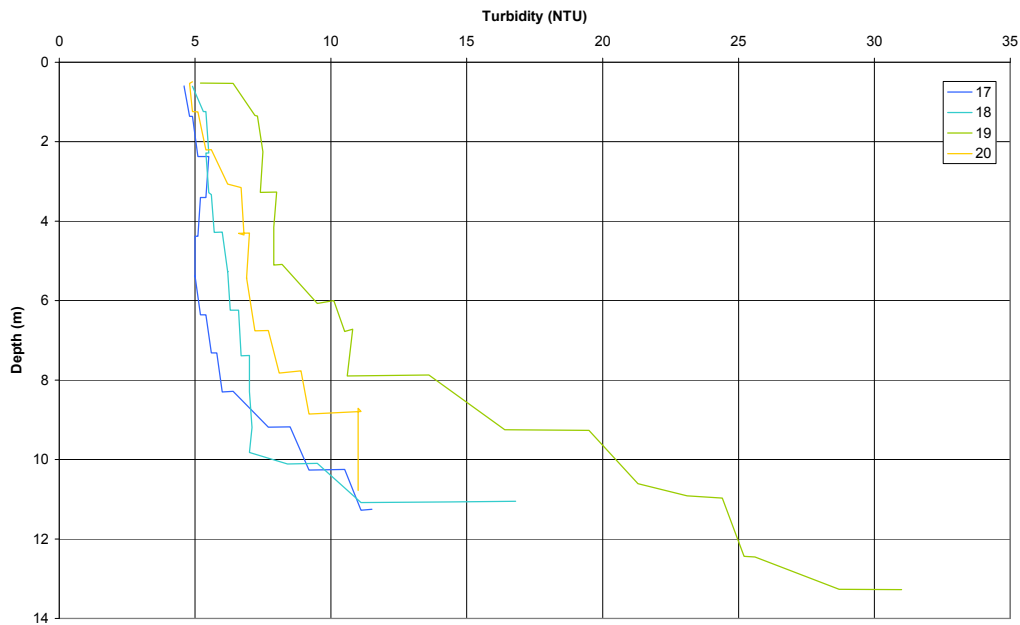


Figure 4-13 Southern sites turbidity- Campaign 1

Noting that the dataset is very small and should not be viewed as representative of long term trends in the area, there are nonetheless some features of the data that deserve comment.

The key feature of all profiles, regardless of location, is the observed increase in turbidity with depth. This is consistent with bedload resuspension being an important process contributing to water column turbidity in the system. This is a well-know characteristic of the Port Curtis marine environment.

The second observation is that there appears to be a gradient in ambient turbidity from north to south, within the constraints of the data set size. This gradient is from approximately 15 NTU in the north to 7 NTU in the south, at mid depth. Allied current measurements at both the north and south locations (which correspond approximately to the spatial divisions adopted in this analysis) over the preceding ebb tides of all measurements show that the northern location consistently experienced peak tidal velocities approximately 10 cm/s greater than in the south. These elevated velocities and turbidities in the northern region are thus again consistent with the notion of tidal bedload resuspension influencing water column turbidity.

This potential relationship was identified in the field after a brief review of the above YSI data, and as such a final suite of profiles was collected at a single (southern) location at the onset of a flooding tide. The results are shown in Figure 4-14.

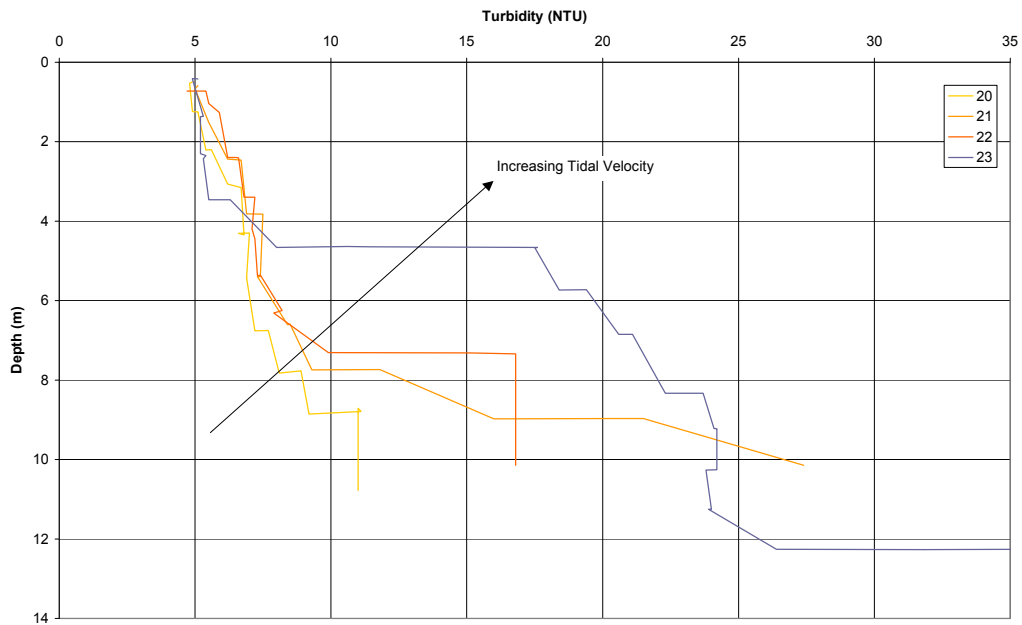


Figure 4-14 YSI turbidity profiles at a single location during the onset of a flood tide-Campaign 1

The data in the figure are again consistent with tidal resuspension of bedload, in that the turbidity profiles show increasing turbidity with depth and time as the flood tide intensifies.

Qualitative field observations were made near RG Tanna wharf on the morning of the 6th February, where significant fresh (and turbid) flows were seen exiting the Calliope River and heading out to sea with the ebbing tide. A photo of these outflows passing the RG Tanna wharf is shown below.



Figure 4-15 Interface of Calliope River turbid freshwater outflow during campaign 1

Campaign 2 (June)

In the second analysis, it was decided to exploit the greater temporal spread of casts around tidal maxima and minima to further investigate the potential influence of tidal currents on ambient turbidity. As such, all 10 high and low water turbidity casts are presented together in Figure 4-16 and Figure 4-17, respectively. Profiles were taken in order of their numerical label, from 1 to 10.

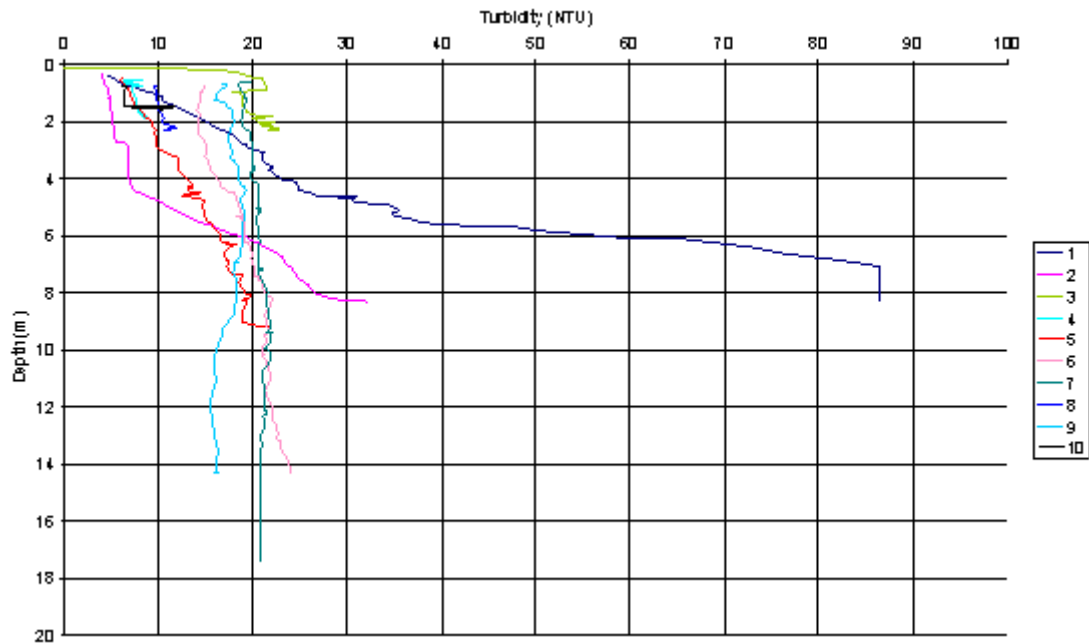


Figure 4-16 YSI turbidity profiles - Campaign 2 High Water

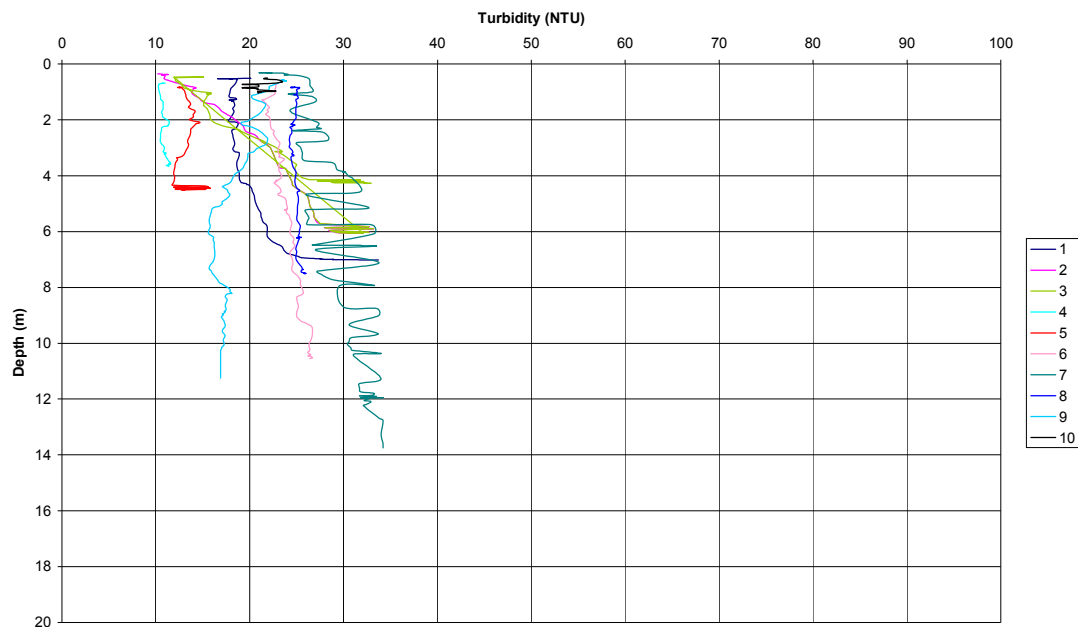


Figure 4-17 YSI turbidity profiles - Campaign 2 Low Water

In general, the magnitudes of the turbidities are similar to those of the first campaign. Both high and low tide surveys show evidence of decreasing vertical variation in turbidity with decreasing tidal velocity, and this is particularly pronounced in the high tide measurements. For example, profiles 1 and 2 show evidence of this stratification, whilst profiles 5, 6 and 7 do not, with the latter being collected close to the top of the tide and low tidal velocities. A similar, although less pronounced, trend is evident in the low tide measurements.

The turbidity timeseries data collected as part of Campaign 2 at the southern current meter site are presented below, together with the recorded current data.

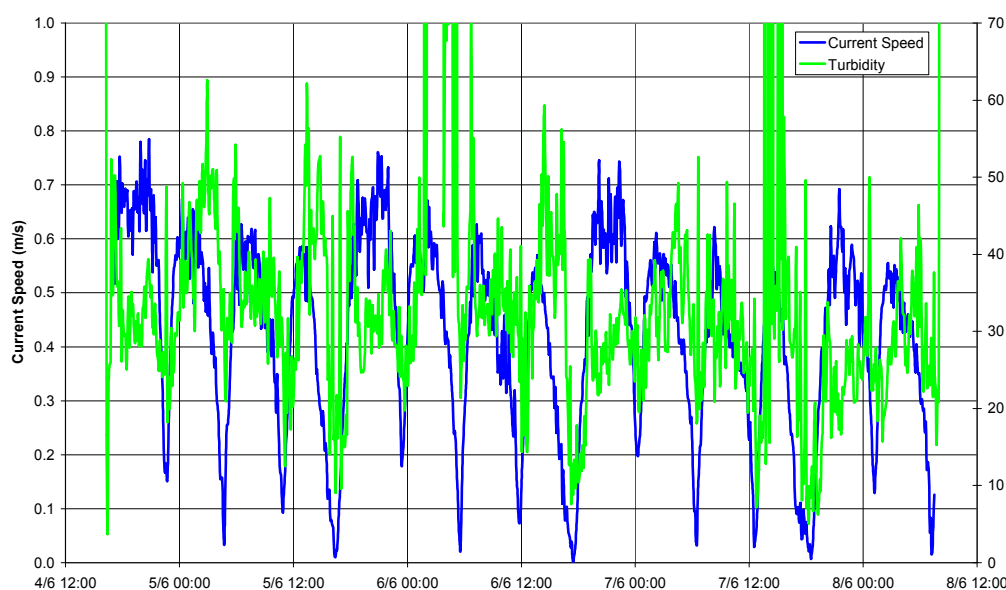


Figure 4-18 Turbidity timeseries at southern S4 site- campaign 2

Figure 4-18 clearly demonstrates the relationship between tidal current speed and turbidity, with the peaks and troughs in both data sets generally being well aligned.

High and low tide water quality grab samples were also collected at 10 locations as part of Campaign 2.

Suspended sediment concentrations are generally consistent with a high energy environment where current-driven sediment resuspension contributes to water column sediment load. Without exception, the TSS concentrations at high tide are less than, or equal to, those at low tide (Table 4-11).

Table 4-11 TSS grab sample results

Site	Tide	TSS (mg/l)
1	H	20
	L	30
2	H	5
	L	25
3	H	30
	L	30
4	H	10
	L	20
5	H	25
	L	25
6	H	30
	L	45
7	H	40
	L	45
8	H	20
	L	45
9	H	30
	L	35
10	H	10
	L	45

4.2.1.8 WBM Port Curtis water quality monitoring program (2001)

A marine water quality monitoring program undertaken by WBM and Capline took place from December 1998 to December 2000 to characterise water quality in the region. Routine sampling was conducted every two months and event based sampling took place following periods of extended or heavy rainfall, major dredging activities or major industrial effluent discharges. The first water quality surveys were designed as a pilot program to trial sampling and measurement techniques and to statistically evaluate the appropriate level of replication for water sampling in subsequent routine and event water quality surveys.

Thirteen routine and four event based surveys were completed in the two year period. The first two event water quality surveys were conducted following significant catchment rainfall in January 1999 and in March 1999. The third survey was conducted in October 1999. The fourth survey was undertaken after heavy catchment rainfall in October 2000.

The water quality monitoring programme used six water quality sampling sites (Figure 4-19) for both routine and event surveys.

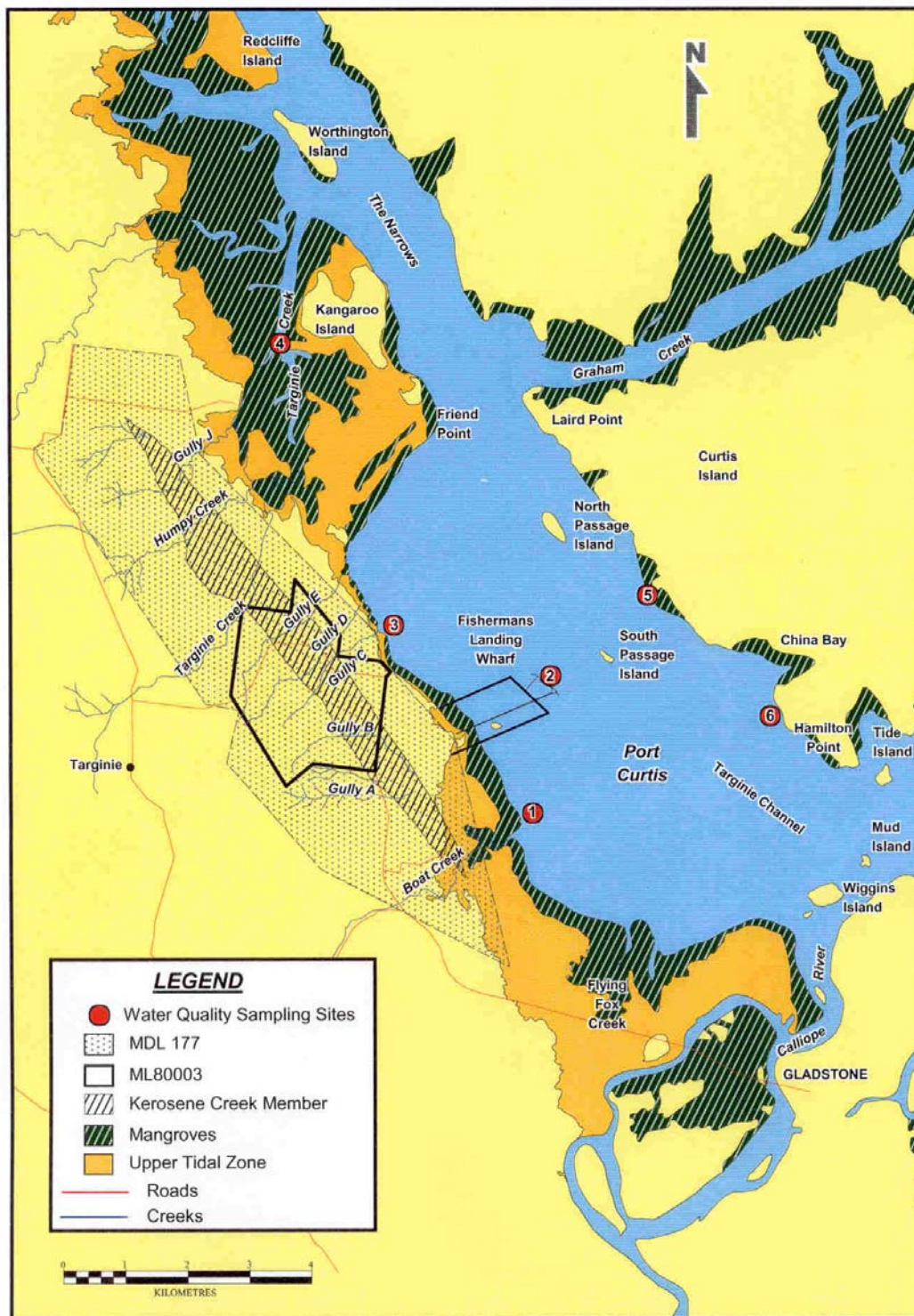


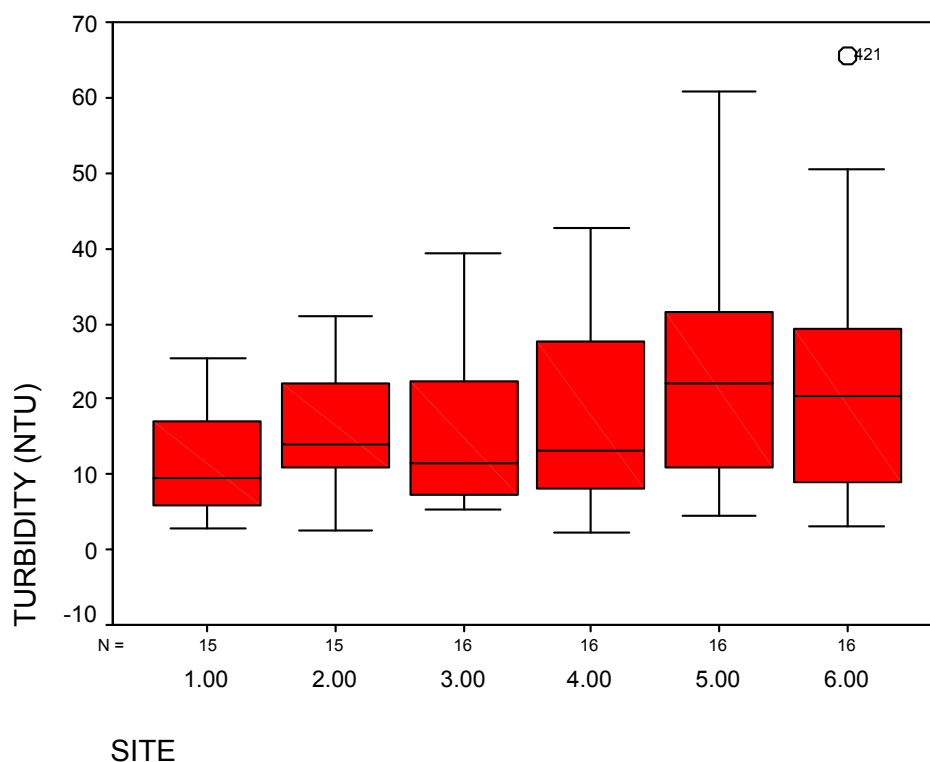
Figure 4-19 WBM water quality monitoring sites (WBM, 2001)

A summary of the mean (plus or minus one standard deviation) and range for all in-situ turbidity measurements and the TSS laboratory analysis from all of the water samples collected from each site is shown in Table 4-12.

Table 4-12 Mean, standard deviation and range of turbidity and TSS (1998- 2000) (BMT WBM, 2001)

Site	Parameter			
	Turbidity (NTU)		TSS	
	Mean $\pm$ standard deviation	Range	Mean $\pm$ standard deviation	Range
1. Boat Creek	13.7 $\pm$ 5.5	2.7 -31.8	26.1 $\pm$ 21	8- 79
2. Fishermans Landing	25.0 $\pm$ 20.9	2.5- 143.0	37.2 $\pm$ 23, 44.9 $\pm$ 28	5- 116
3. Gully C	18.6 $\pm$ 16.0	2.6- 85.0	30.0 $\pm$ 21	7- 81
4. Targinie Creek	20.1 $\pm$ 13.9	2.2- 55.0	34.0 $\pm$ 18	3 -65
5. Curtis Island (1)	28.8 $\pm$ 19.8	4.4- 104.0	46.7 $\pm$ 31.0	2 -113
6. Curtis Island (2)	29.9 $\pm$ 24.3	3.0- 168.8	41.9 $\pm$ 31.0	9- 116

Figure 4-20 presents a box and whisker plot for compiled depth measurements for all in-situ turbidity measurements over the 2 year period. Error bars indicate the range of measurements (i.e. maximum and minimum values) recorded for the in-situ parameters.

**Figure 4-20 Box and whisker plot for turbidity (1998-2000) (BMT WBM, 2001)**

Turbidity concentrations demonstrated considerable variability between and within measurement sites. Generally, turbidity was lowest close to the water surface and highest near the seabed. A single high turbidity measurement near the seabed often inflated the depth averaged turbidity concentration presented for a particular site. In general, the depth averaged water turbidity was lowest at sites 1, 3 and 4 (Boat Creek, Gully Creek and Targinie Creek) and highest at Fisherman's Landing (site 2) and at Curtis Island (control sites 5 and 6). The depth averaged turbidities at sites 1, 3 and 4 typically ranged between 15 and 30 NTU. At sites 2, 5 and 6, the average turbidities were more frequently in the range 30-60 NTU. There was a seasonal trend of reduced turbidity (<20 NTU) at most sites in the cooler months of each year (August and October 1999 and April, June August

and October 2000) which is supported, though more pronounced, by the Secchi disc measurements. The Secchi disc measurements illustrate a seasonal peak in water clarity (i.e. low turbidity) in August and October 1999 and again in June 2000.

Deepwater sites 2 and 6 (Fisherman's Wharf and Curtis Island) tended to display the greatest variation in turbidity concentrations between the surface and the seabed. This was likely due to the considerable tidal current speeds ($>1\text{m/s}$) observed at these locations during spring tides. The strong tidal currents readily suspended fine bed sediments into the water column, thereby increasing the water turbidity.

Turbidities measured following significant catchment runoff in January and March 1999 were elevated, though only slightly, above concentrations measured during some of the routine surveys. However the water turbidities in November 2000 (event survey No.4) were not notably elevated by catchment runoff. Catchment runoff appeared to influence the turbidity of water at Gully C following the rainfall event in March 1999, where discharges from the study area may have increased the turbidity of the receiving water.

It appears that the combination of season, wind speed, direction and tidal range and/or tidal height has as important influence on water turbidities as does catchment runoff. Water quality measurements coincided with very high tides (above a predicted height of 4.3m) and large range tides in February and October 1999 and in August and December 2000. Measured turbidities were on average highest and displayed more variation during conditions of large spring tides and moderate winds in February 1999 than at any other time. However, tides of equal or higher range and height, which occurred at times of light wind, for example during August and December 2000 coincided with lower turbidity conditions. The turbidities measured in August 2000 were by comparison quite low even though the tidal height, range and weather conditions were similar to conditions in December 2000. This suggests that perhaps there are seasonal or other influences (e.g. such as the phase of the spring tide cycle or preceding weather conditions) which are important in controlling the water turbidity.

Suspended solids concentrations were generally highest during the spring tidal conditions in February 1999, February 2000 and December 2000.

The peak suspended solids concentration (116 mg/L) occurred at site 6, (Curtis Island) in February 1999 and also at site 2B (Fisherman's Landing) in March 1999, following significant catchment rainfall. The suspended solids concentration generally varied between 5 and 70 mg/L at most locations. Suspended solids concentrations at or exceeding 80 mg/L were recorded for all locations.

Suspended solids concentrations less than 10 mg/L were recorded at most sites in June 1999. Whilst the suspended solids concentrations, generally based on surface water samples were lowest in June 1999, the highest water clarity (based upon turbidity profiles and Secchi disc measurements) occurred during the August and October 1999 and June 2000 surveys.

4.2.1.9 WBM marine water quality review (1999)

BMT WBM reviewed several historical water quality data sets dating from 1977 to 1999, including several BMT WBM studies. The locations of these studies are shown below in Figure 4-21.

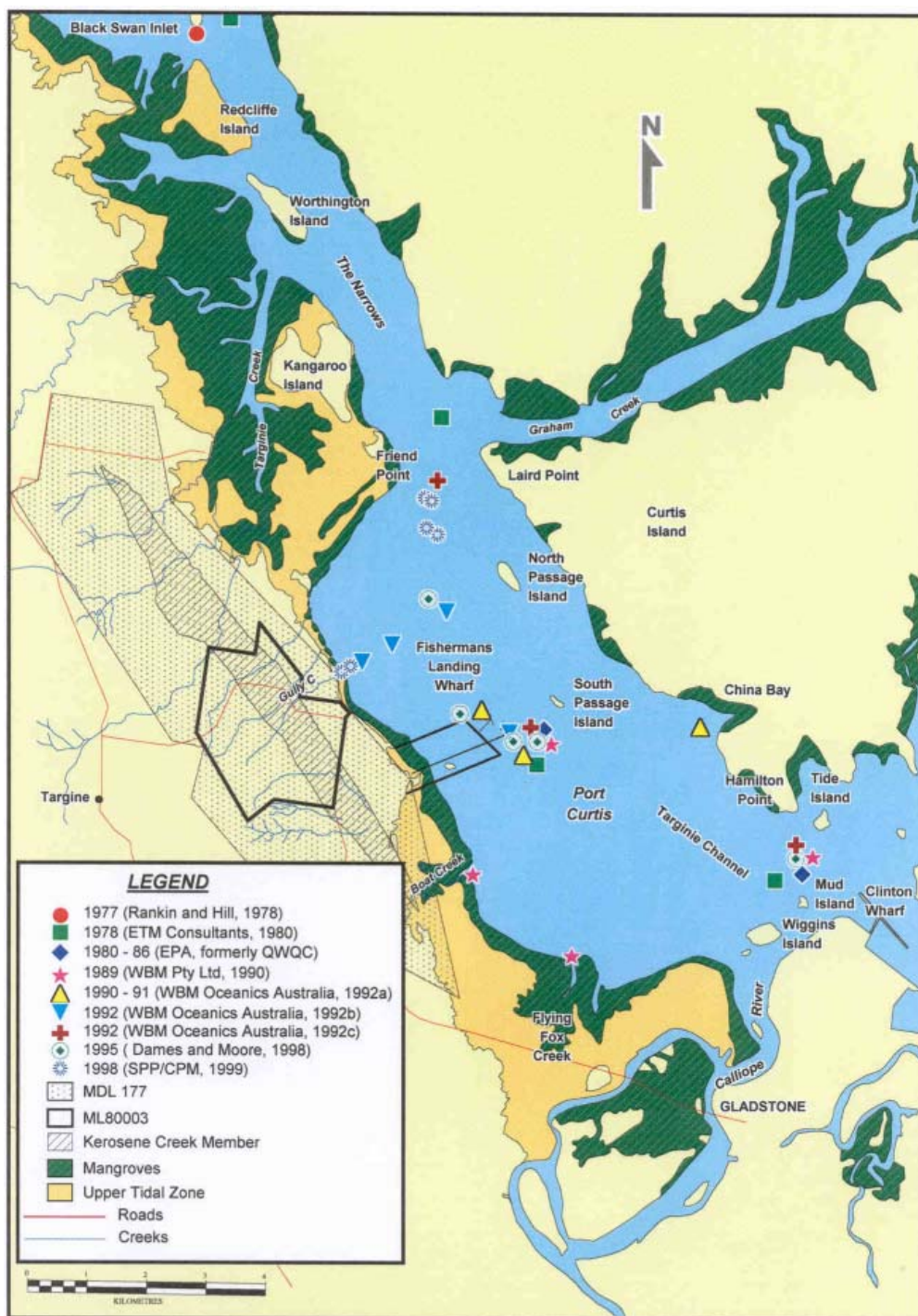


Figure 4-21 Previous water quality sampling locations (WBM, 1999)

As illustrated in Figure 4-21 there exists a wide spatial scatter of previous water quality information collected from Port Curtis between 1977 and 1999. The data also spans a range of tidal and weather conditions. However there are several general sampling locations for which much information already exists. These general locations (to include locations within a 1km radius of the following locations) were selected by WBM in 1999 to provide a summary of the most recent 10 years of collected water quality information from the above studies. These general locations relevant to Port Curtis are:

- 1 Friend Point;

- 2 Gully C;
- 3 Fisherman's Landing wharf; and
- 4 Hamilton Point, Curtis Island.

Table 2-9 below summarises the range of previous water quality data for surface waters at these locations over 10 years (1989-1999).

Table 4-13 Range of turbidity and suspended solids data compiled from previous reports (WBM, 1999)

Parameter	Unit	Friend Point	Gully C	Fishermans Landing	Hamilton Point
Turbidity	NTU	4-10	11-28	3.3-16	7-10
Suspended Solids	mg/L	8-23	-	10-25	8-14

Turbidities and suspended solids concentrations were moderate being generally less than 30 NTU and 30 mg/L respectively.

4.2.2 Sediment Deposition

Sediment traps were deployed by URS at seven sensitive receptor locations (Figure 4-22) around Port Curtis on 27 August 2009 and retrieved on 21 September 2009.



Figure 4-22 URS sediment trap sites

Table 4-14 Sedimentation rate results from URS sediment traps (URS, 2009)

Trap Site	Coordinates		Site Replicate	TSS (mg/L)	SD	Deployment Length (d)	Trap Dimensions				Trap Gross Sediment Mass (mg)	Trap Baseline Sedimentation (mg/cm ² /d)	Mean Site Baseline Sediment MAR (mg dry wt/cm ² /d)
	Latitude	Longitude					Height (cm)	Diameter (cm)	Collection Area (cm ²)	Trap Volume (L)			
1	-23.751638	151.161231	A	10400	1380	25	45	5	19.635	0.884	9189	18.72	17.55
			B	11200		25	45	5	19.635	0.884	9896	20.16	
			C	9400		25	45	5	19.635	0.884	8306	16.92	
			D	8000		25	45	5	19.635	0.884	7069	14.40	
2	-23.751804	151.175639	A	10100	3104	25	45	5	19.635	0.884	8924	18.18	20.93
			B	8020		25	45	5	19.635	0.884	7086	14.44	
			C	14600		25	45	5	19.635	0.884	12900	26.28	
			D	13800		25	45	5	19.635	0.884	12193	24.84	
3	-23.759169	151.174564	A	12200	1430	25	45	5	19.635	0.884	10780	21.96	20.12
			B	12400		25	45	5	19.635	0.884	10956	22.32	
			C	10800		25	45	5	19.635	0.884	9543	19.44	
			D	9320		25	45	5	19.635	0.884	8235	16.78	
4	-23.763383	151.185458	A	16100	1328	25	45	5	19.635	0.884	14226	28.98	25.52
			B	13400		25	45	5	19.635	0.884	11840	24.12	
			C	13200		25	45	5	19.635	0.884	11663	23.76	
			D	14000		25	45	5	19.635	0.884	12370	25.20	
5	-23.769924	151.180984	A	14000	3297	25	45	5	19.635	0.884	12370	25.20	22.94
			B	13900		25	45	5	19.635	0.884	12282	25.02	
			C	15200		25	45	5	19.635	0.884	13430	27.36	
			D	7880		25	45	5	19.635	0.884	6963	14.18	
6	-23.782494	151.190269	A	9080	4004	25	45	5	19.635	0.884	8023	16.34	24.25
			B	13800		25	45	5	19.635	0.884	12193	24.84	
			C	12300		25	45	5	19.635	0.884	10868	22.14	
			D	18700		25	45	5	19.635	0.884	16523	33.66	
7	-23.781767	151.200643	A	9550	1407	25	45	5	19.635	0.884	8438	17.19	16.07
			B	10600		25	45	5	19.635	0.884	9366	19.08	
			C	7520		25	45	5	19.635	0.884	6644	13.54	
			D	8050		25	45	5	19.635	0.884	7113	14.49	

4.2.3 Remote Sensing

4.2.3.1 CRC Port Curtis remote sensing task (2005)

This study utilised Landsat images in conjunction with field measurements (sampling sites in Figure 4-23) to map the constituents controlling the optical properties of water, namely coloured dissolved organic material (CDOM), tripton and total suspended inorganic material (TSM) and also to map the transparency and substratum type and cover (Dekker and Phinn, 2005).



Figure 4-23 Port Curtis sample sites (Dekker and Phinn, 2005)

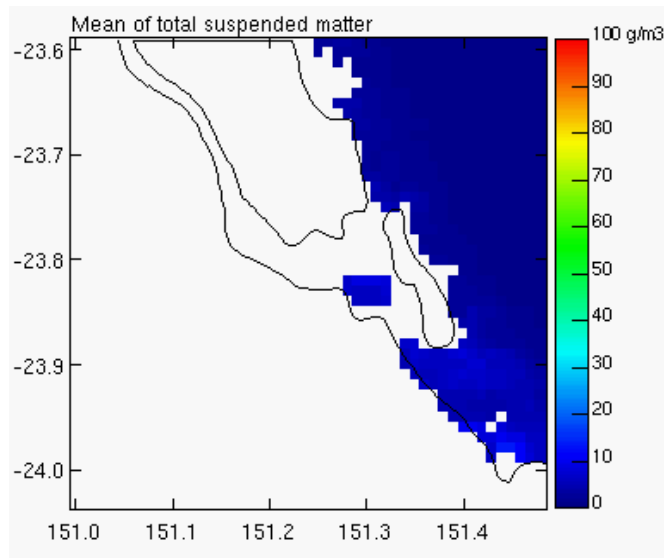
A Total Suspended Matter (TSM) to tripton (lifeless component of suspended matter) ratio close to 1 indicates a dominance of TSM and relatively very low chlorophyll a contents. Table 4-15 shows that the tripton to TSM ratio is very close to 1 at all sites.

Table 4-15 TSM concentrations for Port Curtis sites sampled in January and June 2002 (Dekker and Phinn, 2005)

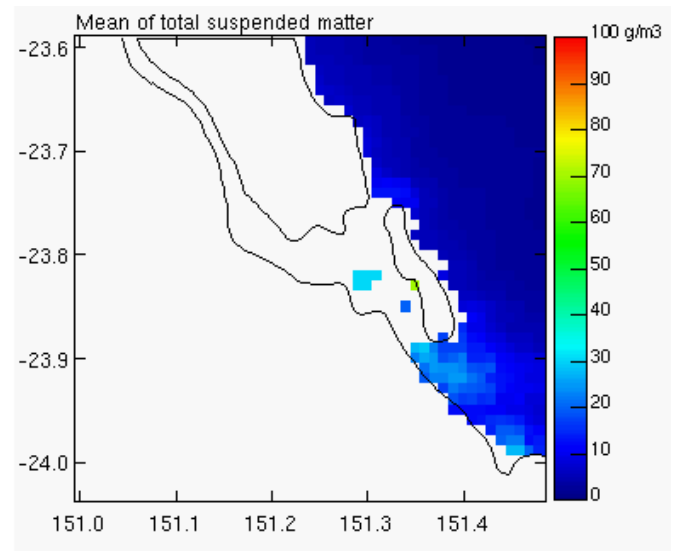
Site	Site description	TSM (mg/L)	Tripton/TSM
PC_OAK	Northern edge of Facing Island at 'The Oakes'	10.8	0.998
PC_QUI	SW of Quoin Island	12.2	0.996
PC_QIS	SW of Quoin Island	10.5	0.994
PC_STI	South Trees Inlet (upstream causeway of QLD alumina)	10.3	0.992
PC_WIG	Wiggins Island (mouth of Calliope River)	12.4	0.995

4.2.3.2 BMT ARGOSS 1km resolution mean TSM spatial maps (2008)

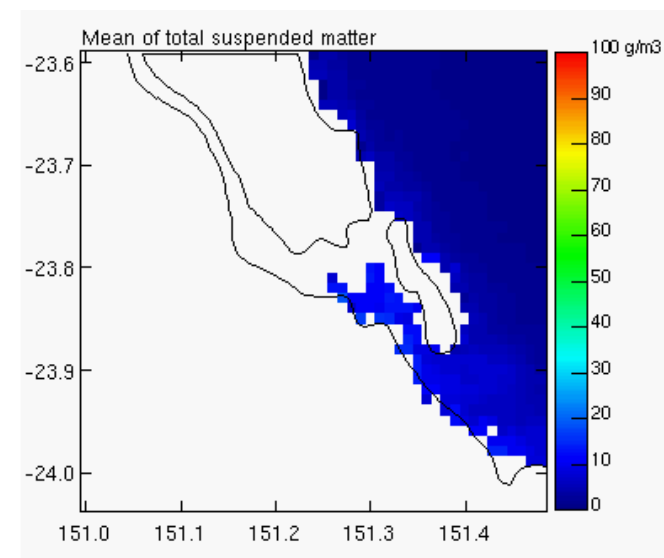
Maps of remotely sensed total suspended matter (TSM – analogous to total suspended solids if there are low algal carbon levels) concentrations have been prepared for this study by BMT WBM via the BMT ARGOSS web-interface. TSM data are retrieved from SeaWiFS SeaStar, MODIS Terra and MODIS Aqua optical remote sensing data at a resolution of 1km. Mean TSM spatial maps are presented below for each month of 2008.



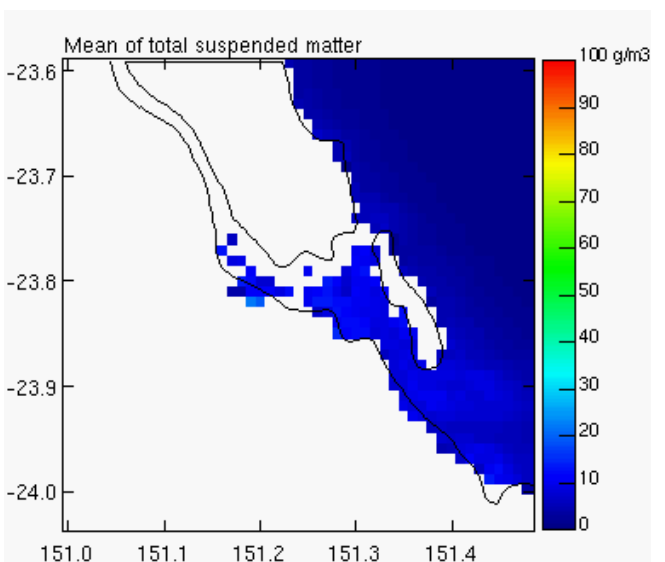
January 2008



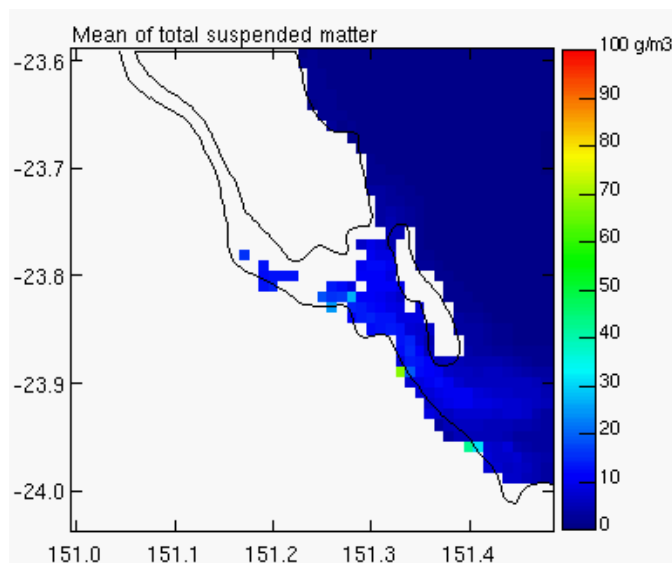
February 2008



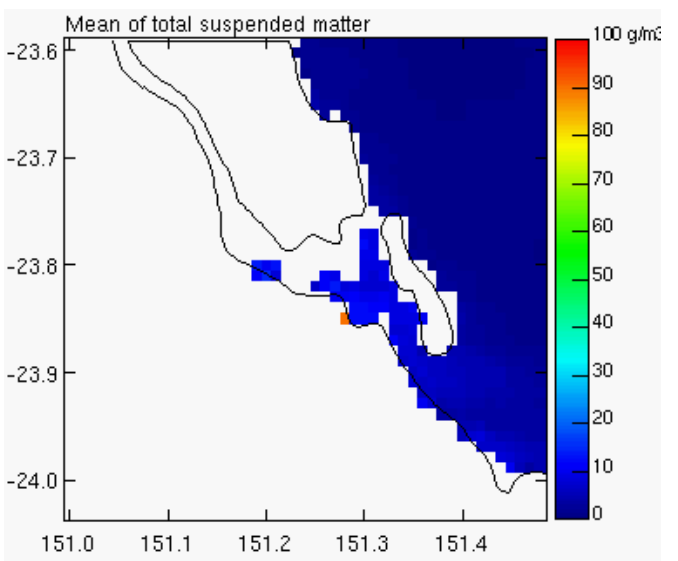
March 2008



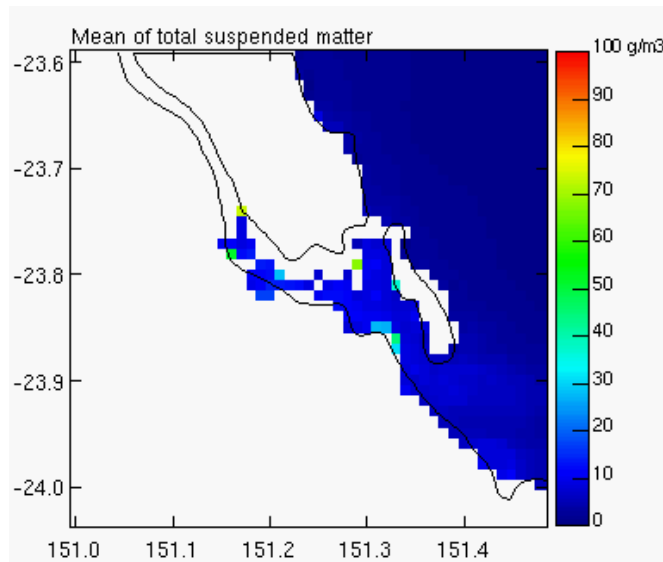
April 2008



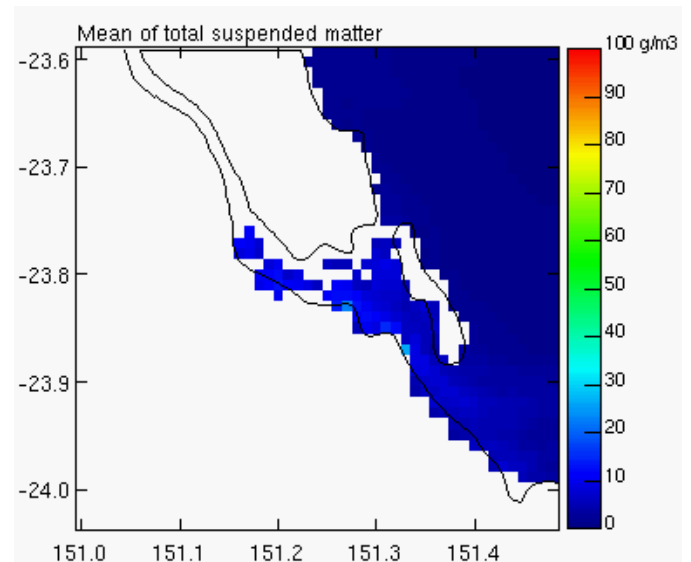
May 2008



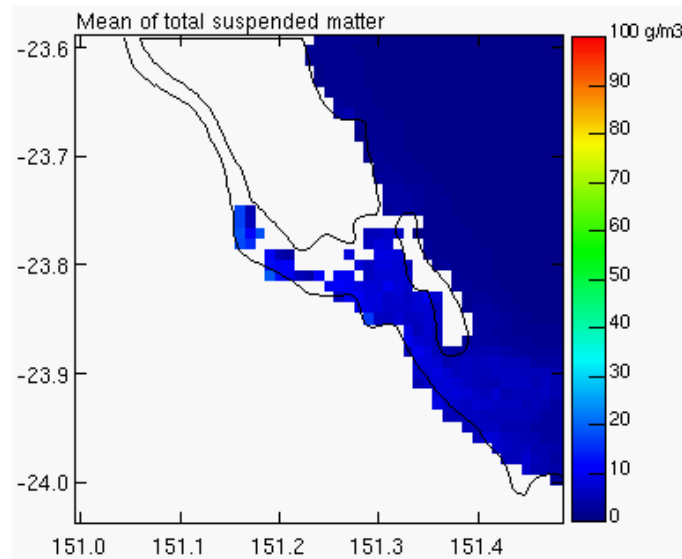
June 2008



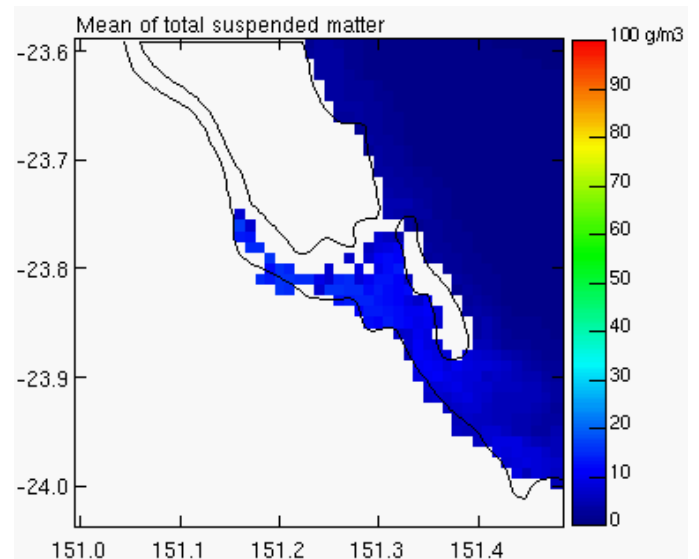
July 2008



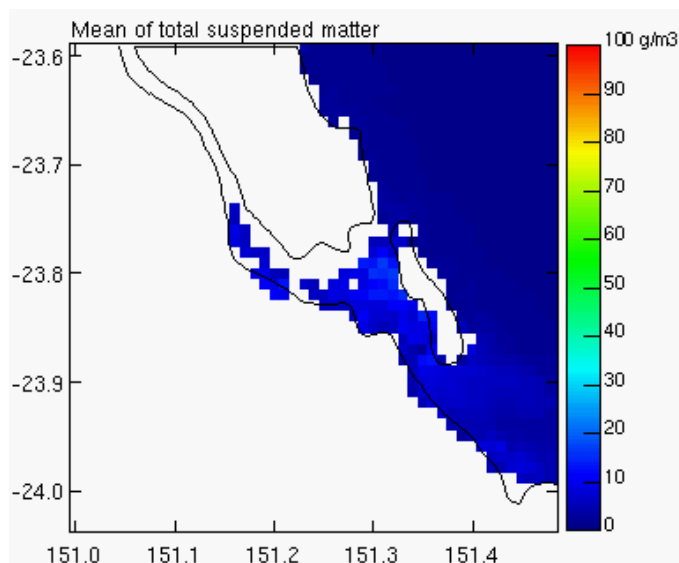
August 2008



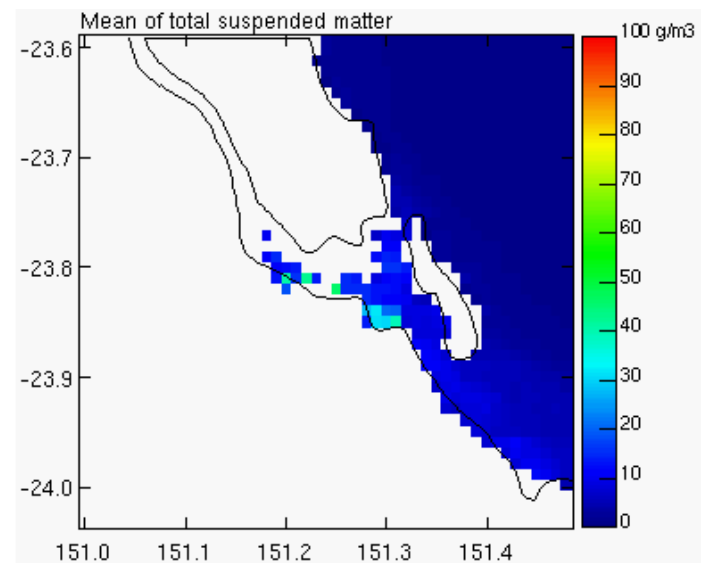
September 2008



October 2008



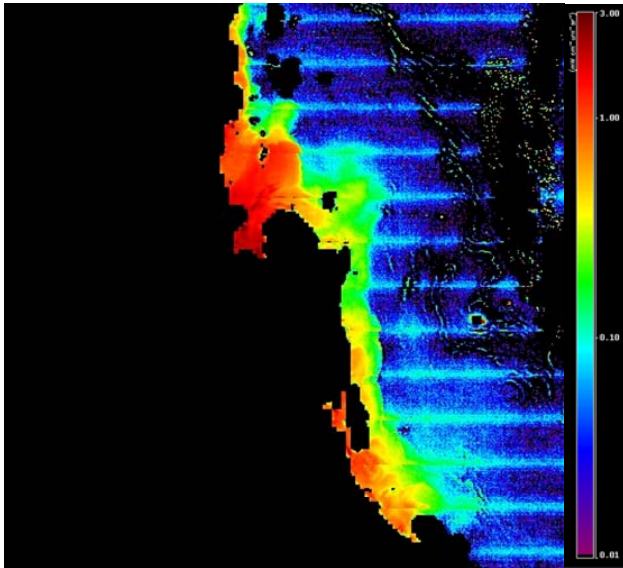
November 2008



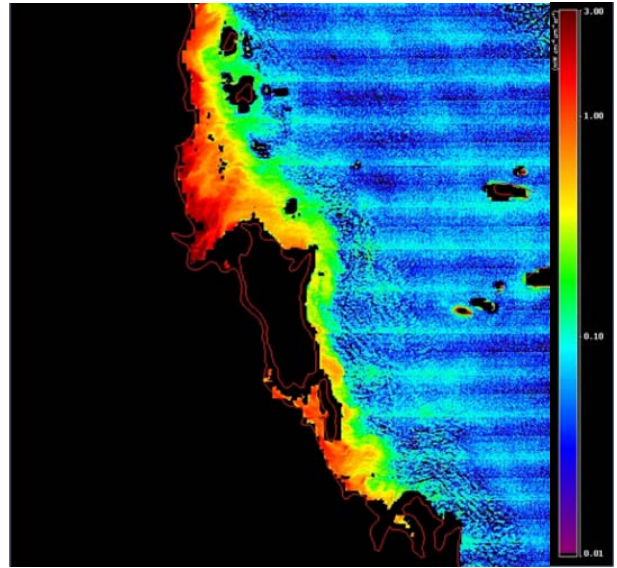
December 2008

4.2.3.3 MODIS 250m resolution spatial maps (2009)

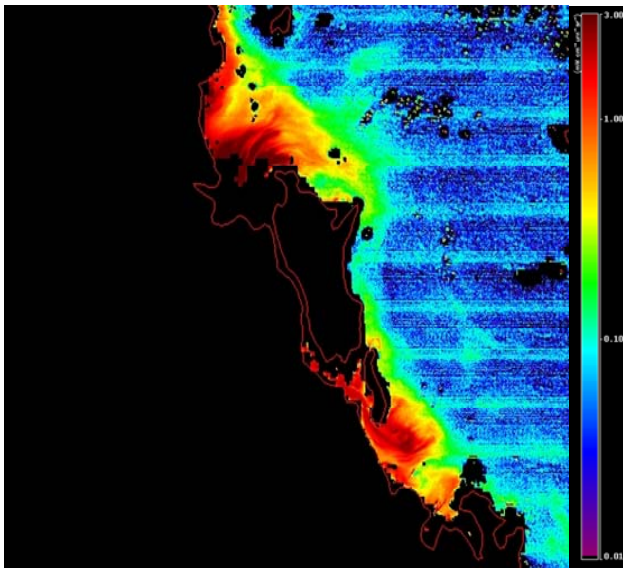
Level 0 MODIS Aqua data was also processed to high resolution level 2 for several recent surveys and displayed with the red 645 bandwidth, which is a good indicator of water column turbidity. These images are displayed below.



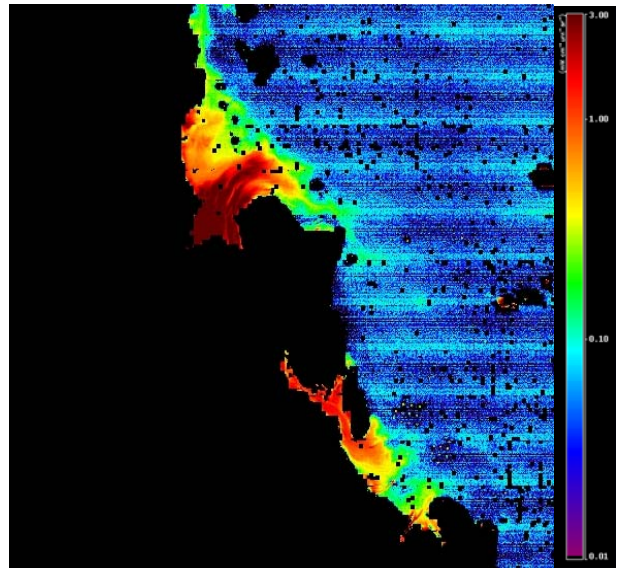
15th February 2009



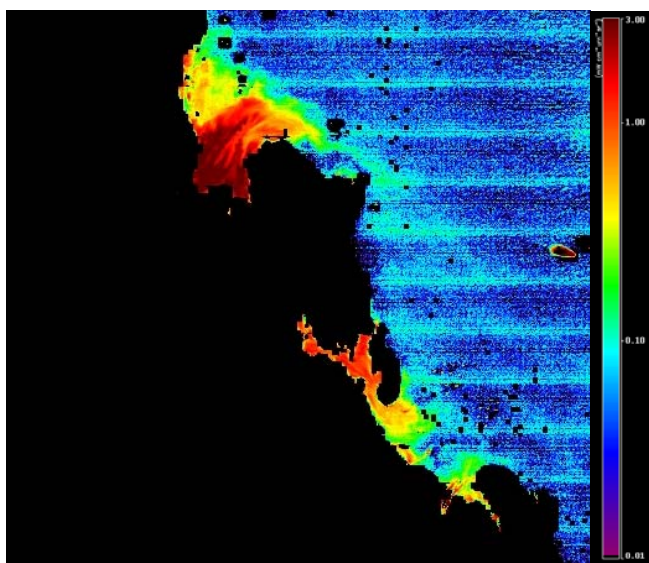
1st April 2009



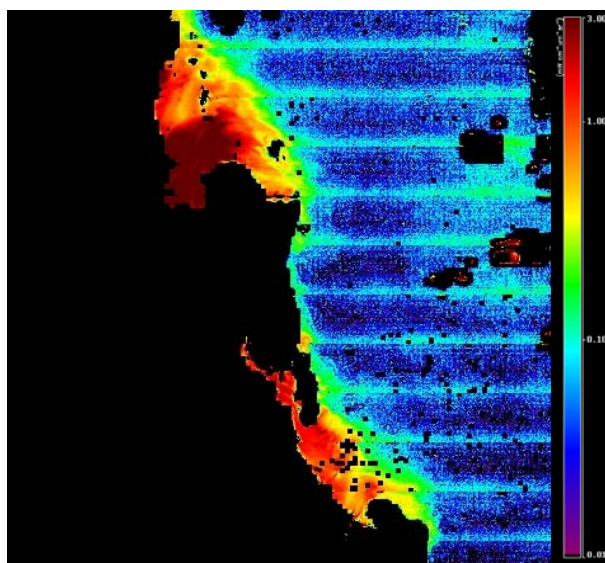
24th April 2009



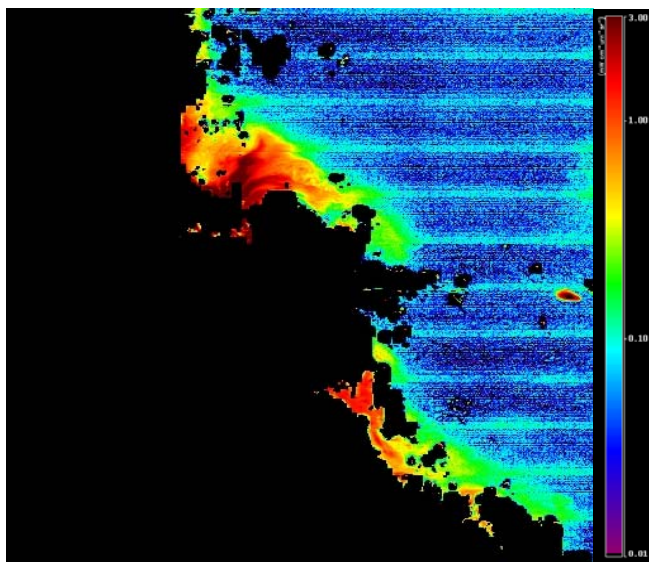
9th June 2009



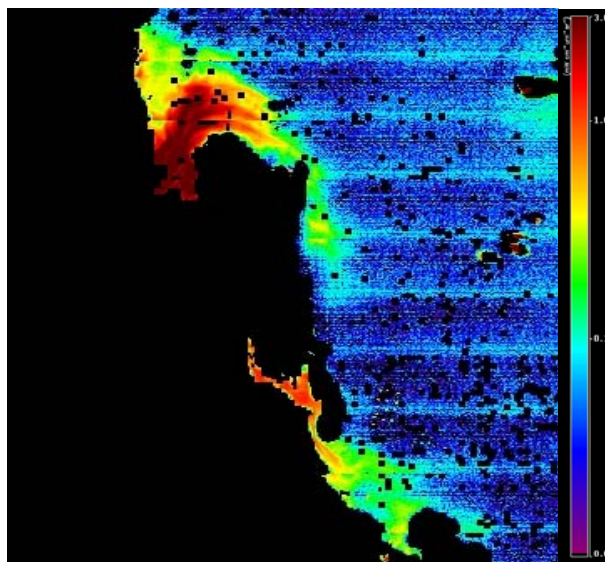
11th June 2009



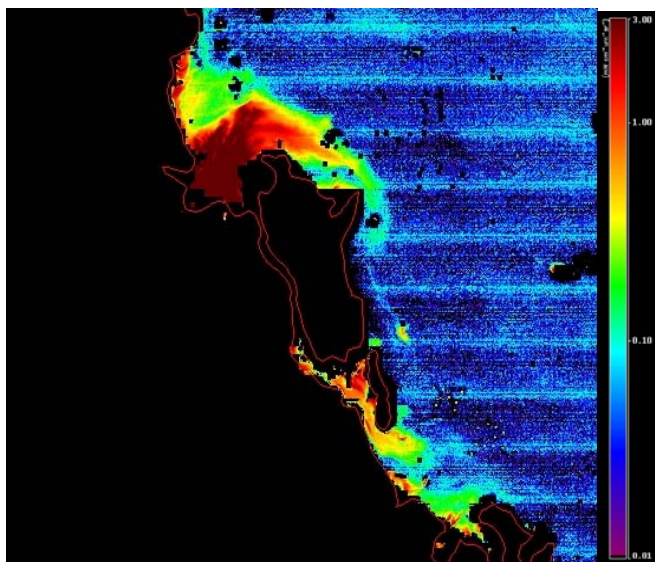
23rd June 2009



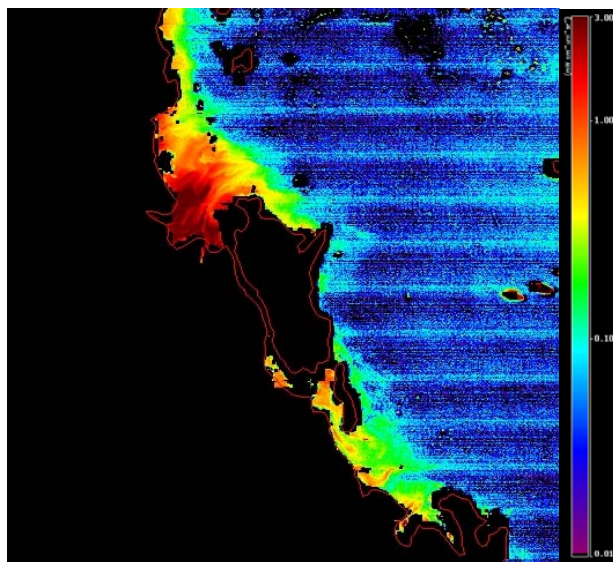
27th June 2009



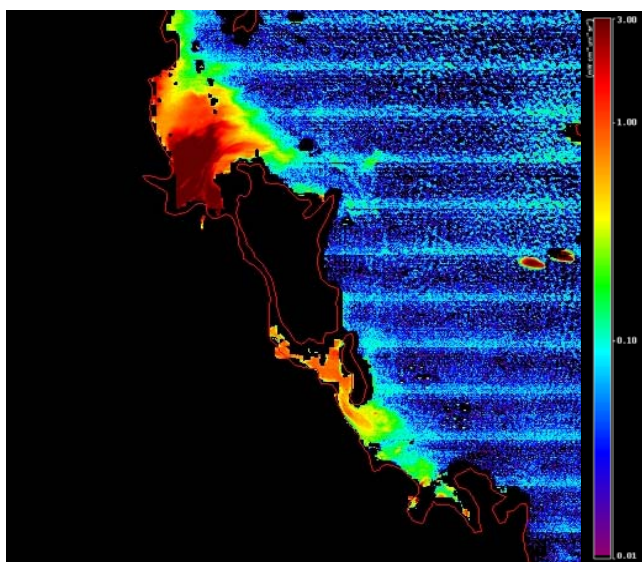
29th June 2009



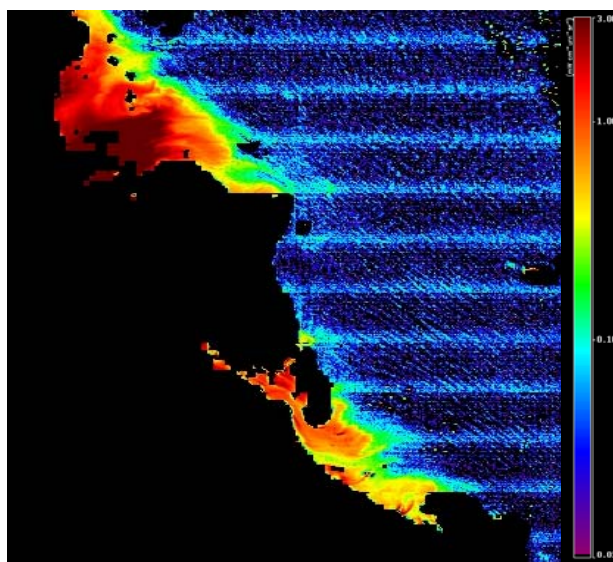
4th July 2009



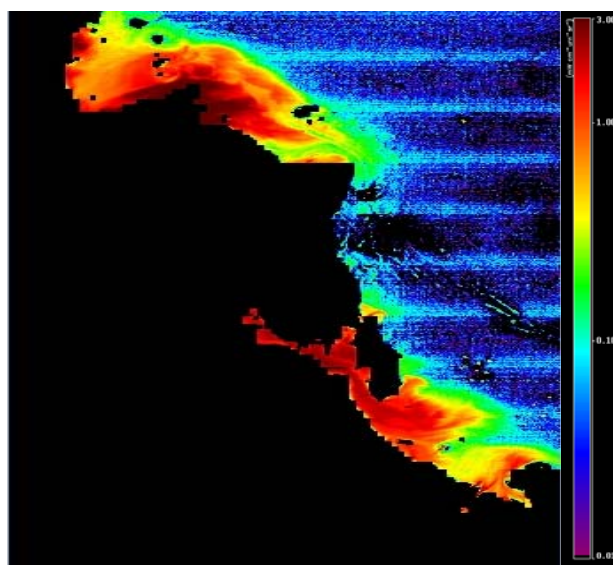
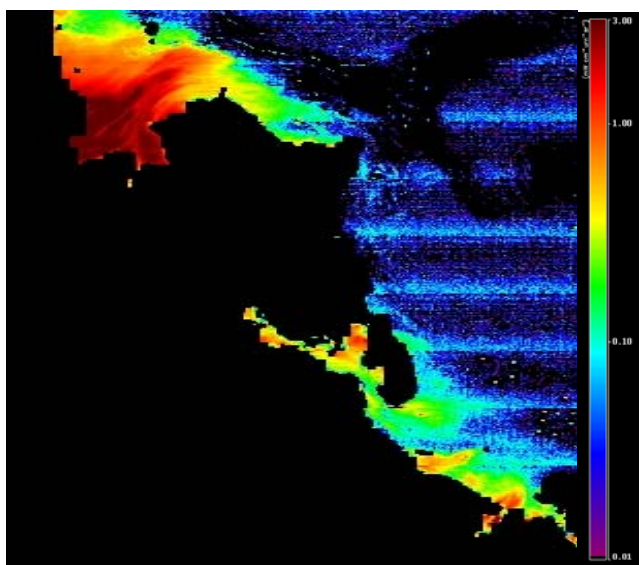
13th July 2009



29th July 2009



5th August 2009



4.3 Summary of Baseline Turbidity and TSS Levels in Eastern Port Curtis

- Primary variations in spatial distribution and nature of Coloured Dissolved Matter, Total Suspended Matter and Secchi depth appear to be controlled by tidal stage and stream flow of major rivers flowing into the harbour;
- Water clarity as defined by Secchi disc visibility is generally poor, being less than 2 m. Similarly, turbidities and suspended solids concentrations are moderate, and also highly variable; and
- Turbidity increases with depth and tidal velocity, most likely due to bottom sediment resuspension.

Table 4-16 Summary of turbidity, TSS and sedimentation data in Eastern Port Curtis

Data Source	Location	Range	Median
Turbidity (NTU)			
DEH/DNR (1999)	Calliope River mouth		<30
EPA (2002-2008)	Calliope River mouth		10
NLWRA (1988 and 2001)	Calliope River mouth		9
GPA (1998)	Clinton and Boyne Island Wharves	1- 40	
PCIMP (2005)	'Site C2' (China Bay)		5.6
PCIMP (2005)	'Site P2' (Hamilton Point)		5.4
PCIMP (2006)	Inner Harbour/ Fishermans Landing		8.8
PCIMP (July 2007)	Inner Harbour/Fishermans Landing		5.7
PCIMP (Sept 2007)	Inner Harbour/Fishermans Landing		3.9
BMT WBM (2009)	North Passage Island channel	2-35	
BMT WBM (February 2008)	Eastern Port Curtis	4-14	
BMT WBM (June 2008)	Eastern Port Curtis	4-26	
WBM (2001)	Curtis Island (1)	4.4- 104.0	28.8
WBM (2001)	Curtis Island (2)	3.0- 168.8	29.9
WBM (1999)	Hamilton Point	7-10	
Total Suspended Solids (mg/L)			
BMT WBM (June 2008)	Eastern Port Curtis	5-45	30
WBM (2001)	Curtis Island (1)	2- 113	46.7
WBM (2001)	Curtis Island (2)	9- 116	41.9
WBM (1999)	Hamilton Point	8-14	
Sedimentation rates (mg dry wt/cm²/d)			
URS	Eastern Port Curtis	16.07- 25.52	

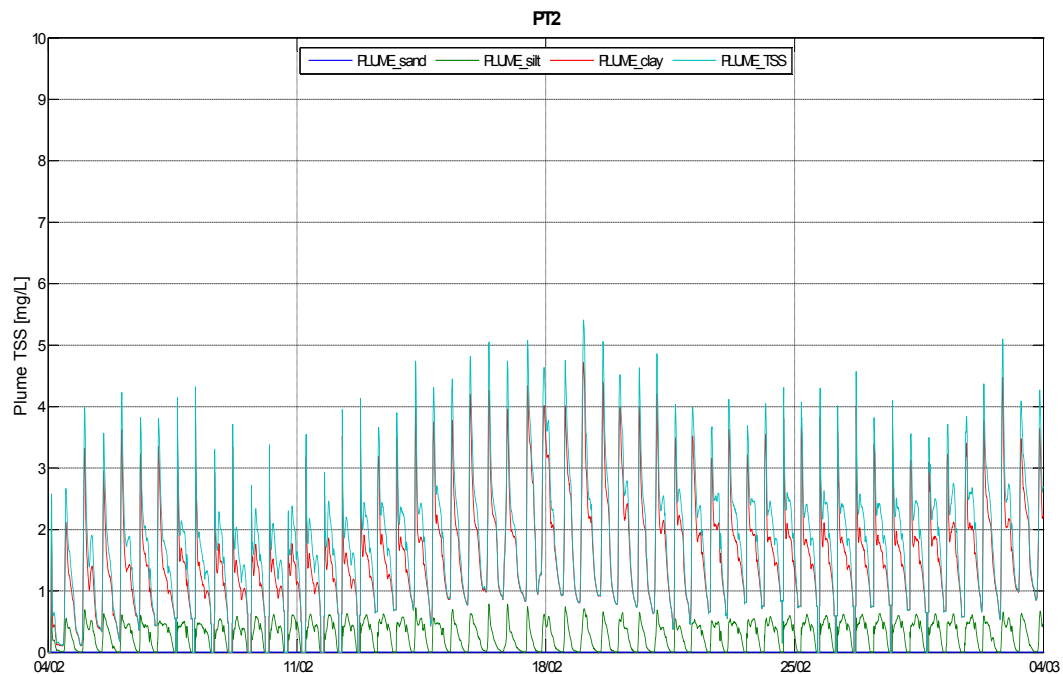
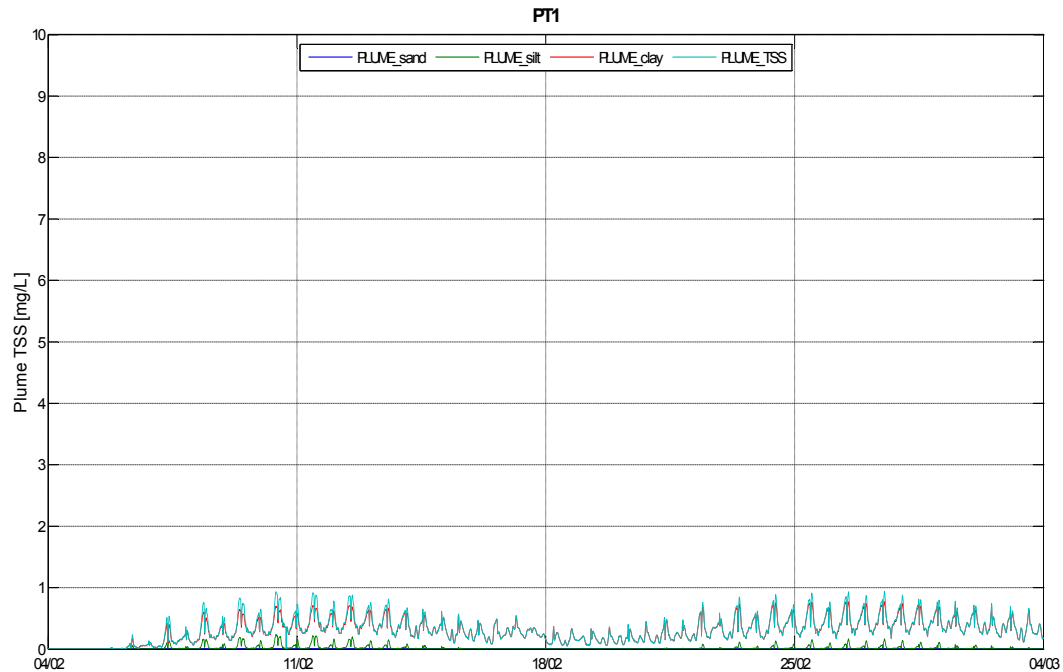
5 REFERENCES

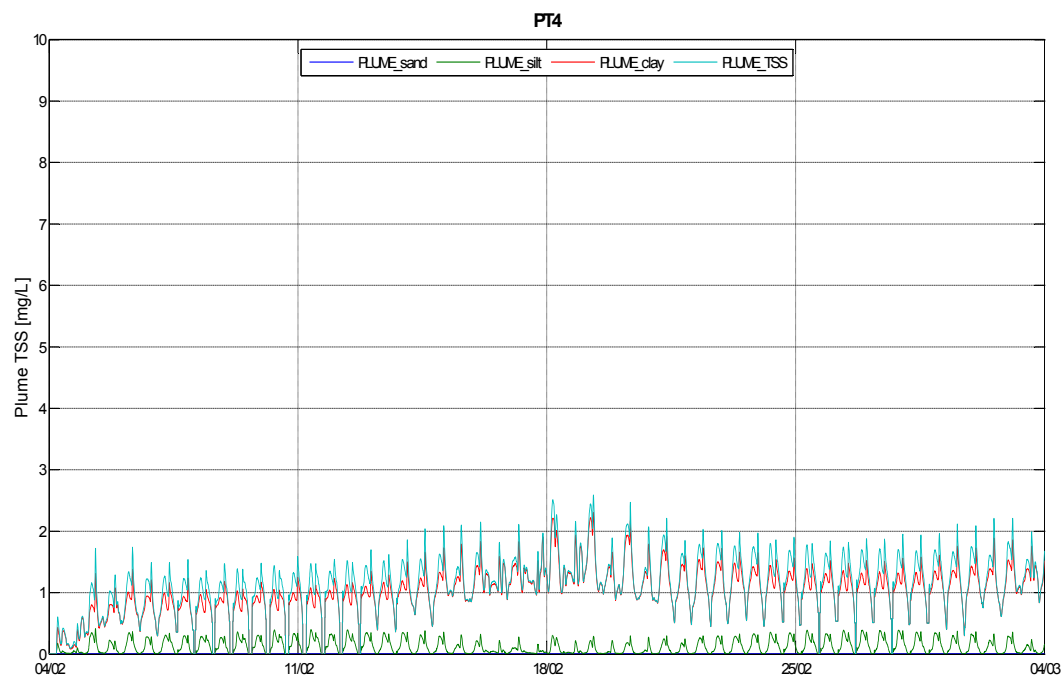
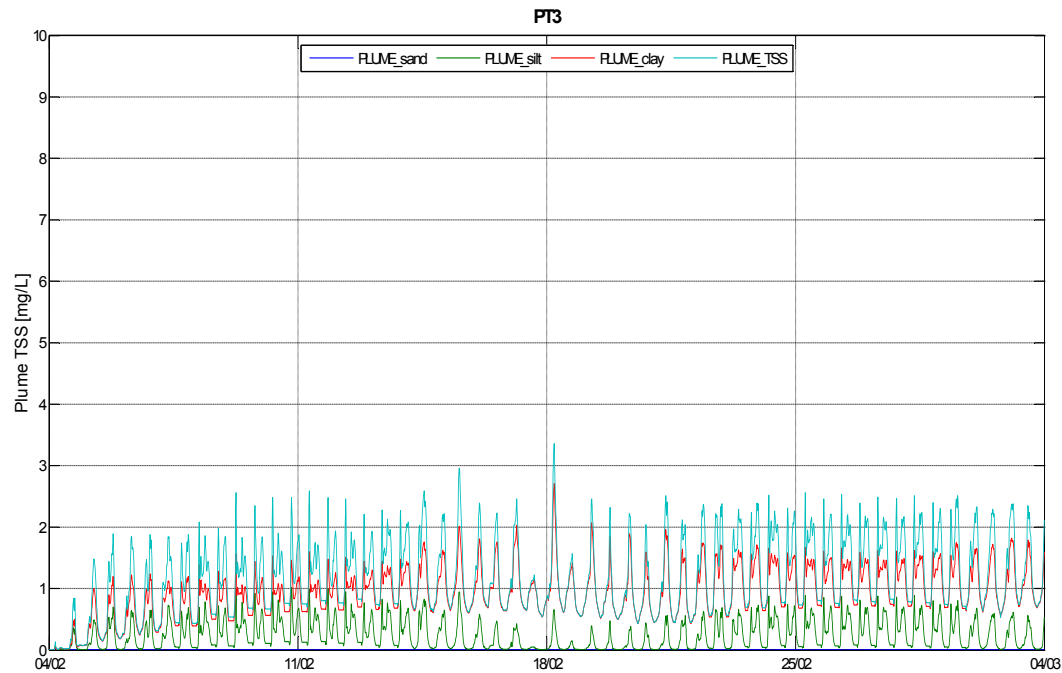
- Anderson, L. E., Melville, F., Teasdale, P.R. and Story, A.W. (2006) 2005 Port Curtis Integrated Monitoring Program: Centre for Environmental Management, Central Queensland University.
- Anderson, L.E., Melville, F., Steinberg, A. N., Teasdale, P.R., Storey, A. W., and Fabbro, L.D. (2007) PCIMP Biomonitoring 2006: Port Curtis Integrated Monitoring Program, Centre for Environmental Management, Central Queensland University.
- Anderson, L.E., Melville, F., Steinberg, A. N., Teasdale, A. W., and Fabbro, L.D. (2008) PCIMP Biomonitoring 2007: Port Curtis Integrated Monitoring Program, Centre for Environmental Management, Central Queensland University.
- Anthony, K.R.N. and Fabricius, K.E. (2000) Shifting roles of heterotrophic and autotrophy in coral energetics under varying turbidity. *Journal of Experimental Marine Biology and Ecology* 252, 221-253.
- ANZECC (2000) National Water Quality Management Strategy. Paper number 4: Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Volume 1. The Guidelines. Chapter 3. http://www.mincos.gov.au/__data/assets/pdf_file/0019/316126/wqg-ch3.pdf
- BMT WBM (2009). Gladstone Harbour Numerical Modelling Calibration and Validation. Report prepared for Gladstone Ports Corporation.
- DEH and DNR (1999) Testing the Waters. A Report on the Quality of Queensland Waters
- Dekker, A.G. and Phinn, S. (2005) Port Curtis and Fitzroy River Estuary Remote Sensing Tasks. Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management. Technical Report No. 23.
- Erftemeijer, P.L.A. and Robin Lewis III, R.R (2006) Environmental impacts of dredging on seagrasses: A review. *Marine pollution Bulletin* 52 1553-1572.
- Harris, P. and O'Brien, P. (1998) Australian Ports: Environmental Data and Risk Analysis Phase 1: Literature review. A report prepared for the Australian Quarantine Inspection Service (ACQUIS). Geoscience Australia
- Hopley, D., Van Woelik, R., Hoyal, D.C.J.P. and Steven, A.D.L. (1991) The effect of disturbing tropical rainforest catchments adjacent to fringing coral reefs through the development of a road: Cape Tribulation, Great Barrier Reef. In *Proc Congress on Coastal and Marine Tourism*, Honolulu, Hawaii. Vol. 2, 328-334.
- HR Wallingford (2009) Gladstone LNG Project. Source terms for plume dispersion modelling. Report prepared for GLNG, HR Wallingford ref EBR4320/111/001.
- Pastorok, R.A., and Bilyard, G.R. (1985) Effects of sewage pollution on coral-reef communities. *Marine Ecology Progress Series* 21, 175-189.
- National Land and Water Resource Audit (NLWRA) (1998 & 2001) Estuarine Assessment for Non-pristine Estuaries.

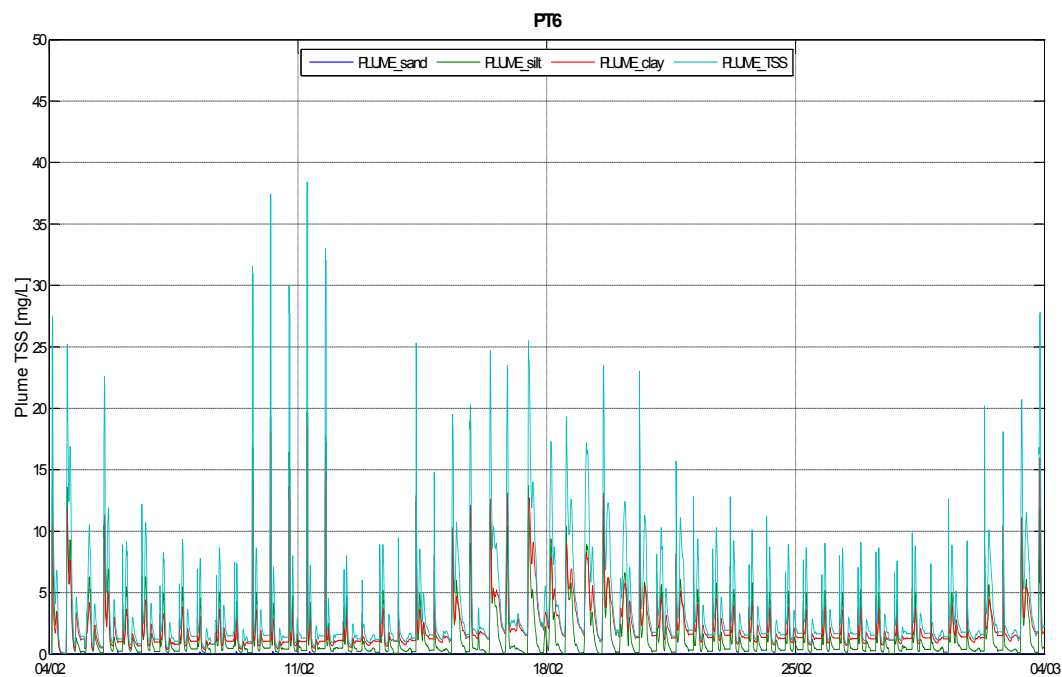
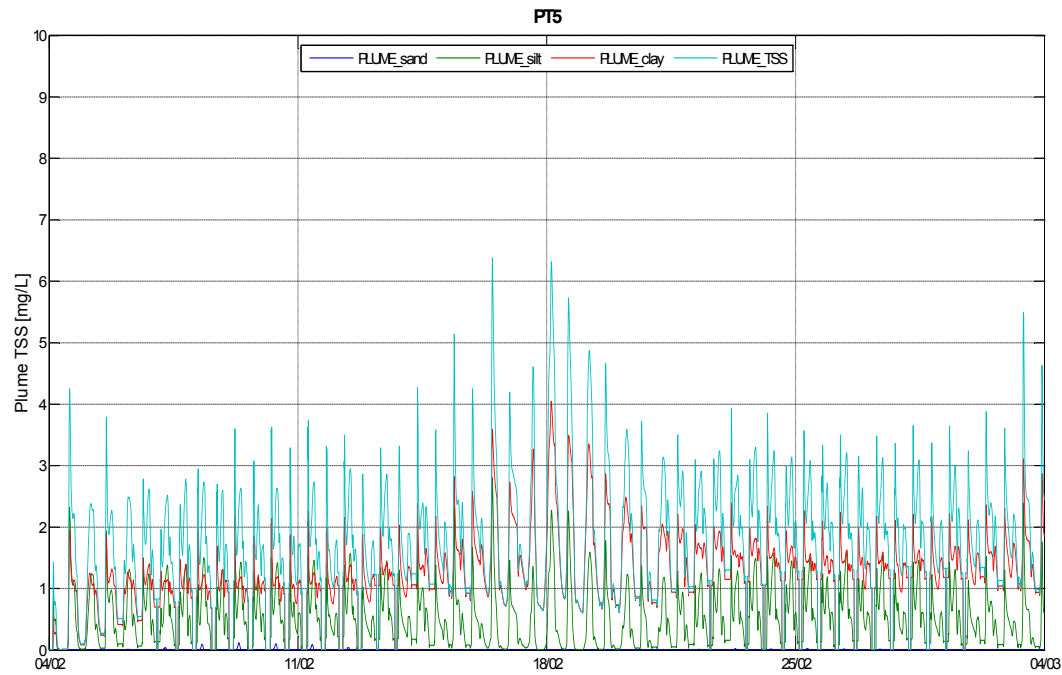
- Van Woesik, R. (1994) Natural disturbances to coral communities. *Journal of Coastal Research* 7, 551-558.

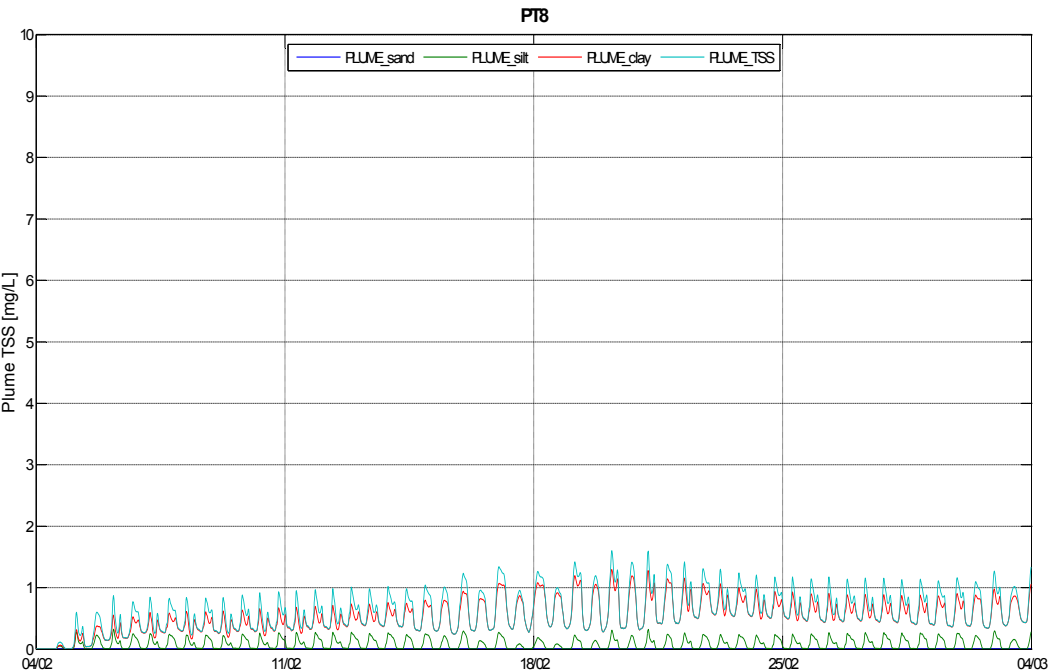
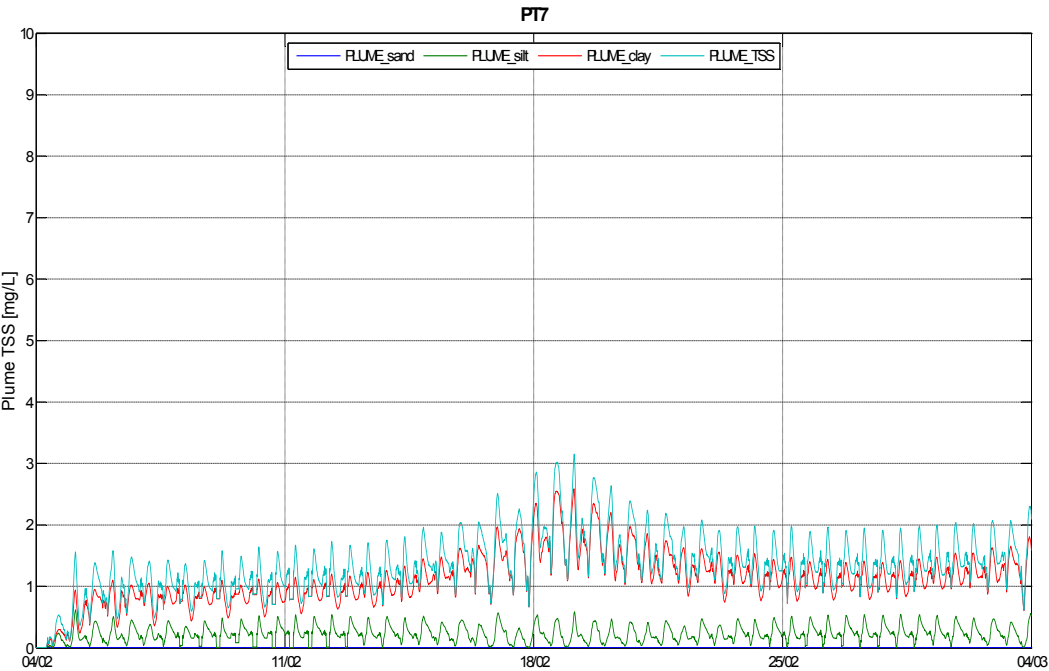
APPENDIX A: PLUME TSS CONCENTRATION TIME SERIES

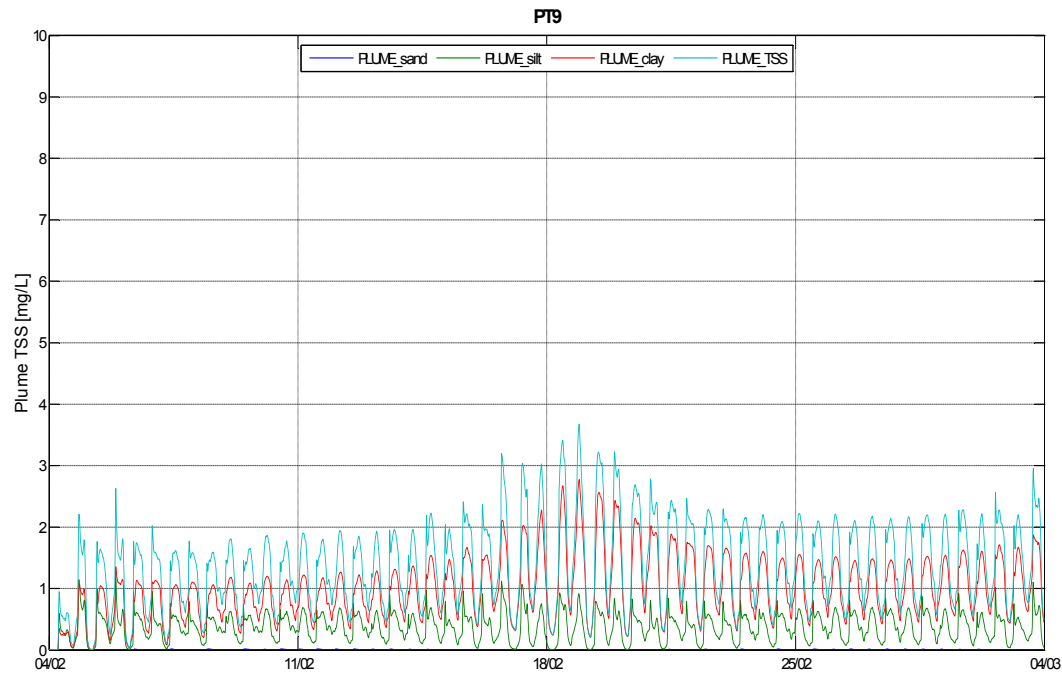
Scenario 1: CSD dredging scenario with 50mg/L decant



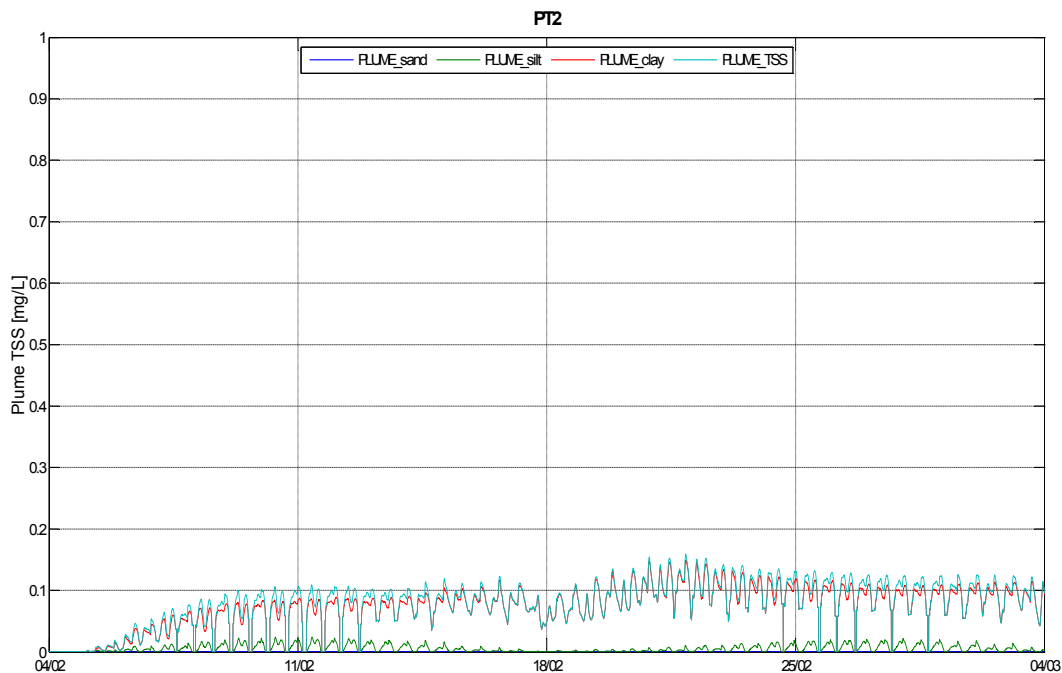
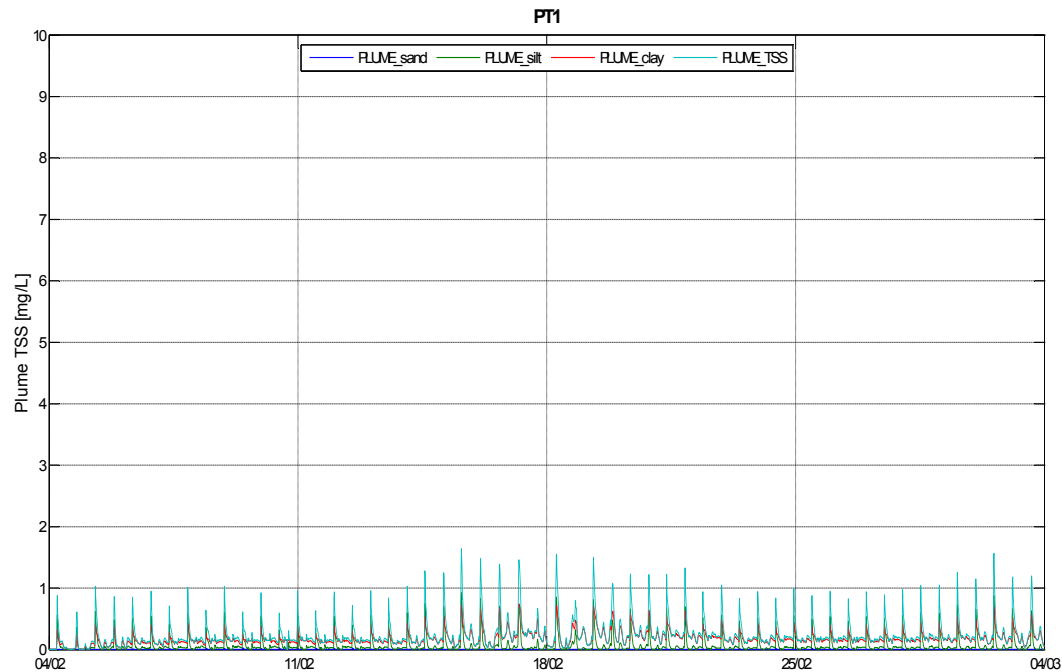


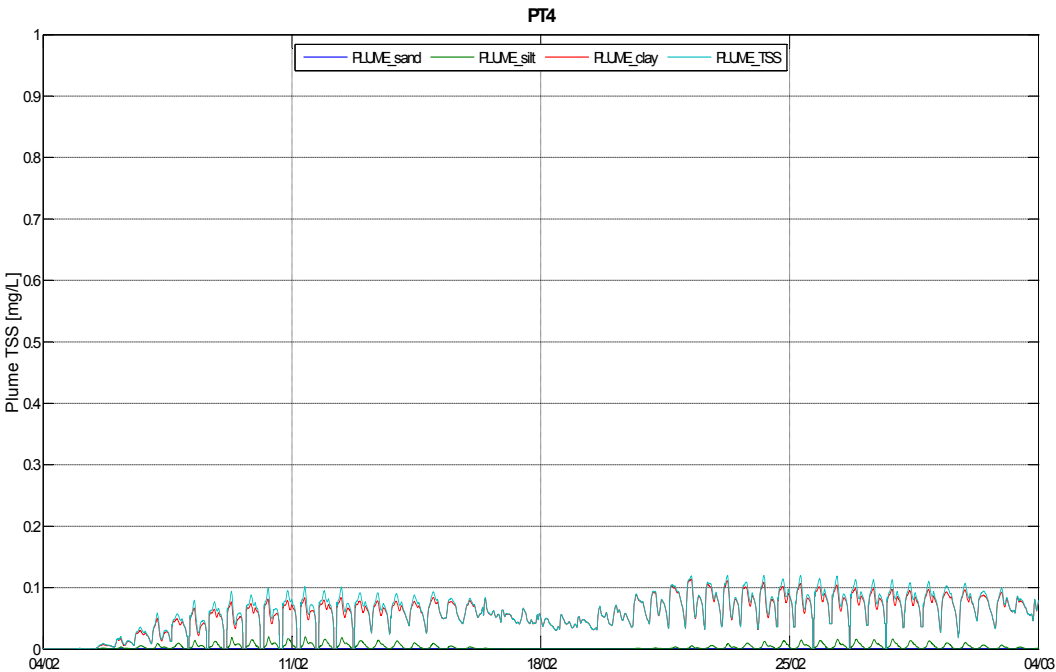
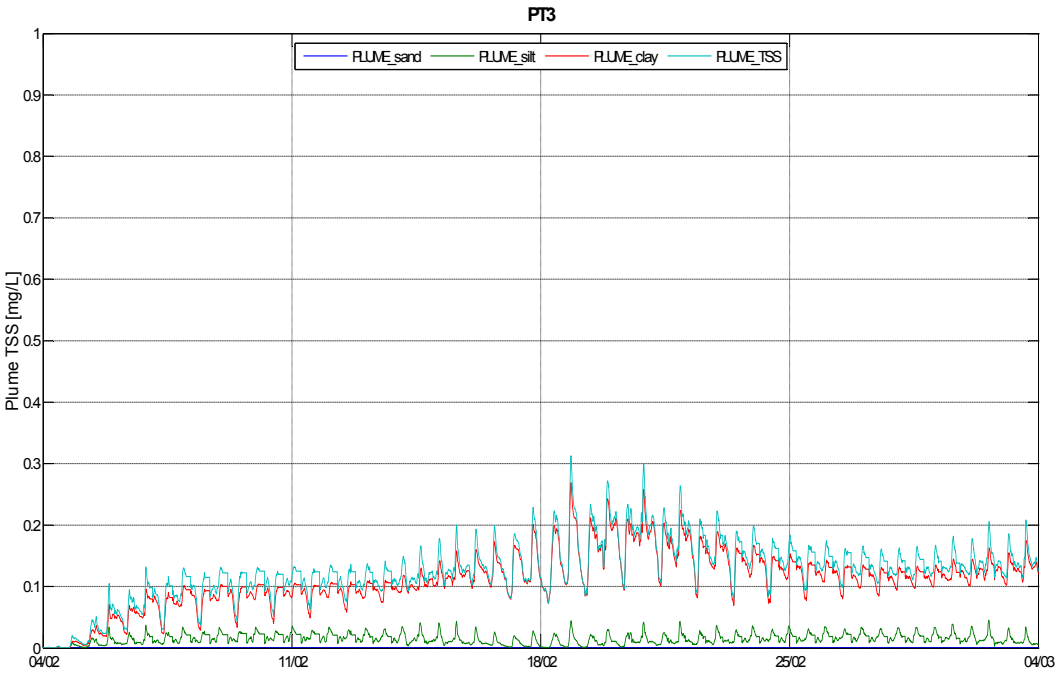


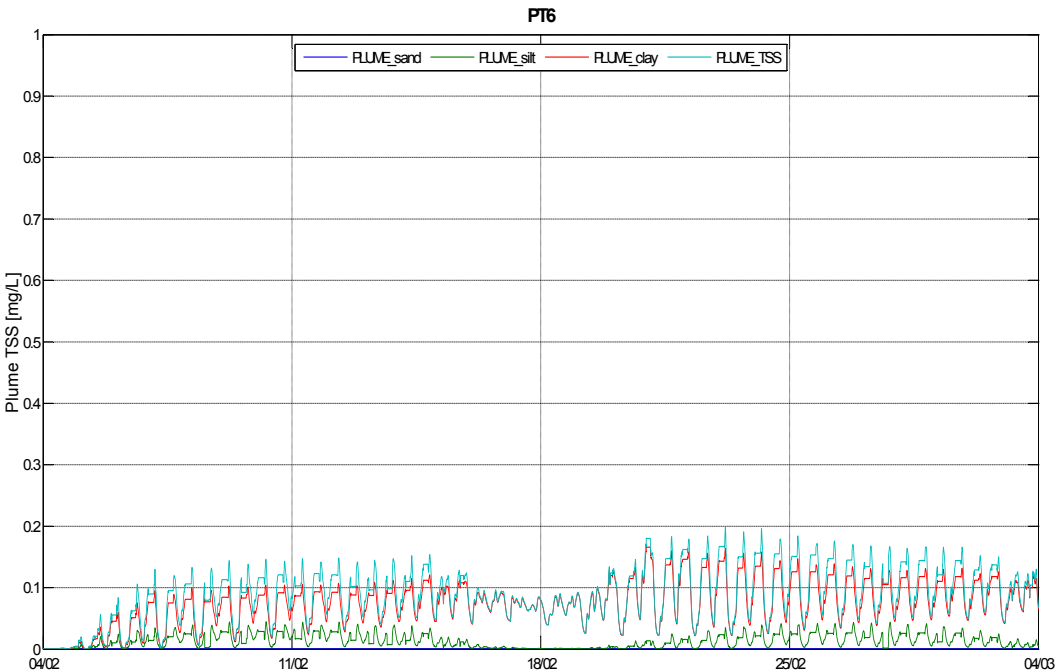
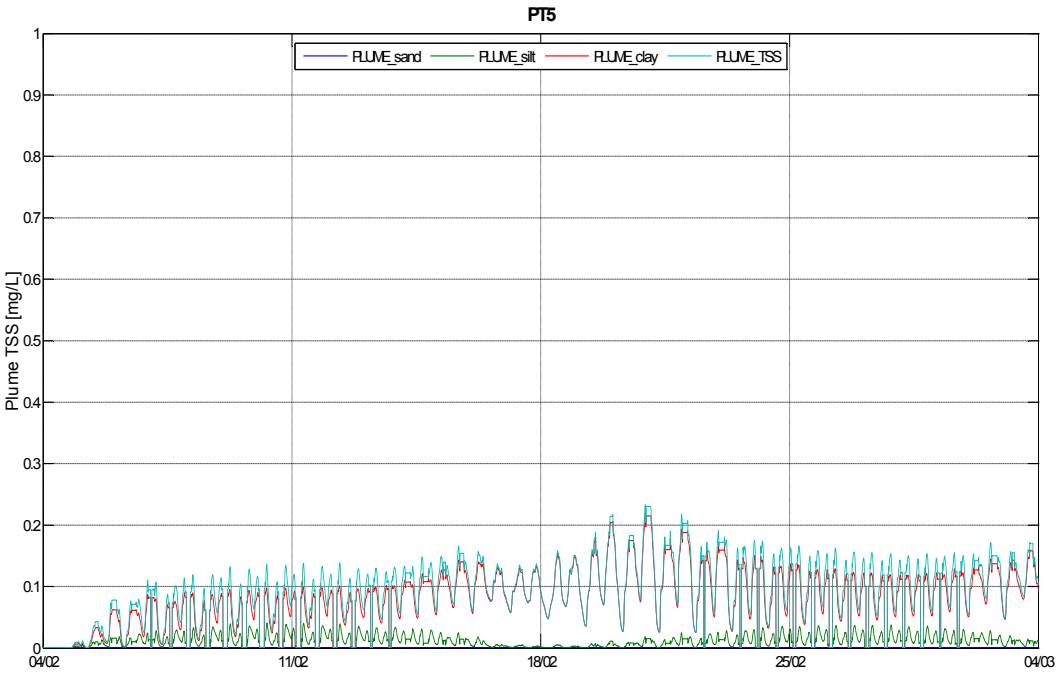


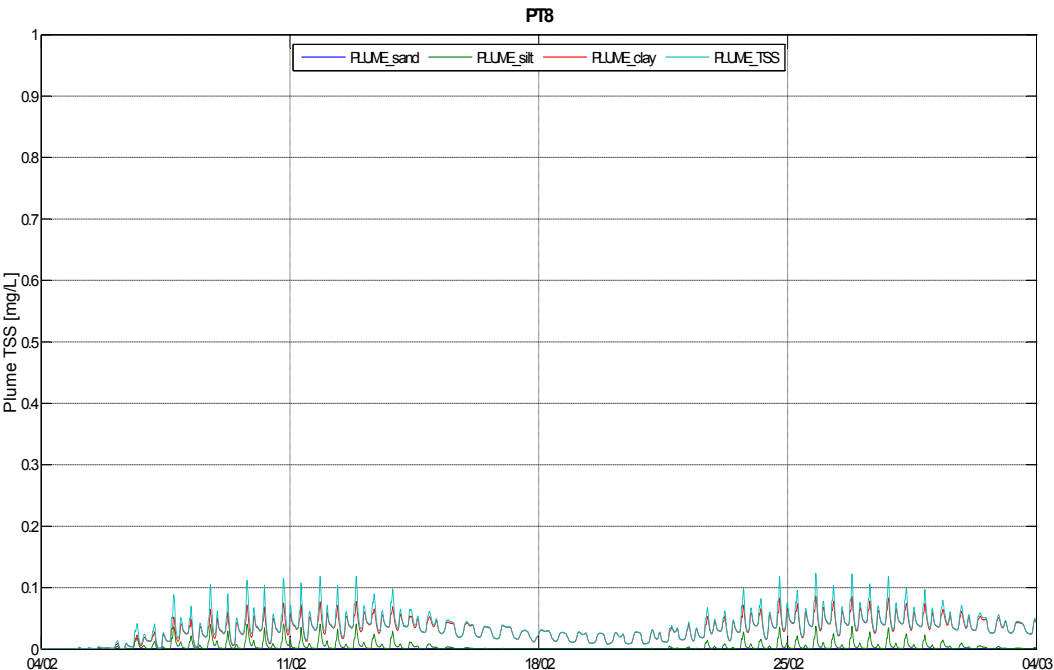
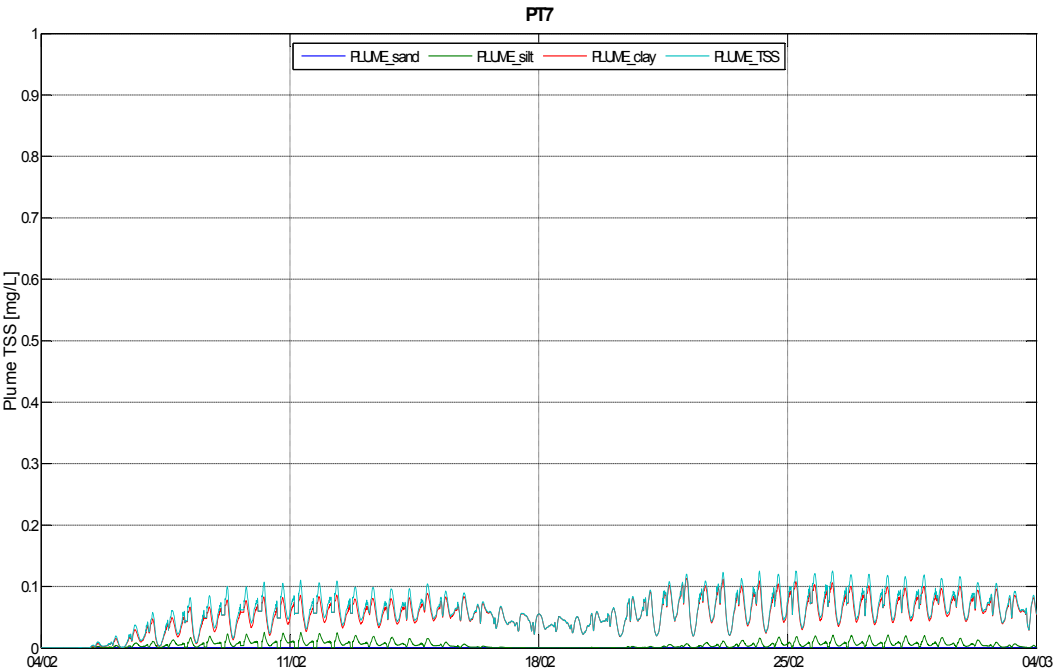


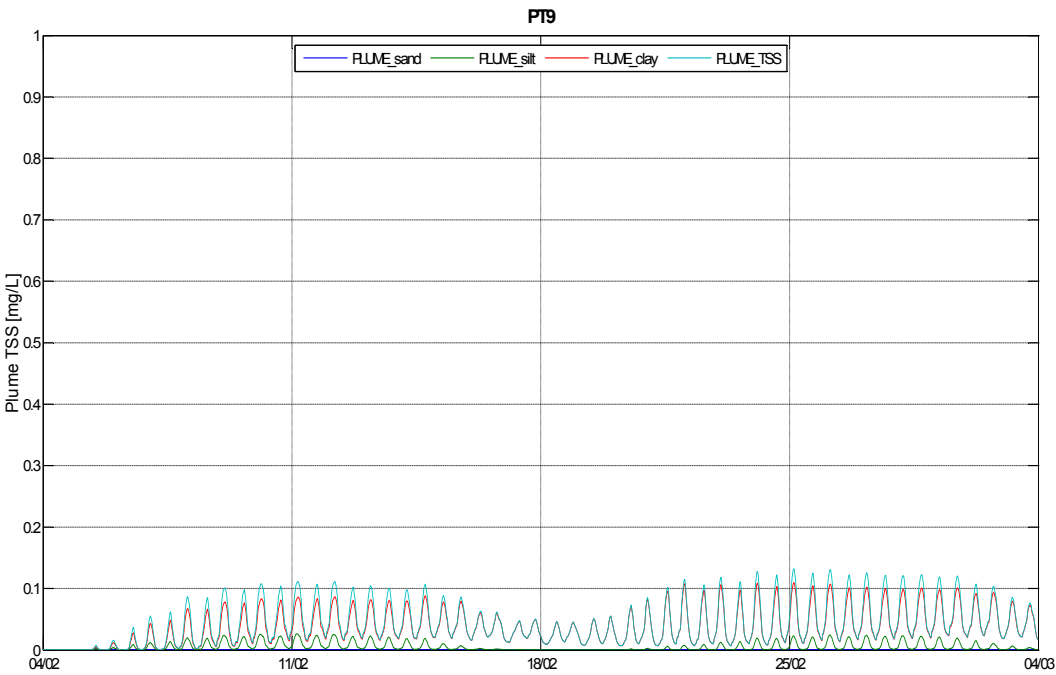
Scenario 2: Pipeline dredging on the western side of Laird – Friend Point Channel

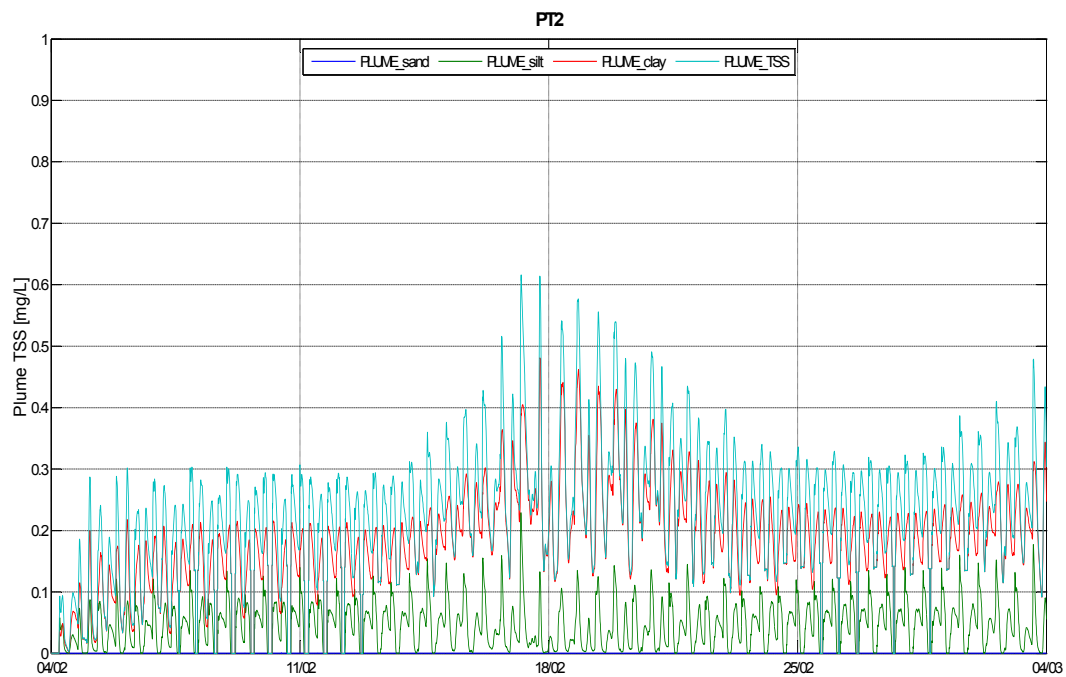
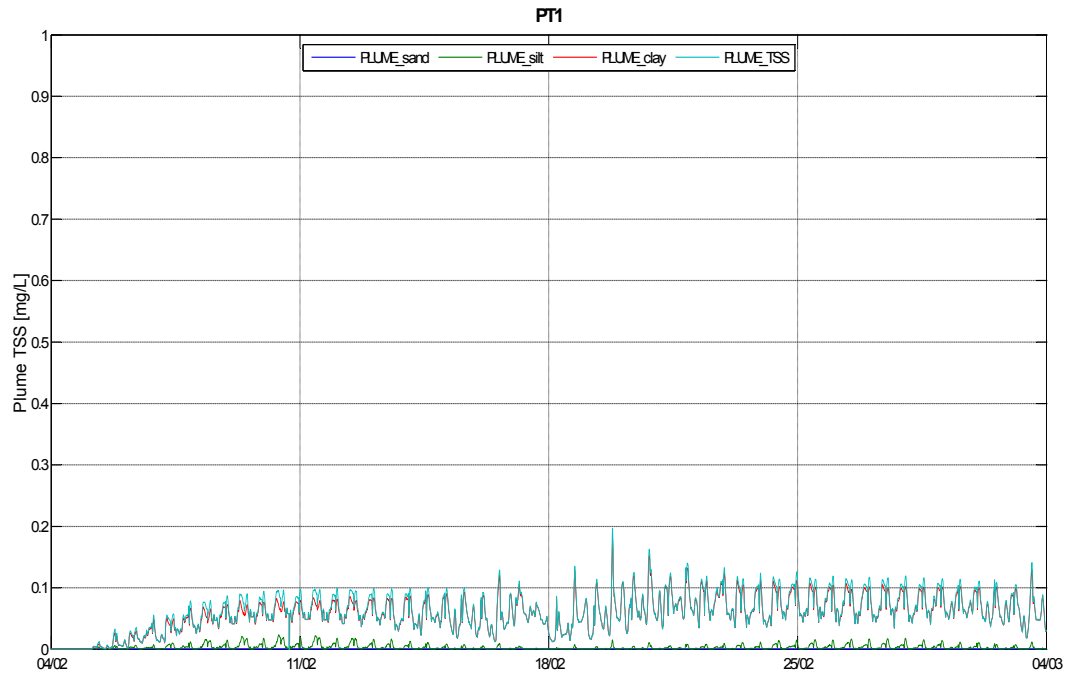


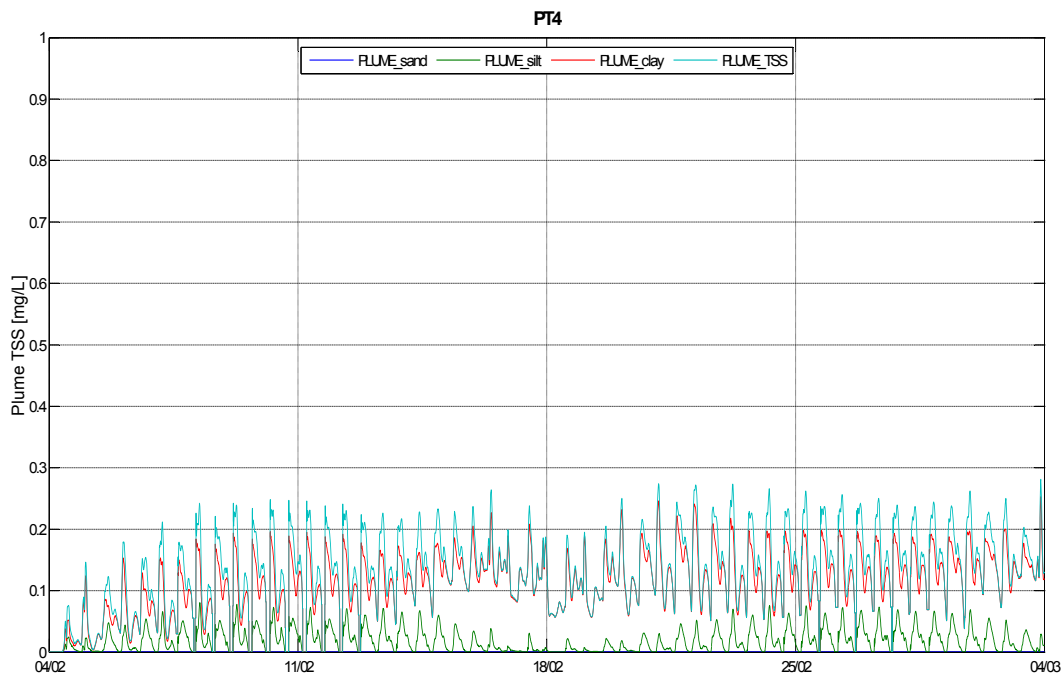
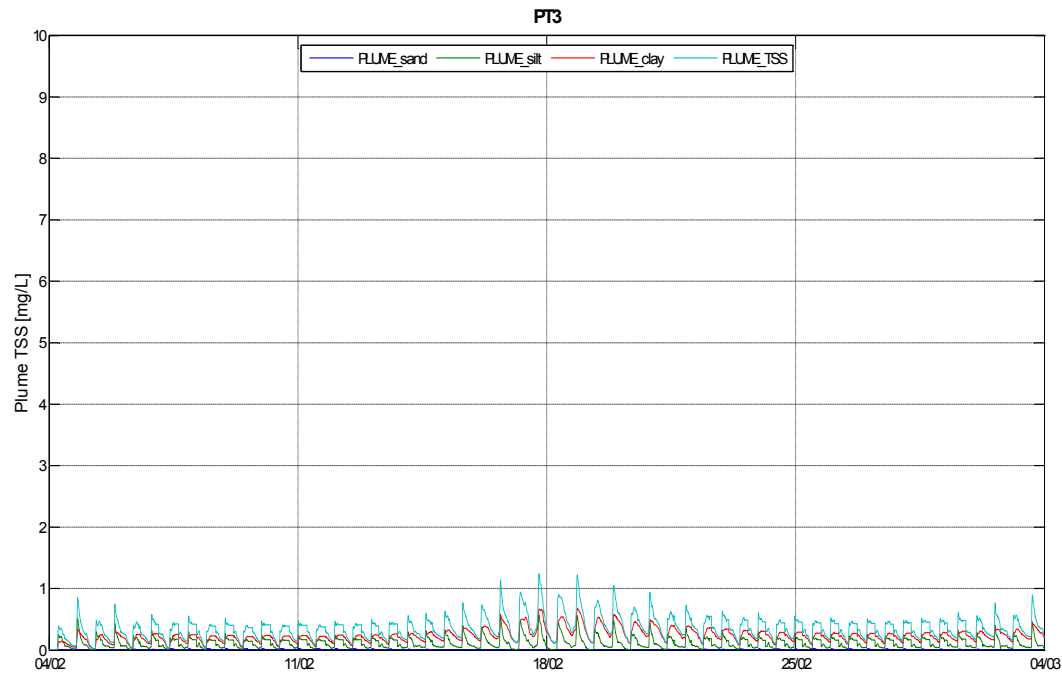


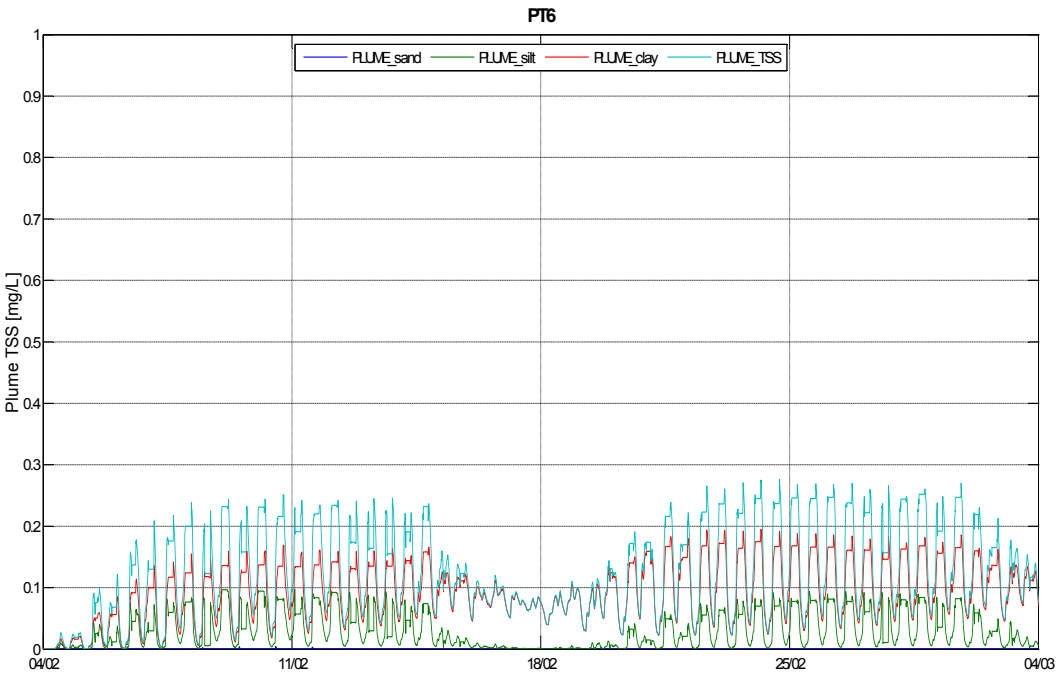
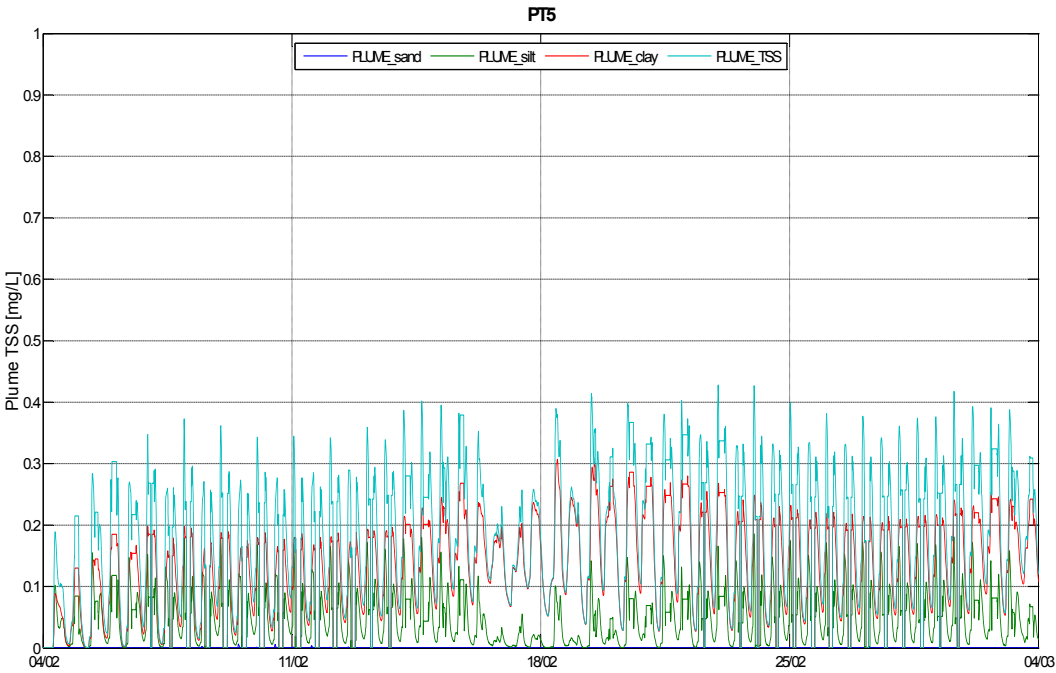


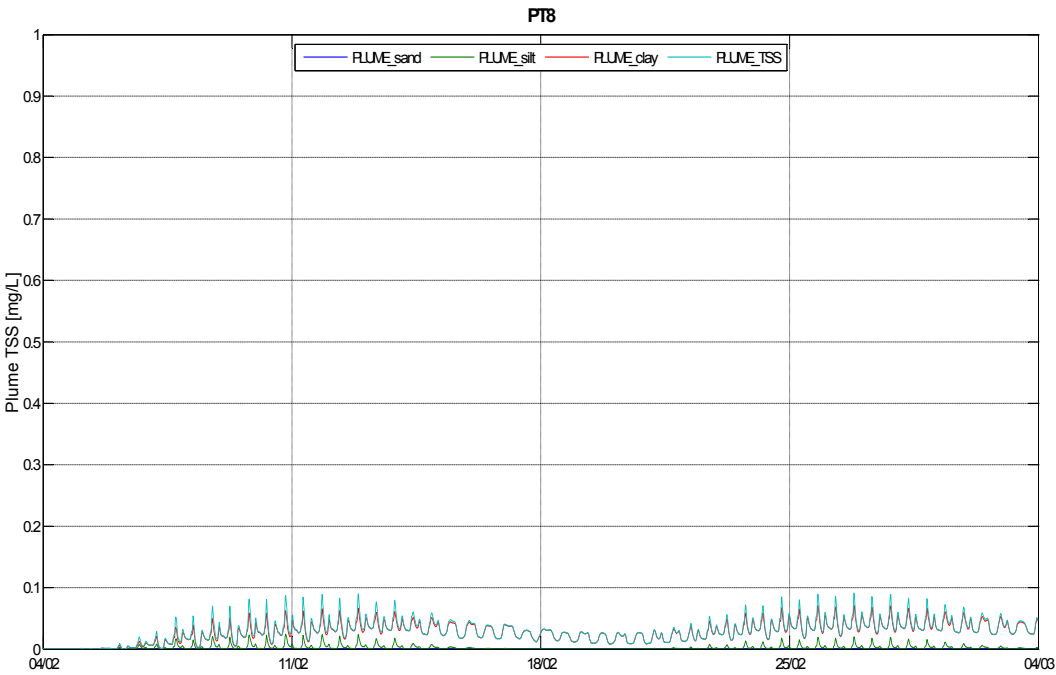
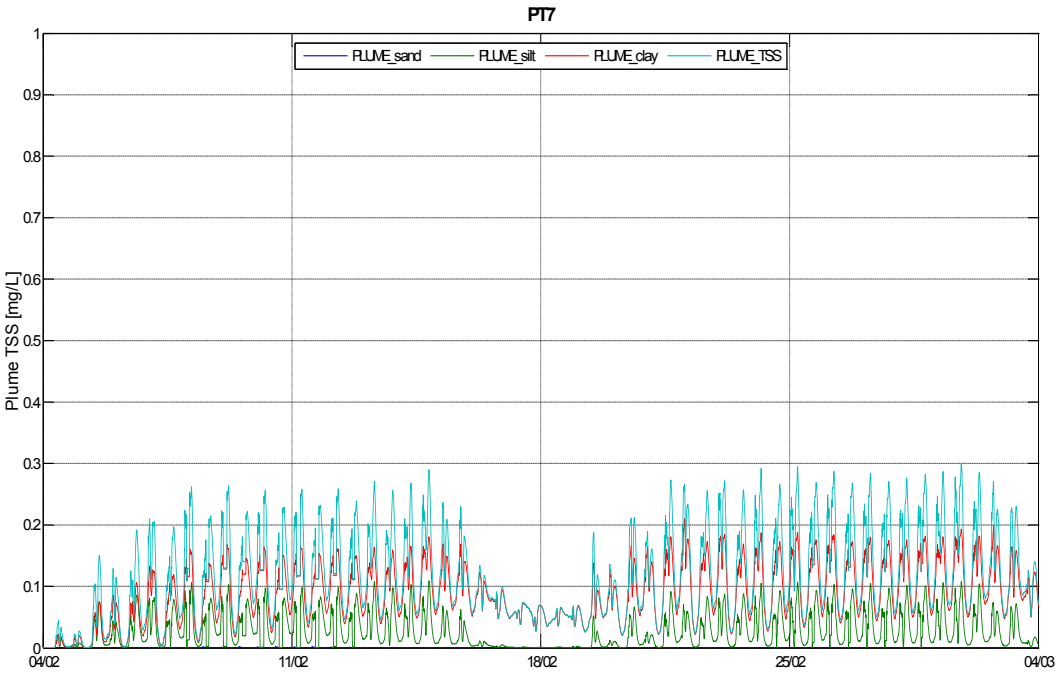


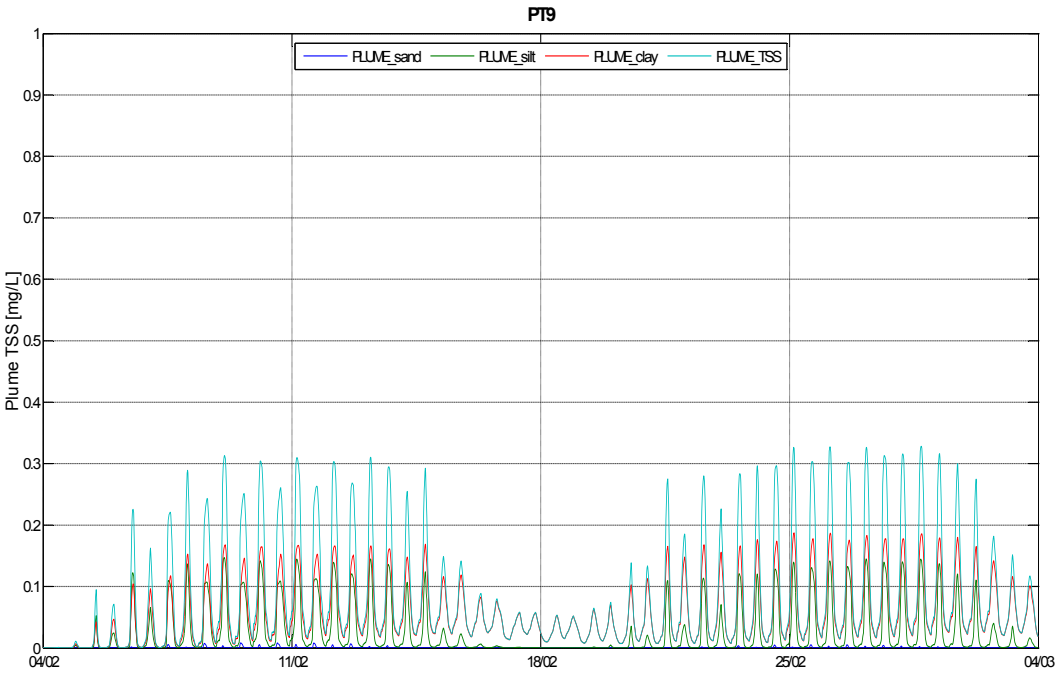


Scenario 3: Pipeline dredging on the eastern side of Laird – Friend Point Channel

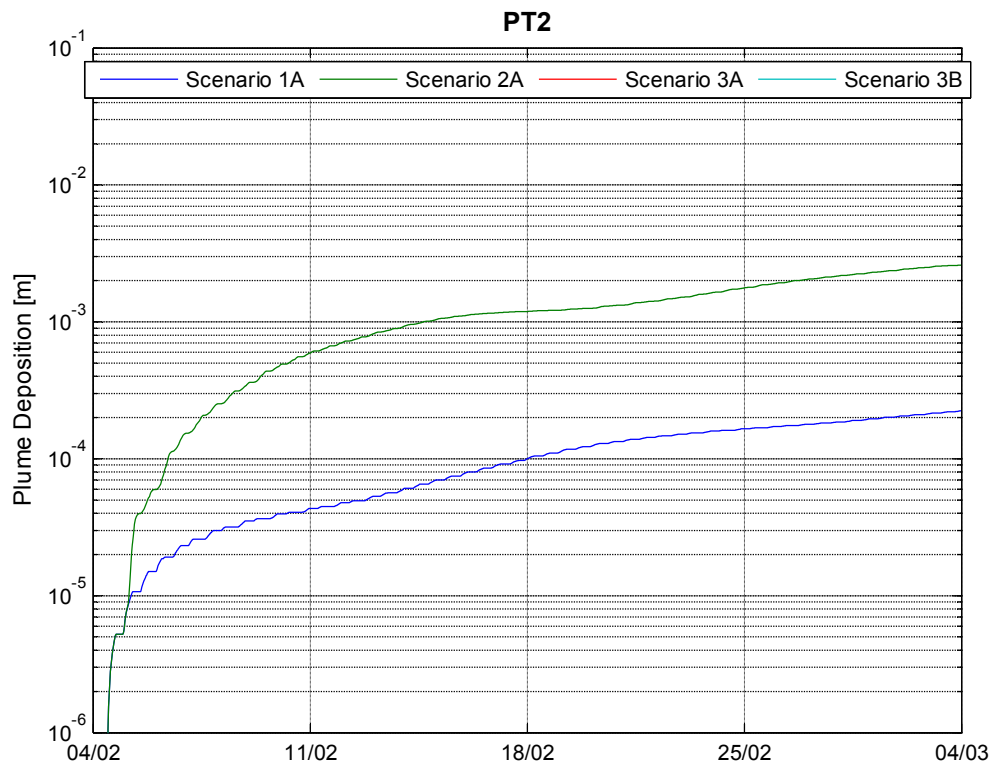
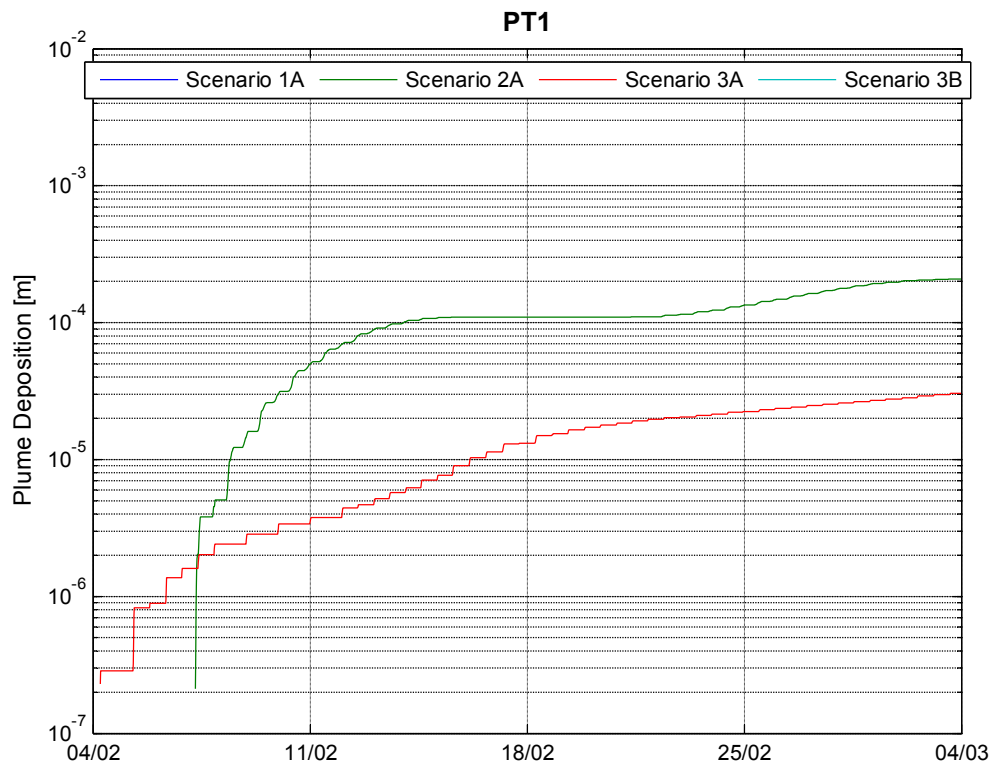


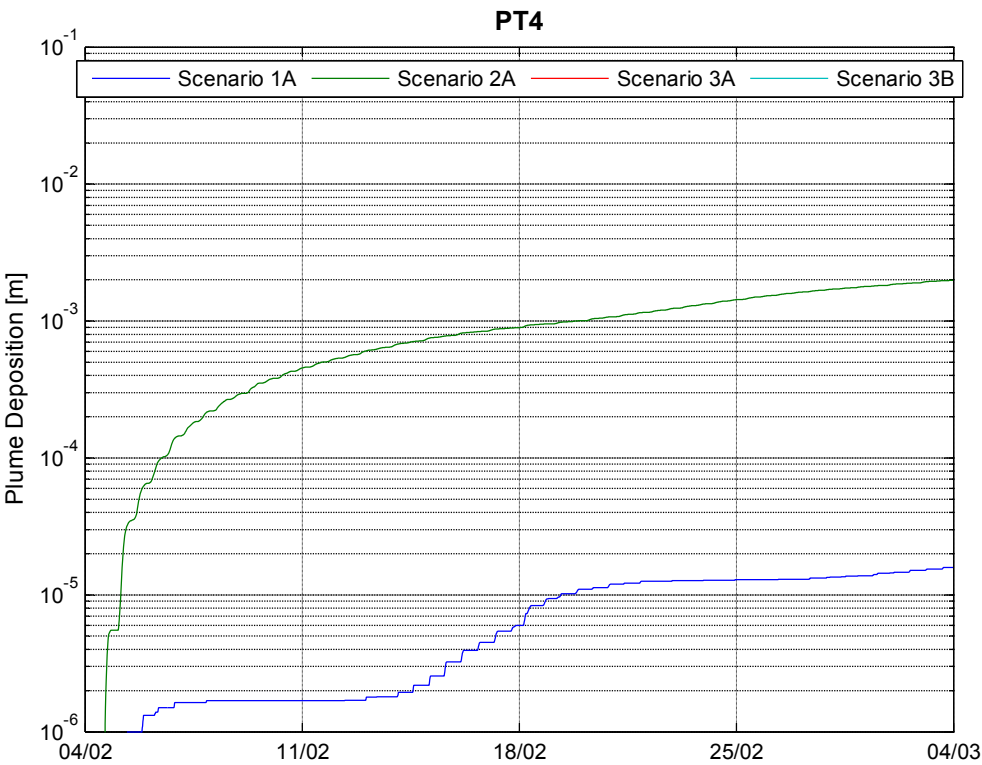
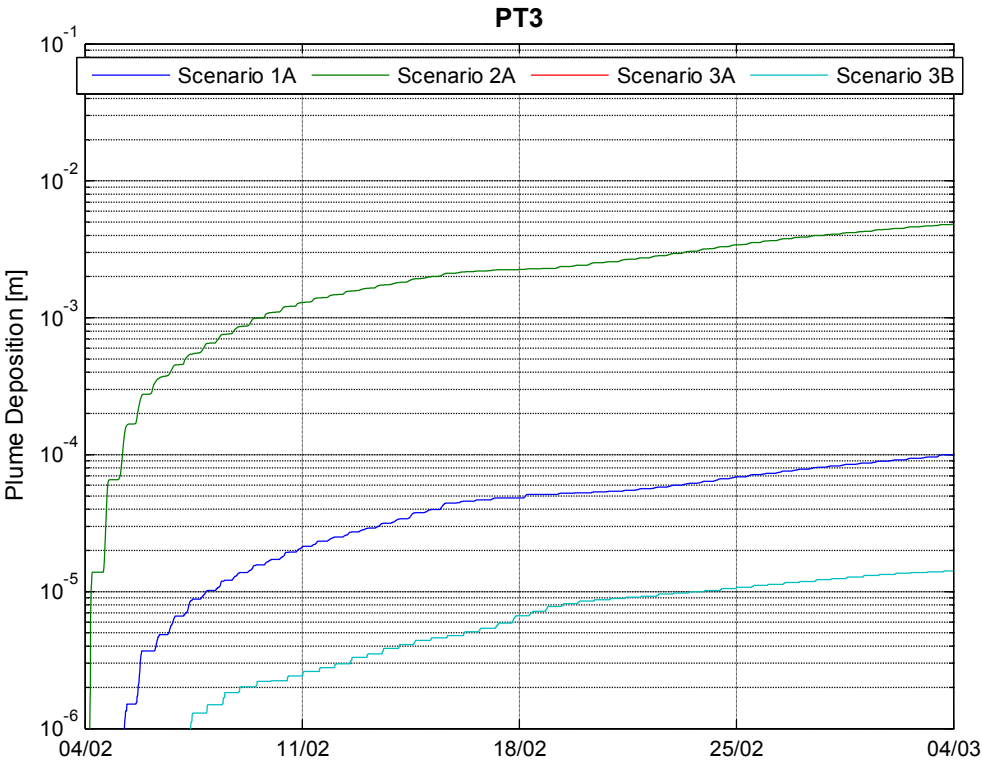


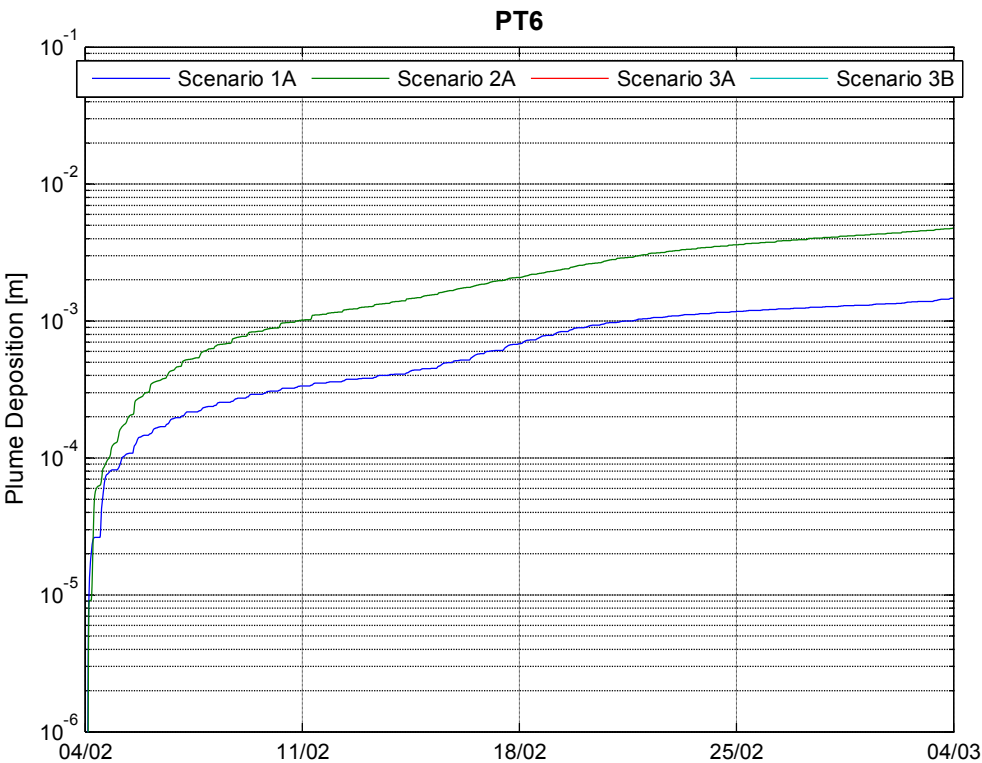
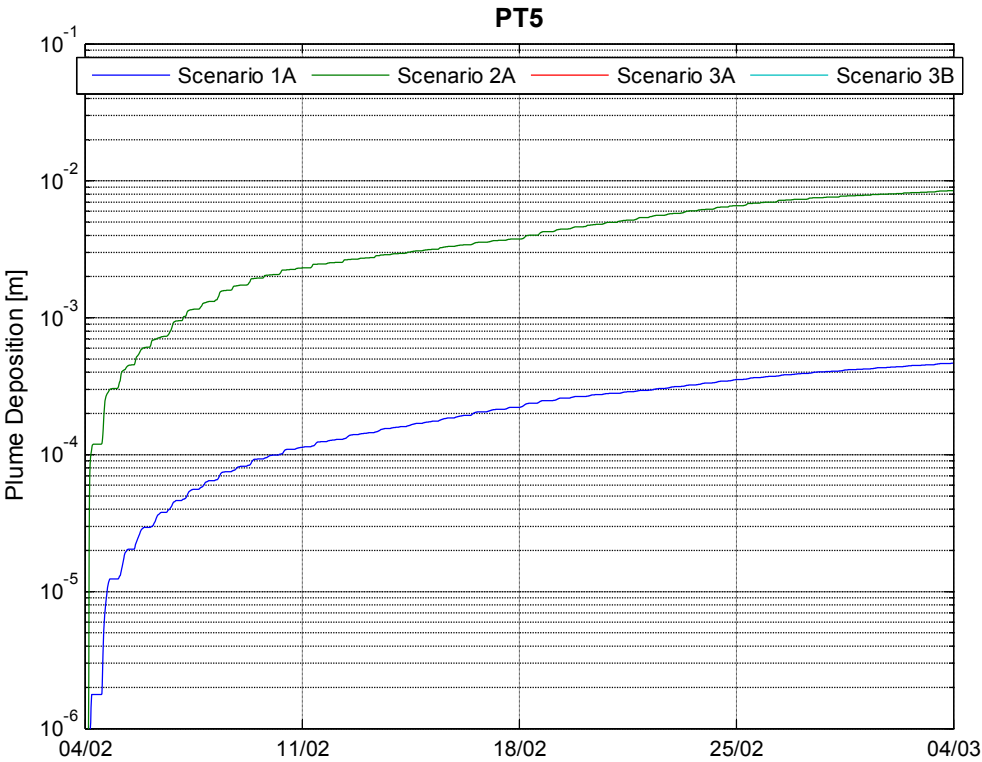


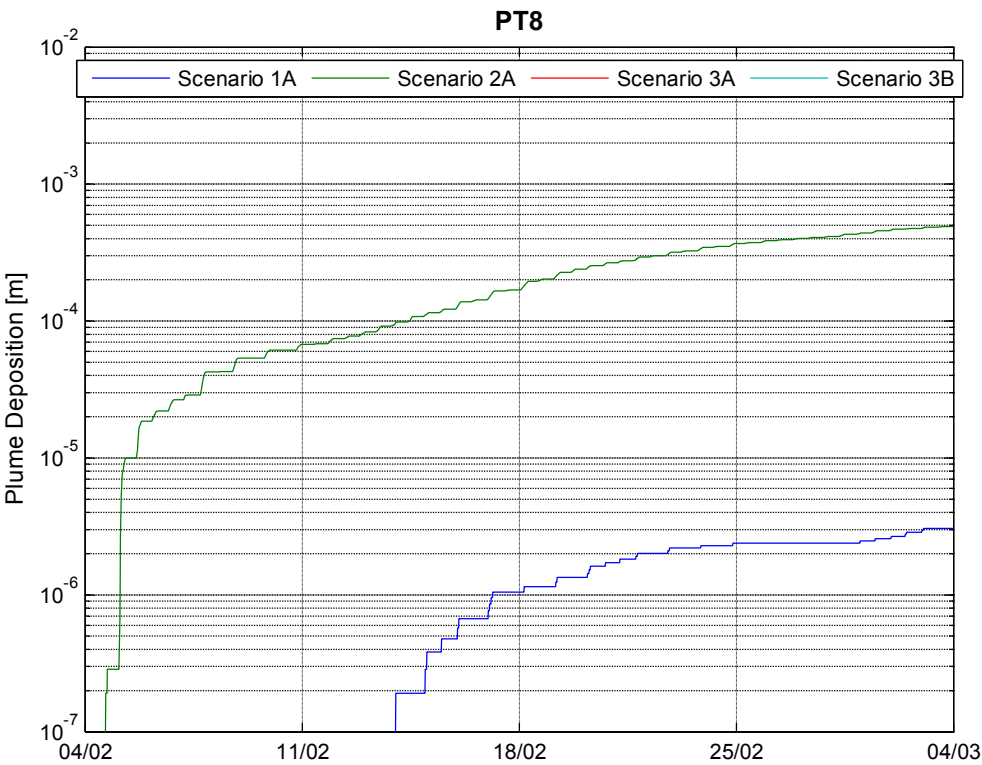
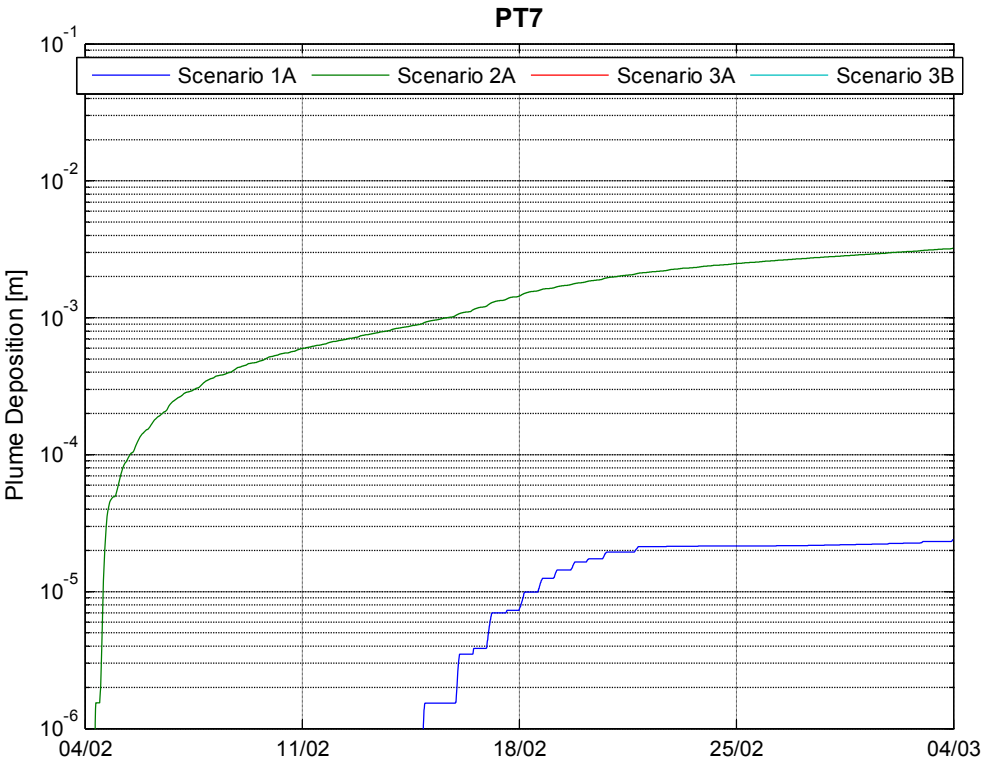


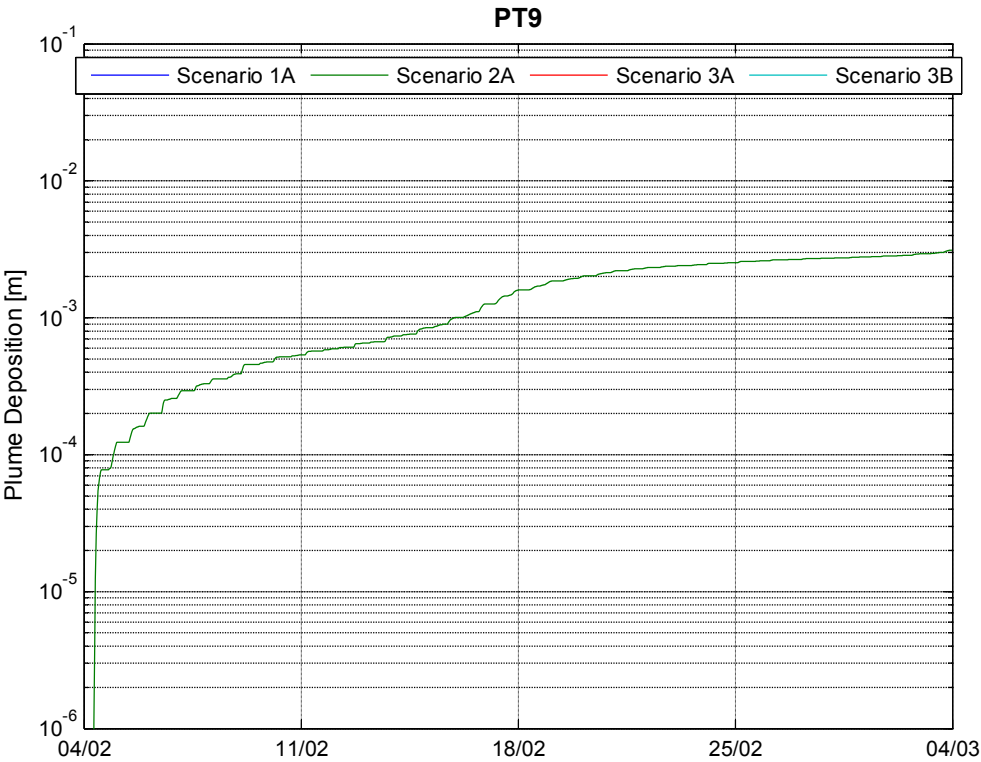
APPENDIX B: PLUME DEPOSITION TIME SERIES













BMT WBM Brisbane
Level 11, 490 Upper Edward Street Brisbane 4000
PO Box 203 Spring Hill QLD 4004
Tel +61 7 3831 6744 Fax +61 7 3832 3627
Email wbm@wbmpl.com.au
Web www.wbmpl.com.au

BMT WBM Denver
14 Inverness Drive East, #B132
Englewood Denver Colorado 80112 USA
Tel +1 303 792 9814 Fax +1 303 792 9742
Email wbm-denver@wbmpl.com.au
Web www.wbmpl.com.au

BMT WBM Mackay
Suite 1, 138 Wood Street Mackay 4740
PO Box 4447 Mackay QLD 4740
Tel +61 7 4953 5144 Fax +61 7 4953 5132
Email wbm-mackay@wbmpl.com.au
Web www.wbmpl.com.au

BMT WBM Melbourne
Level 5, 99 King Street Melbourne 3000
PO Box 604 Collins Street West VIC 8007
Tel +61 3 8620 6100 Fax +61 3 8620 6105
Email wbm-melbourne@wbmpl.com.au
Web www.wbmpl.com.au

BMT WBM Newcastle
126 Belford Street Broadmeadow 2292
PO Box 266 Broadmeadow NSW 2292
Tel +61 2 4940 8882 Fax +61 2 4940 8887
Email wbm-newcastle@wbmpl.com.au
Web www.wbmpl.com.au

BMT WBM Perth
1 Brodie Hall Drive Technology Park Bentley 6102
Tel +61 8 9328 2029 Fax +61 8 9486 7588
Email wbm-perth@wbmpl.com.au
Web www.wbmpl.com.au

BMT WBM Sydney
Level 1, 256-258 Norton Street Leichhardt 2040
PO Box 194 Leichhardt NSW 2040
Tel +61 2 9713 4836 Fax +61 2 9713 4890
Email wbm-sydney@wbmpl.com.au
Web www.wbmpl.com.au

BMT WBM Vancouver
1190 Melville Street #700 Vancouver
British Columbia V6E 3W1 Canada
Tel +1 604 683 5777 Fax +1 604 608 3232
Email wbm-vancouver@wbmpl.com.au
Web www.wbmpl.com.au

Appendix B Sedimentation Rates

Sediment Trap Calculations

Trap Site	Coordinates		Site Replicate	TSS (mg/L)	SD	Deployment Length (d)	Trap Dimensions				Trap Gross Sediment Mass (mg)	Trap Baseline Sedimentation (mg/cm ² /d)	Mean Site Baseline Sediment MAR (mg dry wt/cm ² /d)
	Lat	Long					Height (cm)	Diameter (cm)	Collection Area (cm ²)	Trap Volume (L)			
1	-23.751638	151.161231	A	10400	1380	25	45	5	19.635	0.884	9189	18.72	17.55
			B	11200		25	45	5	19.635	0.884	9896	20.16	
			C	9400		25	45	5	19.635	0.884	8306	16.92	
			D	8000		25	45	5	19.635	0.884	7069	14.40	
2	-23.751804	151.175639	A	10100	3104	25	45	5	19.635	0.884	8924	18.18	20.93
			B	8020		25	45	5	19.635	0.884	7086	14.44	
			C	14600		25	45	5	19.635	0.884	12900	26.28	
			D	13800		25	45	5	19.635	0.884	12193	24.84	
3	-23.759169	151.174564	A	12200	1430	25	45	5	19.635	0.884	10780	21.96	20.12
			B	12400		25	45	5	19.635	0.884	10956	22.32	
			C	10800		25	45	5	19.635	0.884	9543	19.44	
			D	9320		25	45	5	19.635	0.884	8235	16.78	
4	-23.763383	151.185458	A	16100	1328	25	45	5	19.635	0.884	14226	28.98	25.52
			B	13400		25	45	5	19.635	0.884	11840	24.12	
			C	13200		25	45	5	19.635	0.884	11663	23.76	
			D	14000		25	45	5	19.635	0.884	12370	25.20	
5	-23.769924	151.180984	A	14000	3297	25	45	5	19.635	0.884	12370	25.20	22.94
			B	13900		25	45	5	19.635	0.884	12282	25.02	
			C	15200		25	45	5	19.635	0.884	13430	27.36	
			D	7880		25	45	5	19.635	0.884	6963	14.18	
6	-23.782494	151.190269	A	9080	4004	25	45	5	19.635	0.884	8023	16.34	24.25
			B	13800		25	45	5	19.635	0.884	12193	24.84	
			C	12300		25	45	5	19.635	0.884	10868	22.14	
			D	18700		25	45	5	19.635	0.884	16523	33.66	
7	-23.781767	151.200643	A	9550	1407	25	45	5	19.635	0.884	8438	17.19	16.07
			B	10600		25	45	5	19.635	0.884	9366	19.08	
			C	7520		25	45	5	19.635	0.884	6644	13.54	
			D	8050		25	45	5	19.635	0.884	7113	14.49	

MAR - Mass Accumulation Rate

No account has been taken of sediment porosity



Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: EB0915058	Page	: 1 of 8
Client	: URS AUSTRALIA PTY LTD (QLD)	Laboratory	: Environmental Division Brisbane
Contact	: MS JULIAN LONG	Contact	: Tim Kilmister
Address	: GPO BOX 302 BRISBANE QLD, AUSTRALIA 4001	Address	: 32 Shand Street Stafford QLD Australia 4053
E-mail	: julian_long@urscorp.com	E-mail	: Services.Brisbane@alsenviro.com
Telephone	: +61 07 32432111	Telephone	: +61-7-3243 7222
Facsimile	: +61 07 32432199	Facsimile	: +61-7-3243 7218
Project	: 42626452 58000	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----	Date Samples Received	: 23-SEP-2009
C-O-C number	: ----	Issue Date	: 29-SEP-2009
Sampler	: URS (CHRIS RYAN)	No. of samples received	: 28
Site	: Port Curtis	No. of samples analysed	: 28
Quote number	: EB/001/08 V4		

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results



NATA Accredited Laboratory 825

This document is issued in
accordance with NATA
accreditation requirements.

Accredited for compliance with
ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	Position	Accreditation Category
Stephen Hislop	Senior Inorganic Chemist	Inorganics

Environmental Division Brisbane

Part of the **ALS Laboratory Group**

32 Shand Street Stafford QLD Australia 4053

Tel. +61-7-3243 7222 Fax. +61-7-3243 7218 www.alsglobal.com

A Campbell Brothers Limited Company



General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.

LOR = Limit of reporting

^ = This result is computed from individual analyte detections at or above the level of reporting



Analytical Results

Sub-Matrix: WATER

				Client sample ID	1-A	1-B	1-C	1-D	2-A
				Client sampling date / time	[23-SEP-2009]	[23-SEP-2009]	[23-SEP-2009]	[23-SEP-2009]	[23-SEP-2009]
Compound	CAS Number	LOR	Unit		EB0915058-001	EB0915058-002	EB0915058-003	EB0915058-004	EB0915058-005
EA025: Suspended Solids									
^ Suspended Solids (SS)									
	----	1	mg/L		10400	11200	9400	8000	10100



Analytical Results

Sub-Matrix: WATER

				Client sample ID	2-B	2-C	2-D	3-A	3-B
				Client sampling date / time	[23-SEP-2009]	[23-SEP-2009]	[23-SEP-2009]	[23-SEP-2009]	[23-SEP-2009]
Compound	CAS Number	LOR	Unit		EB0915058-006	EB0915058-007	EB0915058-008	EB0915058-009	EB0915058-010
EA025: Suspended Solids									
^ Suspended Solids (SS)									
	----	1	mg/L		8020	14600	13800	12200	12400



Analytical Results

Sub-Matrix: WATER

				Client sample ID	3-C	3-D	4-A	4-B	4-C
				Client sampling date / time	[23-SEP-2009]	[23-SEP-2009]	[23-SEP-2009]	[23-SEP-2009]	[23-SEP-2009]
Compound	CAS Number	LOR	Unit		EB0915058-011	EB0915058-012	EB0915058-013	EB0915058-014	EB0915058-015
EA025: Suspended Solids									
^ Suspended Solids (SS)	----	1	mg/L		10800	9320	16100	13400	13200



Analytical Results

Sub-Matrix: WATER

				Client sample ID	4-D	5-A	5-B	5-C	5-D
				Client sampling date / time	[23-SEP-2009]	[23-SEP-2009]	[23-SEP-2009]	[23-SEP-2009]	[23-SEP-2009]
Compound	CAS Number	LOR	Unit		EB0915058-016	EB0915058-017	EB0915058-018	EB0915058-019	EB0915058-020
EA025: Suspended Solids									
^ Suspended Solids (SS)									
	----	1	mg/L		14000	14000	13900	15200	7880



Analytical Results

Sub-Matrix: WATER

				Client sample ID	6-A	6-B	6-C	6-D	7-A
				Client sampling date / time	[23-SEP-2009]	[23-SEP-2009]	[23-SEP-2009]	[23-SEP-2009]	[23-SEP-2009]
Compound	CAS Number	LOR	Unit		EB0915058-021	EB0915058-022	EB0915058-023	EB0915058-024	EB0915058-025
EA025: Suspended Solids									
^ Suspended Solids (SS)									
	----	1	mg/L		9080	13800	12300	18700	9550



Analytical Results

Sub-Matrix: WATER

				Client sample ID	7-B	7-C	7-D		
				Client sampling date / time	[23-SEP-2009]	[23-SEP-2009]	[23-SEP-2009]	----	----
Compound	CAS Number	LOR	Unit		EB0915058-026	EB0915058-027	EB0915058-028	----	----
EA025: Suspended Solids									
^ Suspended Solids (SS)									
	----	1	mg/L		10600	7520	8050	----	----

Appendix C Sedimentation Core Samples - Ellutriate and BOD



Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: ES0910917	Page	: 1 of 7
Client	: SANTOS LTD	Laboratory	: Environmental Division Sydney
Contact	: MS JULIAN LONG	Contact	: Charlie Pierce
Address	: GPO BOX 302 BRISBANE QLD, AUSTRALIA 4000	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: julian_long@urscorp.com	E-mail	: charlie.pierce@alsenviro.com
Telephone	: +61 07 32432111	Telephone	: +61-2-8784 8555
Facsimile	: ----	Facsimile	: +61-2-8784 8500
Project	: ----	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: 42626234	Date Samples Received	: 23-JUL-2009
C-O-C number	: ----	Issue Date	: 07-AUG-2009
Sampler	: GL GORDON	No. of samples received	: 7
Site	: ----	No. of samples analysed	: 7
Quote number	: EN/039/09		

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results



NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	Position	Accreditation Category
Celine Conceicao	Spectroscopist	Inorganics
Hoa Nguyen	Inorganic Chemist	Inorganics
Phyu Phyu Lwin	Inorganic Chemist	Inorganics
Sarah Millington	Senior Inorganic Chemist	Inorganics
Wisam Abou-Maraseh	Spectroscopist	Inorganics

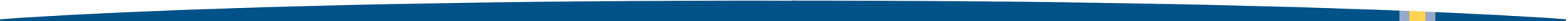
Environmental Division Sydney

Part of the **ALS Laboratory Group**

277-289 Woodpark Road Smithfield NSW Australia 2164

Tel. **+61-2-8784 8555** Fax. +61-2-8784 8500 www.alsglobal.com

A Campbell Brothers Limited Company





General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.

LOR = Limit of reporting

^ = This result is computed from individual analyte detections at or above the level of reporting

- **LCS recovery for Sodium, Manganese and Iron falls outside ALS Dynamic Control Limit. However, it is within the acceptance criteria based on ALS DQO. No further action is required.**



Analytical Results

Sub-Matrix: DI WATER LEACHATE

Client sample ID

Client sampling date / time

Sub-Matrix: DI WATER LEACHATE				Client sample ID	URS/BH01A 0-1.0 DI WATER LEACH	URS/BH01A 1.0-2.1 DI WATER LEACH	URS/BH01A 2.1-2.8 DI WATER LEACH	----	----
Client sampling date / time					02-AUG-2009 12:00	02-AUG-2009 12:00	02-AUG-2009 12:00	----	----
Compound	CAS Number	LOR	Unit	ES0910917-005	ES0910917-006	ES0910917-007	----	----	
EG020W: Water Leachable Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L	1.53	2.58	17.8	----	----	
Antimony	7440-36-0	0.001	mg/L	0.002	0.002	<0.001	----	----	
Arsenic	7440-38-2	0.001	mg/L	0.007	0.012	0.015	----	----	
Cadmium	7440-43-9	0.0001	mg/L	1.64	0.900	<0.0001	----	----	
Chromium	7440-47-3	0.001	mg/L	0.003	0.004	0.029	----	----	
Copper	7440-50-8	0.001	mg/L	0.003	0.005	0.040	----	----	
Lead	7439-92-1	0.001	mg/L	0.002	0.003	0.020	----	----	
Manganese	7439-96-5	0.001	mg/L	0.012	0.018	0.091	----	----	
Nickel	7440-02-0	0.001	mg/L	<0.001	0.002	0.013	----	----	
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	<0.001	----	----	
Zinc	7440-66-6	0.005	mg/L	0.027	0.042	0.126	----	----	
Iron	7439-89-6	0.05	mg/L	1.85	2.86	25.7	----	----	
EG035W: Water Leachable Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	----	----	
EK026G: Total Cyanide By Discrete Analyser									
Total Cyanide	57-12-5	0.004	mg/L	<0.004	<0.004	<0.004	----	----	



Analytical Results

Sub-Matrix: ELUTRIATE

Client sample ID

Client sampling date / time

				URS/BH01A 0-1.0 ELUTRIATE	URS/BH01A 1.0-2.1 ELUTRIATE	URS/BH01A 2.1-2.8 ELUTRIATE	URS/BH01A	----
				ES0910917-001	ES0910917-002	ES0910917-003	ES0910917-004	----
Compound	CAS Number	LOR	Unit					
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	----
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	10	µg/L	<10	<10	<10	<10	----
Antimony	7440-36-0	0.5	µg/L	5.3	6.0	1.0	<0.5	----
Iron	7439-89-6	5	µg/L	<5	<5	<5	<5	----
Arsenic	7440-38-2	0.5	µg/L	7.8	7.0	4.7	0.8	----
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	----
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	----
Copper	7440-50-8	1	µg/L	<1	<1	<1	<1	----
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	----
Manganese	7439-96-5	0.5	µg/L	359	240	282	0.6	----
Nickel	7440-02-0	0.5	µg/L	0.5	<0.5	3.6	1.1	----
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	<0.1	<0.1	----
Zinc	7440-66-6	5	µg/L	<5	<5	<5	<5	----
EK026G: Total Cyanide By Discrete Analyser								
Total Cyanide	57-12-5	0.004	mg/L	<0.004	<0.004	<0.004	<0.004	----
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	1	mg/L	4	3	<1	<1	----
EP030: Biochemical Oxygen Demand (BOD)								
Biochemical Oxygen Demand	----	2	mg/L	<2	<2	<2	<2	----

Page : 6 of 7
 Work Order : ES0910917
 Client : SANTOS LTD
 Project : ----



Analytical Results

Sub-Matrix: SOIL

Client sample ID

Client sampling date / time

				URS/BH01A 0-1.0 ELUTRIATE	URS/BH01A 1.0-2.1 ELUTRIATE	URS/BH01A 2.1-2.8 ELUTRIATE	URS/BH01A	URS/BH01A 0-1.0 DI WATER LEACH
				21-JUL-2009 15:00	21-JUL-2009 15:00	21-JUL-2009 15:00	21-JUL-2009 15:00	21-JUL-2009 15:00
Compound	CAS Number	LOR	Unit	ES0910917-001	ES0910917-002	ES0910917-003	ES0910917-004	ES0910917-005
EN60-DI: Bottle Leaching Procedure								
Final pH	----	0.1	pH Unit	----	----	----	----	10.0
EN68: Seawater Elutriate Testing Procedure								
Seawater Sampling Date	----	0.1	--	21/7/09	21/7/09	21/7/09	21/7/09	----



Analytical Results

Sub-Matrix: SOIL

Client sample ID

Client sampling date / time

Compound	CAS Number	LOR	Unit	URS/BH01A 1.0-2.1 DI WATER LEACH	URS/BH01A 2.1-2.8 DI WATER LEACH			
				21-JUL-2009 15:00	21-JUL-2009 15:00	----	----	----
				ES0910917-006	ES0910917-007	----	----	----
EN60-DI: Bottle Leaching Procedure								
Final pH	----	0.1	pH Unit	9.3	1.0	----	----	----



Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: ES0911058	Page	: 1 of 9
Client	: SANTOS LTD	Laboratory	: Environmental Division Sydney
Contact	: MS JULIAN LONG	Contact	: Charlie Pierce
Address	: GPO BOX 302 BRISBANE QLD, AUSTRALIA 4000	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: julian_long@urscorp.com	E-mail	: charlie.pierce@alsenviro.com
Telephone	: +61 07 32432111	Telephone	: +61-2-8784 8555
Facsimile	: ----	Facsimile	: +61-2-8784 8500
Project	: 42626234	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: 42626234	Date Samples Received	: 24-JUL-2009
C-O-C number	: ----	Issue Date	: 10-AUG-2009
Sampler	: GEOCOASTAL-LG	No. of samples received	: 13
Site	: GLADSTONE	No. of samples analysed	: 13
Quote number	: EN/039/09		

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results



NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

<i>Signatories</i>	<i>Position</i>	<i>Accreditation Category</i>
Celine Conceicao	Spectroscopist	Inorganics
Hoa Nguyen	Inorganic Chemist	Inorganics
Phyu Phyu Lwin	Inorganic Chemist	Inorganics

Environmental Division Sydney

Part of the **ALS Laboratory Group**

277-289 Woodpark Road Smithfield NSW Australia 2164

Tel. +61-2-8784 8555 Fax. +61-2-8784 8500 www.alsglobal.com

A Campbell Brothers Limited Company



General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.

LOR = Limit of reporting

^ = This result is computed from individual analyte detections at or above the level of reporting

- **EG-020A-W : LCS recovery for some elements falls outside ALS Dynamic Control Limit. However, they are within the acceptance criteria based on ALS DQO. No further action is required.**



Analytical Results

Sub-Matrix: DI WATER LEACHATE

Client sample ID

Client sampling date / time

				URSBH08C 0-1.0 DI WATER	URSBH08C 3.0-4.0 DI WATER	URSBH08C 4.75-5.6 DI WATER	URSBH04A 0-0.2 DI WATER	URSBH04A 0.2-0.5 DI WATER
				30-JUL-2009 12:00	30-JUL-2009 12:00	30-JUL-2009 12:00	30-JUL-2009 12:00	30-JUL-2009 12:00
Compound	CAS Number	LOR	Unit	ES0911058-008	ES0911058-009	ES0911058-010	ES0911058-011	ES0911058-012
EG020W: Water Leachable Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.28	16.7	3.00	4.99	13.2
Antimony	7440-36-0	0.001	mg/L	<0.001	0.002	0.002	0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	0.001	0.024	0.009	0.008	0.011
Cadmium	7440-43-9	0.0001	mg/L	0.0005	<0.0001	<0.0001	0.0004	<0.0001
Chromium	7440-47-3	0.001	mg/L	<0.001	0.030	0.005	0.008	0.012
Copper	7440-50-8	0.001	mg/L	<0.001	0.022	0.004	0.006	0.015
Lead	7439-92-1	0.001	mg/L	<0.001	0.012	0.002	0.003	0.006
Manganese	7439-96-5	0.001	mg/L	0.008	0.238	0.054	0.060	0.063
Nickel	7440-02-0	0.001	mg/L	<0.001	0.015	0.002	0.004	0.005
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L	0.020	0.204	0.058	0.087	0.526
Iron	7439-89-6	0.05	mg/L	0.44	21.1	3.89	6.85	16.0
EG035W: Water Leachable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EK026G: Total Cyanide By Discrete Analyser								
Total Cyanide	57-12-5	0.004	mg/L	<0.004	<0.004	<0.004	<0.004	<0.004



Analytical Results

Sub-Matrix: DI WATER LEACHATE

Client sample ID

URSBH04A 0.5-1.0

DI WATER

30-JUL-2009 12:00

Client sampling date / time

ES0911058-013

Compound	CAS Number	LOR	Unit					
EG020W: Water Leachable Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	6.06	----	----	----	----
Antimony	7440-36-0	0.001	mg/L	<0.001	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	0.004	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	0.004	----	----	----	----
Copper	7440-50-8	0.001	mg/L	0.003	----	----	----	----
Lead	7439-92-1	0.001	mg/L	0.003	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	0.018	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	<0.001	----	----	----	----
Silver	7440-22-4	0.001	mg/L	<0.001	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	0.198	----	----	----	----
Iron	7439-89-6	0.05	mg/L	5.52	----	----	----	----
EG035W: Water Leachable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	----	----	----	----
EK026G: Total Cyanide By Discrete Analyser								
Total Cyanide	57-12-5	0.004	mg/L	<0.004	----	----	----	----



Analytical Results

Sub-Matrix: ELUTRIATE

Client sample ID

Client sampling date / time

				URSBH08C 0-1.0 ELUTRIATE	URSBH08C 3.0-4.0 ELUTRIATE	URSBH08C 4.75-5.6 ELUTRIATE	URSBH04A 0-0.2 ELUTRIATE	URSBH04A 0.2-0.5 ELUTRIATE
				31-JUL-2009 12:00	31-JUL-2009 12:00	31-JUL-2009 12:00	31-JUL-2009 12:00	31-JUL-2009 12:00
Compound	CAS Number	LOR	Unit	ES0911058-001	ES0911058-002	ES0911058-003	ES0911058-004	ES0911058-005
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	10	µg/L	10	10	90	<10	<10
Antimony	7440-36-0	0.5	µg/L	<0.5	5.1	3.4	3.7	<0.5
Iron	7439-89-6	5	µg/L	<5	105	317	<5	<5
Arsenic	7440-38-2	0.5	µg/L	2.1	11.2	4.2	6.8	4.8
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Copper	7440-50-8	1	µg/L	<1	<1	<1	2	1
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Manganese	7439-96-5	0.5	µg/L	1180	766	1440	515	63.3
Nickel	7440-02-0	0.5	µg/L	2.3	2.1	0.6	0.9	0.6
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	5	µg/L	<5	6	<5	<5	<5
EK026G: Total Cyanide By Discrete Analyser								
Total Cyanide	57-12-5	0.004	mg/L	<0.004	<0.004	<0.004	<0.004	<0.004
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	1	mg/L	3	4	3	4	1
EP030: Biochemical Oxygen Demand (BOD)								
Biochemical Oxygen Demand	----	2	mg/L	<2	<2	<2	<2	<2



Analytical Results

Sub-Matrix: ELUTRIATE

Client sample ID

				URSBH04A 0.5-1.0 ELUTRIATE	SEA WATER	----	----	----
Client sampling date / time				31-JUL-2009 12:00	31-JUL-2009 12:00	----	----	----
Compound	CAS Number	LOR	Unit	ES0911058-006	ES0911058-007	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	----	----	----
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	10	µg/L	10	<10	----	----	----
Antimony	7440-36-0	0.5	µg/L	<0.5	<0.5	----	----	----
Iron	7439-89-6	5	µg/L	<5	<5	----	----	----
Arsenic	7440-38-2	0.5	µg/L	0.8	1.4	----	----	----
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	----	----	----
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	----	----	----
Copper	7440-50-8	1	µg/L	<1	<1	----	----	----
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	----	----	----
Manganese	7439-96-5	0.5	µg/L	152	<0.5	----	----	----
Nickel	7440-02-0	0.5	µg/L	1.1	<0.5	----	----	----
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	----	----	----
Zinc	7440-66-6	5	µg/L	22	<5	----	----	----
EK026G: Total Cyanide By Discrete Analyser								
Total Cyanide	57-12-5	0.004	mg/L	<0.004	<0.004	----	----	----
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	1	mg/L	2	1	----	----	----
EP030: Biochemical Oxygen Demand (BOD)								
Biochemical Oxygen Demand	----	2	mg/L	<2	<2	----	----	----



Analytical Results

Sub-Matrix: SOIL

Client sample ID

				URSBH08C 0-1.0 ELUTRIATE	URSBH08C 3.0-4.0 ELUTRIATE	URSBH08C 4.75-5.6 ELUTRIATE	URSBH04A 0-0.2 ELUTRIATE	URSBH04A 0.2-0.5 ELUTRIATE
Client sampling date / time				22-JUL-2009 15:00	22-JUL-2009 15:00	22-JUL-2009 15:00	22-JUL-2009 15:00	22-JUL-2009 15:00
Compound	CAS Number	LOR	Unit	ES0911058-001	ES0911058-002	ES0911058-003	ES0911058-004	ES0911058-005
EN68: Seawater Elutriate Testing Procedure								
Seawater Sampling Date	----	0.1	--	22/07/09	22/07/09	22/07/09	22/07/09	22/07/09



Analytical Results

Sub-Matrix: SOIL

Client sample ID

Client sampling date / time

				URSBH04A 0.5-1.0 ELUTRIATE	SEA WATER	URSBH08C 0-1.0 DI WATER	URSBH08C 3.0-4.0 DI WATER	URSBH08C 4.75-5.6 DI WATER
				22-JUL-2009 15:00	22-JUL-2009 15:00	22-JUL-2009 15:00	22-JUL-2009 15:00	22-JUL-2009 15:00
Compound	CAS Number	LOR	Unit	ES0911058-006	ES0911058-007	ES0911058-008	ES0911058-009	ES0911058-010
EN60-DI: Bottle Leaching Procedure								
Final pH	----	0.1	pH Unit	----	----	9.4	9.2	9.1
EN68: Seawater Elutriate Testing Procedure								
Seawater Sampling Date	----	0.1	--	22/07/09	22/07/09	----	----	----



Analytical Results

Sub-Matrix: SOIL

Client sample ID

				URSBH04A 0-0.2 DI WATER	URSBH04A 0.2-0.5 DI WATER	URSBH04A 0.5-1.0 DI WATER	----	----
Client sampling date / time				22-JUL-2009 15:00	22-JUL-2009 15:00	22-JUL-2009 15:00	----	----
Compound	CAS Number	LOR	Unit	ES0911058-011	ES0911058-012	ES0911058-013	----	----
EN60-DI: Bottle Leaching Procedure								
Final pH	----	0.1	pH Unit	9.1	10.1	9.7	----	----



Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: ES0911219	Page	: 1 of 23
Client	: SANTOS LTD	Laboratory	: Environmental Division Sydney
Contact	: MS JULIAN LONG	Contact	: Charlie Pierce
Address	: GPO BOX 302 BRISBANE QLD, AUSTRALIA 4000	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: julian_long@urscorp.com	E-mail	: charlie.pierce@alsenviro.com
Telephone	: +61 07 32432111	Telephone	: +61-2-8784 8555
Facsimile	: ----	Facsimile	: +61-2-8784 8500
Project	: 42626234	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----	Date Samples Received	: 29-JUL-2009
C-O-C number	: ----	Issue Date	: 12-AUG-2009
Sampler	: GEOCOASTAL-LG	No. of samples received	: 43
Site	: GLADSTONE	No. of samples analysed	: 43
Quote number	: EN/039/09		

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results



NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

<i>Signatories</i>	<i>Position</i>	<i>Accreditation Category</i>
Celine Conceicao	Spectroscopist	Inorganics
Hoa Nguyen	Inorganic Chemist	Inorganics
Phyu Phyu Lwin	Inorganic Chemist	Inorganics
Sarah Millington	Senior Inorganic Chemist	Inorganics
Wisam Abou-Maraseh	Spectroscopist	Inorganics

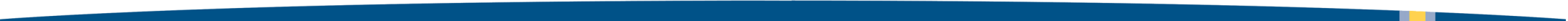
Environmental Division Sydney

Part of the **ALS Laboratory Group**

277-289 Woodpark Road Smithfield NSW Australia 2164

Tel. **+61-2-8784 8555** Fax. +61-2-8784 8500 www.alsglobal.com

A Campbell Brothers Limited Company





General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.

LOR = Limit of reporting

^ = This result is computed from individual analyte detections at or above the level of reporting

- **EG-093AT/EG-093BT : LCS recovery for some elements falls outside ALS Dynamic Control Limit. However, they are within the acceptance criteria based on ALS DQO. No further action is required.**



Analytical Results

Sub-Matrix: DI WATER LEACHATE

Client sample ID

Client sampling date / time

Sub-Matrix: DI WATER LEACHATE				Client sample ID		URS BH17A 0-0.3 DI WATER LEACHATE	URS BH17A 0.3-1.2 DI WATER LEACHATE	URS BH02A 0-1.0 DI WATER LEACHATE	URS BH02A 2.0-2.75 DI WATER LEACHATE	URS BH02A 2.75-3.1 DI WATER LEACHATE
Client sampling date / time						02-AUG-2009 12:00	02-AUG-2009 12:00	02-AUG-2009 12:00	02-AUG-2009 12:00	02-AUG-2009 12:00
Compound	CAS Number	LOR	Unit			ES0911219-027	ES0911219-028	ES0911219-029	ES0911219-030	ES0911219-031
EG020W: Water Leachable Metals by ICP-MS										
Aluminium	7429-90-5	0.01	mg/L			5.44	1.18	0.80	2.15	6.25
Antimony	7440-36-0	0.001	mg/L			0.003	<0.001	<0.001	0.002	<0.001
Arsenic	7440-38-2	0.001	mg/L			0.008	<0.001	0.003	0.017	0.002
Cadmium	7440-43-9	0.0001	mg/L			<0.0001	<0.0001	<0.0001	0.0003	0.0001
Chromium	7440-47-3	0.001	mg/L			0.012	<0.001	0.001	0.004	0.007
Copper	7440-50-8	0.001	mg/L			0.013	0.006	0.002	0.005	0.013
Lead	7439-92-1	0.001	mg/L			0.005	<0.001	<0.001	0.003	0.002
Manganese	7439-96-5	0.001	mg/L			0.081	0.104	0.015	0.068	0.169
Nickel	7440-02-0	0.001	mg/L			0.008	0.001	<0.001	0.003	0.005
Silver	7440-22-4	0.001	mg/L			<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L			0.257	0.025	0.120	0.025	0.072
Iron	7439-89-6	0.05	mg/L			7.40	0.97	1.65	3.72	10.9
EG035W: Water Leachable Mercury by FIMS										
Mercury	7439-97-6	0.0001	mg/L			<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EK026G: Total Cyanide By Discrete Analyser										
Total Cyanide	57-12-5	0.004	mg/L			<0.004	<0.004	<0.004	<0.004	<0.004



Analytical Results

Sub-Matrix: DI WATER LEACHATE

Client sample ID

Client sampling date / time

Sub-Matrix: DI WATER LEACHATE				Client sample ID	URS BH14A 0-1.0 DI WATER LEACHATE	URS BH14A 2.5-3.5 DI WATER LEACHATE	URS BH14A 6.0-7.0 DI WATER LEACHATE	URS BH13A 0-1.0 DI WATER LEACHATE	URS BH13A 6.0-7.0 DI WATER LEACHATE
Client sampling date / time				02-AUG-2009 12:00	02-AUG-2009 12:00	02-AUG-2009 12:00	02-AUG-2009 12:00	02-AUG-2009 12:00	02-AUG-2009 12:00
Compound	CAS Number	LOR	Unit	ES0911219-032	ES0911219-033	ES0911219-034	ES0911219-035	ES0911219-036	
EG020W: Water Leachable Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L	3.08	1.00	0.46	4.30	0.96	
Antimony	7440-36-0	0.001	mg/L	0.001	0.003	<0.001	0.002	0.003	
Arsenic	7440-38-2	0.001	mg/L	0.012	0.009	<0.001	0.015	0.007	
Cadmium	7440-43-9	0.0001	mg/L	0.0011	<0.0001	0.0024	0.0001	<0.0001	
Chromium	7440-47-3	0.001	mg/L	0.005	0.002	<0.001	0.008	0.002	
Copper	7440-50-8	0.001	mg/L	0.005	0.002	<0.001	0.006	0.002	
Lead	7439-92-1	0.001	mg/L	0.002	<0.001	<0.001	0.002	<0.001	
Manganese	7439-96-5	0.001	mg/L	0.036	0.037	0.018	0.059	0.042	
Nickel	7440-02-0	0.001	mg/L	0.003	0.001	<0.001	0.004	0.001	
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	
Zinc	7440-66-6	0.005	mg/L	0.037	0.088	0.166	0.207	0.042	
Iron	7439-89-6	0.05	mg/L	4.39	1.24	0.46	6.20	1.36	
EG035W: Water Leachable Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	
EK026G: Total Cyanide By Discrete Analyser									
Total Cyanide	57-12-5	0.004	mg/L	<0.004	<0.004	<0.004	<0.004	<0.004	



Analytical Results

Sub-Matrix: DI WATER LEACHATE

Client sample ID

Client sampling date / time

				URS BH13A 11.5-12.0 DI WATER LEACHATE	URS BH13A COMP DI WATER LEACHATE	URS BH07A 0-1.0 DI WATER LEACHATE	URS BH07A 2.0-2.8 DI WATER LEACHATE	URS BH07A 3.0-4.0 DI WATER LEACHATE
				02-AUG-2009 12:00	02-AUG-2009 12:00	02-AUG-2009 12:00	02-AUG-2009 12:00	02-AUG-2009 12:00
Compound	CAS Number	LOR	Unit	ES0911219-037	ES0911219-038	ES0911219-039	ES0911219-040	ES0911219-041
ED040W: Water Leachable Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	1	mg/L	----	39	----	----	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	----	291	----	----	----
ED093W: Water Leachable Major Cations								
Calcium	7440-70-2	1	mg/L	----	13	----	----	----
Magnesium	7439-95-4	1	mg/L	----	13	----	----	----
Potassium	7440-09-7	1	mg/L	----	4	----	----	----
EG020T: Total Metals by ICP-MS								
Tungsten	7440-33-7	0.001	mg/L	----	<0.001	----	----	----
EG020W: Water Leachable Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.24	0.32	2.79	0.74	0.27
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	0.004	0.002	<0.001
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	0.019	0.010	<0.001
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	0.0002	0.0003
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	0.005	0.001	<0.001
Cobalt	7440-48-4	0.001	mg/L	----	<0.001	----	----	----
Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	0.005	0.002	<0.001
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	0.002	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L	0.040	0.036	0.051	0.023	0.010
Nickel	7440-02-0	0.001	mg/L	<0.001	<0.001	0.004	0.001	<0.001
Selenium	7782-49-2	0.010	mg/L	----	<0.010	----	----	----
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Titanium	7440-32-6	0.01	mg/L	----	<0.01	----	----	----
Uranium	7440-61-1	0.001	mg/L	----	<0.001	----	----	----
Vanadium	7440-62-2	0.01	mg/L	----	<0.01	----	----	----
Zinc	7440-66-6	0.005	mg/L	0.046	0.133	0.145	0.149	0.146
Boron	7440-42-8	0.05	mg/L	----	0.18	----	----	----
Iron	7439-89-6	0.05	mg/L	0.11	0.30	3.73	0.87	0.44
EG035W: Water Leachable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EG050F: Hexavalent Chromium - Filtered								
Hexavalent Chromium	18540-29-9	0.100	mg/L	----	<0.100	----	----	----
EK026G: Total Cyanide By Discrete Analyser								
Total Cyanide	57-12-5	0.004	mg/L	<0.004	<0.004	<0.004	<0.004	<0.004
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	----	<0.1	----	----	----



Analytical Results

Sub-Matrix: DI WATER LEACHATE

Client sample ID

Client sampling date / time

				URS BH13A 11.5-12.0 DI WATER LEACHATE	URS BH13A COMP DI WATER LEACHATE	URS BH07A 0-1.0 DI WATER LEACHATE	URS BH07A 2.0-2.8 DI WATER LEACHATE	URS BH07A 3.0-4.0 DI WATER LEACHATE
				02-AUG-2009 12:00	02-AUG-2009 12:00	02-AUG-2009 12:00	02-AUG-2009 12:00	02-AUG-2009 12:00
Compound	CAS Number	LOR	Unit	ES0911219-037	ES0911219-038	ES0911219-039	ES0911219-040	ES0911219-041
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	----	0.22	----	----	----
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	----	0.01	mg/L	----	0.09	----	----	----



Analytical Results

Sub-Matrix: DI WATER LEACHATE

Client sample ID

				URS BH18A 2.0-3.0 DI WATER LEACHATE	URS BH18A 10.0-11.0 DI WATER LEACHATE	URS BH18A 11.1-11.5 DI WATER LEACHATE	URS BH18A COMP DI WATER LEACHATE	----
Client sampling date / time				02-AUG-2009 12:00	02-AUG-2009 12:00	02-AUG-2009 12:00	02-AUG-2009 12:00	----
Compound	CAS Number	LOR	Unit	ES0911219-042	ES0911219-043	ES0911219-044	ES0911219-045	----
ED040W: Water Leachable Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	1	mg/L	----	----	----	41	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	----	----	----	308	----
ED093W: Water Leachable Major Cations								
Calcium	7440-70-2	1	mg/L	----	----	----	2	----
Magnesium	7439-95-4	1	mg/L	----	----	----	4	----
Potassium	7440-09-7	1	mg/L	----	----	----	10	----
EG020T: Total Metals by ICP-MS								
Tungsten	7440-33-7	0.001	mg/L	----	----	----	<0.001	----
EG020W: Water Leachable Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	1.17	5.48	17.1	8.27	----
Antimony	7440-36-0	0.001	mg/L	0.002	0.003	<0.001	<0.001	----
Arsenic	7440-38-2	0.001	mg/L	0.014	0.021	0.004	0.004	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	----
Chromium	7440-47-3	0.001	mg/L	0.002	0.009	0.023	0.011	----
Cobalt	7440-48-4	0.001	mg/L	----	----	----	0.005	----
Copper	7440-50-8	0.001	mg/L	0.002	0.021	0.050	0.021	----
Lead	7439-92-1	0.001	mg/L	0.001	0.007	0.006	0.002	----
Manganese	7439-96-5	0.001	mg/L	0.026	0.182	0.296	0.185	----
Nickel	7440-02-0	0.001	mg/L	0.001	0.006	0.015	0.007	----
Selenium	7782-49-2	0.010	mg/L	----	----	----	<0.010	----
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	----
Titanium	7440-32-6	0.01	mg/L	----	----	----	0.15	----
Uranium	7440-61-1	0.001	mg/L	----	----	----	<0.001	----
Vanadium	7440-62-2	0.01	mg/L	----	----	----	0.05	----
Zinc	7440-66-6	0.005	mg/L	0.015	0.164	0.134	0.201	----
Boron	7440-42-8	0.05	mg/L	----	----	----	0.39	----
Iron	7439-89-6	0.05	mg/L	1.63	7.56	36.8	12.7	----
EG035W: Water Leachable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	----
EG050F: Hexavalent Chromium - Filtered								
Hexavalent Chromium	18540-29-9	0.100	mg/L	----	----	----	<0.100	----
EK026G: Total Cyanide By Discrete Analyser								
Total Cyanide	57-12-5	0.004	mg/L	<0.004	<0.004	<0.004	<0.004	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	----	----	----	<0.1	----



Analytical Results

Sub-Matrix: DI WATER LEACHATE

Client sample ID

				URS BH18A 2.0-3.0 DI WATER LEACHATE	URS BH18A 10.0-11.0 DI WATER LEACHATE	URS BH18A 11.1-11.5 DI WATER LEACHATE	URS BH18A COMP DI WATER LEACHATE	----
Client sampling date / time				02-AUG-2009 12:00	02-AUG-2009 12:00	02-AUG-2009 12:00	02-AUG-2009 12:00	----
Compound	CAS Number	LOR	Unit	ES0911219-042	ES0911219-043	ES0911219-044	ES0911219-045	----
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	----	----	----	0.22	----
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	----	0.01	mg/L	----	----	----	0.22	----



Analytical Results

Sub-Matrix: ELUTRIATE

Client sample ID

Client sampling date / time

				URS BH17A 0-0.3 ELUTRIATE	URS BH17A 0.3-1.2 ELUTRIATE	URS BH02A 0-1.0 ELUTRIATE	URS BH02A 2.0-2.75 ELUTRIATE	URS BH02A 2.75-3.1 ELUTRIATE
				03-AUG-2009 12:00	03-AUG-2009 12:00	03-AUG-2009 12:00	03-AUG-2009 12:00	03-AUG-2009 12:00
Compound	CAS Number	LOR	Unit	ES0911219-001	ES0911219-002	ES0911219-003	ES0911219-004	ES0911219-005
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	10	µg/L	60	30	170	50	<10
Antimony	7440-36-0	0.5	µg/L	1.8	<0.5	0.6	4.3	<0.5
Iron	7439-89-6	5	µg/L	83	8	<5	<5	<5
Arsenic	7440-38-2	0.5	µg/L	2.3	<0.5	2.4	5.1	<0.5
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Copper	7440-50-8	1	µg/L	<1	2	<1	<1	<1
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Manganese	7439-96-5	0.5	µg/L	1180	5690	208	1330	2520
Nickel	7440-02-0	0.5	µg/L	0.6	3.5	4.8	4.9	2.3
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	5	µg/L	<5	<5	<5	<5	<5
EK026G: Total Cyanide By Discrete Analyser								
Total Cyanide	57-12-5	0.004	mg/L	<0.004	<0.004	<0.004	<0.004	<0.004
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	1	mg/L	3	1	2	3	1
EP030: Biochemical Oxygen Demand (BOD)								
Biochemical Oxygen Demand	----	2	mg/L	4	<2	<2	<2	<2



Analytical Results

Sub-Matrix: ELUTRIATE

Client sample ID

Client sampling date / time

				URS BH14A 0-1.0 ELUTRIATE	URS BH14A 2.5-3.5 ELUTRIATE	URS BH14A 6.0-7.0 ELUTRIATE	DOL-250709 ELUTRIATE	URS BH13A 0-1.0 ELUTRIATE
				03-AUG-2009 12:00	04-AUG-2009 12:00	04-AUG-2009 12:00	04-AUG-2009 12:00	04-AUG-2009 12:00
Compound	CAS Number	LOR	Unit	ES0911219-006	ES0911219-007	ES0911219-008	ES0911219-009	ES0911219-010
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	10	µg/L	<10	40	70	<10	40
Antimony	7440-36-0	0.5	µg/L	1.2	4.1	<0.5	0.6	3.5
Iron	7439-89-6	5	µg/L	329	443	<5	<5	10
Arsenic	7440-38-2	0.5	µg/L	3.5	2.2	1.0	2.6	6.8
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Copper	7440-50-8	1	µg/L	<1	<1	4	<1	<1
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Manganese	7439-96-5	0.5	µg/L	2050	2130	913	434	738
Nickel	7440-02-0	0.5	µg/L	1.2	<0.5	1.7	0.9	<0.5
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	5	µg/L	<5	10	<5	<5	<5
EK026G: Total Cyanide By Discrete Analyser								
Total Cyanide	57-12-5	0.004	mg/L	<0.004	<0.004	<0.004	<0.004	<0.004
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	1	mg/L	4	2	<1	3	3
EP030: Biochemical Oxygen Demand (BOD)								
Biochemical Oxygen Demand	----	2	mg/L	<2	<2	<2	<2	<2



Analytical Results

Sub-Matrix: ELUTRIATE

Client sample ID

Client sampling date / time

				URS BH13A 6.0-7.0 ELUTRIATE	URS BH13A 11.5-12.0 ELUTRIATE	URS BH07A 0-1.0 ELUTRIATE	URS BH07A 2.0-2.8 ELUTRIATE	URS BH07A 3.0-4.0 ELUTRIATE
				04-AUG-2009 12:00	04-AUG-2009 12:00	05-AUG-2009 12:00	05-AUG-2009 12:00	05-AUG-2009 12:00
Compound	CAS Number	LOR	Unit	ES0911219-011	ES0911219-012	ES0911219-014	ES0911219-015	ES0911219-016
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	10	µg/L	<10	<10	<10	140	<10
Antimony	7440-36-0	0.5	µg/L	3.1	<0.5	4.4	4.6	0.8
Iron	7439-89-6	5	µg/L	688	<5	136	111	14
Arsenic	7440-38-2	0.5	µg/L	2.7	1.1	5.4	3.3	1.4
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	0.6
Copper	7440-50-8	1	µg/L	<1	<1	<1	<1	<1
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Manganese	7439-96-5	0.5	µg/L	2340	1530	814	1470	1070
Nickel	7440-02-0	0.5	µg/L	<0.5	3.9	0.8	0.7	2.1
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	<0.1	<0.1	0.3
Zinc	7440-66-6	5	µg/L	<5	<5	<5	<5	<5
EK026G: Total Cyanide By Discrete Analyser								
Total Cyanide	57-12-5	0.004	mg/L	<0.004	<0.004	<0.004	<0.004	<0.004
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	1	mg/L	3	<1	4	3	<1
EP030: Biochemical Oxygen Demand (BOD)								
Biochemical Oxygen Demand	----	2	mg/L	<2	<2	<2	<2	<2



Analytical Results

Sub-Matrix: ELUTRIATE

Client sample ID

Client sampling date / time

				URS BH18A 2.0-3.0 ELUTRIATE	URS BH18A 10.0-11.0 ELUTRIATE	URS BH18A 11.1-11.5 ELUTRIATE	SEA WATER 17A	SEA WATER 02A
				05-AUG-2009 12:00	05-AUG-2009 12:00	05-AUG-2009 12:00	03-AUG-2009 12:00	03-AUG-2009 12:00
				ES0911219-017	ES0911219-018	ES0911219-019	ES0911219-021	ES0911219-022
Compound	CAS Number	LOR	Unit					
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	10	µg/L	60	60	260	<10	20
Antimony	7440-36-0	0.5	µg/L	3.4	5.9	<0.5	<0.5	<0.5
Iron	7439-89-6	5	µg/L	7	18	6	<5	<5
Arsenic	7440-38-2	0.5	µg/L	14.4	4.9	0.9	1.1	1.1
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	0.8	<0.2	<0.2
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Copper	7440-50-8	1	µg/L	<1	<1	2	<1	<1
Lead	7439-92-1	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2
Manganese	7439-96-5	0.5	µg/L	351	2060	2290	0.6	<0.5
Nickel	7440-02-0	0.5	µg/L	0.7	0.7	1.1	2.0	<0.5
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	5	µg/L	<5	<5	<5	6	<5
EK026G: Total Cyanide By Discrete Analyser								
Total Cyanide	57-12-5	0.004	mg/L	<0.004	<0.004	<0.004	<0.004	<0.004
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	1	mg/L	3	4	2	1	1
EP030: Biochemical Oxygen Demand (BOD)								
Biochemical Oxygen Demand	----	2	mg/L	<2	<2	<2	<2	<2



Analytical Results

Sub-Matrix: ELUTRIATE

Client sample ID

Client sampling date / time

				SEA WATER 14A	SEA WATER 13A	SEA WATER 07A	SEA WATER 18A	----
				04-AUG-2009 12:00	04-AUG-2009 12:00	05-AUG-2009 12:00	05-AUG-2009 12:00	----
Compound	CAS Number	LOR	Unit	ES0911219-023	ES0911219-024	ES0911219-025	ES0911219-026	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	----
EG093T: Total Metals in Saline Water by ORC-ICPMS								
Aluminium	7429-90-5	10	µg/L	<10	<10	30	90	----
Antimony	7440-36-0	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	----
Iron	7439-89-6	5	µg/L	<5	<5	<5	6	----
Arsenic	7440-38-2	0.5	µg/L	1.2	2.0	0.9	1.1	----
Cadmium	7440-43-9	0.2	µg/L	<0.2	<0.2	<0.2	<0.2	----
Chromium	7440-47-3	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	----
Copper	7440-50-8	1	µg/L	<1	<1	1	<1	----
Lead	7439-92-1	0.2	µg/L	1.2	<0.2	<0.2	<0.2	----
Manganese	7439-96-5	0.5	µg/L	<0.5	<0.5	0.8	<0.5	----
Nickel	7440-02-0	0.5	µg/L	0.6	0.5	0.6	0.7	----
Silver	7440-22-4	0.1	µg/L	<0.1	<0.1	<0.1	<0.1	----
Zinc	7440-66-6	5	µg/L	<5	<5	<5	5	----
EK026G: Total Cyanide By Discrete Analyser								
Total Cyanide	57-12-5	0.004	mg/L	<0.004	<0.004	<0.004	<0.004	----
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	1	mg/L	<1	<1	1	1	----
EP030: Biochemical Oxygen Demand (BOD)								
Biochemical Oxygen Demand	----	2	mg/L	<2	<2	<2	<2	----



Analytical Results

Sub-Matrix: SOIL

Client sample ID

				URS BH17A 0-0.3 ELUTRIATE	URS BH17A 0.3-1.2 ELUTRIATE	URS BH02A 0-1.0 ELUTRIATE	URS BH02A 2.0-2.75 ELUTRIATE	URS BH02A 2.75-3.1 ELUTRIATE
Client sampling date / time				25-JUL-2009 15:00	25-JUL-2009 15:00	25-JUL-2009 15:00	25-JUL-2009 15:00	25-JUL-2009 15:00
Compound	CAS Number	LOR	Unit	ES0911219-001	ES0911219-002	ES0911219-003	ES0911219-004	ES0911219-005
EN68: Seawater Elutriate Testing Procedure								
Seawater Sampling Date	----	0.1	--	25/07/09	25/07/09	25/07/09	25/07/09	25/07/09



Analytical Results

Sub-Matrix: SOIL

Client sample ID

				URS BH14A 0-1.0 ELUTRIATE	URS BH14A 2.5-3.5 ELUTRIATE	URS BH14A 6.0-7.0 ELUTRIATE	DOL-250709 ELUTRIATE	URS BH13A 0-1.0 ELUTRIATE
Client sampling date / time				24-JUL-2009 15:00	24-JUL-2009 15:00	24-JUL-2009 15:00	25-JUL-2009 15:00	24-JUL-2009 15:00
Compound	CAS Number	LOR	Unit	ES0911219-006	ES0911219-007	ES0911219-008	ES0911219-009	ES0911219-010
EN68: Seawater Elutriate Testing Procedure								
Seawater Sampling Date	----	0.1	--	25/07/09	24/07/09	24/07/09	24/07/09	24/07/09



Analytical Results

Sub-Matrix: SOIL

Client sample ID

				URS BH13A 6.0-7.0 ELUTRIATE	URS BH13A 11.5-12.0 ELUTRIATE	URS BH07A 0-1.0 ELUTRIATE	URS BH07A 2.0-2.8 ELUTRIATE	URS BH07A 3.0-4.0 ELUTRIATE
Client sampling date / time				24-JUL-2009 15:00	24-JUL-2009 15:00	23-JUL-2009 15:00	23-JUL-2009 15:00	23-JUL-2009 15:00
Compound	CAS Number	LOR	Unit	ES0911219-011	ES0911219-012	ES0911219-014	ES0911219-015	ES0911219-016
EN68: Seawater Elutriate Testing Procedure								
Seawater Sampling Date	----	0.1	--	24/07/09	24/07/09	23/07/09	23/07/09	23/07/09



Analytical Results

Sub-Matrix: SOIL

Client sample ID

				URS BH18A 2.0-3.0 ELUTRIATE	URS BH18A 10.0-11.0 ELUTRIATE	URS BH18A 11.1-11.5 ELUTRIATE	SEA WATER 17A	SEA WATER 02A
Client sampling date / time				23-JUL-2009 15:00	23-JUL-2009 15:00	23-JUL-2009 15:00	25-JUL-2009 15:00	25-JUL-2009 15:00
Compound	CAS Number	LOR	Unit	ES0911219-017	ES0911219-018	ES0911219-019	ES0911219-021	ES0911219-022
EN68: Seawater Elutriate Testing Procedure								
Seawater Sampling Date	----	0.1	--	23/07/09	23/07/09	23/07/09	25/07/09	25/07/09



Analytical Results

Sub-Matrix: SOIL

Client sample ID

Client sampling date / time

				SEA WATER 14A	SEA WATER 13A	SEA WATER 07A	SEA WATER 18A	URS BH17A 0-0.3 DI WATER LEACHATE
				24-JUL-2009 15:00	24-JUL-2009 15:00	23-JUL-2009 15:00	23-JUL-2009 15:00	25-JUL-2009 15:00
Compound	CAS Number	LOR	Unit	ES0911219-023	ES0911219-024	ES0911219-025	ES0911219-026	ES0911219-027
EN60-DI: Bottle Leaching Procedure								
Final pH	----	0.1	pH Unit	----	----	----	----	9.1
EN68: Seawater Elutriate Testing Procedure								
Seawater Sampling Date	----	0.1	--	24/07/09	24/07/09	23/07/09	23/07/09	----



Analytical Results

Sub-Matrix: SOIL

Client sample ID

				URS BH17A 0.3-1.2 DI WATER LEACHATE	URS BH02A 0-1.0 DI WATER LEACHATE	URS BH02A 2.0-2.75 DI WATER LEACHATE	URS BH02A 2.75-3.1 DI WATER LEACHATE	URS BH14A 0-1.0 DI WATER LEACHATE
Client sampling date / time				25-JUL-2009 15:00	25-JUL-2009 15:00	25-JUL-2009 15:00	25-JUL-2009 15:00	24-JUL-2009 15:00
Compound	CAS Number	LOR	Unit	ES0911219-028	ES0911219-029	ES0911219-030	ES0911219-031	ES0911219-032
EN60-DI: Bottle Leaching Procedure								
Final pH	----	0.1	pH Unit	8.8	9.3	8.9	8.8	9.3



Analytical Results

Sub-Matrix: SOIL

Client sample ID

				URS BH14A 2.5-3.5 DI WATER LEACHATE	URS BH14A 6.0-7.0 DI WATER LEACHATE	URS BH13A 0-1.0 DI WATER LEACHATE	URS BH13A 6.0-7.0 DI WATER LEACHATE	URS BH13A 11.5-12.0 DI WATER LEACHATE
Client sampling date / time				24-JUL-2009 15:00	24-JUL-2009 15:00	24-JUL-2009 15:00	24-JUL-2009 15:00	24-JUL-2009 15:00
Compound	CAS Number	LOR	Unit	ES0911219-033	ES0911219-034	ES0911219-035	ES0911219-036	ES0911219-037
EN60-DI: Bottle Leaching Procedure								
Final pH	----	0.1	pH Unit	9.0	8.7	9.3	9.2	8.5



Analytical Results

Sub-Matrix: SOIL

Client sample ID

				URS BH13A COMP DI WATER LEACHATE	URS BH07A 0-1.0 DI WATER LEACHATE	URS BH07A 2.0-2.8 DI WATER LEACHATE	URS BH07A 3.0-4.0 DI WATER LEACHATE	URS BH18A 2.0-3.0 DI WATER LEACHATE
Client sampling date / time				24-JUL-2009 15:00	23-JUL-2009 15:00	23-JUL-2009 15:00	23-JUL-2009 15:00	23-JUL-2009 15:00
Compound	CAS Number	LOR	Unit	ES0911219-038	ES0911219-039	ES0911219-040	ES0911219-041	ES0911219-042
EN60-DI: Bottle Leaching Procedure								
Final pH	----	0.1	pH Unit	8.4	9.1	9.1	8.8	9.2



Analytical Results

Sub-Matrix: SOIL

Client sample ID

				URS BH18A 10.0-11.0 DI WATER LEACHATE	URS BH18A 11.1-11.5 DI WATER LEACHATE	URS BH18A COMP DI WATER LEACHATE	----	----
				23-JUL-2009 15:00	23-JUL-2009 15:00	23-JUL-2009 15:00	----	----
Compound	CAS Number	LOR	Unit	ES0911219-043	ES0911219-044	ES0911219-045	----	----
EN60-DI: Bottle Leaching Procedure								
Final pH	----	0.1	pH Unit	9.5	9.7	9.3	----	----



URS Australia Pty Ltd
Level 16, 240 Queen Street
Brisbane, QLD 4000
GPO Box 302, QLD 4001
Australia

T: 61 7 3243 2111

F: 61 7 3243 2199

www.ap.urscorp.com