1 INTRODUCTION

This volume provides an update to *Volume 6* of the draft Environmental Impact Statement (EIS) for the Queensland Curtis LNG (QCLNG) Project.

The reference case for dredging works has been modified from that previously described. Supplementary EIS *Volume 2, Chapter 14* describes the revised dredging case and describes those elements of dredging for which QGC will be responsible, versus those which Gladstone Ports Corporation (GPC) will provide. In essence, QGC will be responsible for the early works important for to the commencement of construction of the QCLNG Project, and for dredging unrelated to GPC's port operations mandate (that is, the export pipeline across The Narrows). GPC's operational mandate means that it will provide dredged access to all operating facilities within the Port of Gladstone.

The scope of dredging assessed by the QCLNG EIS no longer includes dredging for construction of GPC's Curtis LNG Precinct channels or swing basins, or the disposal of the resulting dredged materials. Similarly, it does not include minor dredging works to provide access to new transfer infrastructure to be located at Auckland Point or the RG Tanna facility. These dredging and disposal works will be undertaken by GPC, and are variously described in GPC's Fisherman's Landing Northern Expansion (FLNE) EIS (released October 2009), Western Basin Dredging and Disposal Project (WBDDP) EIS (released November 2009), or other minor works approvals.

GPC's WBDDP EIS assumes that GPC will provide each Curtis Island project proponent with dredged access to a Materials Offloading Facility (MOF). GPC's EIS therefore includes assessment of dredging and dredge material disposal for QGC's (and others') MOF structure.

While it is QGC's generally intention to rely upon GPC's approval processes, QGC is concerned that any delay to GPC's approvals process for major dredging and disposal items, the swing basin and channel, may place its construction schedule at risk. QGC has therefore sought to manage this risk by including in its own assessment early items, including the MOF. QGC's assessment (below) also includes fall-back options for MOF and Construction Dock dredging and material disposal.

This volume addresses the physical environmental impact of the QCLNG Project dredging and material disposal components as described above. Impacts on marine ecology (fauna and flora) are described in *Volume 5, Chapter 8*.

Specifically, this Volume addresses the dredging and spoil disposal associated with QCLNG Project early works, including:

- Construction Dock
- Materials Offloading Facility (MOF)
- The Narrows Pipeline crossing

Several documents should be considered to obtain a comprehensive understanding of the QCLNG dredging program and its potential impacts. These include:

- The QCLNG Project Draft EIS
- *Volume 2, Chapter 14* – Project Description of Dredging for Marine Facilities
- *Volume 5, Chapter 8* – Marine Ecology
- *Volume 6* – Assessment for Dredging of Marine Facilities
- *Volume 13* – Environment Protection and Biodiversity Conservation Act Assessment Report: Additional Information on Potential Impacts on Matters of National Environmental Significance
- *Appendix 6.1* – draft Dredge Management Plan.

In addition to the physical impacts of early works dredging and disposal required for the QCLNG Project, *Volume 6* of this supplementary EIS addresses -submissions received through the public consultation process for the draft EIS. Issues raised in these submissions, and QGC's responses, are provided below in *Table 6.1.1*.

Table 6.1.1 Response to Submissions on Draft EIS: Dredging

Issue Raised	QCLNG Response	Relevant Submission(s)
Submissions were made concerning possible environmental impacts associated with the cumulative impacts from multiple dredging operations.	Cumulative impacts of dredging operations are addressed in GPC's WBDD EIS. The assessment of dredging currently proposed by QGC is addressed in *Volume 5, Chapter 8, and Volume 6.*	22, 24, 26, 30, 32, 38, 40,
A submission was made requesting that the Dredge Management Plan provide a practical and enforceable set of management actions that can be reflected in the conditions of approval by the Coordinator-General.	The Draft Dredge Management Plan has been revised to include practical and enforceable management actions for the dredging works described in the sEIS.	32
A submission was made requesting description of contingency plans in the event of marine fauna being injured by blasting during dredging.	Blasting is not planned for the dredging works. Should it become necessary, a separate management plan, that includes the contingency issues raised, will be developed to the satisfaction of DERM.	25
A submission was made requesting further information on the proposed management of acid sulfate soils known to occur in this area during backhoe dredge operations.	The Draft Dredge Management Plan, presented in *Volume 6, Chapter 1.5.3* includes an acid sulfate soils management plan. Note that both the Draft Dredge Management Plan and the draft Acid Sulfate Soils Management Plan *(Appendix 2.2)* will be	22, 32

Issue Raised	QCLNG Response	Relevant Submission(s)
	updated once the EPC contractor is appointed and detailed design of the dredging works has been finalised. These plans will be submitted to DERM during the approval processes required for the dredging works.	
A submission requested that the effect of light attenuation caused by increased activity associated with dredging be considered in more detail with emphasis on the potential impact to seagrass communities. The submission also requested that the potential for re-establishment of seagrass communities be addressed.	Changes in light attenuation caused by dredge-released suspended solids and the impacts on seagrass are addressed in *Volume 6, Ch 4.2.2.* and *4.3.2.* This concludes that there is a risk of temporary and indirect impacts to seagrasses located in the harbour.	32
A number of submissions were made regarding the potential environmental impacts of land reclamation at the Western Basin.	The Fisherman's Landing Reclamation and the Western Basin Reclamation are projects proposed by Gladstone Ports Corporation. These projects are currently undergoing environmental impact assessments through State and Commonwealth processes.	22, 32, 40
A submission was made requesting further information on the basis for the assumed sediment loading to waters and the settling rate for suspended sediment used in modelling.	Dredge plume modelling has been revised. Assumptions and methods for modelling of suspended solids and light attenuation are presented in *Appendices 6.2 and 6.3* and discussion of the results are presented in *Chapter 2* below.	32
A submission was received regarding impacts on fauna and flora from the proposed dredging works described in the Draft EIS.	An assessment of the direct and indirect impacts to marine fauna and flora, drawing upon the modelling results reported in this Volume, is presented in *Volume 5, Chapter 8.*	6
It was submitted that the EIS should include a detailed offset strategy for the LNG Facility and the dredging works.	An offset strategy applicable to the LNG facility and dredging works is discussed in *Volume 5 Chapter 7* and provided in *Appendix 2.3.* This includes an offset strategy for mangroves. Other marine plants are not expected to be significantly impacted and are therefore not part of the offset strategy for this Project. With regard to the GPC dredging program, QGC will support the Port's offset initiatives.	24

2 IMPACT ASSESSMENT – PHYSICAL ENVIRONMENT

2.1 SCOPE OF DREDGING ACTIVITIES PROPOSED

As described in *Section 1* and in *Volume 2, Chapter 14*, the scope of this volume is limited to assessing the physical impacts of dredging and spoil disposal associated with QCLNG early works, including:

- Construction Dock
- Materials Offloading Facility (MOF)
- The Narrows Pipeline crossing.

This assessment includes only new or changed material, updated since the draft EIS, or information which appeared in the draft EIS but on the basis of comments received warrants a more detailed explanation.

2.2 DREDGE METHODOLOGY

The QCLNG Project dredging program will involve a range of dredging works in different environments which are constrained as a result of ecological values, engineering and logistical aspects and other environmental factors. Therefore, the dredging program will employ different methods for different locations.

All preferred dredging methods (Scenario 1) and fall-back options (Scenario 2 and Scenario 3) are based around the use of cutter suction dredges (CSDs) and/or backhoe dredges (BHDs). The benefits of these in relation to dredging works, and how they will be used, are described below.

2.2.1 Cutter Suction Dredge (CSD)

CSDs are primarily used when material can be pumped ashore for reuse in applications such as land reclamation.

A CSD is a near-stationary dredger, consisting of a pontoon positioned by a combination of one or more spud pole(s) and side anchor(s). The cutter head works in an arc from the spud pole. Once one swing is completed by the cutter head, the dredge moves forwards on the spud carriage system. Both the spud carriage advance rate and the cutter swing rate are slow enough, and the dredging operation noisy enough, that mobile animals can swim away from an operating dredge.

There is no overflow from a CSD. The main sources of sediment plume generation occur at the cutter head and in decant water from the sediment receiving ponds.

If it is not possible to use the GPC-designated dredged material disposal sites as indicated in the WBDDP or FLNE EISs, CSD may be equipped to facilitate loading directly into split hopper barges (SHBs) allowing for the material to be barged to an approved location for disposal.

2.2.2 Backhoe Dredge (BHD)

The BHD is one of the most commonly used dredges in Queensland. It is either vessel or barge mounted. In shallow areas, BHDs are more effective than other types of dredges.

One or more BHDs may be used if it is difficult to secure a CSD within the necessary construction schedule. A BHD may also be used for very shallow areas, such as the upper areas of the Construction Dock or MOF footprint.

2.2.3 Jetting

Narrow pipeline trenches, such as that anticipated for The Narrows Pipeline crossing, are often cut using a jetting system. This operation is described in more detail in sEIS *Volume 2 Chapter 12.* If soil conditions are not suitable for jetting, the pipeline trench is likely to be cut with a BHD.

2.2.4 Approach to the Dredging Assessment

Both a CSD and BHD are likely to be contracted to undertake dredging for QCLNG Project early works. Dredge requirements for the areas to be dredged are provided in *Section 2.2* of this volume.

The Draft Dredge Management Plan which is attached to this volume also describes how dredging operations are likely to be conducted and those mitigation measures and performance standards which QGC has committed to.

A pre-dredge hydrographic survey of the entire work area will be undertaken before dredging commences. This will provide the basis for the development of a dredging plan. This plan will describe the engineering and logistical aspects and constraints which the proposed dredging program will need to meet. The dredging plan to be approved by regulatory agencies will consist of the:

- dimensions of the area to be dredged
- location and dimensions of fixed structures
- quantities of material to be dredged
- position of the dredges and other necessary equipment
- expected duration of operations in each area.

Dredging will be conducted to the lines, levels and profiles as required and as accurately as practically possible within the physical limitations of the dredge being used.

Once the final dredging methodology and the dredging plan have been agreed between QGC, QGC's dredging contractors and the owners of dredge material disposal facilities, the dredging plan will need to be approved by the relevant government agencies prior to QGC commencing any dredging works for the QCLNG Project.

Separately to this and as prescribed by regulation, QGC has developed a Draft Dredge Management Plan which identifies those mitigation strategies and monitoring requirements which will be used to manage and mitigate those environmental impacts described in this volume and *Volume 5, Chapter 8*. The Draft Dredge Management Plan is attached as *Appendix 6.1*.

QGC has commissioned a number of studies to ensure that:

- both these plans accurately identify the impacts of the dredging program
- mitigation strategies ensure that the environmental values of the Gladstone Harbour are maintained
- the dredging program is based on best available scientific information.

Commissioned studies include:

- advanced dredge plume modelling
- light attenuation modelling
- acid sulfate soils management framework
- seagrass shading studies.

The outcomes of these studies are reported in this Volume and inform the discussion of potential impacts to marine ecology in *Volume 5, Chapter 8*.

Seagrass shading studies, which commenced in November 2009, will be completed in February 2010. The outcome of these will be used to refine criteria for response levels which are outlined in the Draft Dredge Management Plan attached as *Appendix 6.1*. In particular, trigger levels for light attenuation will be updated once these studies have been concluded and discussions with regulatory agencies have been completed. It is expected that these findings will be finalised by the end of February 2010.

2.3 DREDGE PLUME MODELLING

2.3.1 Description of Additional Modelling

Dredge plume modelling was undertaken by QGC to determine the impact of sediment plumes on fauna, flora, water quality, visual amenity and other environmental factors.

Dredge plumes are sediment-laden water created during dredging of material from the seabed, during transport of dredged materials, or during the placement of dredged material in its disposal area. Dredge plumes can occur as follows:

- Sediments can be released into the water column during the dredging (up-lift) operation. This can occur as a result of losses at the cutting head. In some types of equipment these losses can also occur from propellers used to maneuver a dredge, or from leakage or overflow as dredge material is temporarily stored in barges or hoppers.
- When dredged material (also known as dredge spoil) is placed in a reclamation area, decant or tail water (excess water) is discharged through settling ponds into the marine environment. Although this discharge must meet licence conditions designed to minimize environmental nuisance or harm, plumes can occur.
- Disposal to an offshore spoil ground such as the currently used East Banks Spoil Disposal Ground will generate turbidity in the water column as the dumped material settles.

Sediment plumes comprise of a mixture of course and fine sediments, depending upon the nature of the sediments dredged and the dredging method employed. Sediment plumes can migrate with water currents. As they do, more course sediments settle most quickly, and finer sediments can be carried longer distances. This leads to three key impact mechanisms:

- Sedimentation, or the ‘rain’ of sediments caused by particles settling onto seabed surfaces. A heavy deposition of sediments can ‘smother’ flora and fauna in some circumstances.
- Total suspended sediments (or TSS), which refers to those sediments too fine to have settled to the seabed at any given time. Suspended sediments generally do not have a direct impact, but cause problems with light attenuation (see below).
- Light attenuation, whereby suspended sediments act like a cloud, reducing the amount of sunlight which can penetrate through the water and sustain photosynthesis in plants. The outcome of increased light attenuation is shading of the seabed.

The hydrodynamic processes by which these plumes breakup and where they finally settle can impact a range of environmental values such as marine fauna and flora.

Sediment plume modelling was conducted to identify the impact of any sediment plume(s) as a result of early works dredging and the likelihood of the sediment plume migrating and settling in environmentally sensitive areas, or remaining suspended but shading plants and animals that rely on light.

While sediment plume modelling was presented in the Draft EIS, and has been performed by GPC and others for other development proposals within Gladstone harbour, additional modelling was performed for the supplementary

EIS for the purpose of refining impact assessments. These most recent models incorporated the following refinements:

- improved estimates of source rates, based on particular dredging method scenarios for QGC's proposed dredging
- three-dimensional modelling
- better detail on the different behaviours of a range of finer sediments
- ambient turbidity and resuspension of settled particles
- modelling of light attenuation directly, rather than just inferring light attenuation from suspended sediment concentrations.

Modelling was undertaken for MOF and construction dock dredging, as well as for The Narrows Pipeline crossing. Modelling for the MOF and Construction Dock described three key scenarios and the different ways in which plumes migrate, based on known currents which occur in Port Curtis. Modelling for The Narrows Pipeline crossing assessed scenarios for both the BHD and jetting construction methods. The modelling assessed how the sediments would settle based on the types of sediments likely to be dredged and how these particular sediments settle in time.

Modelling of sediment plume migration and settlement was undertaken by BMT WBM (water movement) and APASA (sediment and light). Copies of these reports are attached as *Appendix 5.4, 6.2 and 6.3*, however, the results and assessment of impacts are described below.

2.3.2 Description of Modelled scenarios

Three scenarios were modelled for the development of the MOF and Construction Dock. Two relate to the earliest dredging works required for the Construction Dock and the MOF Stage 1. These two scenarios reflect the two alternative dredging methods that may be employed in these shallow areas, pending availability of particular dredgers. The third scenario, appropriate for MOF Stage 2, uses larger equipment better suited to the greater size of this stage. These scenarios are described below:

- Scenario 1 (53 days duration) – This is the preferred scenario for removal of sediment from MOF Stage 1 and the Construction Dock. It assumes that Fisherman's Landing is available as a receiving site in the required timeframe (mid 2010), and that the appropriate equipment is available at that time. It assumes the use of a small-medium CSD (removing approximately 500 m^3/hr), with spoil pumped to a Fisherman's Landing reclamation site via a floating or submerged hydraulic pipeline. Excess water (tail-water) is returned to the marine environment from the north-west corner of the proposed Western Basin reclamation site via a series of outflow pipes.
- Scenario 2 (90 days duration) – This is a fall-back scenario, which would be implemented if the Fisherman's Landing receiving area is not available when required, or if a small-medium CSD is not available at that time.

It assumes the use of two BHD to remove material within the MOF and Construction Dock areas. Each BHD would deposit sediments directly into three supporting (six in total) split hopper barges (SHB). These barges would dispose of the dredged material to an existing approved offshore spoil ground.

- Scenario 3 (64 days duration) – This scenario is effectively a fall-back scenario for MOF Stage 2, as it is intended that GPC would have completed dredging of the access channel by the time MOF Stage 2 is required. If this has not been done, then QGC would remove the sediment from MOF Stage 2 using a large CSD (approximately 1,500 m^3/hr) with spoil pumped to an approved Fisherman's Landing receiving site via a floating or submerged hydraulic pipeline. Again, tail-water would be returned to the marine environment through a series of overflow pipes.

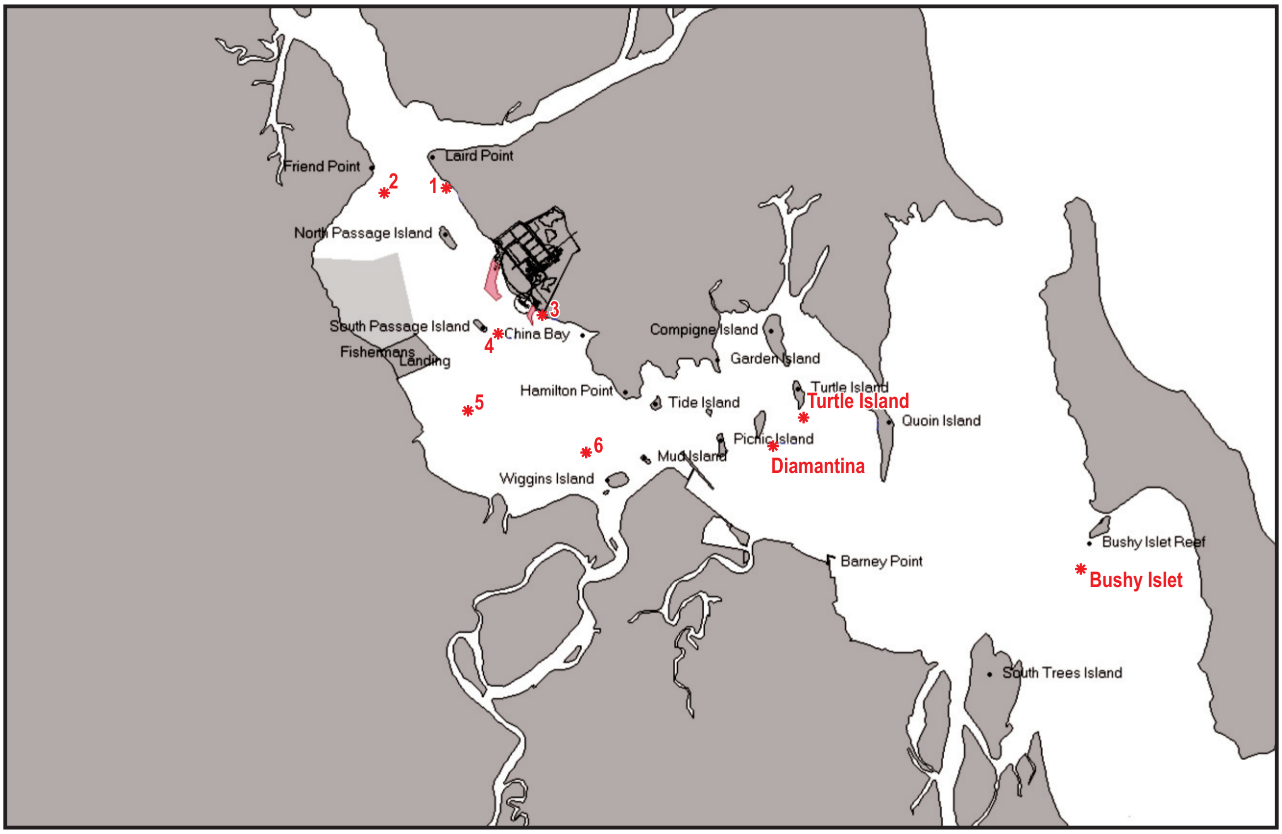
Each of the three dredge scenarios comprise multiple, independently modelled dredging and disposal sediment sources. Individual model outputs (for each source) were combined to gain an understanding of the overlapping sediment sources and therefore an understanding of the overall effects from dredging and disposal, for each modelled scenario.

Two dredging methods were modelled for The Narrows Pipeline crossing; BHD to be used for excavating the trench and subsequent backfilling of trench once pipeline is laid; and jetting for burial of pipeline where a BHD can't operate.

Model results are presented in a number of forms to highlight the spatial and temporal patterns of sedimentation, suspended sediments, and impacts to the amount of light reaching the seabed. These include:

- snapshots of the spatial extent of model-predicted TSS and deposited sediment due to individual sediment sources at particular times. In these plots the value chosen is not the sediment concentration which would be visible from the surface, but the highest concentration which might exist anywhere in the water column.
- time series graphs of the maximum predicted suspended sediment concentrations for known sensitive receptor habitats as shown in *Figure 6.2.1 and Figure 6.2.2.*
- interpretive mapping of the highest occurrences of suspended sediments over the entire dredging duration. These interpretive maps draw together hourly predictions over the entire modelled period for each location (represented as 0.5 m depth layers within each 40 m x 40 m grid cell within the model domain). Contour lines are drawn to encompass all cells on the basis of frequency of exposure. The 50th percentile maps show median (or the most commonly occurring) values and indicates more typical results, while the 80th and 95th percentiles reveal the extreme upper values. It is important to recognise that these figures do not represent snapshots of a plume at any point in time.

- interpretive mapping as above, but for sedimentation rates, again highlighting the highest occurrences over the entire dredging duration. The 50th percentile again represents median values and indicates a more typical result, while the 95th percentile reveals the extreme upper values.
- calculated differences in the amount of light reaching the seabed for the pre-dredging scenario versus that during dredging.



Source:
Asia Pacific ASA Pty Ltd
QCLNG EarlyWorks Dredge Plume Modelling Final
Prepared for British Gas, 7 January 2010

Not To Scale

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QUEENSLAND CURTIS LNG A BG Group business	Project **Queensland Curtis LNG Project** Client **QGC - A BG Group business**	Title **Location of Time Series Output Sites MOF and Construction Dock**
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB | **sEIS Volume 5** **Figure S6.2.1** Approved RS | File No: 0086165b_SUP_CDR001_S6.2.1 Date 07/01/10 | Revision 0	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.

Source:
Asia Pacific ASA Pty Ltd
QCLNG - Pipeline Burial Sediment Plume Modelling
Prepared for British Gas, 23 December 2009

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Project	**Queensland Curtis LNG Project**		
Client	**QGC - A BG Group business**		
Drawn KP	**sEIS Volume 5**	**Figure S6.2.2**	
Approved RS	File No:	0086165b_SUP_CDR036_S6.2.2	
Date 21/01/10	Revision 0		

Title **Location of Time Series Output Sites Narrows Pipeline Crossing**

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2.3.3 *Dredge Plume Modelling Summary of Results*

QGC has taken the existing hydrodynamic models for Gladstone Harbour which have been used for a range of environmental impact statements and other environmental studies and extended these to ensure that the model accurately describes the dredging works. A conservative approach was taken in determining any model assumptions or inputs so that impacts would not be underestimated. The assumptions used in the model are detailed in *Appendix 6.2* of this Volume.

2.3.3.1 *Cutter Suction Dredging*

The cutter head is the greatest single source of sediment loss when using CSDs. Modelling has predicted:

- vertically, significantly higher concentrations occur near the seabed (above 80 mg/L), reducing exponentially to the water surface (approximately 10 mg/L)
- Horizontally, plumes are concentrated (approximately 100 mg/L above ambient) adjacent to the MOF and Construction Dock, with concentrations decreasing exponentially as a function of distance and current strength.

Figure 6.2.3 provides a snapshot of the maximum predicted TSS concentrations (above background) generated by the cutter head while dredging within the MOF (the larger CSD used in Stage 2). This snapshot was modelled for the maximum water current which would occur in a typical ebb and flood cycle.

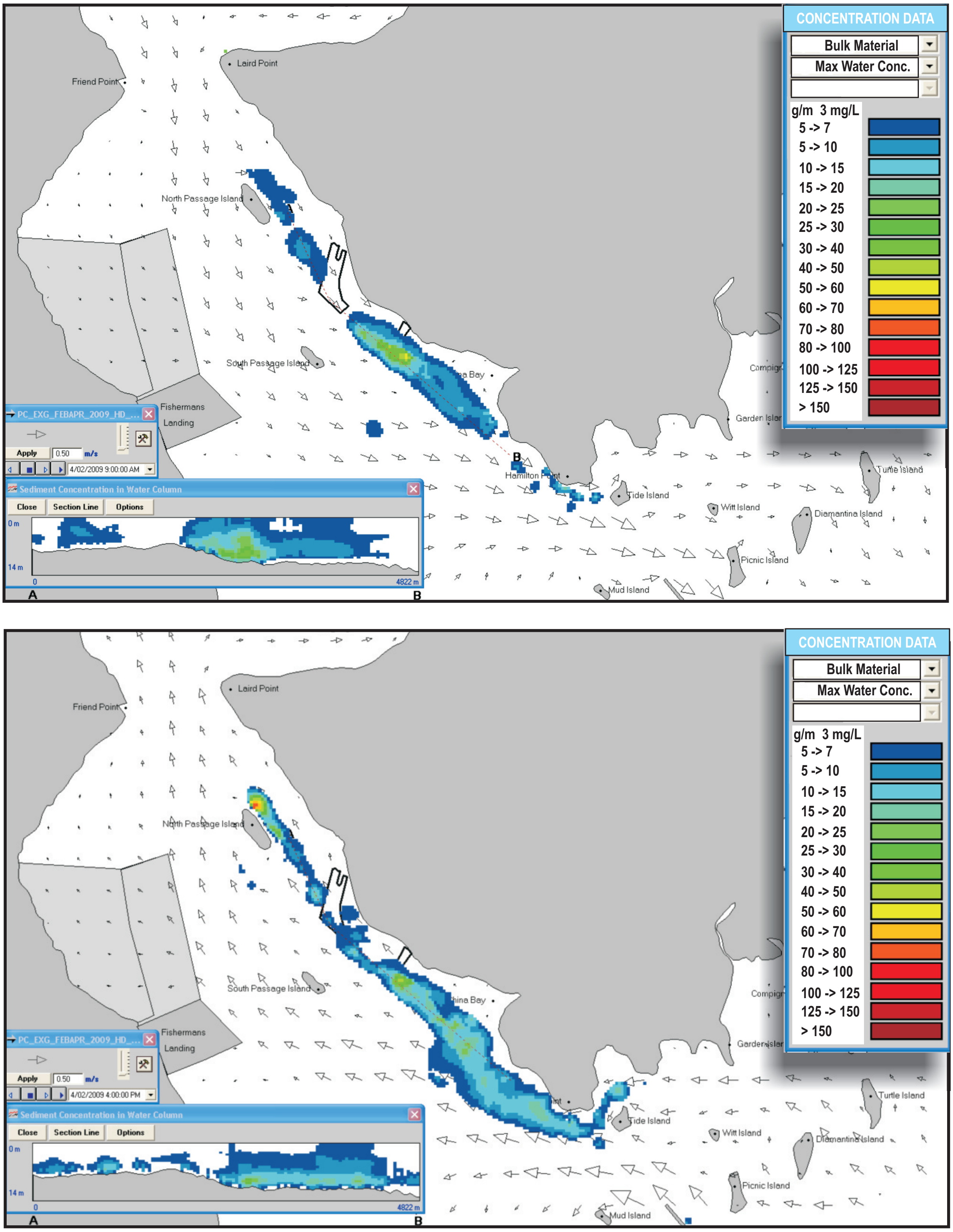
During the out-going tide the sediment plumes moved south-east from the dredge operation towards Tide Island, approximately 5.5 km south-east from the MOF dredge footprint. At this point TSS concentrations had reduced to 15 – 30 mg/L above background concentrations. At the turn of the tide, the plume was pushed back up the main channel towards the mouth of Grahams Creek and The Narrows, albeit at lower concentrations (approximately 5 mg/L above ambient).

Figure 6.2.4 illustrates the change in maximum TSS as hourly time series plots, during a typical ebb tide.

The model predicts a number of high turbidity events which occur as isolated patches within the main plume. These occur when flowing water encounters land masses (i.e. South Passage Island) and splits into multiple streams. Modelling has also indicated that the common occurrence of strong currents (up to 2 m/s) scours and re-suspends fine (< 130 μm) dredged sediment within the vicinity of the dredged site.

The model has predicted that the thickness of deposited sediment will increase adjacent to the cutter head, mainly due to the settlement of coarser sediment. Finer sediment is predicted to be transported with the prevailing currents. These sediments momentarily settle at the turn of the tide, before re-suspending as water velocities increase. With the on-going re-suspension of sediments during the dredge operation, the distribution and thickness of deposited sediments is predicted to continue evolving.

Figure 6.2.5 highlights the change in bottom thickness of deposited sediments as hourly time series plots, during a typical ebb tide.



Source:
Asia Pacific ASA Pty Ltd
QCLNG EarlyWorks Dredge Plume Modelling Final
Prepared for British Gas, 7 January 2010

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Project	Queensland Curtis LNG Project		
Client	QGC - A BG Group business		
Drawn	JB	sEIS Volume 5	Figure S6.2.3
Approved	RS	File No:	0086165b_SUP_CDR002_S6.2.3
Date	21/01/10	Revision	0

Title **Snapshot of maximum predicted TSS concentration plume (above ambient) generated from loss at the cutter head during dredging of the MOF Stage II, during a typical February ebb (top) and flood (bottom) peak current**

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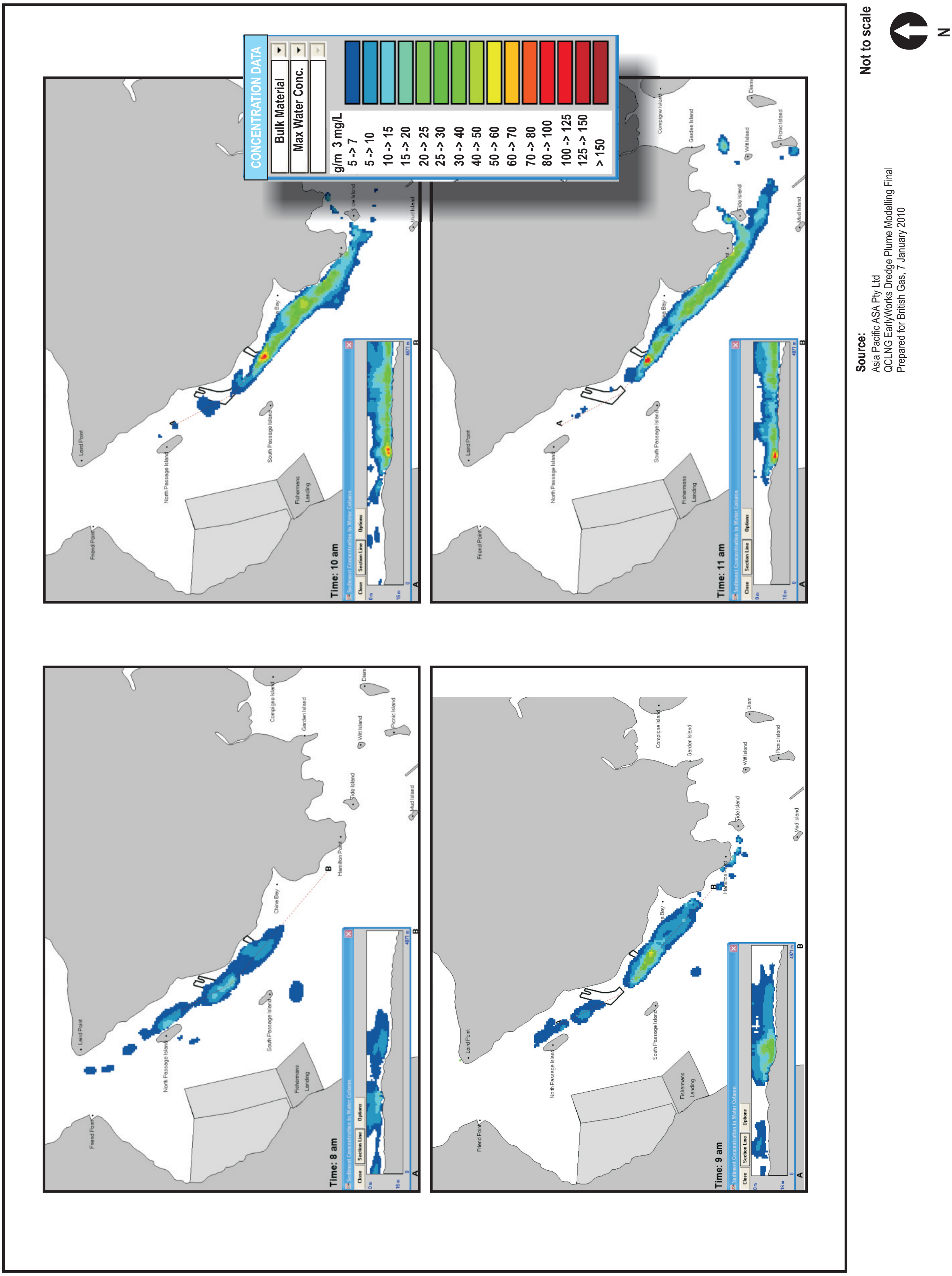
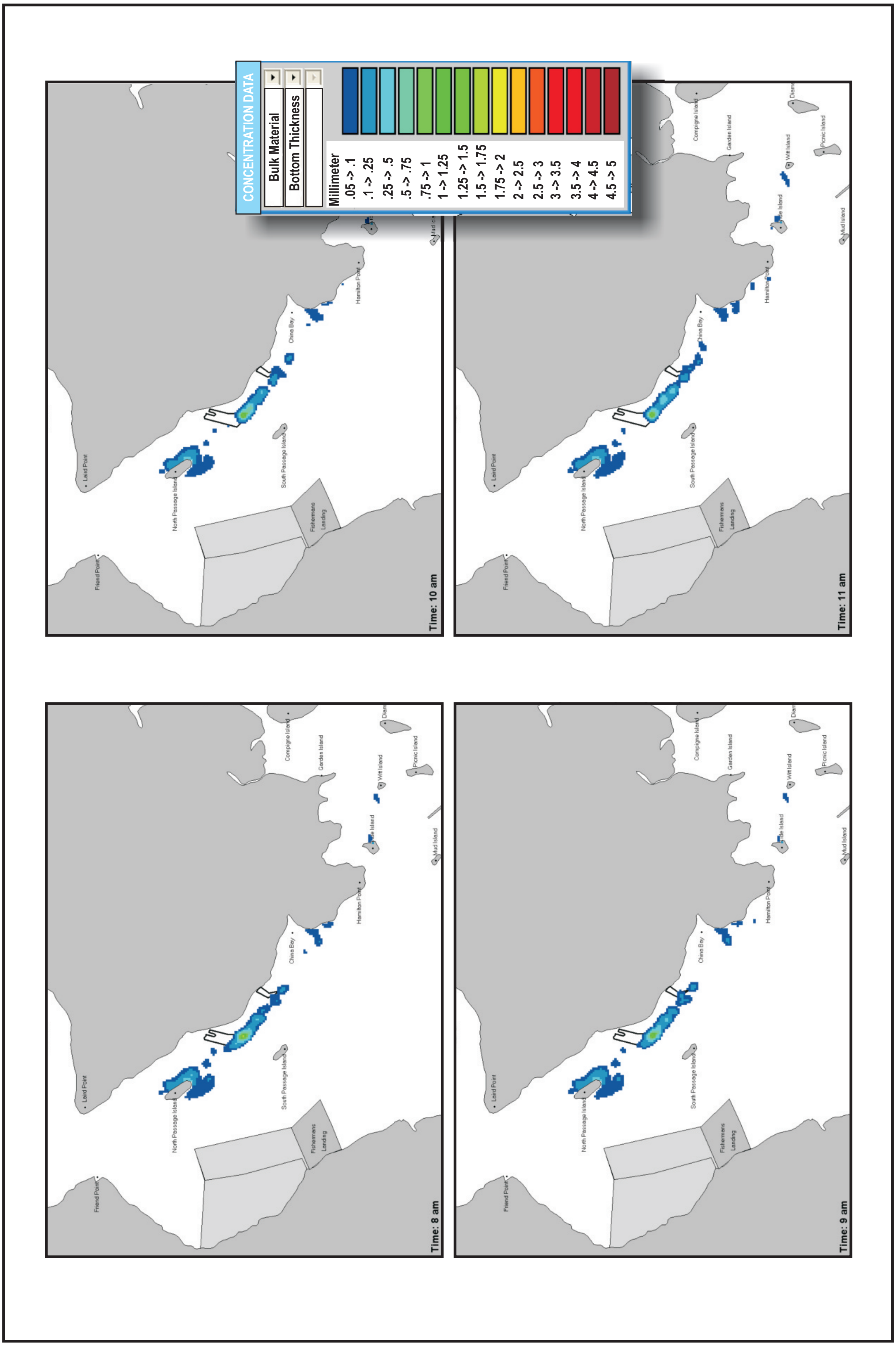


QUEENSLAND CURTIS LNG A BG Group business	Project	Queensland Curtis LNG Project	Title	Hourly time-series plots (8 am, 9 am, 10 am and 11 am 4th February 2009) of maximum TSS plumes (mg/L) generated from loss at the cutter head while dredging within the MOF (Stage 2)
	Client	QGC - A BG Group business		
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB	sEIS Volume 5 Figure S6.2.4	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.	
	Approved RS	File No: 0086165b_SUP_CDR003_S6.2.4		
	Date 21/01/10	Revision 0		



Not to scale

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Source:
Asia Pacific ASA Pty Ltd
QCLNG EarlyWorks Dredge Plume Modelling Final
Prepared for British Gas, 7 January 2010

QUEENSLAND CURTIS LNG A BG Group business	Project	**Queensland Curtis LNG Project**	Title **Hourly time-series plots (8 am, 9 am, 10 am and 11am 4th February 2009) of bottom thickness (millimetres) generated from loss at the cutter head while dredging within the MOF (Stage 2)**
	Client	**QGC - A BG Group business**	
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB	**sEIS Volume 5** **Figure S6.2.5**	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved RS	File No: 0086165b_SUP_CDR004_S6.2.5	
	Date 21/01/10	Revision 0	

2.3.3.2 *Tail-Water Discharge*

An outcome of discharging dredged material to reclamation is that it needs to be dewatered. This is achieved by gravity separation of the solids from the water, followed by decanting excess water, through a series of detention ponds, back to the marine environment.

One assumption used in the modelling of tail-water discharges was that discharge criteria historically applied to discharges from the Fisherman's Landing reclamation (40 NTU) would continue to be applied to proposed works. Based on local turbidity versus suspended sediment relationships, this equates to a calculated TSS of approximately 110 mg/L.

The model determined that the highest TSS concentrations in tail-water (< 50 mg/L above ambient) would likely occur within 300 m of the discharge cell and would reduce to 5 mg/L above ambient at the north-east point of the reclamation site (approximately 2.2 km). During flood tides, the fine sediment (< 75 µm) would migrated towards Friend Point, resulting in episodic spikes of low concentrations (5 mg/L above ambient) of TSS. In the following ebb tide, the material would disperse back toward the northern sector of the proposed reclamation site.

Figure 6.2.6 demonstrates the movement of the tail-water plume as hourly plots, at the start of an out-going tide.

QUEENSLAND CURTIS LNG A BG Group business	Project: Queensland Curtis LNG Project		Title: **Hourly time-series plots (9 am, 10 am, 11 am and 12am) of maximum TSS plumes (mg/L) generated by the tail-water discharge at the north-western sector of the reclamation site**
	Client: QGC - A BG Group business		
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB	sEIS Volume 5 — Figure S6.2.6	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved RS	File No: 0086165b_SUP_CDR005_S6.2.6	
	Date 21/01/10	Revision 0	

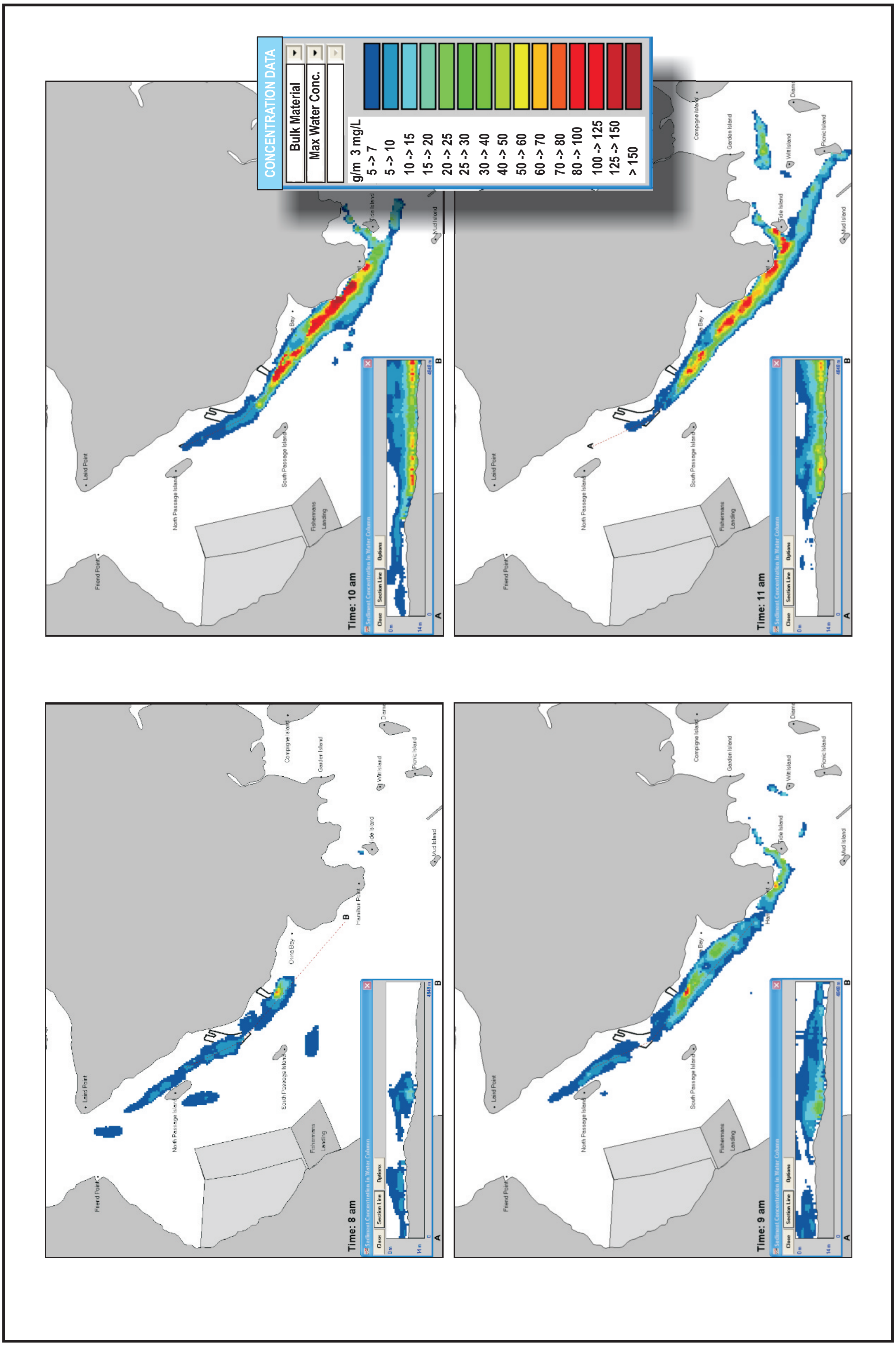
2.3.3.3 *Backhoe Dredging*

In contrast to CSD simulations, BHD operations are predicted to result in larger and more concentrated suspended sediment plumes at the water surface and near the seabed. This is because sediment is lost from the grab on the seabed, and throughout the water column during the lift process. These water column losses allow finer material to be carried by the current for some distance before initial settlement.

For the MOF and Construction Dock, during an ebb tide the plume was predicted to move south-east beyond Turtle Island, and north-west to Laird Point during a prevailing in-coming tide. The plume concentrations were found to vary over time due to changes in current strength as illustrated by *Figure 6.2.7*.

For the Targinie Creek section of The Narrows Pipeline crossing, plumes were generally restricted to Humpy and Targinie Creeks, although patchy plumes were occasionally predicted to emerge from Targinie Creek during spring ebb tides. This is illustrated by *Figure 6.2.8*.

For operations in The Narrows for the pipeline crossing, sediment plumes generated by BHD operation on the west side of the channel were predicted to migrate as a relatively narrow plume along the west side of the tidal channel through Port Curtis. Sediment plumes generated by BHD operations on the east side of the crossing were also predicted to migrate toward the west side of the tidal channel. Plumes were also predicted to have markedly shorter upstream migrations during flooding tides than downstream migrations during ebbing tides. TSS concentrations were also predicted to build up during flood tides and decrease during ebb tides. This is illustrated in *Figure 6.2.9*.



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QUEENSLAND CURTIS LNG A BG Group business	Project: Queensland Curtis LNG Project		Title: Hourly time-series plots (8 am, 9 am, 10 am and 11 am 4th February 2009) of maximum TSS plumes (mg/L) generated from loss at the BHD bucket while dredging within the MOF (Stage 1)
	Client: QGC - A BG Group business		
ERM Environmental Resources Management Australia Pty Ltd	Drawn: JB	sEIS Volume 5 — Figure S6.2.7	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
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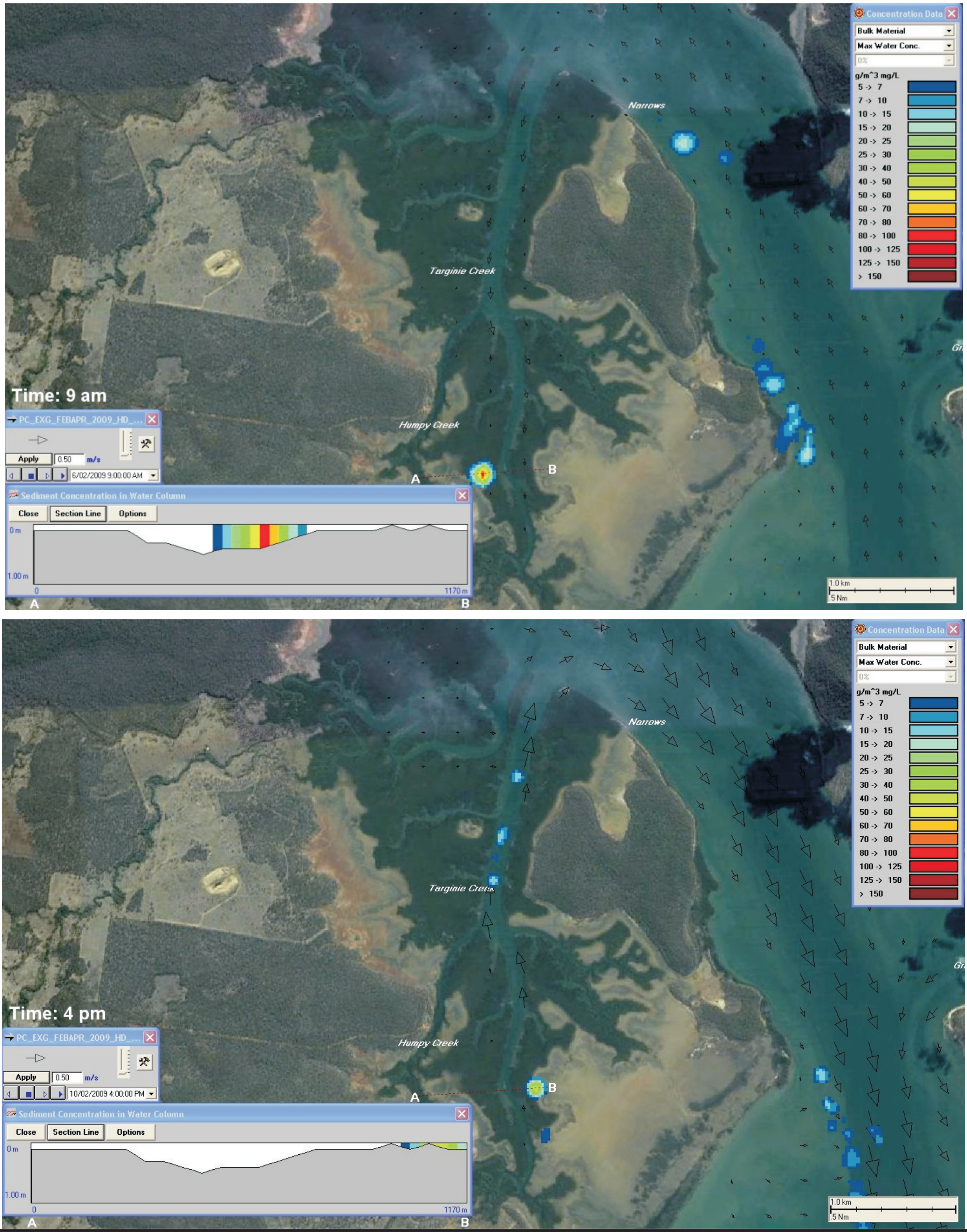
	Date: 21/01/10	Revision: 0	



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Prepared for British Gas, 23 December 2009

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QUEENSLAND CURTIS LNG A BG Group business	Project **Queensland Curtis LNG Project**	Title **Snapshot of the maximum predicted suspended sediment concentration at any depth layer (above background) generated from losses by the BHD while trenching within Targinie Creek during a sample February 2009, flood (above) and ebb (below) tide.**
	Client **QGC - A BG Group business**	
ERM Environmental Resources Management Australia Pty Ltd	Drawn KP | **sEIS Volume 5** **Figure S6.2.8**	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
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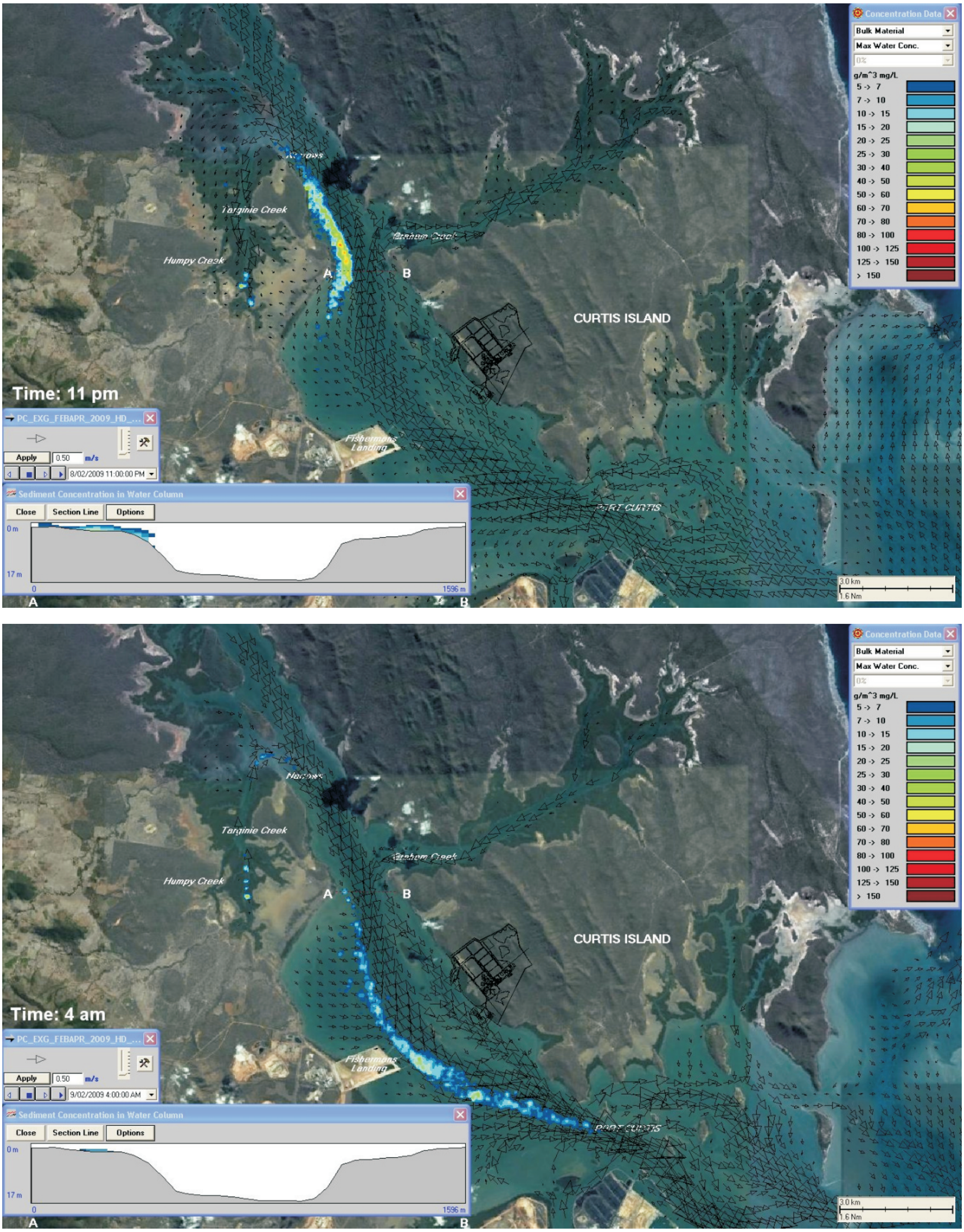

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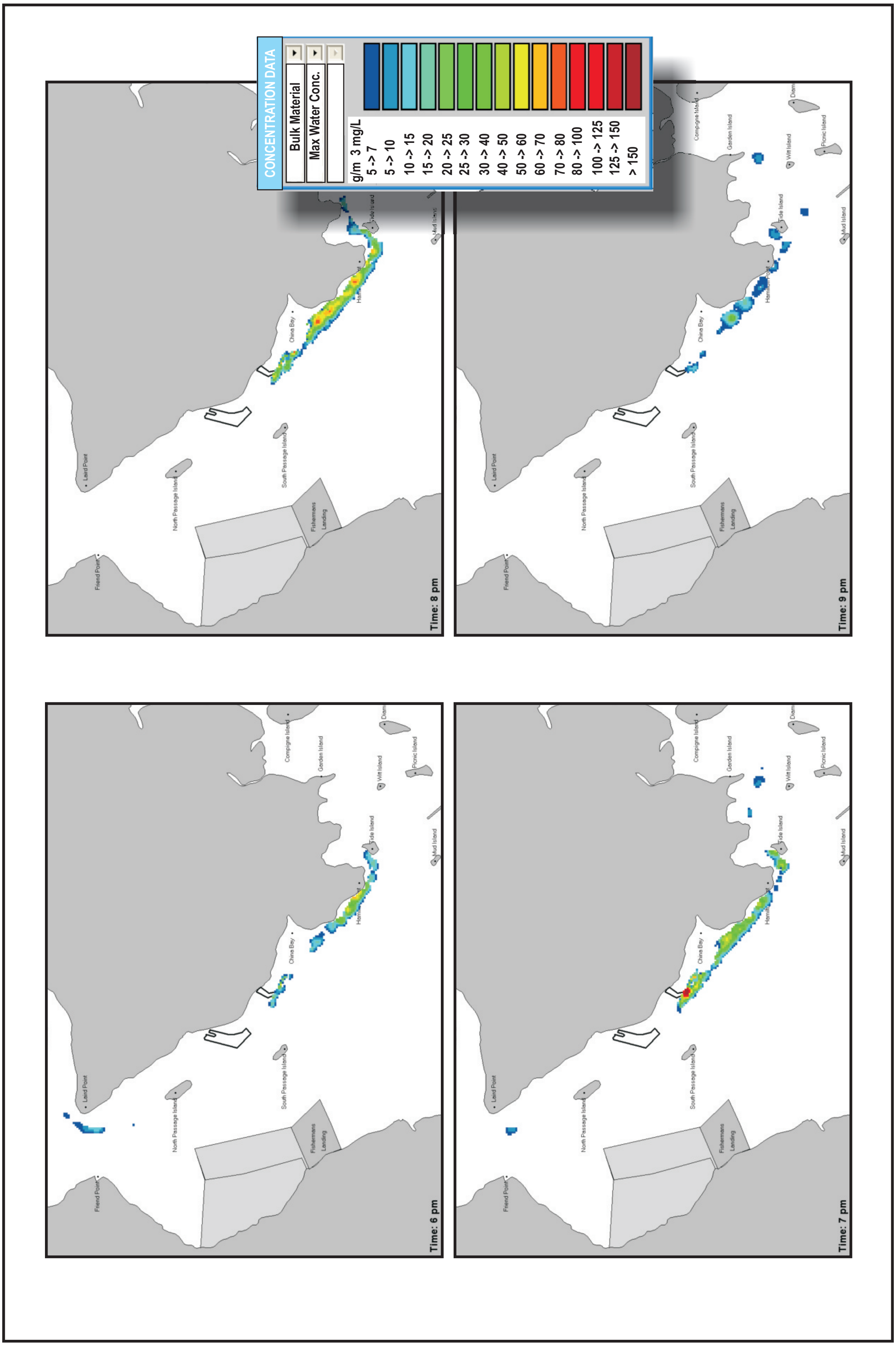
Project	**Queensland Curtis LNG Project**		
Client	**QGC - A BG Group business**		
Drawn KP	**sEIS Volume 5**	**Figure S6.2.9**	
Approved RS	File No:	0086165b_SUP_CDR038_S6.2.9	
Date 21/01/10	Revision 0		

Title **Snapshot of the maximum predicted suspended sediment concentration (above background) at any depth level generated from losses by the BHD when trenching on the west side of The Narrows section during a sample February 2009, flood (above) and ebb (below) spring tide.**

2.3.3.4 *Propeller Wash*

Propeller wash can cause sediment to be resuspended from the seabed. This impact is only relevant to Scenario 2, where SHBs are used to carry material from the BHD to the disposal site. SHBs may be self-propelled, or may be propelled by tugs.

Thrust from barge or tug propellers (prop-wash) in shallow waters was predicted to generate highly variable suspended sediment plumes that were detectable at the surface at concentrations of up to 50 to 80 mg/L (above ambient) immediately behind the vessel. Concentrations above 100 mg/L were predicted to develop in the water column after the vessel had passed. Coarser sediment was predicted to settle over a range of tens of metres to the north-west and south-east of a moving vessel, following the alignment of the tidal axis. Plumes of finer particles were predicted to drift for hundreds of metres and to disperse with the tide. *Figure 6.2.10* shows time series plots at hourly intervals of the prop-wash induced plumes.



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Prepared for British Gas, 7 January 2010

QUEENSLAND CURTIS LNG A BG Group business	Project: **Queensland Curtis LNG Project** Client: **QGC - A BG Group business**		Title: **Hourly time-series plots (6 pm, 7 pm, 8 pm and 9 pm 1st February 2009) of maximum TSS plumes (mg/L) generated from the propeller wash**
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB Approved RS Date 21/01/10	**sEIS Volume 5** **Figure S6.2.10** File No: 0086165b_SUP_CDR007_S6.2.10 Revision 0	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.

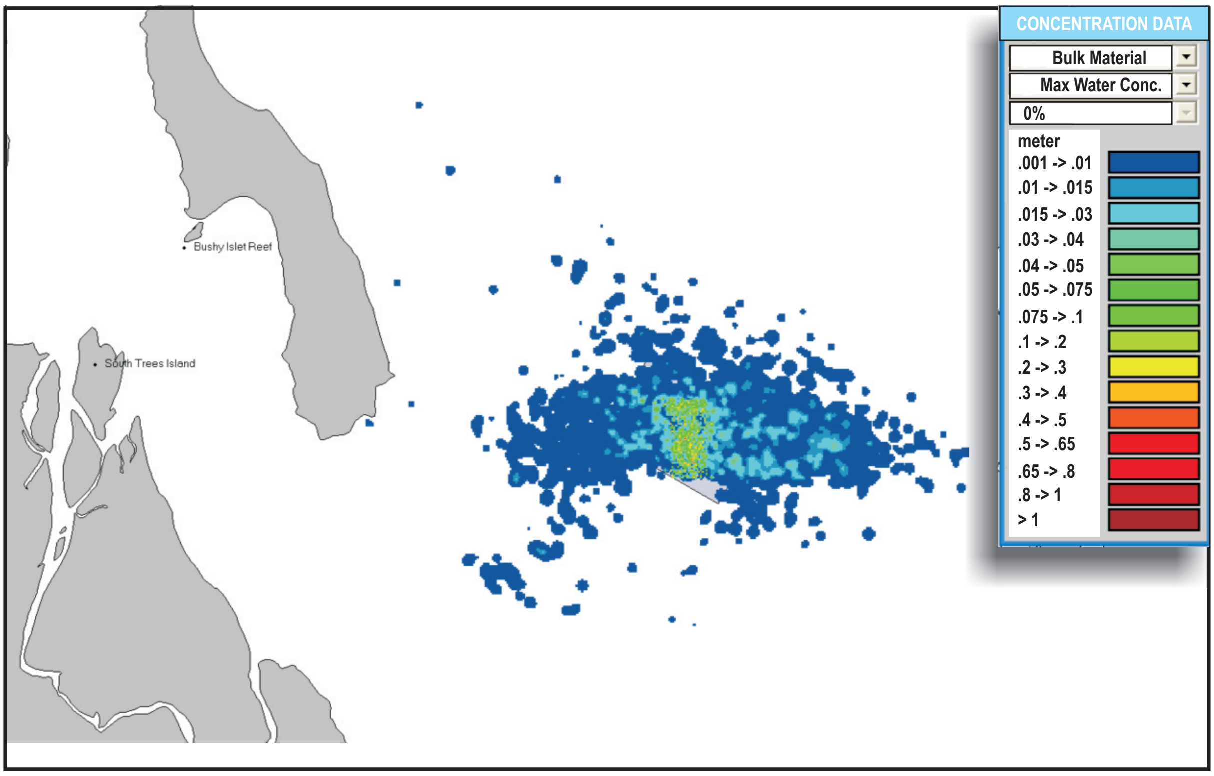
2.3.3.5 *Disposal from Barge Dumping*

Disposal operations from SHBs were predicted to give rise to very high local TSS concentrations within the sinking plume, with the entrainment of coarser sediment expected to limit the suspension time for finer sediments. Given the strong currents which run east-west, simulations indicated that the major depositional axis would be along the east-west axis. The highest sedimentation rates occurred in the centre of the existing spoil ground and tapered off exponentially towards the edges. *Figure 6.2.11* shows the predicted cumulative bottom thickness (metres) from 91 days of dredged sediment disposal within the GPC spoil ground.

Table 6.2.1 presents the corresponding area of coverage as a function of thickness (in metres). The predicted maximum area of exposure was 41 km^2 receiving at least 0.001 m (or 1 mm) thickness of deposited sediments. Seventy-nine per cent of the area (or 32.2 km^2) had a thickness less than 0.01 m (1 cm). A total of 8.88 km^2, almost entirely contained within the spoil ground, would be covered by a layer of material more than 1 cm deep. Only 0.125 km^2 (1,250 ha) would be covered by thicker than 0.2 m (20 cm) of spoil.

Table 6.2.1 Predicted area of coverage as a function of thickness, calculated from a 91 day disposal operation at the existing GPC offshore spoil ground

Bottom Thickness (metres)	*Area of coverage (km^2)*	*Percentage of cumulative area covered (%)*
Above 0.001	32.190	100.000
Above 0.010	3.712	21.622
Above 0.015	3.225	12.584
Above 0.030	0.523	4.732
Above 0.040	0.324	3.459
Above 0.050	0.463	2.672
Above 0.075	0.222	1.545
Above 0.100	0.289	1.006
Above 0.200	0.060	0.303
Above 0.3 -> 0.4	0.055	0.158
Above 0.400	0.010	0.024



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Drawn	JB	**sEIS Volume 5**	**Figure S6.2.11**
Approved	RS	File No:	0086165b_SUP_CDR008_S6.2.11
Date	21/01/10	Revision	0

Title **Cumulative bottom thickness (metres) from 91 days of discharge at a rate of 6 discharges per day into the centre of the Gladstone Ports Corporation existing spoil ground**

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2.3.3.6 Jetting

Jet trenching operations for The Narrows Pipeline crossing were generally predicted to result in lower TSS and less sedimentation than BHD operations for The Narrows Pipeline crossing, primarily because of the very short duration of works (approximately 3 weeks) as the trench is advanced across The Narrows. The following discussions of TSS and sedimentation therefore focus on the BHD method.

2.3.4 Total Suspended Solids

This section describes the predicted change in total suspended solids (TSS) caused by dredging and disposal activities described in Scenarios 1 to 3 modelled for the MOF, Construction Dock works and for The Narrows Pipeline crossing.

The findings conclude that elevations of TSS can be considered to be negligible for all scenarios. As good practise, a Draft Dredge Management Plan (*Appendix 6.1*) has been prepared to ensure that these findings eventuate and dredging impacts are appropriately managed.

2.3.4.1 MOF and Construction Dock Scenario One

Figure 6.2.12, *Figure 6.2.13* and *Figure 6.2.14* compare the maximum predicted TSS concentrations generated by CSD dredging at MOF Stage 1 and the Construction Dock, and the tail-water discharge from a Fisherman's Landing receival area. Outputs are assessed at nine locations (see *Figure 6.2.1*). Each graph depicts the highest concentration (that is, the highest individual concentration for any time step in the modelled 91-day period) at any depth within the water column, with background TSS included. As a result, the y-axis (concentration) scale varies with background levels.

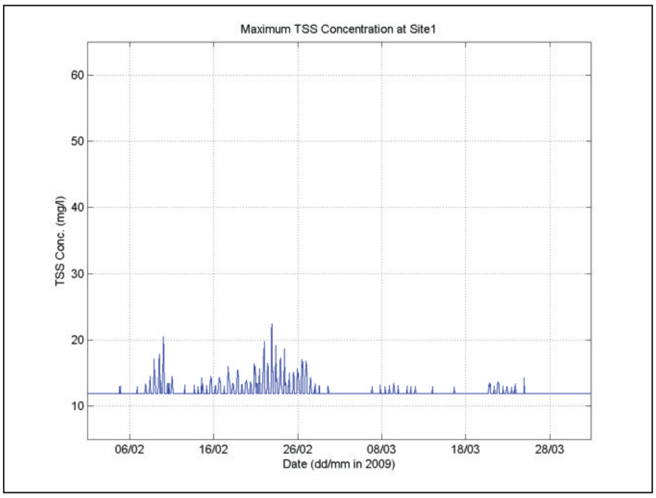
Site 1 (the seagrass meadow adjacent to Laird Point) is predicted to reach a peak concentration of 20 mg/L (8 mg/L above ambient) early in the modelled period, with a second spike of approximately 22 mg/L (10 mg/L above ambient) when similar neap tide conditions return. Predicted concentrations at Site 1 were then largely reduced for the remainder of the time series.

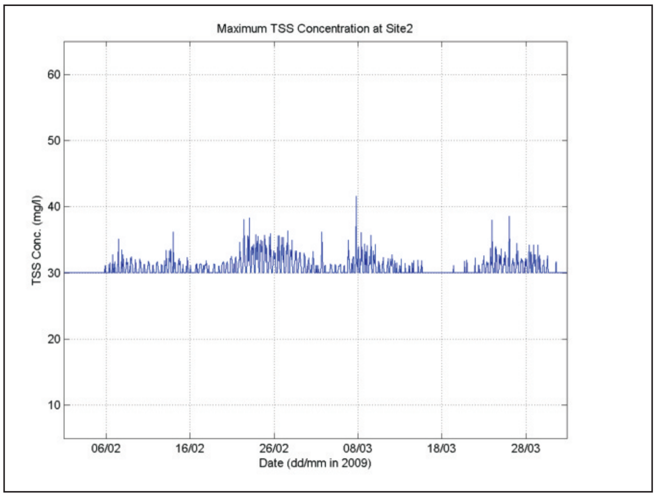
Site 3 (the small seagrass meadow immediately adjacent to the Construction Dock) is predicted to receive longer periods of exposure, with higher and more variable exposure levels than Site 1. Numerous events are predicted with concentrations > 18 mg/L (8 mg/L above ambient). The maximum concentrations reach > 26 mg/L (16 mg/L above ambient).

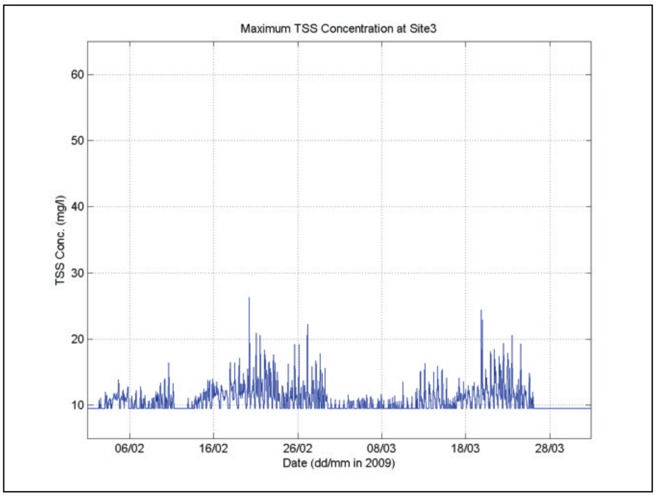
Sites 4 and 5 (south of Passage Island and south of Fisherman's Landing) are characterised by more intermittent pulses of sediment with clusters of events occurring either side of a neap tide period. Concentration increases are predicted to be the same at the two locations (approximately 4 mg/L). No increases of background TSS concentrations are predicted for Site 6 (north of Wiggins Island).

Figure 6.2.14 shows two clusters of high TSS occurring during two periods of approximately 10 days at Turtle Island. A maximum concentration of 25 mg/L (5 mg/L above background) was predicted for Diamantina Reef. No increase in TSS concentrations is predicted for Bushy Islet.

It is concluded that for Scenario 1, sites 1 to 5, elevated TSS concentrations fall within the normal bounds of TSS variations in the upper parts of Port Curtis. For further detail on the impact of this on environmental values, refer to *Volume 5, Chapter 8*.







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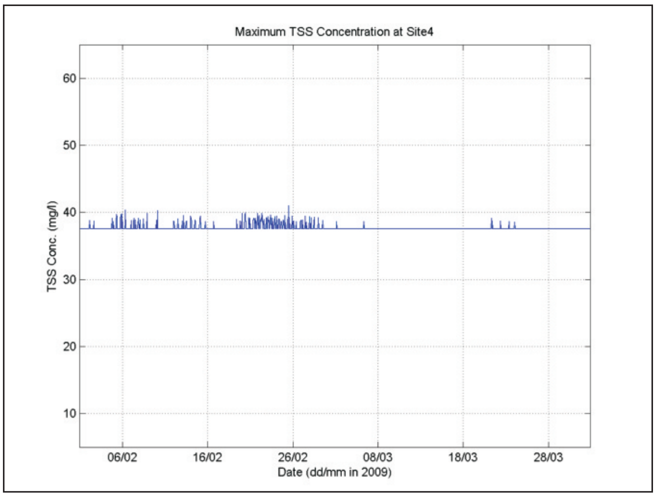
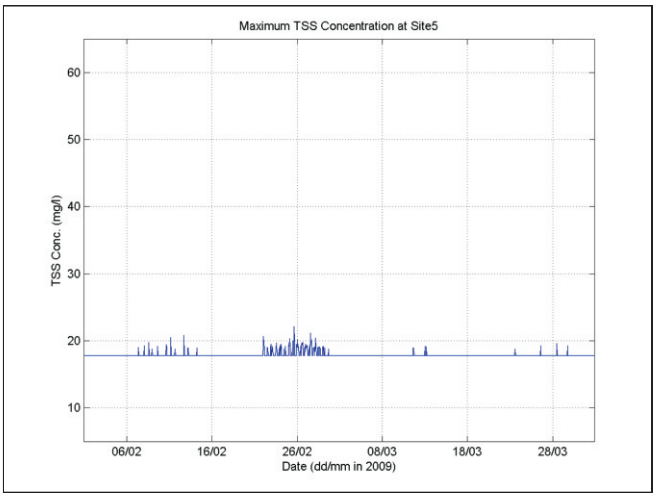
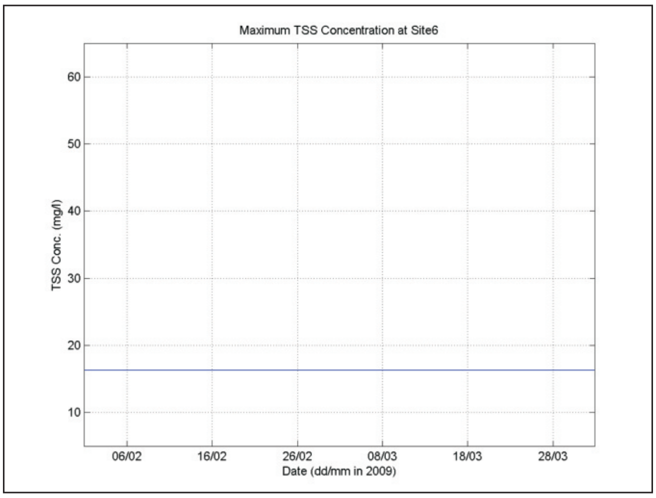
Project	**Queensland Curtis LNG Project**
Client	**QGC - A BG Group business**
Title	**Time-series graphs of maximum predicted TSS concentration (above background) at Sites 1, 2 and 3. Results are based on sediment sources identified in Scenario 1**

Drawn	JB	**sEIS Volume 5**	**Figure S6.2.12**
Approved	RS	File No:	0086165b_SUP_CDR009_S6.2.12
Date	21/01/10	Revision	0







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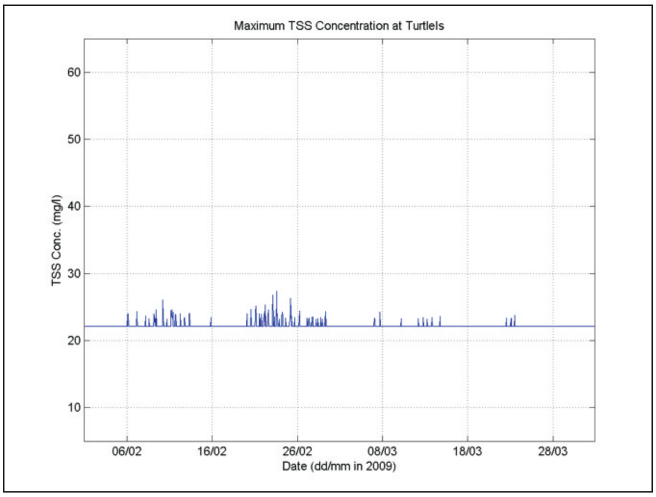
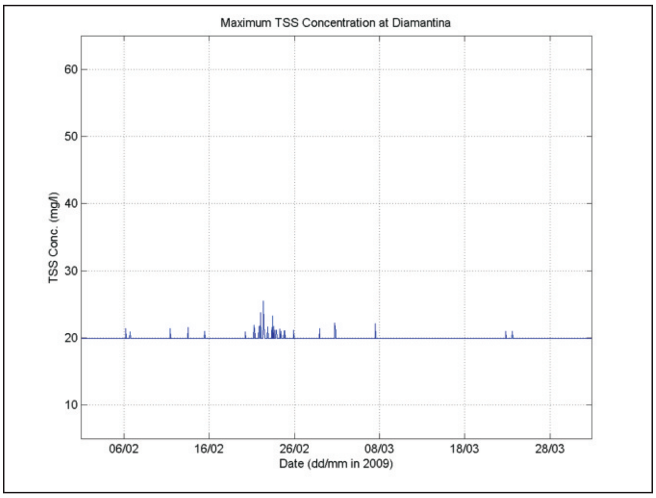
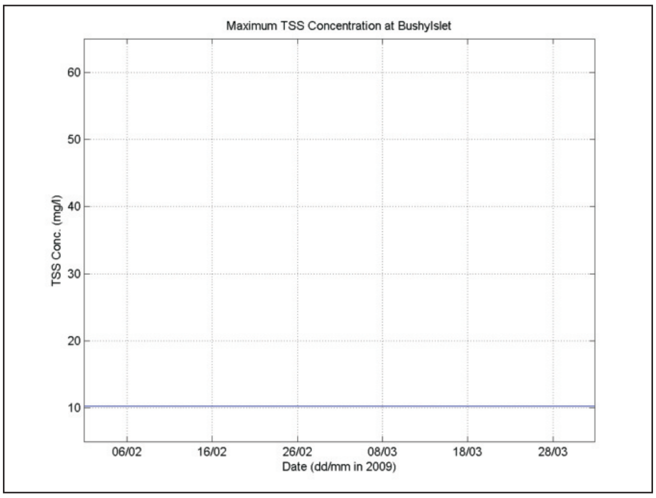
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB — **sEIS Volume 5** — **Figure S6.2.13** Approved RS — File No: 0086165b_SUP_CDR010_S6.2.13 Date 21/01/10 — Revision 0	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.







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QUEENSLAND CURTIS LNG A BG Group business	Project **Queensland Curtis LNG Project**		Title **Time-series graphs of maximum predicted TSS concentration (above background) at Turtle Island, Diamantina and Bushy Islet. Results are based on sediment sources identified in Scenario 1**
	Client **QGC - A BG Group business**		
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB	**sEIS Volume 5** **Figure S6.2.14**	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
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2.3.4.2 *MOF and Construction Dock Scenario Two*

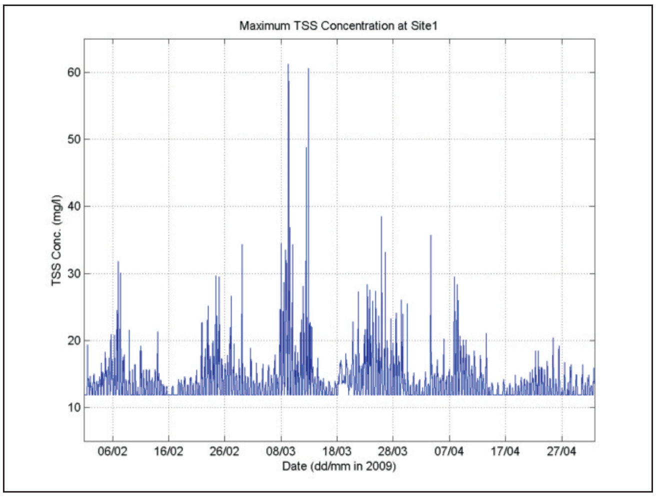
Figure 6.2.15, *Figure 6.2.16* and *Figure 6.2.17* compare the maximum predicted TSS concentrations generated by BHD dredging of MOF Stage 1 and the Construction Dock, including the effects of propeller wash. Again, model outputs are evaluated for nine locations (see *Figure 6.2.1*. Each graph depicts the highest concentration at any depth within the water column, with background TSS included.

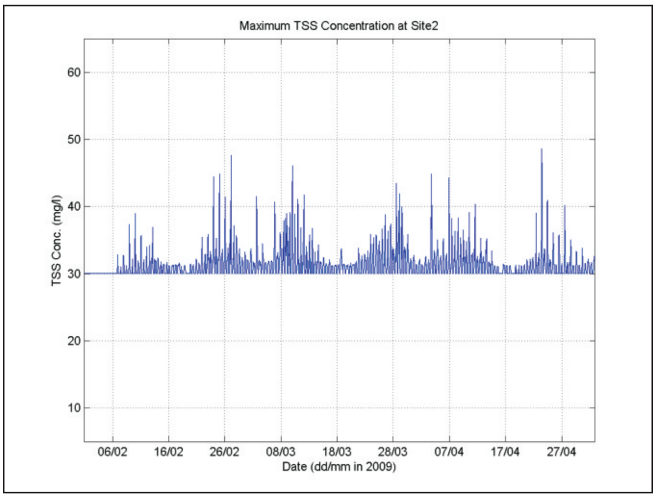
Sites 1 to 3 are characterised by highly elevated concentrations on a near-daily basis. Elevated concentration peaks show a cyclic pattern indicating the influence of the spring/neap tidal regime on the TSS concentrations within the Port environment. A spike of 62 mg/L (50 mg/L above background) was predicted for Site 1. The highest TSS event for the 91 day modelled operation (130 mg/L) was predicted at Site 3.

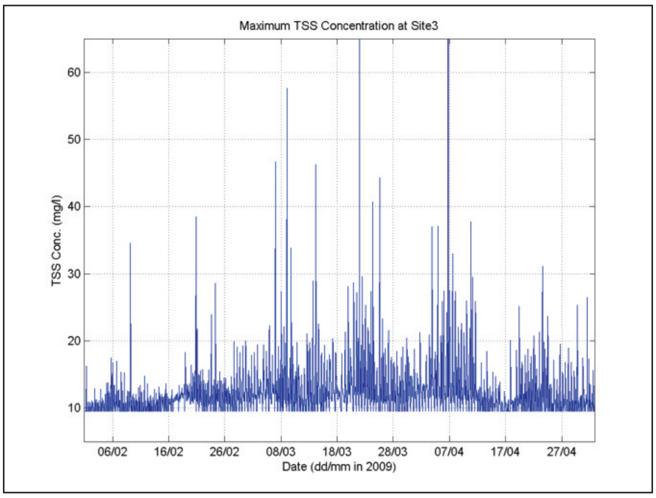
A similar time series trend was predicted for Sites 4 and 5 with near daily increases of background TSS concentrations. Maximum concentrations also follow cyclic patterns, presumably as a result of the tidal regime of the Port. Peaks at Site 4 typically exceed 42 mg/L (background was 37 mg/L), while at Site 5 TSS were above 26 mg/L (background level 17 mg/L) on numerous occasions.

Turtle Island and Diamantina Island are also predicted to receive near daily increases in TSS concentrations (*Figure 6.2.17*). These are predicted to be greater near Turtle Island than around Diamantina Reef, with a larger number of events greater than 40 mg/L (background level 19 mg/L) and a number of peaks occurring > 60 mg/L. A single spike of 140 mg/L occurred at Turtle Island (120 mg/L above background). No increases in TSS concentrations are predicted for Bushy Islet.

Although, these levels of TSS are uncommon, these levels do occur routinely in Port Curtis. It is important to note that these spikes are temporary and, as they represent the highest values within the dredging period, may last no more than a few hours (the model time step was hourly).







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Drawn	JB	sEIS Volume 5	Figure S6.2.15
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Date	21/01/10	Revision	0

Title **Time-series graphs of maximum predicted TSS concentration (above background) at Sites 1, 2 and 3. Results are based on sediment sources identified in Scenario 2**

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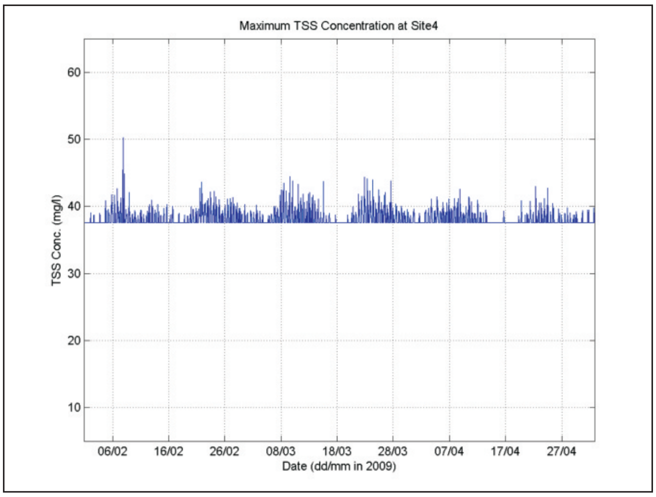

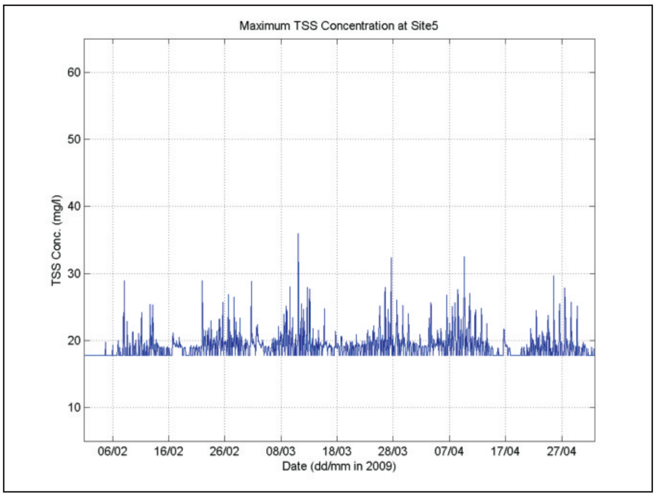

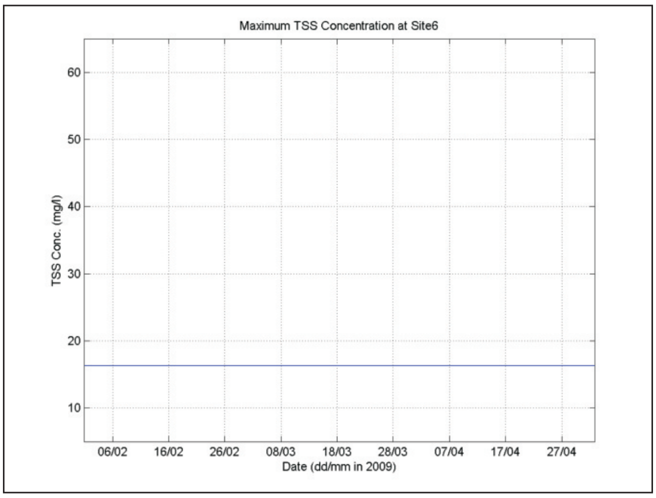

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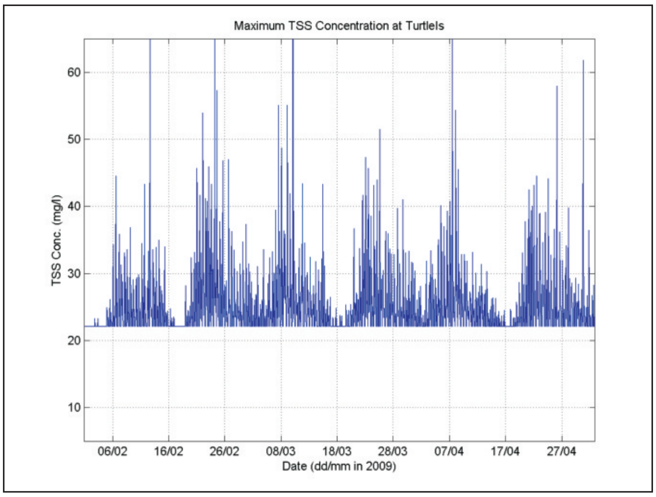

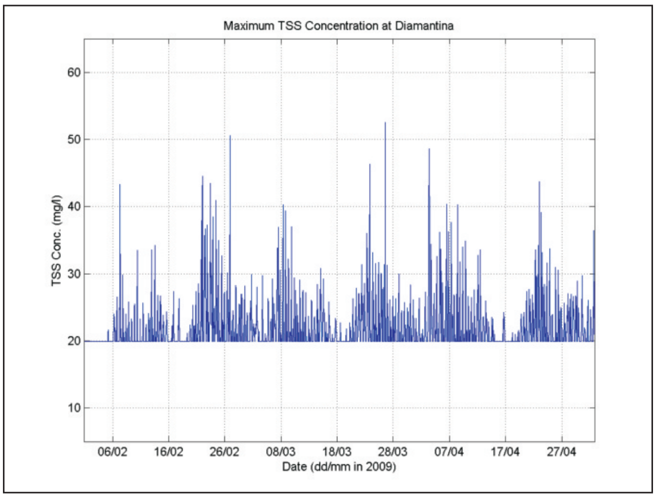

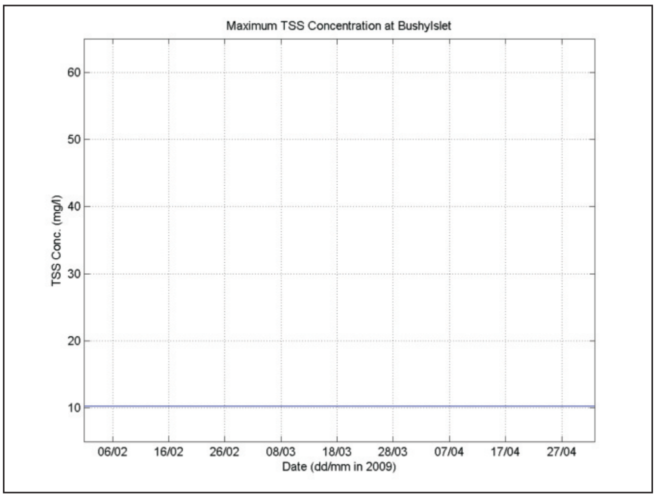

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QUEENSLAND CURTIS LNG A BG Group business	Project **Queensland Curtis LNG Project** Client **QGC - A BG Group business**	Title **Time-series graphs of maximum predicted TSS concentration (above background) at Turtle Island, Diamantina and Bushy Islet. Results are based on sediment sources identified in Scenario 2.**
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB | **sEIS Volume 5** **Figure S6.2.17** Approved RS | File No: 0086165b_SUP_CDR014_S6.2.17 Date 21/01/10 | Revision 0	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.

2.3.4.3 MOF and Construction Dock Scenario Three

Figure 6.2.18, *Figure 6.2.19* and *Figure 6.2.20* compare the maximum predicted TSS concentrations generated by CSD dredging for MOF Stage 2, including tail-water discharge from a Fisherman's Landing receiving area. Outputs are again presented for nine locations (*Figure 6.2.1*). Each graph again depicts the highest concentration at any depth within the water column, with background TSS included.

At Site 1, the increase in background concentrations typically occurred within the neap tide portion of dredging operations. Two peak periods are identified, with levels exceeding 18 mg/L (6 mg/L above ambient).

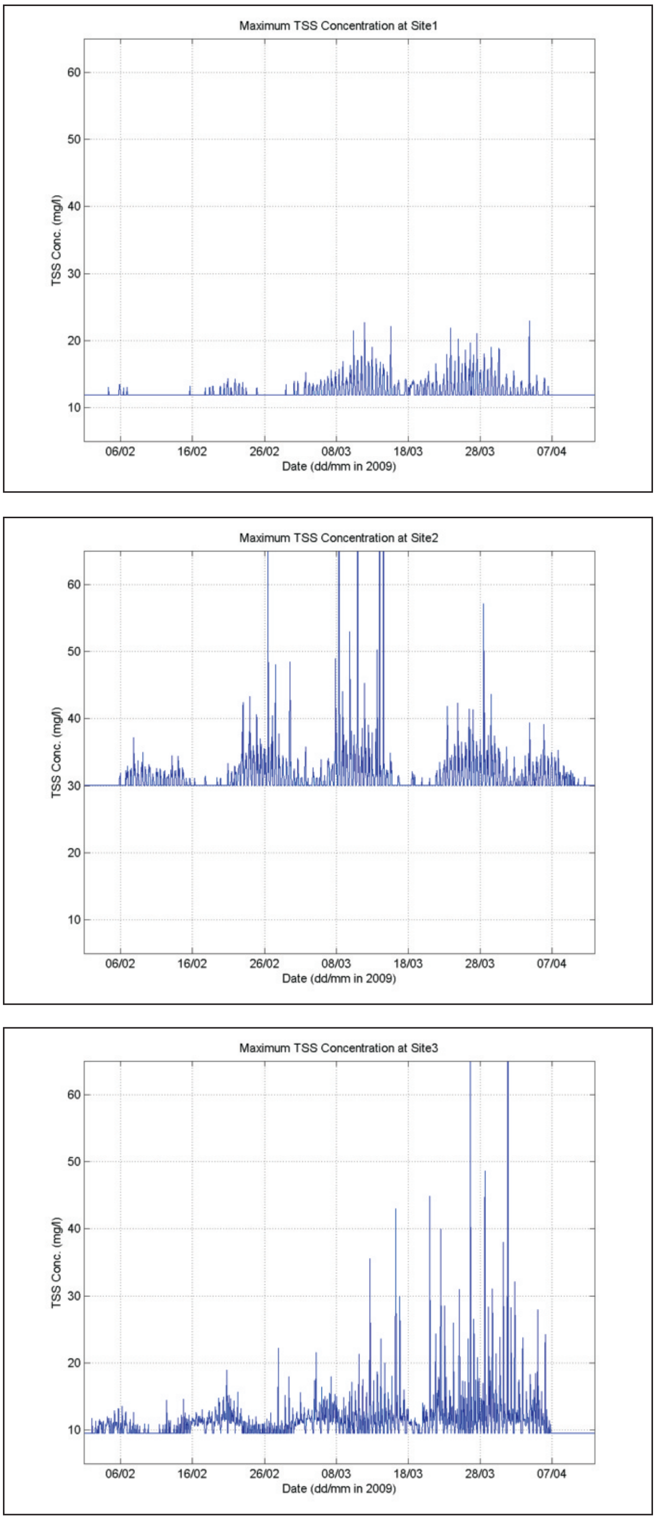
Much higher concentrations are predicted for Site 2. The influence of the tidal regime is again evident with cyclic patterns of minimum and maximum concentrations occurring during the modelled period. Concentrations of 70 mg/L or greater are predicted to occur at least five times.

Site 3 also shows a near daily occurrence of elevated TSS concentrations with a maximum concentration of 80 mg/L (70 mg/L above ambient). Similar to Site 1, peak concentrations are predicted to occur in the neap tide portion of the modelled period.

Site 4 is characterised by intermittent peaks > 42 mg/L (5 mg/L above background). Concentrations at Site 5 show cyclic pulses above the background and TSS levels typically exceeded 20 mg/L with maximum concentration nearing 28 mg/L (10 mg/L above ambient). No increases in TSS concentrations are predicted for Site 6.

Figure 6.2.20 shows pulses of increased concentration at Turtle Island and Diamantina Reef. Sustained periods of increased concentrations are more frequent at Turtle Island with concentrations predicted to be 6 mg/L above ambient (22 mg/L). Maximum concentrations at Turtle Island and Diamantina are predicted to be approximately 38 and 32 mg/L, respectively. No increases in TSS concentrations are predicted for Bushy Islet.

Again, these TSS levels lie within the normal bounds of variation within Port Curtis.



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A BG Group business

Project **Queensland Curtis LNG Project**

Client **QGC - A BG Group business**

Title **Time-series graphs of maximum predicted TSS concentration (above background) at Sites 1, 2 and 3. Results are based on sediment sources identified in Scenario 3**

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Drawn	JB	**sEIS Volume 5**	**Figure S6.2.18**
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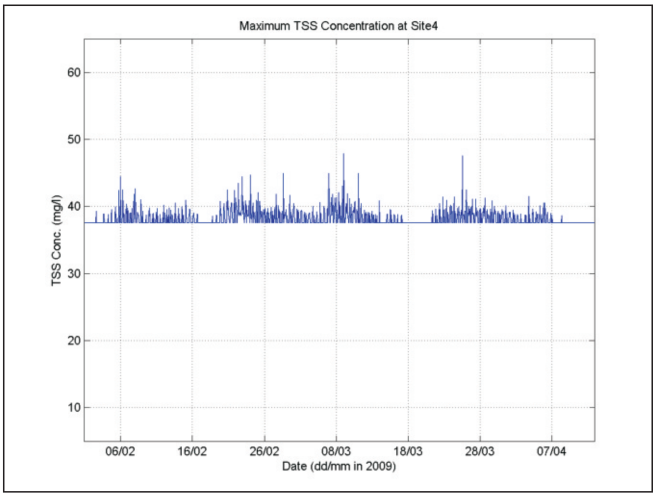

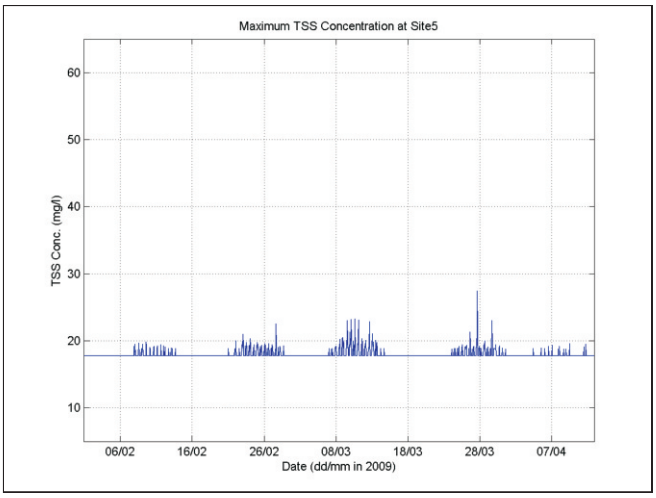

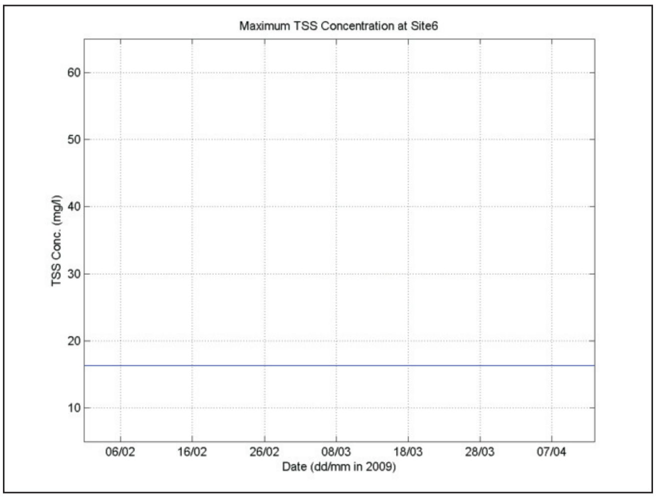

Source:
Asia Pacific ASA Pty Ltd
QCLNG EarlyWorks Dredge Plume Modelling Final
Prepared for British Gas, 7 January 2010

Not to scale

QUEENSLAND CURTIS LNG
A BG Group business

Project	Queensland Curtis LNG Project	
Client	QGC - A BG Group business	
Drawn JB	sEIS Volume 5	Figure S6.2.19
Approved RS	File No:	0086165b_SUP_CDR016_S6.2.19
Date 21/01/10	Revision 0	

Title **Time-series graphs of maximum predicted TSS concentration (above background) at Sites 4, 5 and 6. Results are based on sediment sources identified in Scenario 3**

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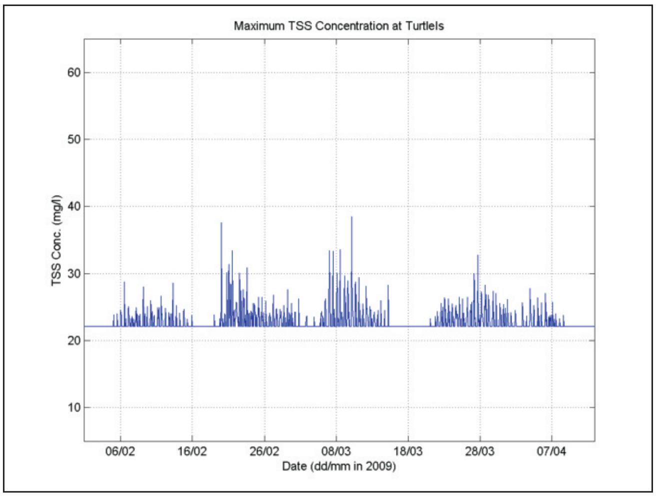

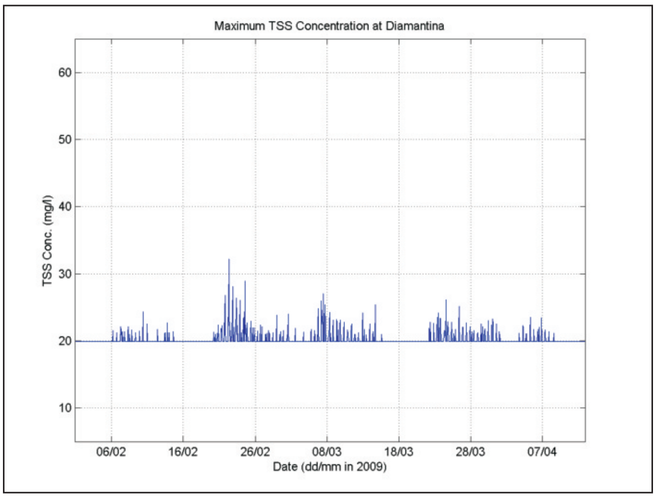

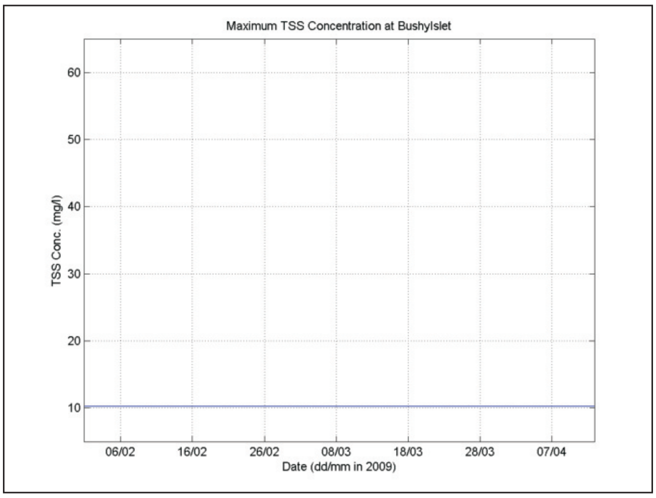

Source:
Asia Pacific ASA Pty Ltd
QCLNG EarlyWorks Dredge Plume Modelling Final
Prepared for British Gas, 7 January 2010

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QUEENSLAND CURTIS LNG A BG Group business	Project **Queensland Curtis LNG Project**	Title **Time-series graphs of maximum predicted TSS concentration (above background) at Turtle Island, Diamantina and Bushy Islet. Results are based on sediment sources identified in Scenario 3**
	Client **QGC - A BG Group business**	
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB | **sEIS Volume 5** **Figure S6.2.20** Approved RS | File No: 0086165b_SUP_CDR017_S6.2.20 Date 21/01/10 | Revision 0	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.

2.3.4.4 Narrows Pipeline Crossing

Figure 6.2.21 and *Figure 6.2.22* compare the maximum predicted TSS concentrations generated by BHD operations for The Narrows and Targinie Creek pipeline crossings. These were modelled at seven locations. Each graph again depicts the highest concentration at any depth within the water column, with background TSS included.

During trenching in the creek, concentrations midway along Targinie Creek (Sites 2 & 3) and at the entrance (Site 1) were predicted to peak at 8 -10 mg/L above background for short durations (1-2 hours), during spring ebb tides. Concentrations at the upper extent of the creek, near to the operation (site 4), were predicted to exceed 20 mg/L above ambient TSS concentrations (> 40 mg/L combined), with levels sustained above ambient for extended periods (days). However, such extremes are only expected periodically and the median predicted concentrations over time at all sites were at ambient levels in the simulation.

During backfilling operations in the creek, TSS concentrations in the creek were predicted to reduce to ambient within one or two tidal cycles of completion of works, suggesting that flushing and settlement will reduce TSS suspensions quickly. Plumes that emerge from Targinie Creek during these operations are expected to disperse to background concentrations before reaching The Narrows and no build up of turbidity is indicated within the waters of Port Curtis from this part of the operation.

During trenching operations across The Narrows, concentrations were also predicted to build up during the flooding tides and decrease during the ebbing tides. This outcome is related to the bathymetry of the waterway, with flooding tides pushing the suspended sediment plume into shallower water and ebbing tides tending to draw sediments down the slope of the channel. Hence, concentrations of the order of 25 to 80 mg/L are predicted to build up within 1,600 m upstream on the flooding tide but concentrations > 5 mg/L TSS above background are not expected to extend far beyond the confluence of Targinie Creek. In contrast, plumes > 5 mg/L TSS are predicted to occur, low in the water column, as far as Tide Island on the ebbing tide. Due to the predicted vertical distribution of the sediments, the plume is unlikely to be visible over the extent predicted for ebbing tides, for observers above water level. Again, backfilling operations with the BHD were predicted to generate similar concentrations and plume distributions to the initial trenching operations with this equipment.

2.3.5 Depth Averaged Total Suspended Solids Concentration

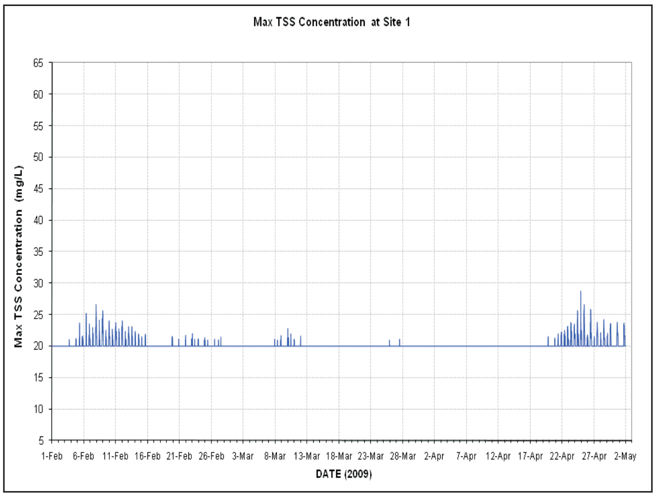
This section presents the depth-averaged median (i.e. the 50^{th} percentile value), 80^{th} and 95^{th} percentile TSS contours calculated at hourly intervals for each location (represented as 0.5 m depth layers within each 40 m x 40 m grid cell within the model domain).

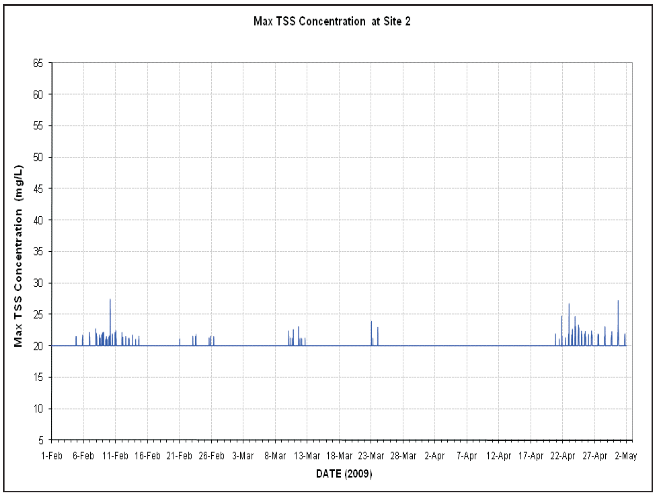
2.3.5.1 *MOF and Construction Dock Scenario One*

The depth averaged TSS concentration 50th percentile map shown in *Figure 6.2.23* (top) showed an increase of 5 mg/L (above ambient) for waters directly adjacent to the MOF and Construction Dock, whereas increases of 25 to 50 mg/L were predicted immediately adjacent to the tail-water discharge location.

The 95th percentile map, which is indicative of the worst case predictions (*Figure 6.2.24*), shows a predicted concentration contour of 5 mg/L stretching from Grahams Creek in the north, along the western shoreline of Curtis Island, and past North and South Passage Islands. Occurrences of 10 mg/L concentrations (above background) were predicted next to the MOF and Friend Point, while 25 mg/L (above background) concentrations were predicted within 300 m of the tail-water outfall, along the shorelines of the Construction Dock, North Passage Island and Tide Island.

Given the natural patterns of turbidity described in *Volume 5, Chapter 8*, these TSS impacts fall within the normal bounds of TSS variations in the upper parts of Port Curtis. For further detail on the impact of this on environmental values, refer to *Volume 5, Chapter 8*.





Source:
Asia Pacific ASA Pty Ltd
QCLNG EarlyWorks Dredge Plume Modelling Final
Prepared for British Gas, 7 January 2010

Not to scale

QUEENSLAND CURTIS LNG
A BG Group business

Project	Queensland Curtis LNG Project		Title: **Maximum TSS concentrations predicted at any depth level over time at Site 1 (above) and Site 2 (below) within Targinie Creek (inclusive of average background TSS estimates)**
Client	QGC - A BG Group business		
Drawn KP	**sEIS Volume 5**	**Figure S6.2.21**	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
Approved RS	File No: 0086165b_SUP_CDR040_S6.2.21		
Date 21/01/10	Revision 0		

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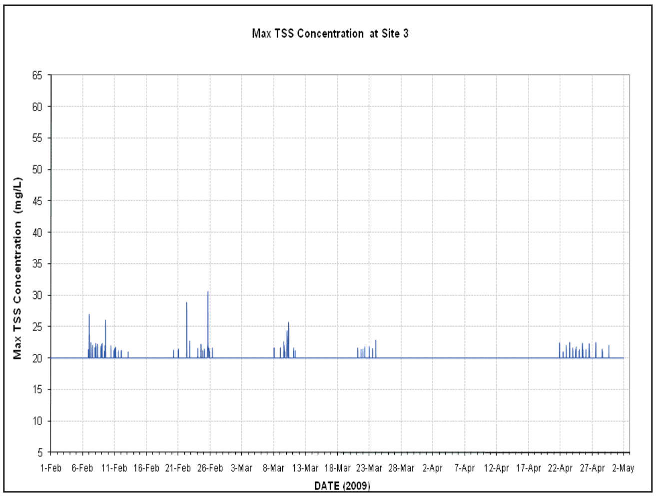
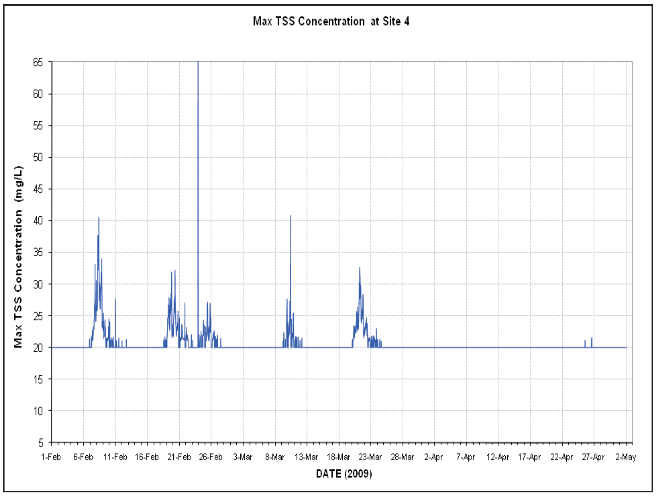
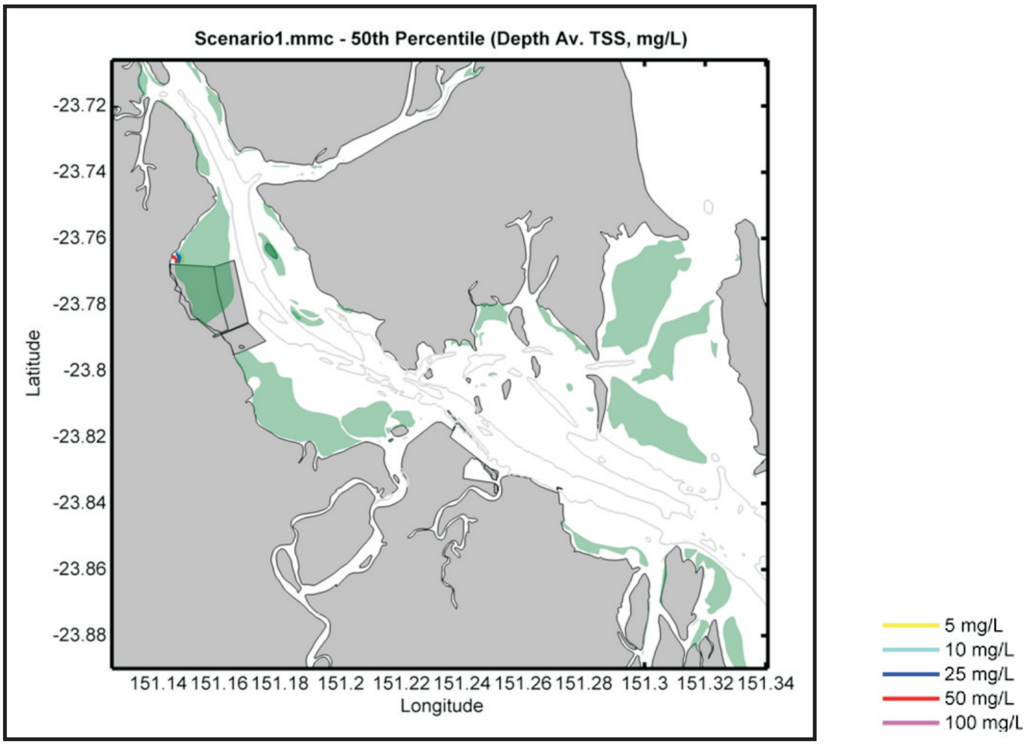


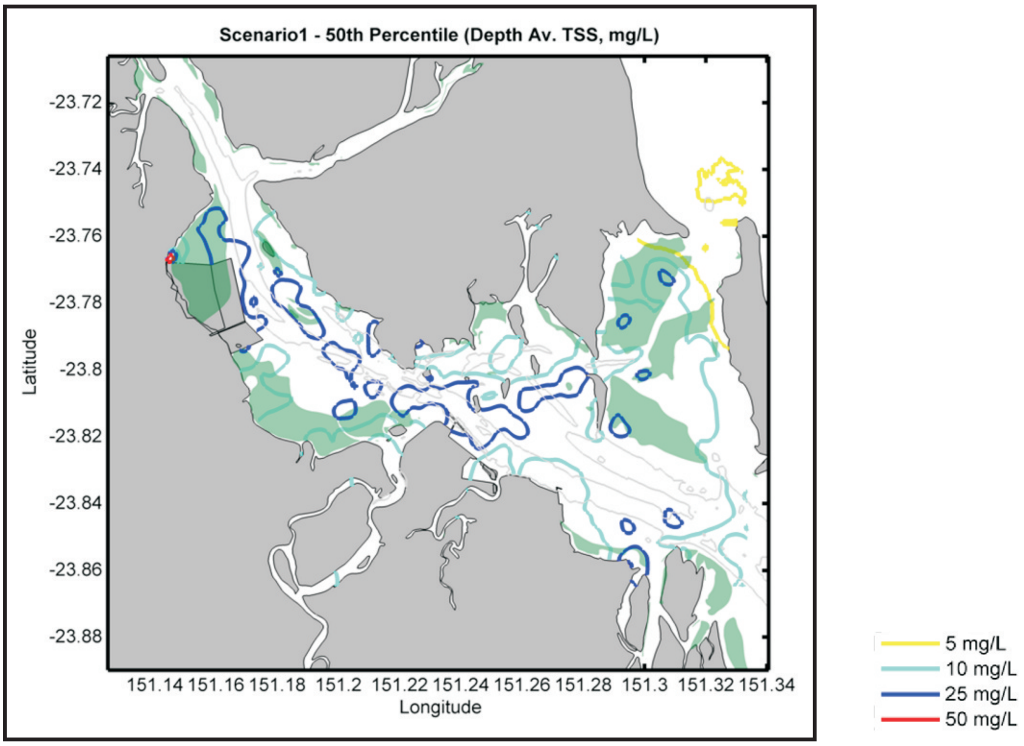


Source:
Asia Pacific ASA Pty Ltd
QCLNG EarlyWorks Dredge Plume Modelling Final
Prepared for British Gas, 7 January 2010

Not to scale

QUEENSLAND CURTIS LNG A BG Group business	Project **Queensland Curtis LNG Project**	Title **Maximum TSS concentrations predicted at any depth level over time at Site 3 (above) and Site 4 (below) within Targinie Creek (inclusive of average background TSS estimates)**
	Client **QGC - A BG Group business**	
ERM Environmental Resources Management Australia Pty Ltd	Drawn KP / **sEIS Volume 5** **Figure S6.2.22**	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved RS / File No: 0086165b_SUP_CDR041_S6.2.22	
	Date 21/01/10 / Revision 0	



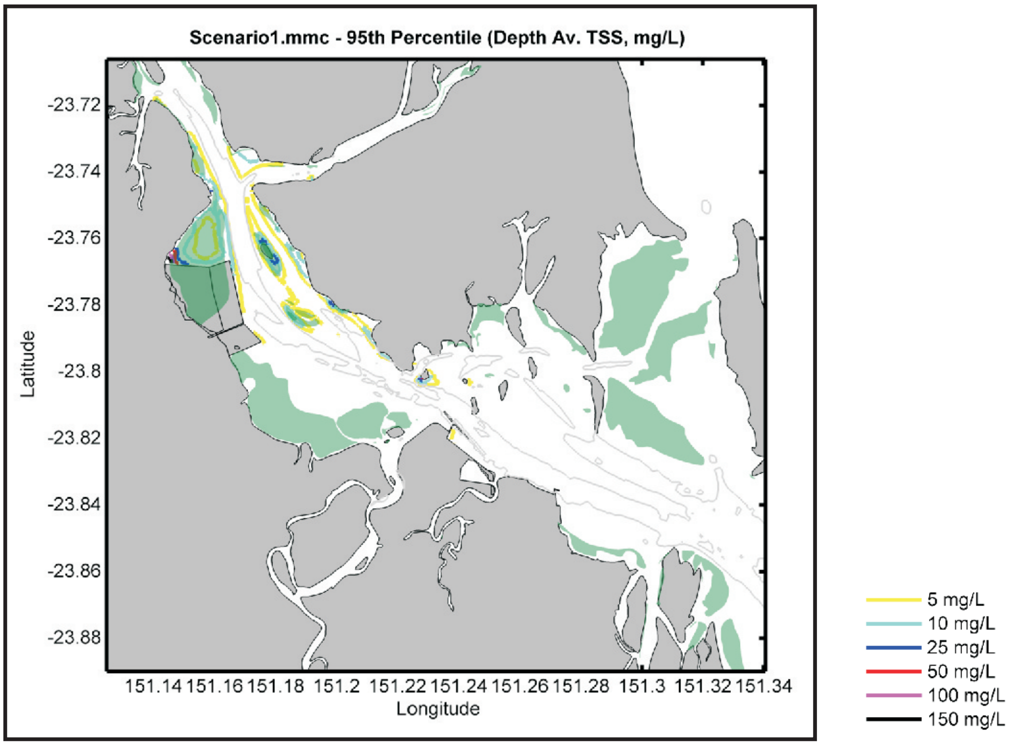


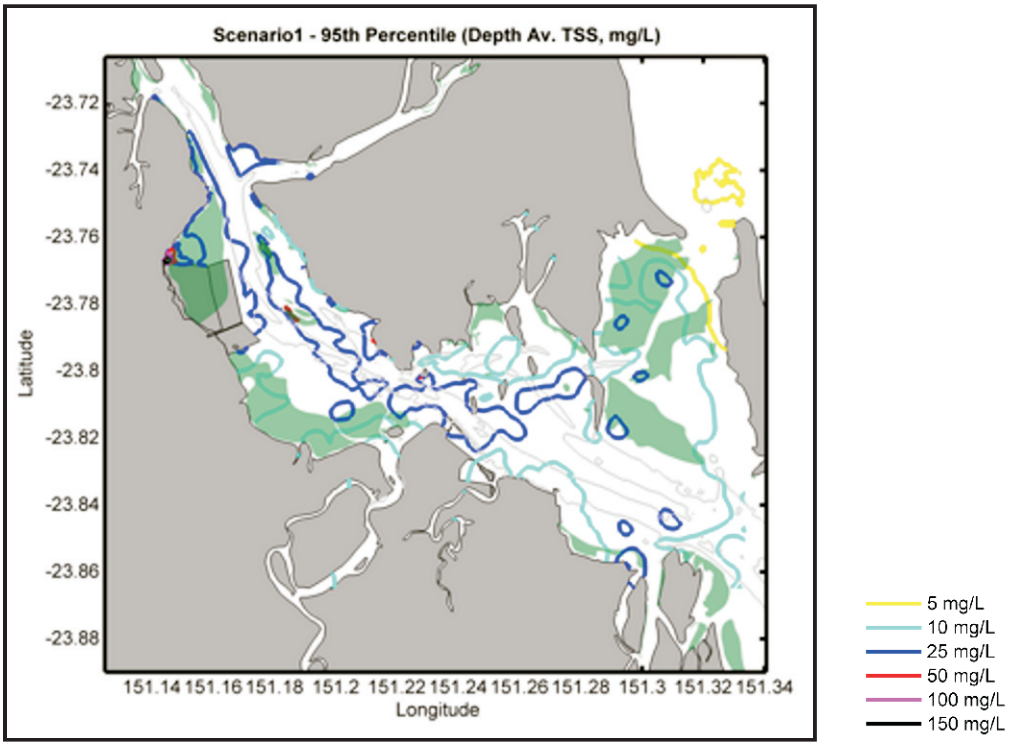
Source:
Asia Pacific ASA Pty Ltd
QCLNG EarlyWorks Dredge Plume Modelling Final
Prepared for British Gas, 7 January 2010

Not to scale

N

QUEENSLAND CURTIS LNG A BG Group business	Project **Queensland Curtis LNG Project**		Title **Scenario 1 TSS depth-averaged 50th percentile concentration contour plots without (top) and with background levels included (bottom)**
	Client **QGC - A BG Group business**		
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB	**sEIS Volume 5** **Figure S6.2.23**	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved RS	File No: 0086165b_SUP_CDR018_S6.2.23	
	Date 21/01/10	Revision 0	





Source:
Asia Pacific ASA Pty Ltd
QCLNG EarlyWorks Dredge Plume Modelling Final
Prepared for British Gas, 7 January 2010

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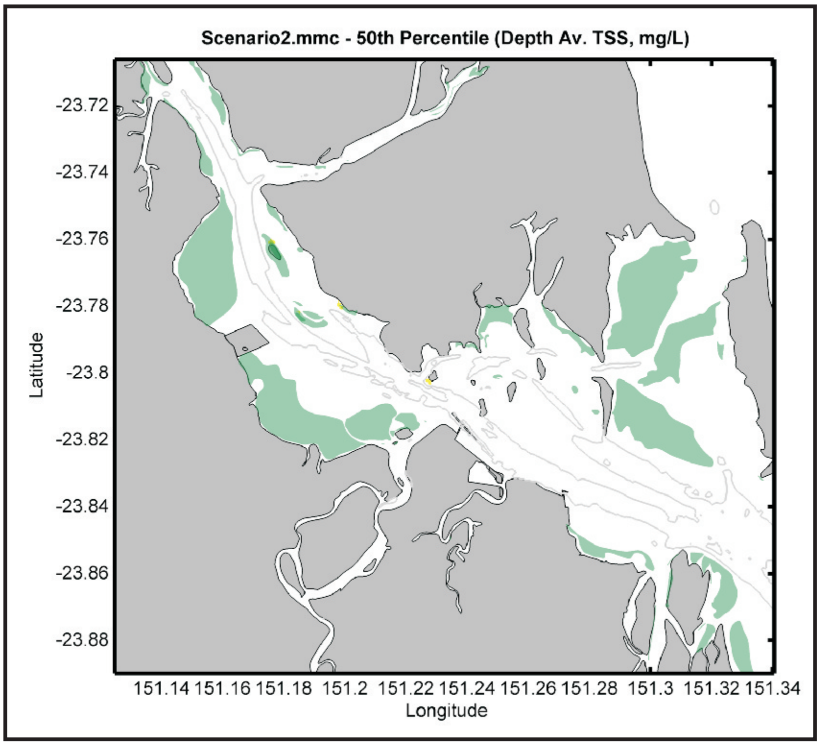
QUEENSLAND CURTIS LNG A BG Group business	Project **Queensland Curtis LNG Project**		Title **Scenario 1 TSS depth-averaged 95th percentile concentration contour plots without (top) and with background levels included (bottom)**
	Client **QGC - A BG Group business**		
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB	**sEIS** Volume 5 **Figure S6.2.24**	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved RS	File No: 0086165b_SUP_CDR019_S6.2.24	
	Date 21/01/10	Revision 0	

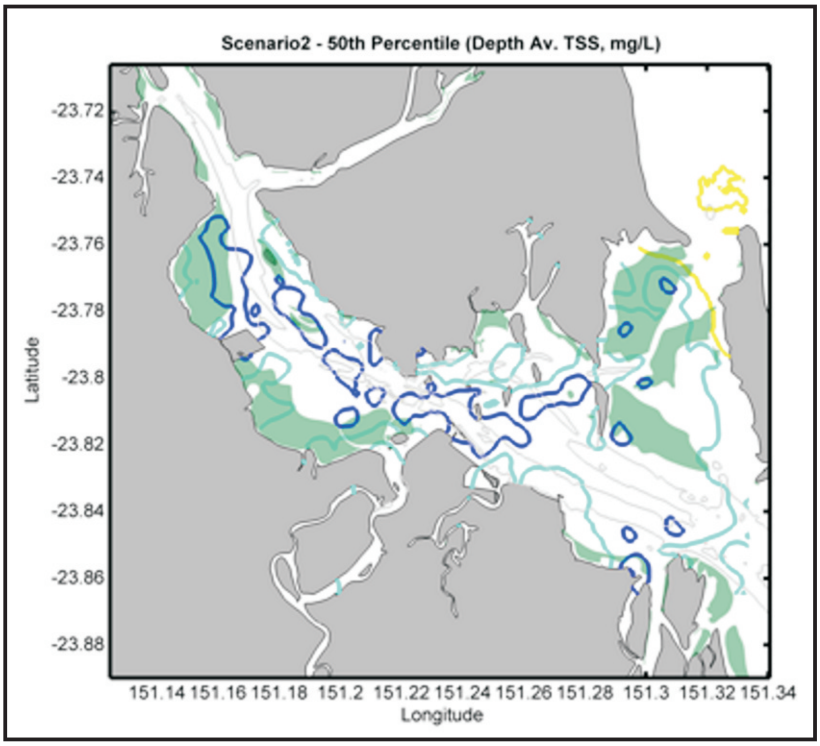
2.3.5.2 *MOF and Construction Dock Scenario Two*

The depth averaged TSS median percentile plot shown in *Figure 6.2.25* (top) indicates waters adjacent to the Construction Dock and Tide Island, reaching 5 mg/L (above ambient).

Based on the 95th percentile statistics (*Figure 6.2.26* top), predicted concentrations of 5 mg/L above ambient stretched over 16 km of Port Curtis, from waters south of Turtle Island to the north of Grahams Creek. A concentration increase of 10 mg/L was predicted to occur along the fringes of the seagrass meadows 3.5 km north of Fisherman's Landing. Regular peaks of 25 mg/L (above ambient) are predicted within waters surrounding the MOF and Construction Dock dredge areas.

Although these levels of TSS are uncommon, they do occur as part of the normal variation in TSS within Port Curtis.





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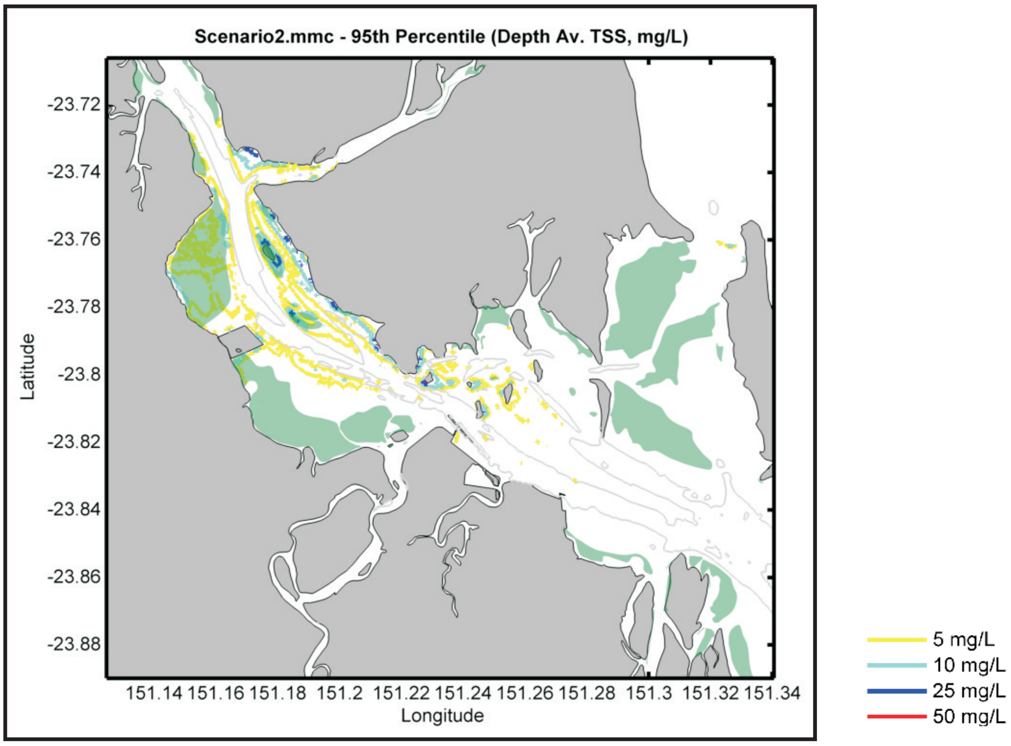
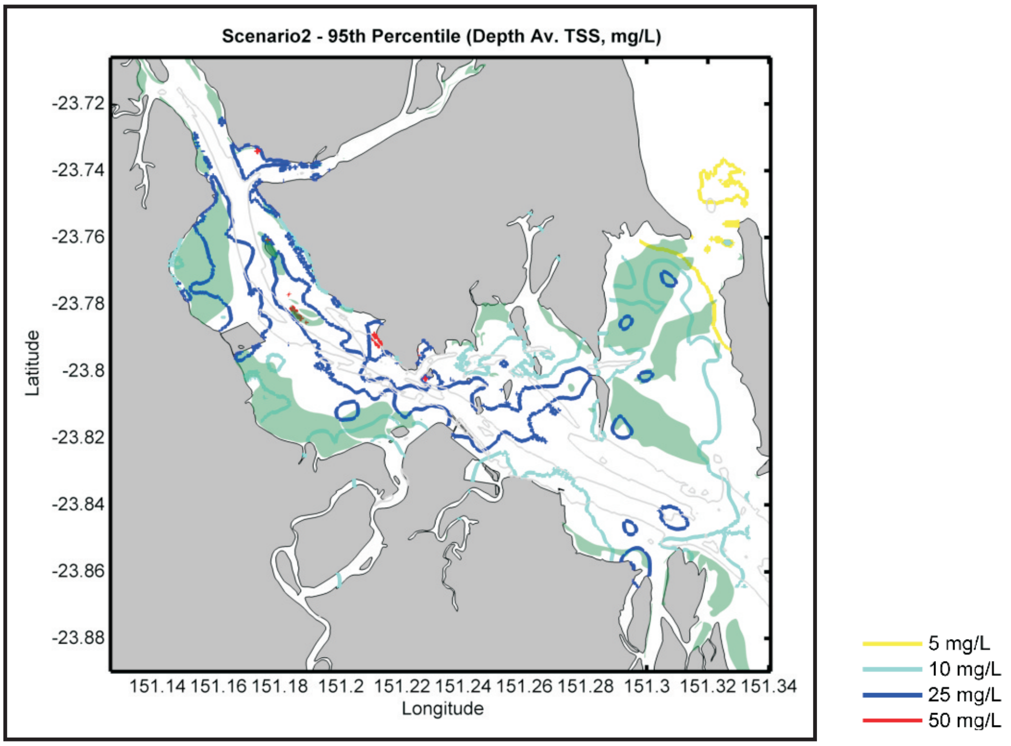
Project	**Queensland Curtis LNG Project**		
Client	**QGC - A BG Group business**		
Drawn JB	**sEIS Volume 5**	**Figure S6.2.25**	
Approved RS	File No:	0086165b_SUP_CDR020_S6.2.25	
Date 21/01/10	Revision 0		

Title **Scenario 2 TSS depth-averaged 50th percentile concentration contour plots without (top) and with background levels included (bottom)**





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QCLNG EarlyWorks Dredge Plume Modelling Final
Prepared for British Gas, 7 January 2010

Not to scale

N

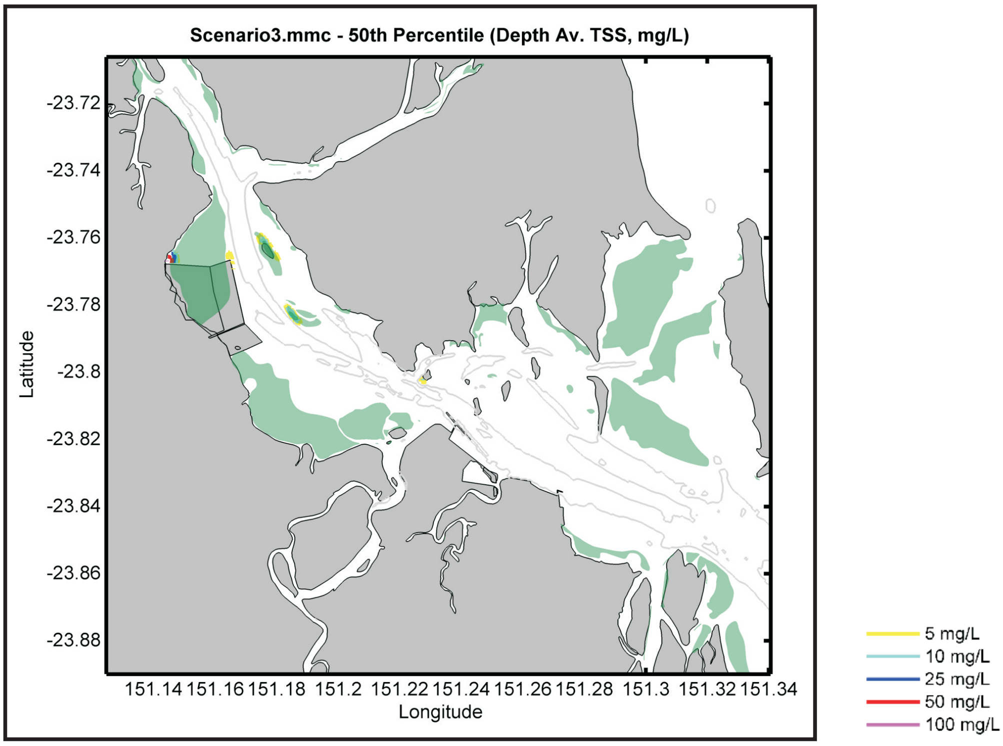
QUEENSLAND CURTIS LNG A BG Group business	Project **Queensland Curtis LNG Project**		Title **Scenario 2 TSS depth-averaged 95th percentile concentration contour plots without (top) and with background levels included (bottom)**
	Client **QGC - A BG Group business**		
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB	**sEIS Volume 5** **Figure S6.2.26**	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved RS	File No: 0086165b_SUP_CDR021_S6.2.26	
	Date 21/01/10	Revision 0	

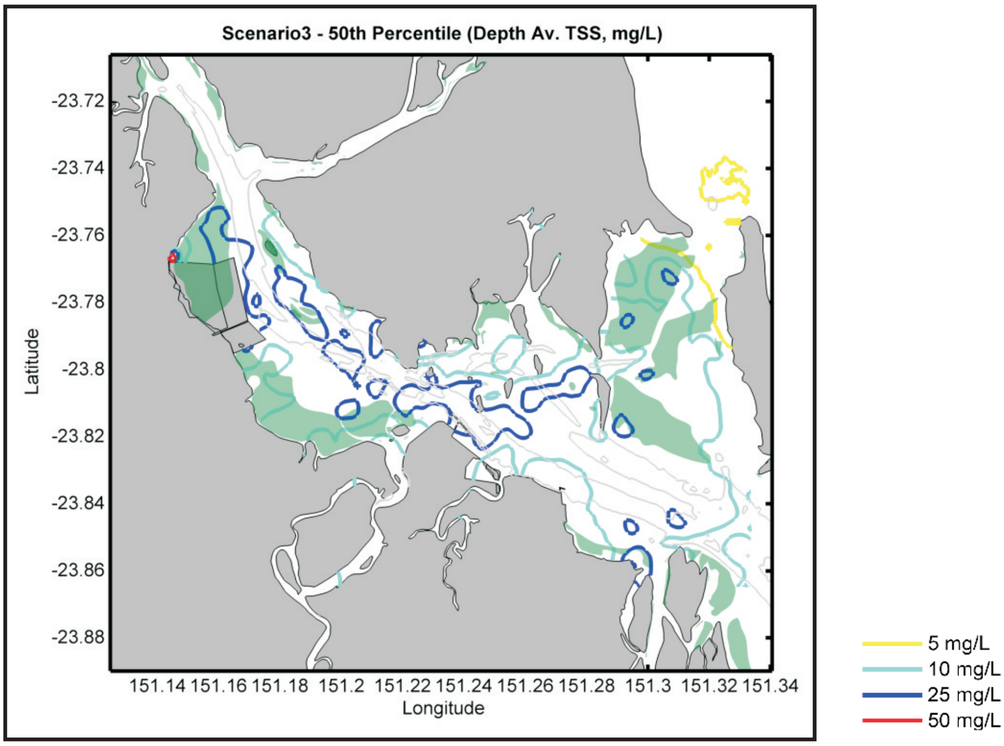
2.3.5.3 *MOF and Construction Dock Scenario Three*

The 50th percentile analysis of Scenario 3 dredge simulations (*Figure 6.2.27*) indicate that elevated concentrations of 5 mg/L will occur in waters adjacent to North Passage Island, Tide Island and the north-east point of the reclamation site. Concentrations of 25 and 50 mg/L (above ambient) were estimated for waters immediately adjacent to the tail-water discharge location.

The 95th percentile assessment (*Figure 6.2.28*) indicated that increased concentrations of 5 mg/L extended approximately 16.5 km from Grahams Creek in the north to waters surrounding Picnic Island. Concentrations of 10 mg/L above ambient were predicted for waters surrounding North and South Passage Islands, Tide Island, and also near to the tail-water discharge site. Elevated concentrations of 50 mg/L are predicted for waters in the south-west corner of Tide Island, North Passage Island and in the immediate vicinity of the tail-water discharge site.

As such, for Sites 1 to 6, the model found that maximum levels of TSS would be within the range of naturally occurring TSS within Port Curtis.



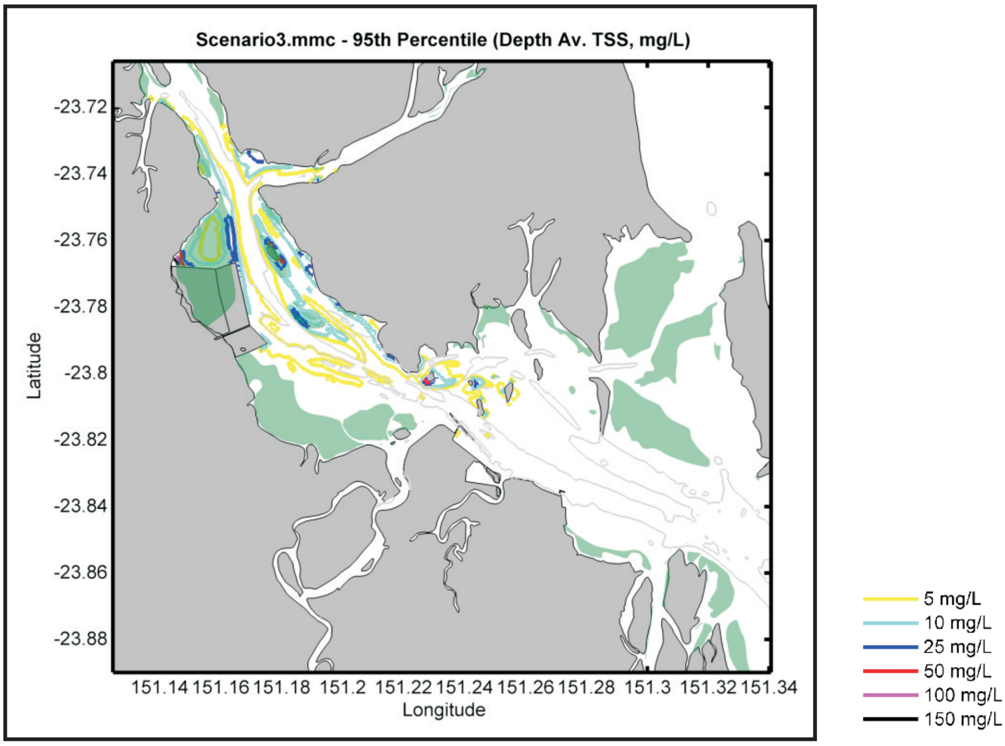


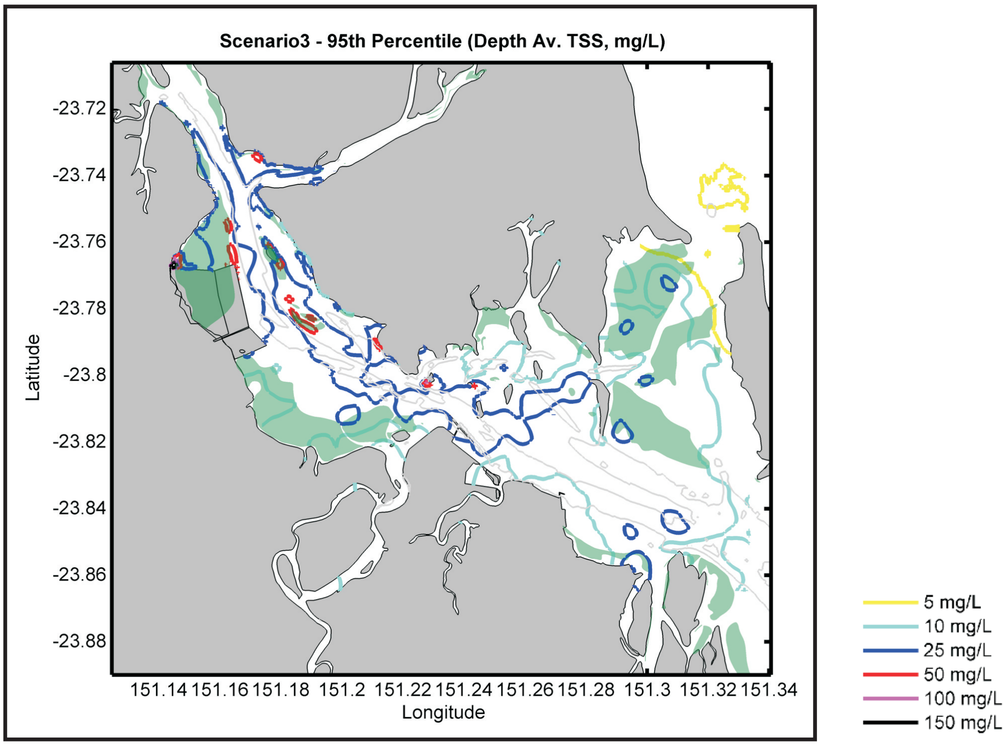
Source:
Asia Pacific ASA Pty Ltd
QCLNG EarlyWorks Dredge Plume Modelling Final
Prepared for British Gas, 7 January 2010

Not to scale

N

QUEENSLAND CURTIS LNG A BG Group business	Project **Queensland Curtis LNG Project** Client **QGC - A BG Group business**	Title **Scenario 3 TSS depth-averaged 50th percentile concentration contour plots without (top) and with background levels included (bottom)**
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB | **sEIS Volume 5** **Figure S6.2.27** Approved RS | File No: 0086165b_SUP_CDR022_S6.2.27 Date 21/01/10 | Revision 0	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.





Source:
Asia Pacific ASA Pty Ltd
QCLNG EarlyWorks Dredge Plume Modelling Final
Prepared for British Gas, 7 January 2010

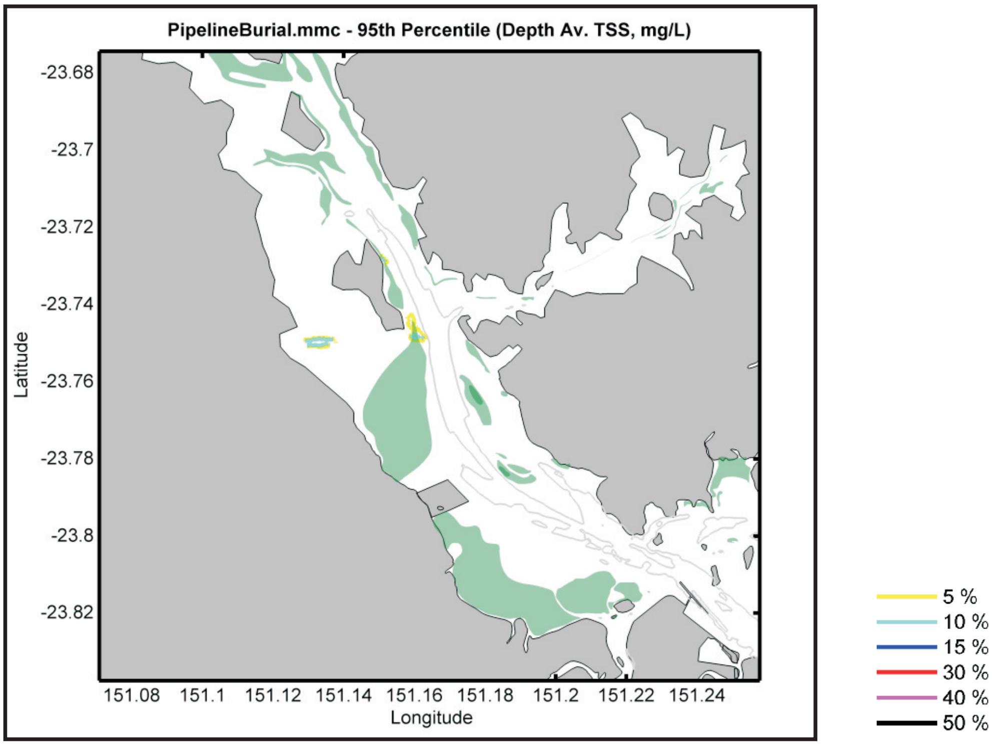
Not to scale

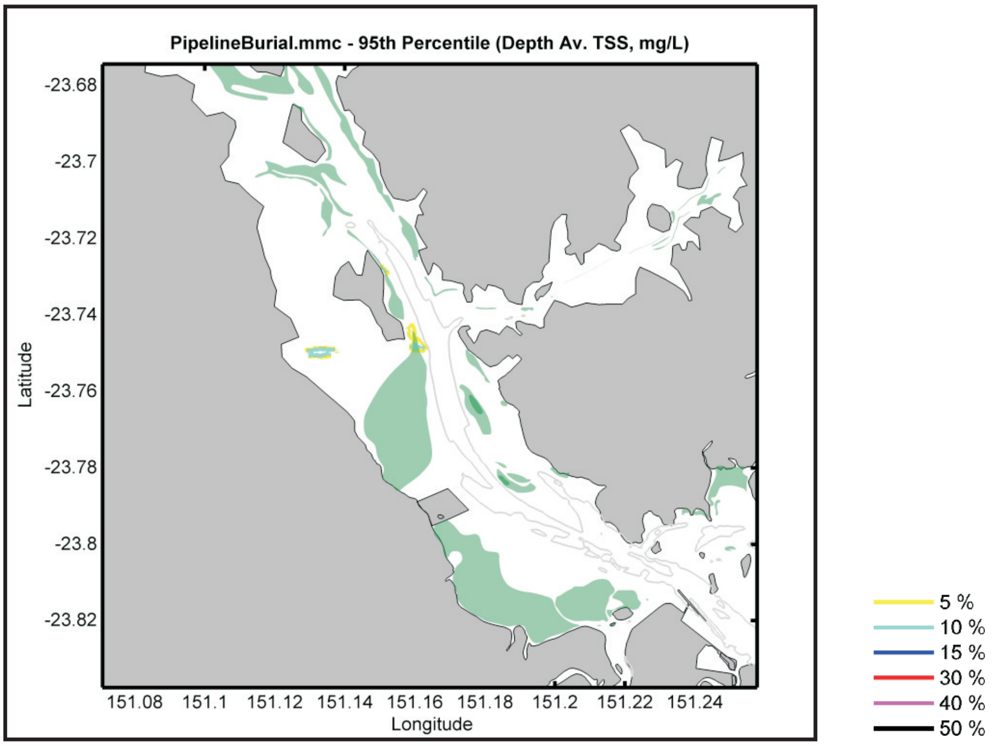
N

QUEENSLAND CURTIS LNG — A BG Group business	Project: Queensland Curtis LNG Project		Title: Scenario 3 TSS depth-averaged 95th percentile concentration contour plots without (top) and with background levels included (bottom)
	Client: QGC - A BG Group business		
ERM — Environmental Resources Management Australia Pty Ltd	Drawn: JB	sEIS Volume 5 — Figure S6.1.28	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved: RS	File No: 0086165b_SUP_CDR023_S6.1.28	
	Date: 21/01/10	Revision: 0	

2.3.5.4 *Narrows Pipeline Crossing*

Due to the relatively short duration of individual dredging operations, (the trenching is expected to progress across The Narrows in approximately 3 weeks), with periods between these when there will be no discharges, the median increases in depth-averaged TSS concentrations were within the natural range in background estimates when calculated over the full duration of the operation. The distribution of more extreme concentrations, as indicated by the 95th percentile of the depth-averaged TSS concentrations is presented in *Figure 6.2.29* for both the background conditions and with the addition of dredging estimates. These calculations indicate that TSS concentrations higher (by 5-10 mg/L) than background would be generated at the upstream end of Targinie Creek and immediately up and downstream of The Narrows operations but these concentrations would not be persist over the duration of the operation. As previously noted, BHD operations generate higher concentrations than would be generated during jetting operations and hence represent the 'worst case' construction methodology of the two methods.





Source:
Asia Pacific ASA Pty Ltd
QCLNG - Pipeline Burial Sediment Plume Modelling
Prepared for British Gas, 23 December 2009

Not to scale

N

QUEENSLAND CURTIS LNG A BG Group business	Project: Queensland Curtis LNG Project		Title: Estimates for the 95th percentile concentrations over time calculated for depth-averaged TSS. Results are shown with (above) and without (below) background estimates
	Client: QGC - A BG Group business		
ERM Environmental Resources Management Australia Pty Ltd	Drawn KP	sEIS Volume 5 Figure S6.2.29	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved RS	File No: 0086165b_SUP_CDR039_S6.2.29	
	Date 21/01/10	Revision 0	

2.3.6 Sedimentation

This section presents typical and worst-case sedimentation rate contours. The sedimentation rate was calculated at hourly intervals for each cell location within the model domain over the duration of the modelled dredge scenario.

The findings of this modelling based on the reference case of this sEIS, indicated that the sedimentation for the three scenarios is unlikely to cause significant adverse impacts. This is further discussed in *Volume 5, Chapter 8.*

2.3.6.1 *MOF and Construction Dock Scenario One*

The 50th and 95th percentile of the predicted increases to sedimentation rate, as a result of the dredge operations of Scenario 1, are presented in *Figure 6.2.30* (top and bottom).

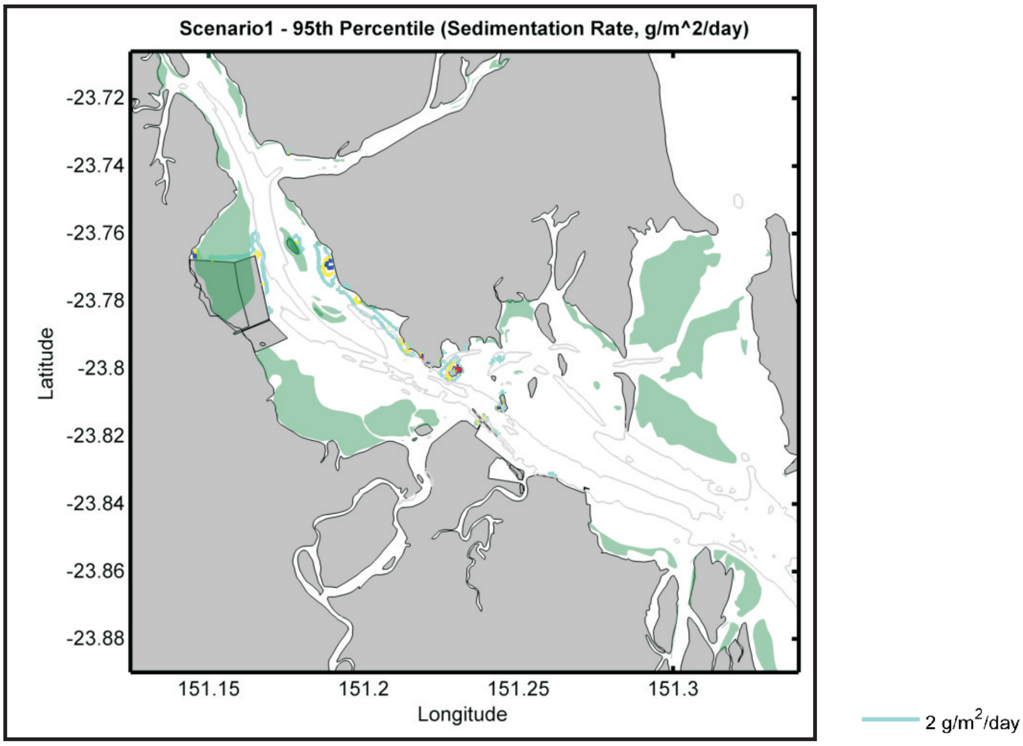
For the 50th percentile a small area adjacent to the tail-water discharge site is predicted to receive a sedimentation rate of 2 g/m^2/day (0.06 mm/month).

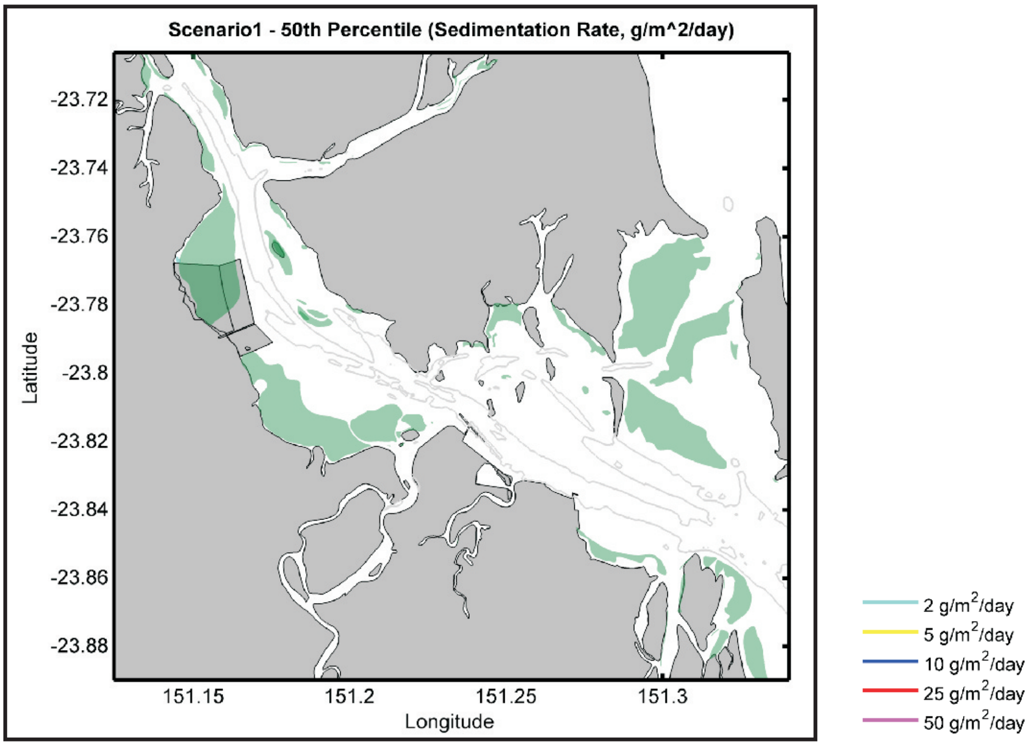
The 95th percentile map indicates two distinct areas influenced by sedimentation rates of 2 and 5 g/m^2/day, respectively (0.06 mm/month and 0.16 mm/month). These areas occur along the western shoreline of Curtis Island from the MOF site to areas surrounding Hamilton Point; and adjacent the tail-water discharge site along the northern bounds of the proposed reclamation site to the north of Fisherman's Landing.

Additional areas characterised by sedimentation rates of 2 g/m^2/day include a small area adjacent the shoreline north-east of Barney Point and areas surrounding and to the north of Picnic Island. Increased sedimentation rates of 10 g/m^2/day are predicted to occur at the immediate vicinity of the MOF dredge location and immediately adjacent the tail-water discharge site. Maximum rates of 25 g/m^2/day (0.78 mm/month) are predicted for the north-eastern tip of Tide Island.

The model found that for Scenario 1, the predicted sedimentation rates are low and would only occur for short periods of time (pulses of several hours duration primarily during neap tide periods, over approximately 2 months of dredging and thus the impact would be negligible.

For further information on the impacts of this scenario to marine ecology, refer to *Volume 5, Chapter 8*.





Source:
Asia Pacific ASA Pty Ltd
QCLNG EarlyWorks Dredge Plume Modelling Final
Prepared for British Gas, 7 January 2010

Not to scale

N

QUEENSLAND CURTIS LNG — A BG Group business	Project **Queensland Curtis LNG Project**	Title **Predicted 50th percentile (top) and 95th percentile (bottom) sedimentation rate (g/m2/day) from dredging operations in Scenario 1**
	Client **QGC - A BG Group business**	
ERM — Environmental Resources Management Australia Pty Ltd	Drawn JB / **sEIS Volume 5** **Figure S6.2.30**	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved RS / File No: 0086165b_SUP_CDR024_S6.2.30	
	Date 21/01/10 / Revision 0	

2.3.6.2 *MOF and Construction Dock Scenario Two*

The 50^{th} and 95^{th} percentile of sedimentation rates predicted to result from dredge operations in Scenario 2, are presented in *Figure 6.2.31* (top and bottom).

The median (50^{th}) percentile plot indicates a 2 g/m^2/day sedimentation rate surrounding the MOF and Construction Dock regions, extending south to Hamilton Point. A sedimentation rate of 5 g/m^2/day is predicted within the immediate vicinity of the MOF dredge area.

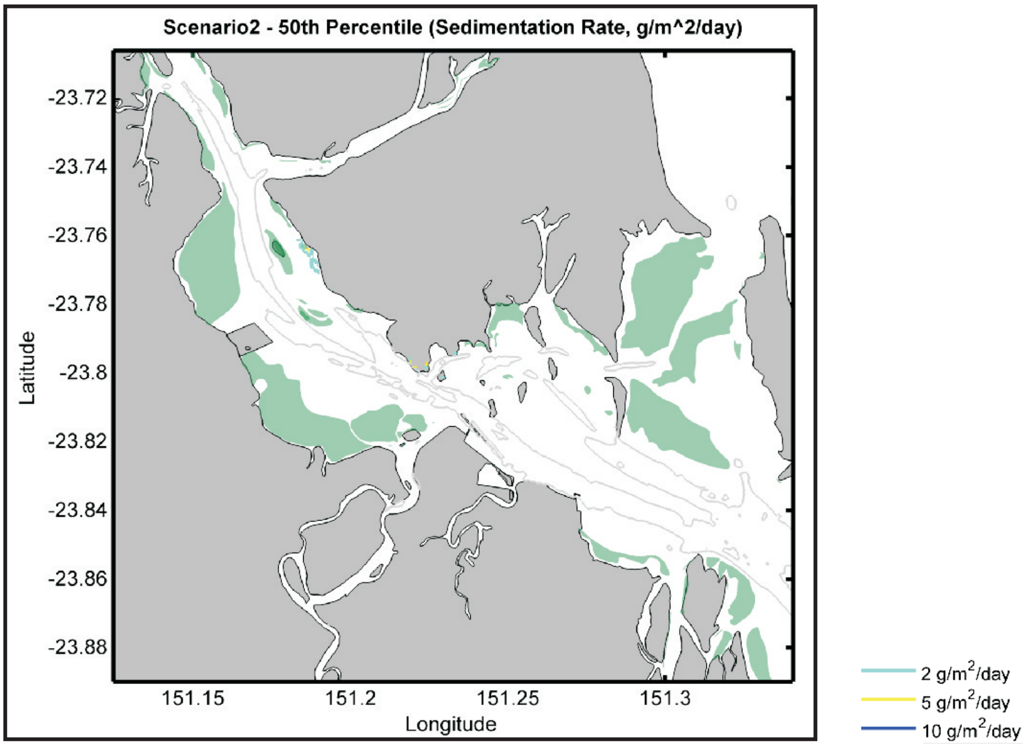
The 95^{th} percentile map shows extended areas of increased sedimentation rates resulting from the BHD operations, ranging between 2 and 100 g/m^2/day. Sedimentation rates of 2 g/m^2/day are predicted to occur along the length of the estuary from The Narrows and Grahams Creek in the north to the deep channel waters at the entrance of the Port. Closely banded with these areas are zones predicted to experience sedimentation rates of 5 g/m^2/day.

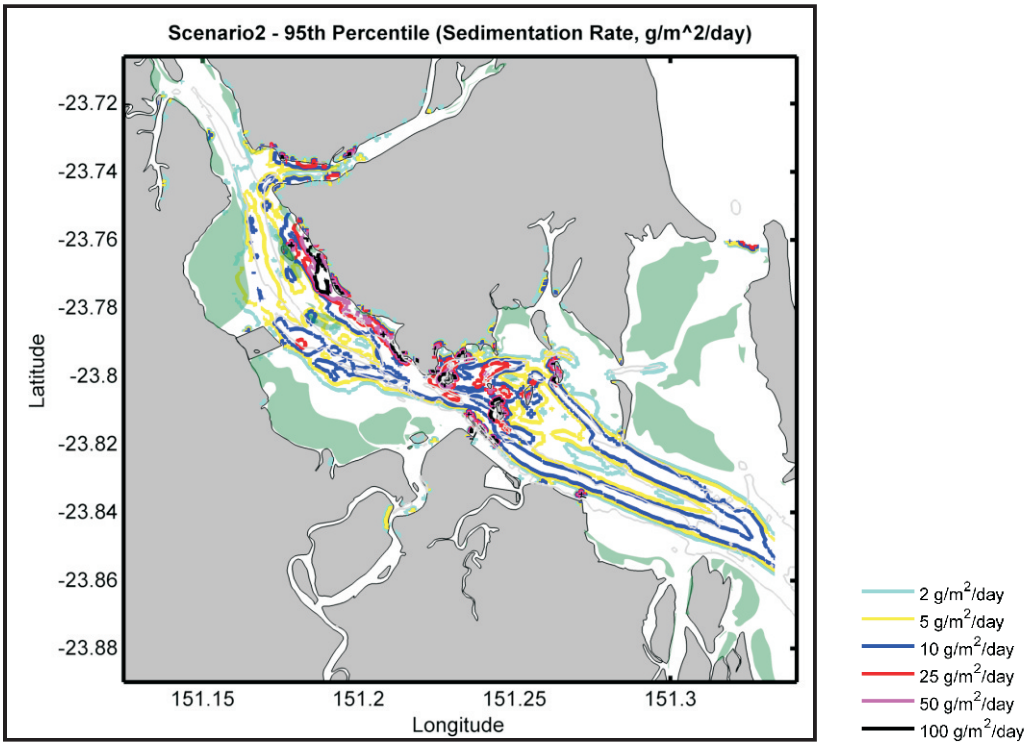
Sedimentation rates surrounding Hamilton Point and the small group of adjacent islands are predicted to be >5 g/m^2/day with rates as high as 100 g/m^2/day (3.1 mm/month). Elevated sedimentation rates >25 g/m^2/day are also predicted for a small region to the east of Fisherman's Landing, along the western side of Curtis Island within the direct vicinity of the MOF, Construction Dock and the entrance of Grahams Creek.

Assessment of the ecological impact of these sedimentation rates on environmental values (refer to *Volume 5, Chapter 8*) determined that the nature of the sensitive receptors and the short period of these impacts would mean that impacts are minor.

If dredging Scenario 2 is exercised, it will be necessary to monitor and manage (via the Dredging Management Plan) potential risks to soft coral communities in deeper water on Hamilton Point, which will occasionally be exposed to sedimentation rates in excess of 2 g/m^2/day.

For further information on impacts of this scenario on marine ecology, refer to *Volume 5, Chapter 8.*





Source:
Asia Pacific ASA Pty Ltd
QCLNG EarlyWorks Dredge Plume Modelling Final
Prepared for British Gas, 7 January 2010

Not to scale

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QUEENSLAND CURTIS LNG A BG Group business	Project **Queensland Curtis LNG Project** Client **QGC - A BG Group business**	Title **Predicted 50th percentile (top) and 95th percentile (bottom) sedimentation rate (g/m2/day) from dredging operations in Scenario 2**
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB	**sEIS Volume 5** **Figure S6.2.31** Approved RS	File No: 0086165b_SUP_CDR025_S6.2.31 Date 21/01/10	Revision 0	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.

2.3.6.3 MOF and Construction Dock Scenario Three

The 50th and 95th percentile of the predicted sedimentation rate, as a result of the dredge operations of Scenario 3, are presented in *Figure 6.2.32* (top and bottom).

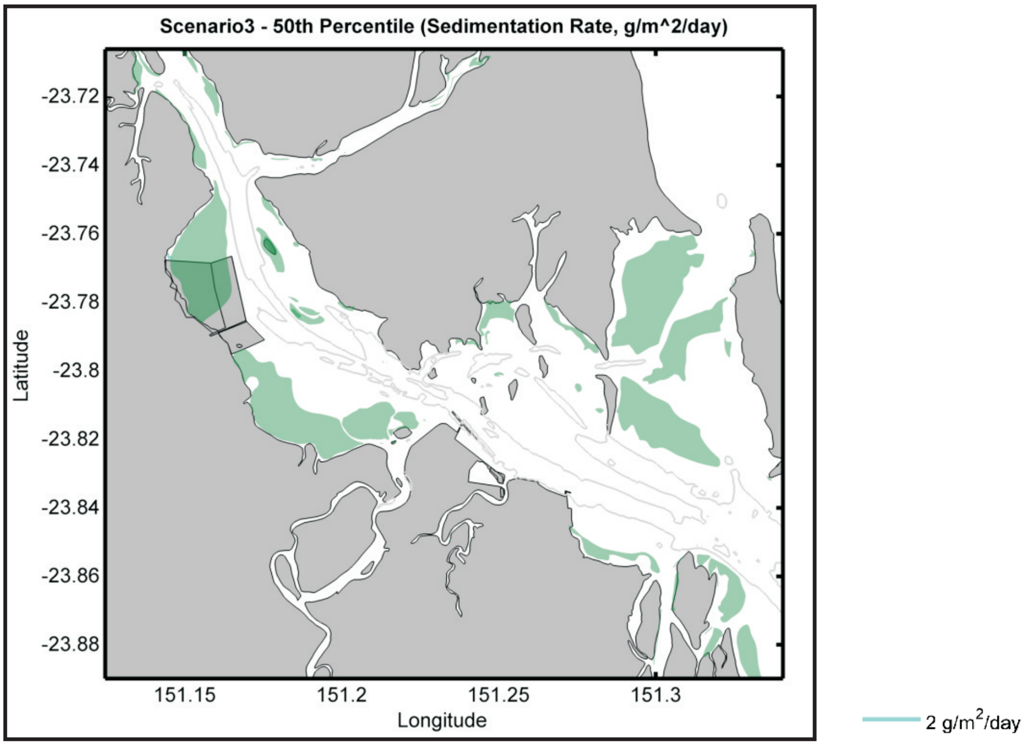
The median percentile map indicates predicted localised sedimentation rates of 2 $g/m^2/day$ directly adjacent to the tail-water discharge site.

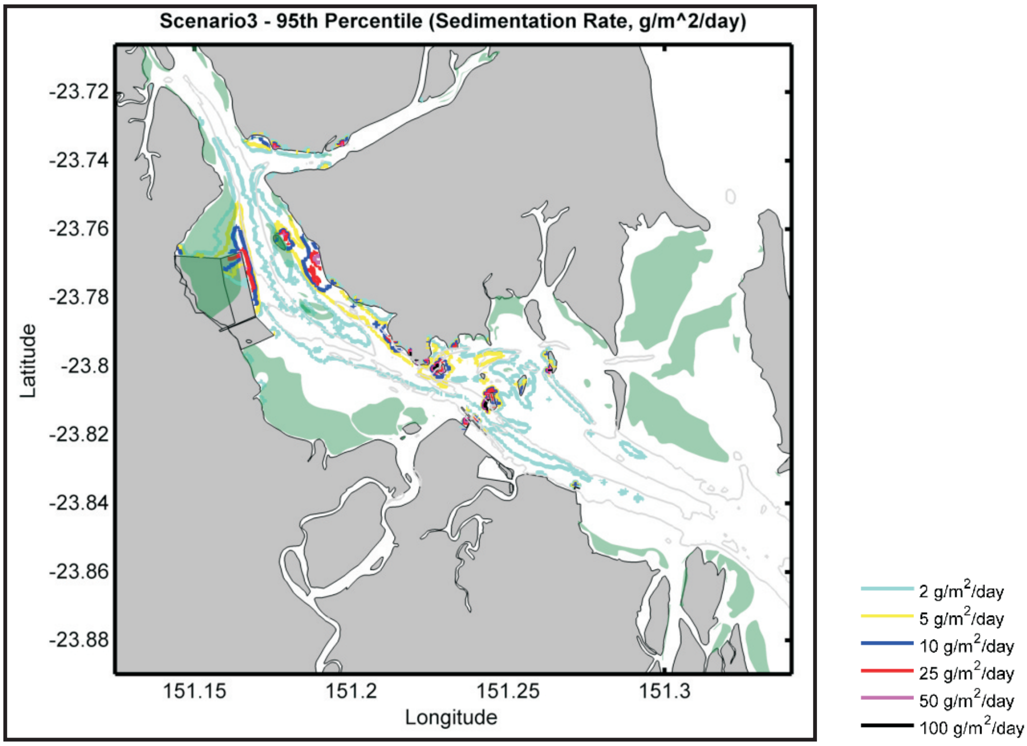
The 95th percentile map indicates predicted sedimentation rates ranging between 2 and 100 $g/m^2/day$. Predicted sedimentation rates of 2 $g/m^2/day$ occur in a predominantly continuous contour from Barney Point and South Trees Island, to Friend Point and Laird Point in the north of the estuary. Sedimentation rates of 5 $g/m^2/day$ or greater were scattered amongst Laird Point and waters near the tail-water discharge site on the western side of Port Curtis.

Regions between the MOF and Picnic Island on the eastern side of the Port were characterised by more uniform sedimentation zones. Predicted zones of sedimentation rates of 25 $g/m^2/day$ or greater were concentrated at the entrance of Grahams Creek, North Passage Island and immediately adjacent the proposed land reclamation site in the northern region of the Port and surrounding Hamilton Point and Picnic Island in the central Port region.

Again, these predicted sedimentation rates are low and only occur for short periods of time as pulses of several hours duration, primarily during neap tide periods over approximately 3 months of dredging, and thus impacts would be negligible. If dredging Scenario 3 is exercised, it will be necessary to monitor and manage (via the Dredging Management Plan) potential risks to soft coral communities in deeper water on Hamilton Point, which will occasionally be exposed to sedimentation rates in excess of 2 $g/m^2/day$.

For further information on impacts of this scenario on marine ecology, refer to *Volume 5, Chapter 8*.





Source:
Asia Pacific ASA Pty Ltd
QCLNG EarlyWorks Dredge Plume Modelling Final
Prepared for British Gas, 7 January 2010

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QUEENSLAND CURTIS LNG
A BG Group business

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Project **Queensland Curtis LNG Project**		Title **Predicted 50th percentile (top) and 95th percentile (bottom) sedimentation rate (g/m2/day) from dredging operations in Scenario 3**
Client **QGC - A BG Group business**		
Drawn JB	**sEIS Volume 5** **Figure S6.2.32**	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
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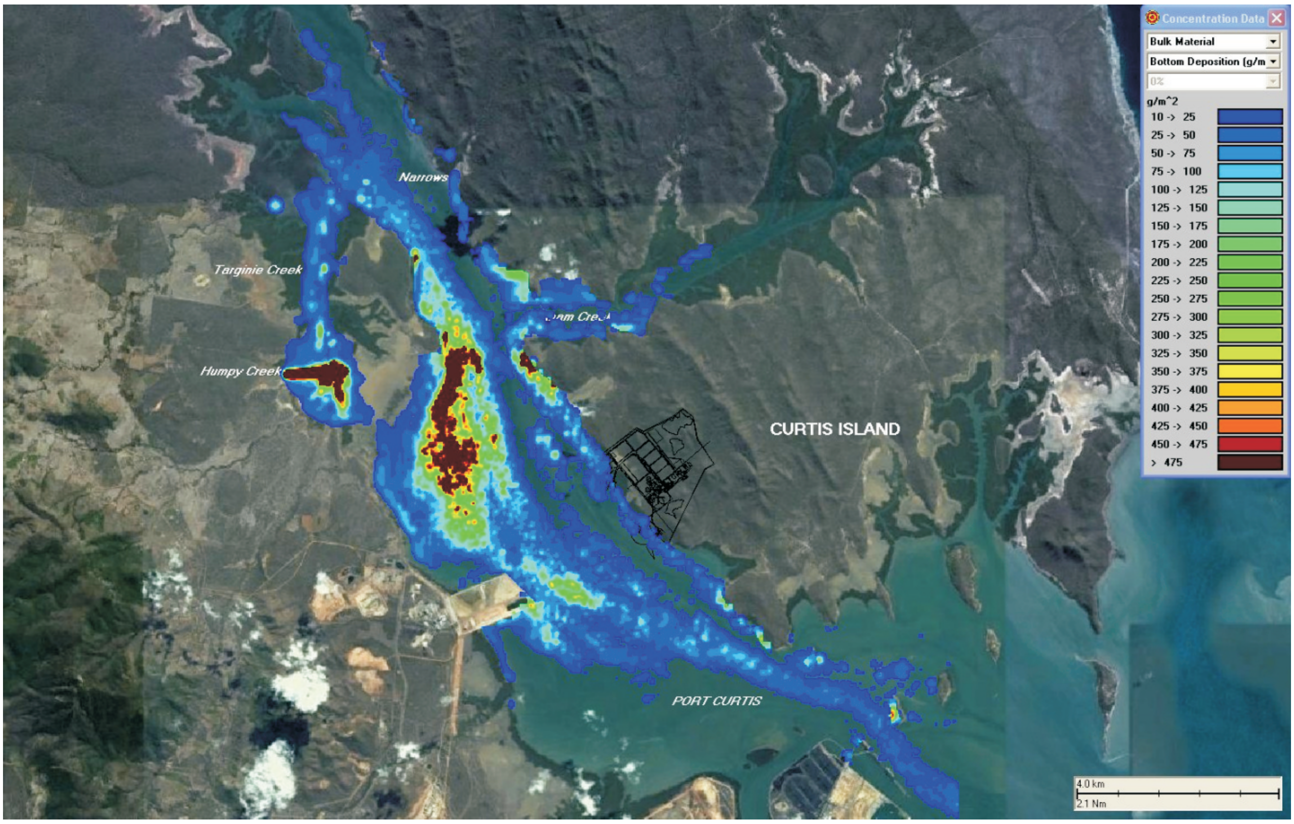
Date 21/01/10	Revision 0	

2.3.6.4 *The Narrows Pipeline Crossing*

Estimates of cumulative sedimentation (refer *Figure 6.2.33)* indicate that fine sediments would be spread widely but thinly throughout the creek and estuary, with a downstream bias. Due to the lower current speeds in the creek, highest accumulations were predicted immediately around the operation crossing this section, with the finer sediments being distributed along the creek and accumulating in deeper pockets along the channel. In contrast, the stronger currents through The Narrows are predicted to transport sediment released from this section upstream and downstream with the tide and finer sediments were predicted to settle as far downstream as the estuary mouth. Upstream settlement is predicted to extend up to 6 km beyond The Narrows and midway along Graham Creek. Highest sedimentation was indicated for locations to the sides of the channels where current speeds are weaker, corresponding to locations where mud banks currently exist, for this same reason. It is also noted that localised accumulation at relatively low levels is predicted for the south end of Curtis Island and on Tide Island.



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Asia Pacific ASA Pty Ltd
QCLNG - Pipeline Burial Sediment Plume Modelling
Prepared for British Gas, 23 December 2009

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QUEENSLAND CURTIS LNG A BG Group business	Project **Queensland Curtis LNG Project** Client **QGC - A BG Group business**	Title **Estimates for the Cumulative Sedementation (above background) due to the Combined Operations**
ERM Environmental Resources Management Australia Pty Ltd	Drawn KP | **sEIS Volume 5** **Figure S6.2.33** Approved RS | File No: 0086165b_SUP_CDR035_S6.2.33 Date 21/01/10 | Revision 0	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.

2.4 LIGHT ATTENUATION

The main environmental feature of concern within Port Curtis is considered to be the seagrass meadows and associated fauna. Other than by direct removal within dredging footprints, dredging can affect seagrasses by decreased light availability caused by the shading effects of suspended solids in the water column. This section presents a summary of modelling undertaken to predict the effect of dredge-released sediment on light penetration through the water column.

In developing the methodology for this modeling, QGC brought together a Working Group of experts from DEEDI, Melbourne University, specialist hydrodynamic and sediment modelling consultants, a dredging expert and QGC's key environmental and technical consultants to formulate an approach to determining the impacts of sediment on seagrasses in regard to light. This Working Group developed two key strategies:

1. The use of an initial literature review of physiological thresholds for seagrass impacts as the basis for interim impact predictions
2. A high level design of the methodology that would ultimately be used to refine the impacts assessment and management processes for light attenuation on seagrasses.

Both of these studies provided information which has allowed QGC to effectively assess potential impacts of the dredging works for this Project on seagrasses.

2.4.1 Methodology

Increased turbidity can reduce the availability of light and in turn the productivity of seagrasses. A key objective of this supplementary EIS is to relate the predicted TSS concentrations as described in the previous section of this volume to the difference in the amount of light, before and during dredging, for the three modelled scenarios.

The following methodology was determined to assess the impact of decreased light availability and its impact on seagrasses. This methodology is described below.

- Generate a map of background TSS concentrations for Port Curtis from long term MODIS satellite data (see *Volume 5, Chapter 8*);
- Derive predictive relationships between TSS and light attenuation coefficients (Kd), as a step-wise process:
  - Collate and review local (Port Curtis) field data where turbidity (NTU) and light attenuation (Kd) were measured concurrently. Use this to determine the locally-specific relationship between turbidity and Kd
  - Use the derived NTU-Kd relationship from (2a) to convert the more extensive local turbidity (NTU) dataset to Kd values

− Develop rules to relate locally-specific Kd values to modelled or measured TSS concentrations.

Based on the above analysis, the site specific relationships for deriving K_d from TSS concentrations are:

TSS: 0 to 5 mg/L	$K_d = 0.0774(TSS) + 0.5175$
TSS: > 5 mg/L	$K_d = 0.0395(TSS) + 0.7064$

1. Adjust model parameters to account for:
   a. Periods of exposure to daylight hours only (night hours were excluded)
   b. tidal variability (depth, and hence the amount of light received, will vary as the tide changes)
   c. aerial exposure (it was assumed that during periods of exposure above the water line seagrass are unable to photosynthesise and therefore light received during exposure was excluded).
2. Determine the level of light in the photosynthetically active radiation spectrum at the water surface (I_o) using six-hourly (morning, noon and evening) solar radiation data for Gladstone derived from a global atmospheric model, together with predictions of hour-by-hour radiation levels throughout each day, for the duration of the dredge activity being modelled
3. Calculate the amount of light reaching the seabed (I_z) over the model domain, using the equation:

$$\frac{I_o}{I_z} = \exp^{-z.k_d}$$

   where: Io and Iz are the amounts of light at the surface and depth z, respectively and Kd is the light attenuation coefficient.
4. Divide Io by Iz to calculate the fraction of surface irradiance measured at depth z, expressed as %SI
5. Generate 50th and 95th percentile plots of ambient %SI for the background TSS concentrations (from Step 1)
6. Convert time series TSS concentrations for each of the dredge modelling scenarios using the Kd relationship and calculate the time series of Iz
7. Compare the calculated time series of I_z for the modelled dredging case and background case, and determine the change in amount of light for each model cell (40 m by 40 m)
8. Generate 50^{th} and 95^{th} percentile plots of the difference in percentage of surface irradiation (%SI) reaching the seabed as a result of the dredging operation for each of the three dredge scenarios.

2.4.2 *Results of Light Attenuation Modelling*

The derived ambient levels of %SI at the seabed for Port Curtis for the duration of the dredge period modeled are plotted in *Figure 6.2.34* and *Figure 6.2.35*. Contours are presented for 5, 10, 15, 30, 40 and 50 %SI. Derived values were validated by a comparison between the derived %SI values and field measurements of %SI at several locations. Good agreement, within 1-3 %SI, was found between the derived and measured data.

The interpretive value of %Si mapping for impact assessment purposes can be seen by overlaying the derived %SI contour plots with maps showing the distribution of existing seagrass meadows within Port Curtis. The deeper limits of seagrass meadows approximate closely to the 5 %SI contour, with the notable exception being north of Fisherman's Landing where seagrass meadows extend deeper than the 5 %SI contour line. From this it can be inferred that the minimum light requirement required to support seagrass in Port Curtis, for the purpose of impact evaluation, is in the order of 5 %SI.

In a parallel exercise, Department of Employment, Economic Development and Innovation (Fisheries Queensland) seagrass scientists reviewed published scientific literature on minimum light tolerances for locally occurring seagrass species[1]. These are summarised in *Table 6.2.2* and *Table 6.2.3*. This review suggests threshold values between 4.4 %SI and 30 %SI, varying among species, localities and exposure duration.

What is clear from the studies commissioned to address the working group methodology is that an absolute threshold of 30%Si is too conservative for Port Curtis. A review of light attenuation contours (*Figure 6.2.34* and *Figure 6.2.35*) identifies very little of the known existing seagrass beds that experience 30 %SI. The implied derived %SI threshold of 5 per cent falls at the lower limit of reported literature values. This may be real (i.e., Port Curtis seagrasses may be adapted to low light conditions as a consequence of the turbid local environment), or it may represent an imprecise understanding (therefore modelling) of the metabolic and light physiology of local seagrasses (i.e. it is possible that the models do not yet properly accommodate the role of aerial exposure, temperature, carbohydrate reserves etc on seagrass health).

For the purposes of this impact assessment, it has been assumed that seagrass beds which are consistently exposed (median of predicted values) to TSS of 25mg/L will be impacted, and that seagrasses which are only exposed to these levels for 20 per cent of the dredging period (a maximum of two weeks over a three month period for the longest dredging scenario) are likely to suffer temporary impacts. The nature and significance of these are discussed in more detail in *Volume 5, Chapter 8*.

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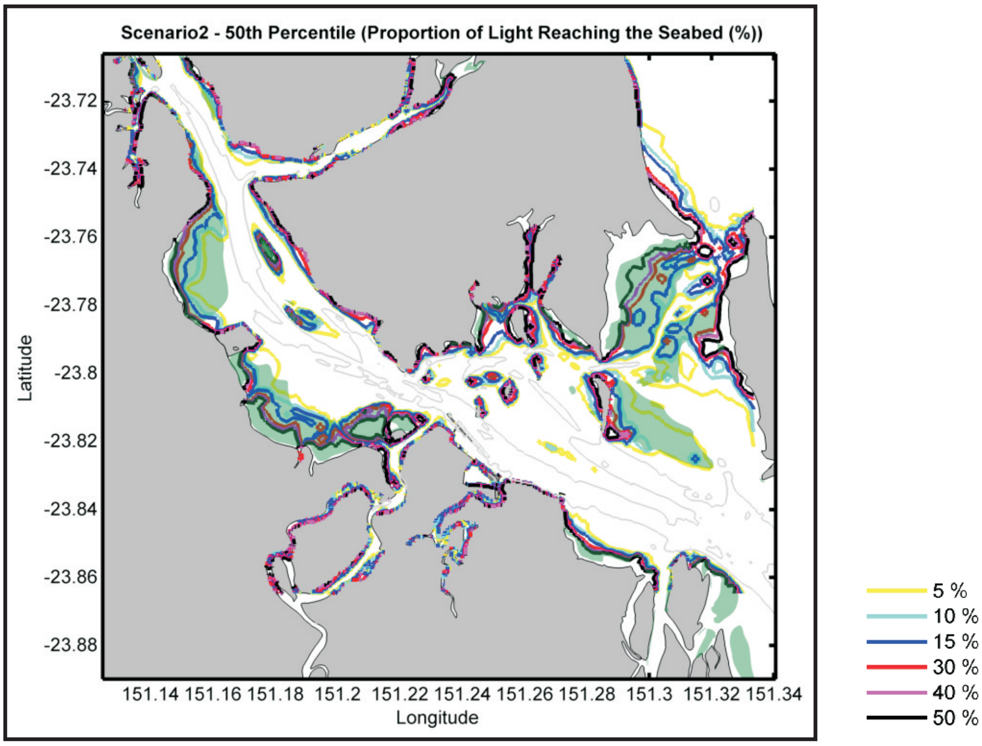
1 Chartrand, K and M Rasheed, 2009. "Light requirements for Gladstone seagrass species: Initial literature derived values for model input", unpubl. report to QGC by Marine Ecology Group, Fisheries Queensland, Department of Employment, Economic Development and Innovation, 4pp.

QGC commenced field studies investigating the light requirements for Gladstone seagrasses in November 2009[2], which will continue until February 2010. These studies and their analysis will continue in parallel with refinement of the Dredging EMP.

2 The study referred to addresses the impact of light reduction on the major seagrass communities, their tolerances to sustained shading and ability to recover from light related stress; and develops measurements of seagrass resilience, productivity and capacity for recovery of the major seagrass meadow types likely to be impacted by the dredging.



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QCLNG EarlyWorks Dredge Plume Modelling Final
Prepared for British Gas, 7 January 2010

Not to scale

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QUEENSLAND CURTIS LNG A BG Group business	Project **Queensland Curtis LNG Project**	Title **Derived 50th percentile ambient levels, in absence of dredging, of %SI at the seabed for Port Curtis over the modeled period**
	Client **QGC - A BG Group business**	
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB / **sEIS Volume 5** / **Figure S6.2.34**	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
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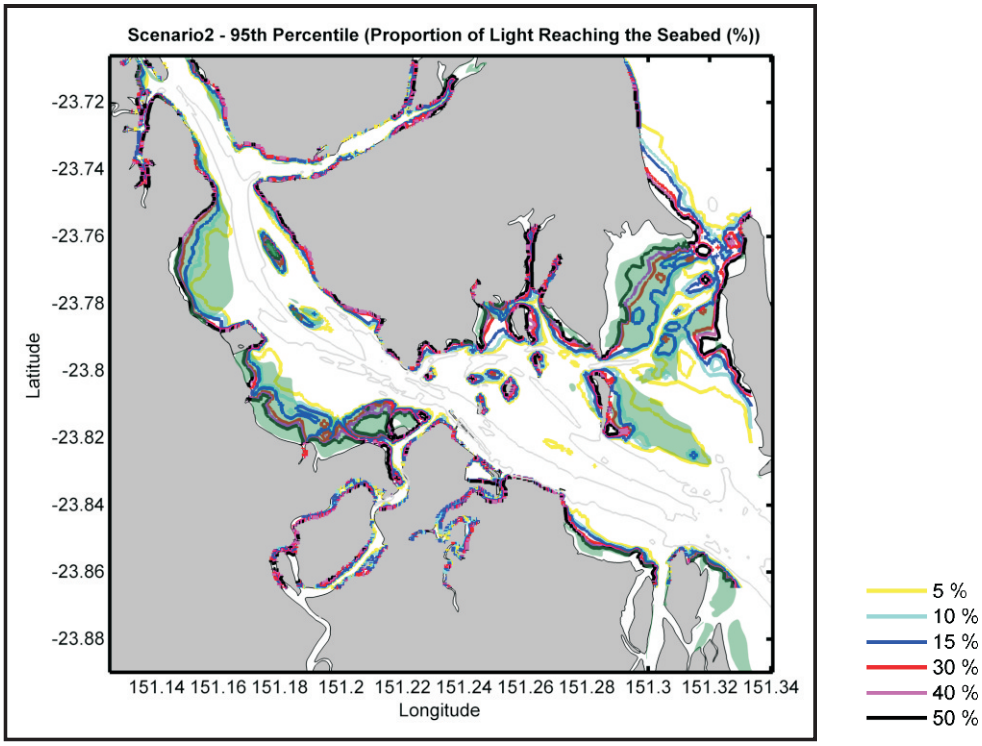

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QUEENSLAND CURTIS LNG A BG Group business	Project **Queensland Curtis LNG Project** Client **QGC - A BG Group business**	Title **Derived 95th percentile ambient levels, in absence of dredging, of %SI at the seabed for Port Curtis over the modeled period**
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB | **sEIS Volume 5** **Figure S6.2.35** Approved RS | File No: 0086165b_SUP_CDR028_S6.2.35 Date 21/01/10 | Revision 0	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.

Table 6.2.2 Published values of minimum light requirements by species, for locally occurring or morphologically similar species

Species	%SI	Location	Reference
Zostera capricorni	30	Moreton Bay, Qld,	Longstaff *et al.* 1999
Zostera capricorni	30	Moreton Bay, Qld,	Abal & Dennison 1996
Halophila ovalis	16	Zanzibar, Tanzania	Schwartz *et al.* 2000
Halophila decipiens	4.4	St Croix, Caribbean US,	Williams & Dennison 1990
Halophila decipiens	8.8	Cuba,	Williams & Dennison 1990
Halodule uninervis narrow (H. pinifolia)	14	Karumba, Qld,	Longstaff & Dennison 1999
Halodule wrightii	22	North Carolina, US,	Biber *et al.* 2005
Halodule wrightii	24-37	Florida, US,	Kenworthy & Fonseca 1996

Table 6.2.3 Time and light levels where seagrass declines were significant and/or mortality was observed, for locally occurring or morphologically similar species

Species	%SI	Time to Death (Days)	Time for significant decline (Days)	Location	Reference
Zostera capricorni	23	86		Port Hacking, NSW,	Fyfe 2004
Zostera capricorni	23		13	Port Hacking, NSW,	Fyfe 2004
Zostera capricorni	31		61	Magnetic Island, Qld,	Collier & Waycott 2009
Zostera capricorni	50		30	Moreton Bay, Qld,	Grice *et al.* 1996
Halophila ovalis	1	25	14	Magnetic Island, Qld,	Collier & Waycott 2009
Halophila ovalis	60		46	Magnetic Island, Qld,	Collier & Waycott 2009
Halophila ovalis	0	30		Moreton Bay, Qld,	Longstaff *et al.* 1999
Halophila ovalis	0	38		Karumba, Qld,	Longstaff & Dennison 1999
Halodule uninervis narrow (H. pinifolia)	0	100	78	Karumba, Qld,	Longstaff & Dennison 1999
Halodule wrightii	13 - 16	9 months		Florida, US,	Czerny & Dunton 1995

2.4.2.1 *Scenario One*

The 50th percentile map[3] (*Figure 6.2.36*) indicates a reduction in %SI due to dredge-related light attenuation of 1 %SI at the fringe of the seagrass meadow north of GPC's proposed Fisherman's Landing reclamation site. This impact increased to 2 %SI within 300 m of the outfall, while in close proximity to the tail-water outfall the impact increased to 25 %SI.

The 95th percentile map[4] (*Figure 6.2.37*) shows impacts of 2 %SI for seagrass meadows south of Fisherman's Landing. There is the potential for a 15 %SI impact for seagrass meadows at both North and South Passage Islands. The seagrasses adjacent to Laird Point would experience a 10 %SI impact. Seagrass meadows north of the proposed Fisherman's Landing reclamation site would experience an impact of 5 %SI to 25 %SI, depending on their proximity to the tail-water outfall.

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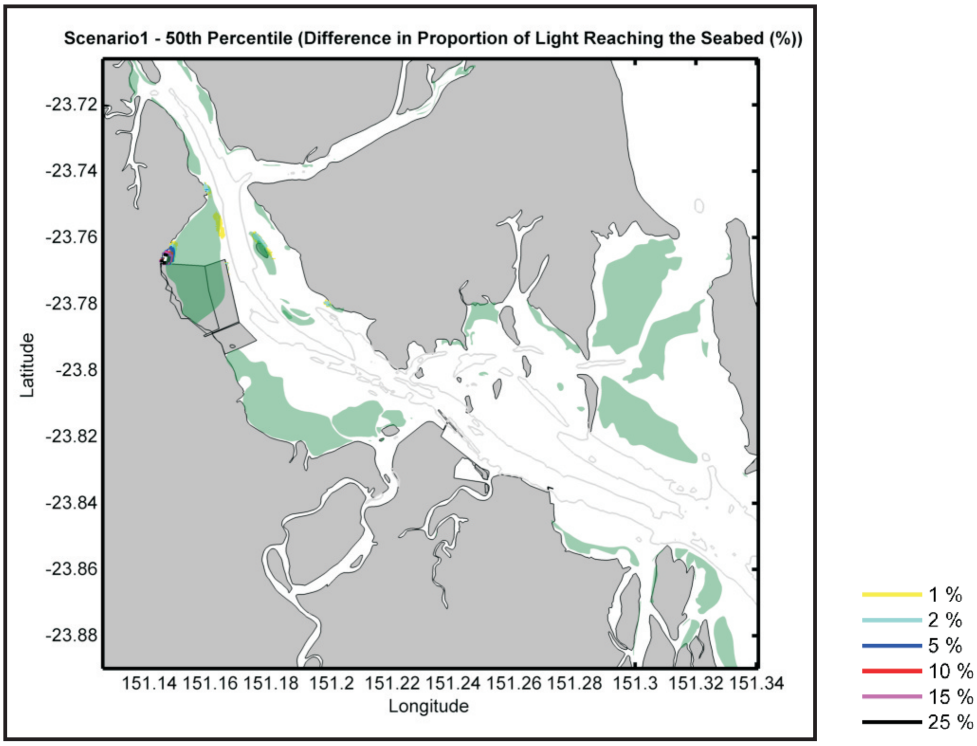
3 The 50th percentile contours graphically join areas where the %SI reduction will be at a given level for 50% of the time (i.e. this represents the average %SI)

4 The 95th percentile contours graphically join areas where the %SI reduction will be above a given level for 5% of the time (i.e. this represents the worst case %SI)



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Prepared for British Gas, 7 January 2010

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QUEENSLAND CURTIS LNG A BG Group business	Project **Queensland Curtis LNG Project**	Title **Derived difference in 50th percentile levels of %SI (ambient versus dredge conditions) at the seabed for Port Curtis over the modeled period, for Scenario 1**
	Client **QGC - A BG Group business**	
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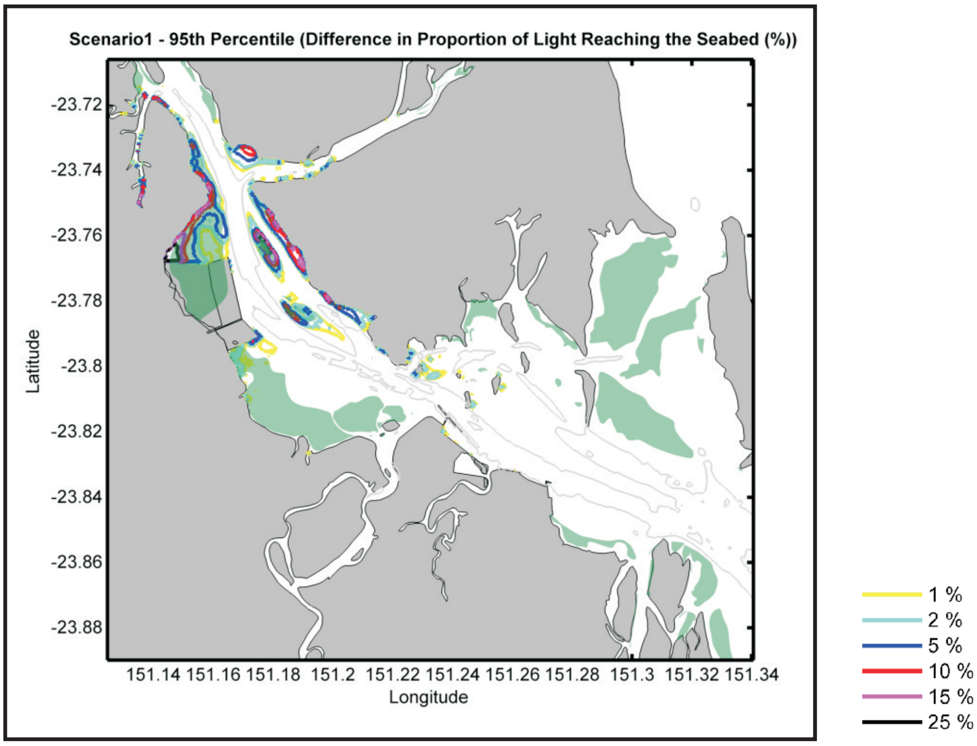

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QUEENSLAND CURTIS LNG A BG Group business	Project **Queensland Curtis LNG Project**	Title **Derived difference in 95th percentile levels of %SI (ambient versus dredge conditions) at the seabed for Port Curtis over the modeled period, for Scenario 1**
	Client **QGC - A BG Group business**	
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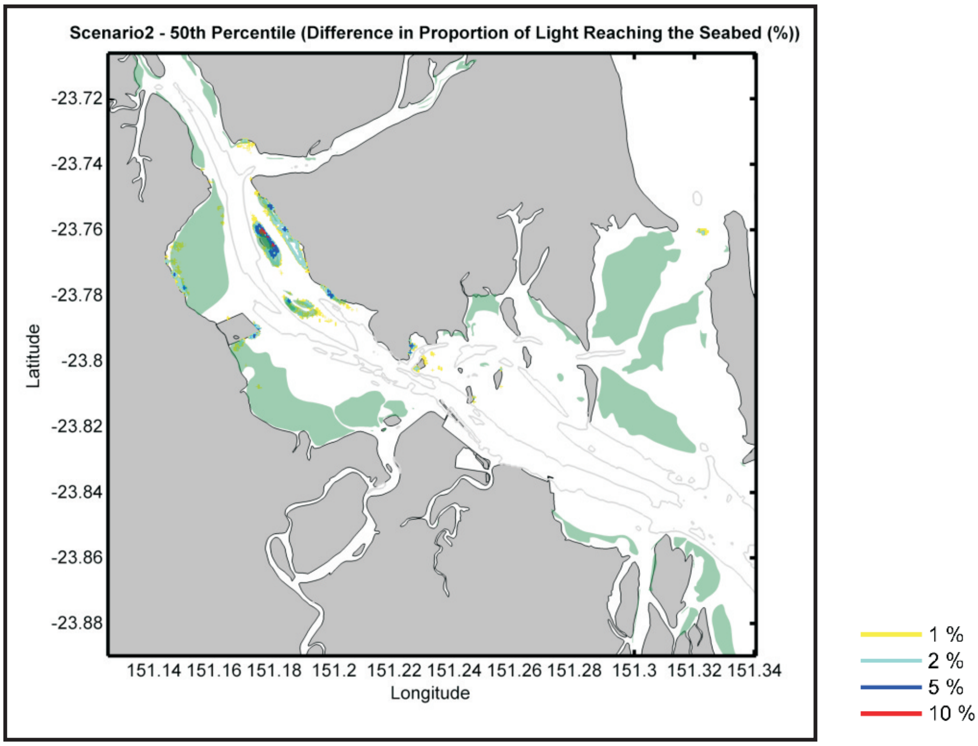
	Date 21/01/10 · Revision 0	

2.4.2.2 *Scenario Two*

The Scenario 2 median (50^{th}) percentile map (*Figure 6.2.38*) shows %SI impacts of 2 %SI to 5 %SI for seagrass meadows north and south of Fisherman's Landing. Up to 10 %SI impacts occur at the tip of North Passage Island and 5 %SI impacts were predicted for meadows adjacent to Laird Point and South Passage Island.

The 95^{th} percentile map (*Figure 6.2.39*) for Scenario 2 shows %SI impacts of 10 %SI west of Compigne Island and 5 %SI near Garden Island. The seagrass meadows along the coastline south of Fisherman's Landing are predicted to experience an impact of 5 %SI to 10 %SI, while for seagrasses adjacent to Laird Point and North and South Passage Islands the impact is estimated to be 15 %SI. A 15 %SI impact is also predicted for seagrass located along the coast north of Fisherman's Landing.



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Prepared for British Gas, 7 January 2010

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QUEENSLAND CURTIS LNG A BG Group business	Project **Queensland Curtis LNG Project**	Title **Derived difference in 50th percentile levels of %SI (ambient versus dredge conditions) at the seabed for Port Curtis over the modeled period, for Scenario 2**
	Client **QGC - A BG Group business**	
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB / **sEIS Volume 5** **Figure S6.2.38**	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
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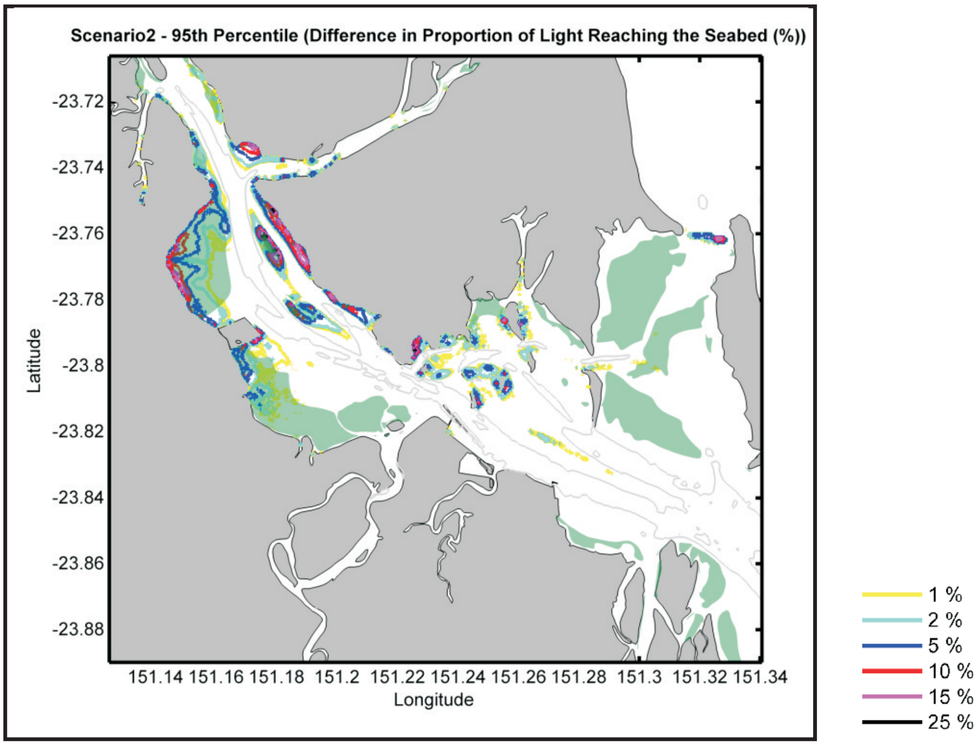

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QUEENSLAND CURTIS LNG A BG Group business	Project **Queensland Curtis LNG Project**		Title **Derived difference in 95th percentile levels of %SI (ambient versus dredge conditions) at the seabed for Port Curtis over the modeled period, for Scenario 2**
	Client **QGC - A BG Group business**		
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB	**sEIS** Volume 5 **Figure S6.2.39**	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
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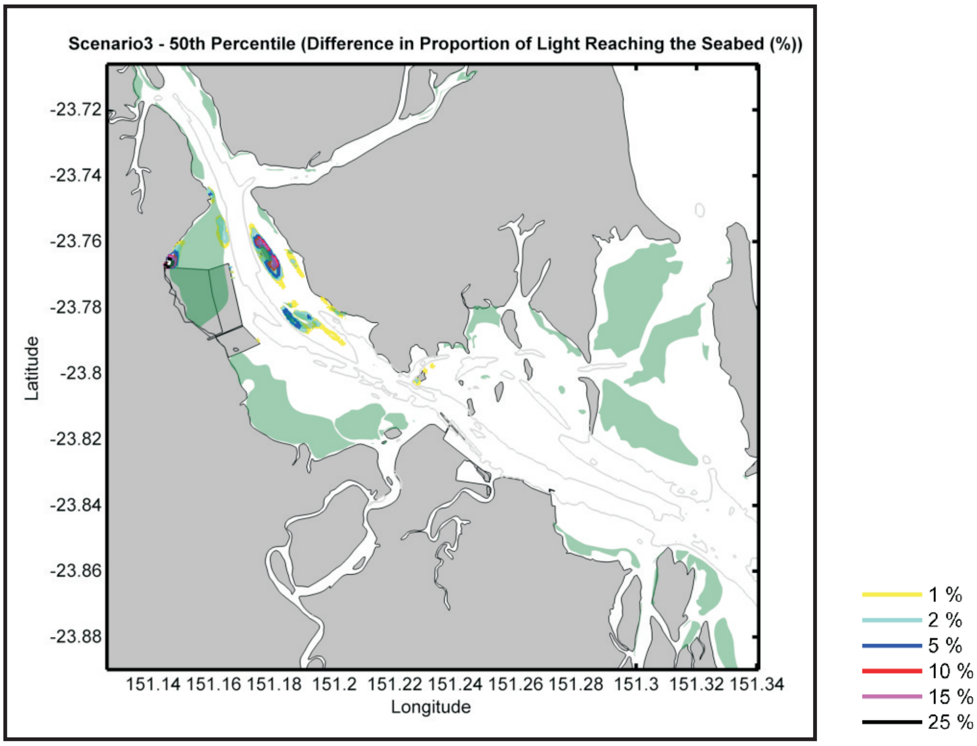
	Date 21/01/10	Revision 0	

2.4.2.3 *Scenario Three*

For Scenario 3, the 50th percentile map (*Figure 6.2.40*) indicates a 5 %SI impact for seagrasses at South Passage Island and 10 %SI at North Passage Island. A 2 %SI impact is predicted for meadows adjacent to the proposed Construction Dock. The seagrass meadows north of the proposed reclamation site are predicted to experience a 2 %SI impact along the fringes of the structure and a 25 %SI impact at the south-western corner adjacent to the proposed tail-water outfall.

The 95th percentile map for Scenario 3 (*Figure 6.2.41*) indicates a 15 %SI impact for meadows adjacent to Hamilton Point and along the western coastline of Curtis Island. Seagrasses located at North and South Passage Islands could experience an impact of 10 %SI. The model predicted impacts of up to 2 %SI for meadows south of Fisherman's Landing and 2 %SI to 25 %SI for seagrasses north of Fisherman's Landing.



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QCLNG EarlyWorks Dredge Plume Modelling Final
Prepared for British Gas, 7 January 2010

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QUEENSLAND CURTIS LNG A BG Group business	Project **Queensland Curtis LNG Project**		Title **Derived difference in 50th percentile levels of %SI (ambient versus dredge conditions) at the seabed for Port Curtis for the modeled period, for Scenario 3**
	Client **QGC - A BG Group business**		
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB	**sEIS Volume 5** **Figure S6.2.40**	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
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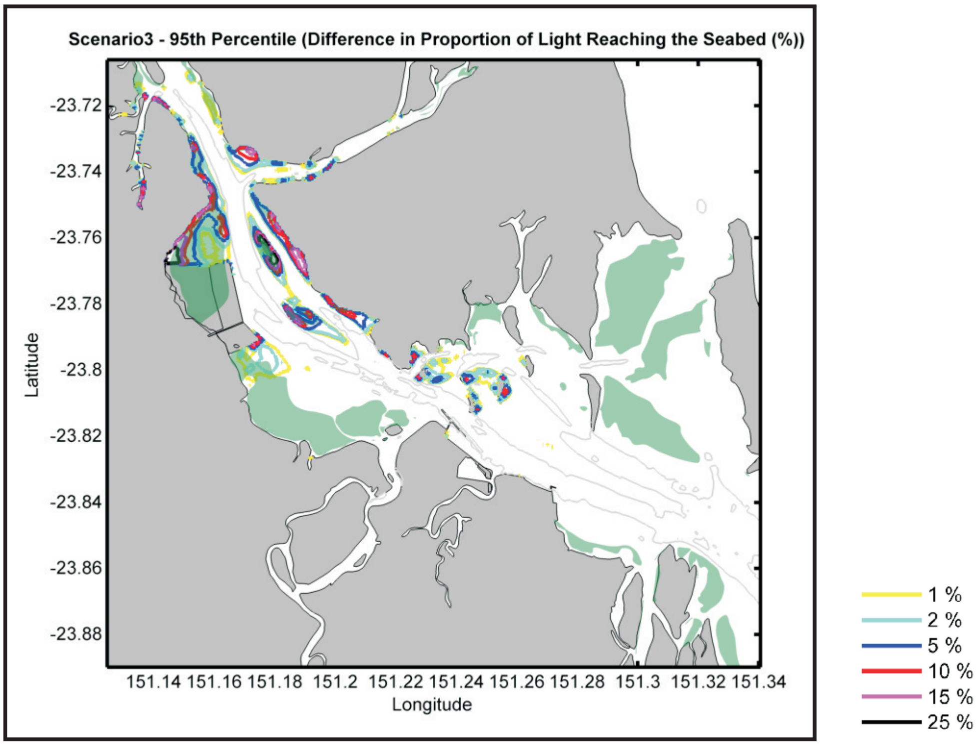

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QUEENSLAND CURTIS LNG A BG Group business	Project **Queensland Curtis LNG Project** Client **QGC - A BG Group business**	Title **Derived difference in 95th percentile levels of %SI (ambient versus dredge conditions) at the seabed for Port Curtis over the modeled period, for Scenario 3**
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB — **sEIS Volume 5** — **Figure S6.2.41** Approved RS — File No: 0086165b_SUP_CDR034_S6.2.41 Date 21/01/10 — Revision 0	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.

This modelling indicates that there are localised areas where there will be potential adverse effects to seagrasses based on a comparison between predicted light levels and those reported in the scientific literature as necessary to maintain seagrass health. Importantly, in their review of published light requirements, DEEDI seagrass ecologists also identified a duration of exposure before seagrass impacts are likely to appear. A review of the predicted duration of exposure (as indicated by TSS concentration over time at seagrass sites presented in *Section 2.34* suggests that the duration of exposure to reduced %SI as a result of QCLNG dredging is short term and may not cause significant impact.

The QCLNG Project has commenced studies to evaluate the effect of different periods of exposure to reduced %SI on local seagrasses within Port Curtis. This information will provide a more accurate prediction of potential impacts. In the interim a conservative approach to evaluating the potential scale of the impact on seagrass has been adopted and is further discussed in *Volume 5, Chapter 8*.

2.5 ACID SULFATE SOILS

QGC identified in its Draft EIS the potential for construction impacts arising from disturbance to acid sulfate soils. This has also been identified in submissions received through the EIS public consultation process. Further assessment has now been completed, and is presented below.

2.5.1 Construction Dock and MOF

Acid sulfate soil studies have been undertaken at the sites of the proposed Construction Dock and MOF. These examined near shore and adjacent offshore areas of Curtis Island.

The studies found that the pre-Holocene substrate adjacent to the QCLNG Project site reveals that a shelved or benched margin of Curtis Island underpins the modern estuarine/marine deposition. This shelf lies at approximately 0 to -1m LAT, and rises toward terrestrial foothills onshore. Across most of the study area the physical character of this substrate was generally consistent with being a residual product of the weathered Wandilla parent from which this part of Curtis Island is derived, being primarily greenish grey, stiff/very stiff plastic clays (kaolinitic in places) with beds of fine to coarse, angular/subangular gravel (with a high chert content).

The morphology of this island margin is revealed to a degree by the modern seabed bathymetry despite a substantial mantle of Holocene-age deposition. The substrate gently broadens below the proposed MOF area. Sediment deposits are identified as mixture of coarse fluvial sediments with marine reworking evidenced by telltale signs of fractured shells. The coarseness of the gravels testifies to transport energy levels greater than found in the modern marine setting which, even in the peak energy zones, are only capable of transporting locally sourced sand. Therefore, the gravel and cobble sized sediments currently found in places on the modern seabed are an in situ remnant of a bygone depositional regime.

Sediments have deposited in close proximity to the mangrove shoreline as it transgresses the landscape during the final stages of the postglacial sea level rise. This depositional environment represents the classic scenario for acid sulfate soil formation: low-energy, tidal exchange of sulfate/bicarbonate, borderline tropical climate, organic-rich, anaerobic sediments with little inherent neutralisation capacity. A wedge of transgressive mangrove silt clay facies is identified occupying the shelf area and is contiguous with modern mangrove shoreline deposits. These 'unripe' Holocene-age, dark greenish grey mangrove muds typically have a high proportion of silt and as such are very soft and weakly cohered.

There is generally no clear sedimentary demarcation between the offshore platform and the transgressive silt/clay underlying, particularly in the immediate nearshore where it has the same very soft, weak, clayey silt character with abundant organic debris. This mantle of soft mud has been able to aggrade within a current low-energy zone along the nearshore platform and, although not apparent to the naked eye, the sigmoidal geometry of this deposit suggests that it has progressively translated the original shelf edge identified in the underlying substrate seaward in a sequence of clinoform, offlaping deposits. An x-ray of a core through this deposit would be likely to reveal a layered depositional history. Consistent with expectation, this unit becomes progressively more shelly in a seaward direction.

Field-measured pH values for samples within the MOF sector ranged from 3.06 through to 9.42. Of the 422 samples tested only two had values less than 4.5, indicating very minor occurrence of actual acidity. Net Acidity values were predominantly negative (75 per cent of samples) with a further 7 per cent less than the action threshold. Eight samples had NA values in the high hazard category (greater than 1.6 %S or 1000 mol H+/t), and 15 per cent of samples were greater than 0.03 %S but less than 0.32 %S (200 mol H+/t), considered to be in the low to moderate categories. These results are reflected in the mean NA of the area, which was -0.64 %S.

The proposed Construction Dock exploits a prominent shoal extending from the shore, which is shown in both seismic profiling and from coring, to form a weathered residual extension of the island proper. This has significantly impacted on Holocene-age deposition in two ways:

- it has limited the accommodation for the normally high acid sulfate soil-bearing, transgressive mangrove silt/clay sediments which commonly forms the basal unit of the Holocene sequence along this stretch of coast
- it has projected the foundation substrate available for receiving Holocene-age sediments into a moderate energy zone which has resulted in a ubiquitous sand and winnowed shell content.

As a consequence of this depositional architecture the only sediments to exhibit an overall positive net acidity occur as a thin (0.25-0.5m thick) surface veneer extending some 50 m seaward of the current mangrove line. Net acidity levels recorded within this near shore zone fall into the low to moderate categories. The remaining Holocene-aged sediments within the proposed excavation footprint exhibited a high excess neutralising capacity, consistent with the higher energy levels and marine progradational provenance.

Where positive potential acid sulfate soils (PASS) deposits have been identified they are limited in volume, and well defined in the both the vertical and horizontal plane, providing a good foundation for sound management. In particular, the immediate near shore area bordering the present mangrove shore is the only area within the offshore Construction Dock area that will require close management. The great majority of the site has the inherent capability to balance any spot occurrences of latent acid potential with an overwhelming excess neutralising capacity.

Dredging for the Construction Dock will mix the material sufficiently to neutralise the thin acidic layer. The material can then be placed in a reclamation area on land or disposed of to the offshore spoil ground. An activity specific Acid Sulfate Soil (ASS) Management Plan will be developed, consistent with the ASS Management Plan presented in *Volume 11*, prior to commencement of dredging activities.

The acid sulfate soil investigation carried out for the jetty optimisation study was of a broader nature than that conducted for the Construction Dock. No actual ASS was encountered, but there were some isolated occurrences of PASS in Holocene-aged sediment pockets and limited upper pre-Holocene material. While less stratigraphically predictable, these positive net acidity occurrences are surrounded by an excess of acid neutralising capacity and are rare. Therefore they are not considered a potential environmental risk.

A detailed survey to further define the location and extent of any ASS at the MOF location has recently been carried out and will be used to inform preparation of the activity specific ASS Management Plan prior to commencement of dredging.

2.5.2 Crossing of The Narrows

Additional studies have also been conducted along the submarine sections of the proposed pipeline route between the mainland and Curtis Island[5]. This route transects Phillipies Landing, Humpy and Targinie Creeks (Creek Section), and The Narrows crossing between Friend Point and Laird Point (Narrows Section). Preliminary ASS and contaminant assessment along the proposed route was carried out in conjunction with a geotechnical seabed coring program. A total of nine sites were investigated for acid sulfate soil.

The four sites cored in Humpy and Targinie Creeks revealed that tidal currents had maintained a coarse gravel creek bed over pre-Holocene clay substrate that is atypical of the sodic silt/clay sediments surrounding the creeks. Consistent with expectation in the high-current velocity constriction of The Narrows opening, Holocene-aged sedimentation on the western flank and in the central channel area of the passage has been restricted largely to a relatively thin coarse sand and gravel lag. By contrast, a considerable depth of Holocene-age sequence has been able to build on the eastern flank due to protection from a hydraulic headland effect caused by the confluence of currents from Graham Creek and the main Narrows flow.

The provenance of the pre-Holocene clay substrate on either slope of the passage appears to reflect the respective Tertiary and Devonian/Carboniferous geological formations that straddle the major eastern bounding fault of The Narrows Graben over which The Narrows passage has developed. The floor of the passage is underlain by several depositional generations of pre-Holocene, coarse (gravelly) sediments. Largely as a result of the high depositional energies operating in this passage opening, there is a general climate of excess neutralisation in the Holocene-age sediments of The Narrows. Two isolated positive net acidity results were recorded (one moderate, one marginal) in the Holocene sequence blanketing the

5 GeoCoastal Australia Pty Ltd, November 2009. QCLNG PIPELINE ROUTE, GLADSTONE HARBOUR, QUEENSLAND. Preliminary Acid Sulfate Soil and Geomorphological Modelling Survey. Report prepared for QGC LTD.

eastern slope, however, these results occur within a general background of sediments with a substantial excess neutralisation capacity. Two marginally positive acidities were recorded in the pre-Holocene sediments, but again this is against a general trend of neutral to alkaline sediments.

A single marginal positive acidity result occurred in the creek bed gravels and clays of the Creeks Section but, somewhat surprisingly given the nature of the sediments surrounding the creek sites, there was an overall significant excess neutralisation at both of these sites. Overall these preliminary results seem to indicate that acid sulfate soil is not a major issue in The Narrows, and further investigation may establish that management is not necessary. The absence of significant net acidity in the Creek Section cores needs to be considered within the context of the high acid sulfate soil (i.e. AASS and PASS) known to exist as closely as the creek banks.

2.6 *ACID SULFATE SOILS MANAGEMENT PLAN FRAMEWORK*

QGC has prepared a Project-wide Acid Sulfate Soils Management Plan Framework, which will serve as guidance for construction contractors on all portions of the Project site. It will also serve as the basis for development and approval of site-specific management plans. The ASS Management Plan Framework is included in draft in *Appendix 2.2*.

2.7 *OFFSETS*

Mangrove offsets are included amongst matters discussed in *Volume 5 Chapter 7*.

Direct impacts of QCLNG Project dredging on seagrasses and other sub-tidal communities are not significant, and therefore no offsets are proposed.

As a port user, QGC anticipates contributing indirectly to offsets associated with channel and swing basin dredging via its fee-for-service arrangements with GPC.

2.8 *SEDIMENT QUALITY*

QGC has completed an assessment of marine sediments in the Construction Dock and MOF dredging areas. The assessment has been conducted to National Assessment Guidelines for Dredging (NAGD) 2009 standards.

NAGD 2009 requires assessment of the 95% Upper Confidence Limits (UCL) against Screening Level guidelines provided for a wide range of potential contaminants of concern.

The 95% Upper Confidence Limits (UCLs) of all contaminants of concern were below the NAGD Screening Levels for QCLNG Project sediments.

During the course of sediment investigations three individual samples reported levels of arsenic (22.2 mg/kg to 24.1 mg/kg) above the NAGD Screening Level (20 mg/kg). As required by NAGD 2009, these samples were subjected to Dilute Acid Extraction (DAE) testing to provide additional information on the bioavailability of this metalloid. The results of DAE analyses of these three samples ranged from 1.1 mg/kg to 3.8 mg/kg, falling well within Guideline levels.

In earlier research in Gladstone Harbour, Vicente-Beckett et al. (2006) demonstrated by multivariate analyses that naturally occurring concentrations of arsenic in the Port Curtis region are at levels which are "*…very close to the ANZECC ISQG-low guidelines.*"

On the basis that sediment sampling and analysis results demonstrated that no contaminants had 95% UCL of the mean exceeding the NAGD (2009) Screening Levels, it is considered that this material is suitable for disposal, including if necessary for unconfined ocean disposal.

2.9 CONCLUSION

This volume describes modifications to the QCLNG Project base case for dredging, addresses matters raised in public submissions, and extends impact assessments based on a more comprehensive assessment of hydrodynamics, sediments and light attenuation.

Sediment-related impacts (total suspended sediments, sedimentation and light attenuation) have been described for three dredging scenarios. A small-medium cutter suction dredge (Scenario 1, the preferred scenario) will lead to the smallest plumes, and to lowest plume intensities. Backhoe dredging (Scenario 2) will lead to the most extensive plumes, and to the highest plume intensities. However, assessment of the significance of these impacts concludes that, even for backhoe dredging, the absolute magnitude of changes will fall within the range of normally occurring sediment characteristics within Port Curtis, and that combined with the short exposure period will result in negligible to minor impact on the environment.

Notwithstanding this conclusion, as part of this impact assessment process, a Draft Dredge Management Plan has been prepared to guide the conduct of these operations and the monitoring and mitigation measures that would be employed to ensure that environmental nuisance or harm as described under the *Environmental Protection Act 1994* is avoided or reduced as far as practicable.