C4

VOLUME C: MIDDLE BANKS, MORETON BAY

Water Quality

Water Quality

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KEY FINDINGS

Current condition

- The operation of the dredge vessel has the potential to generate sediment and nutrient plumes. This Chapter assesses the dredging operations to determine any impacts from this activity on water quality in the Eastern Bay.
- The area around the Middle Banks dredge footprint, while containing several other sand extraction leases, is also adjacent to an area defined as having a High Ecological Value (HEV) and so any potential impacts have been identified in relation to short, medium or long duration effects on water quality.
- Sparse seagrass areas were sampled at Middle Banks to the west of the proposed dredge footprint as outlined in Chapter C5. Impacts to these areas from operation of the dredge and the generation of turbid plumes has also been assessed.
- A water quality model was developed to predict the likely extent of sediment and nutrient plumes and the overall impacts of these plumes on compliance with pre-defined Water Quality Objectives (WQOs) for the site. The model simulated total nitrogen (TN), total phosphorus (TP) and total suspended sediment (TSS) – all of which are key parameters when assessing water quality.
- Along with this modelling, a series of bore hole tests were undertaken at the site of the dredging, and the results of several studies on sand extraction at Middle Banks, including the Moreton Bay Sand Extraction Studies (MBSES), were also considered.

Impact assessment

- Twelve dredging scenarios developed around the direction of the dredge vessel, tidal ranges and the state of the tide were selected to assess the extent of impacts from the dredge plumes. Areas of seagrass closest to the area to be dredged and HEV areas were plotted with plume data overlaid.
- The behaviour of the plume is consistent with previous monitoring of dredges in Middle Banks in that the dredge plume is confined primarily to the dredge area and dissipates rapidly.
- The extent of the plume is governed by the direction of the dredge relative to tidal movements.
- The observable plume at any one particular time would be vastly different and will vary during the dredge and tidal cycle as shown in snapshot figures created by the model at varying times through the dredge cycle.
- Various dredge tracks (western, centre and eastern) were modelled to determine if any noticeable differences in plumes would result. This work showed the maximum plume extents do not change appreciably. However, for a western track, higher concentrations of suspended solids are observable over the seagrass area, while the eastern track shows higher concentrations over the HEV area.
- The dilution of the porewater (water that comes from the sand as it is dredged) by water that is collected during extraction will significantly reduce concentration of nutrients prior to flowing back into the Bay.
- The plume extent for nitrogen and phosphorus is limited to the immediate area of dredging.

KEY FINDINGS CONT.

- The overall impact from dredging on nutrient concentrations within the vicinity of Middle Banks, and for the whole of Eastern Moreton Bay appears to be insignificant. This is consistent with the MBSES – Phase 2 which states that only minimal effects are likely beyond the visible plume.
- Toluene was detected in the porewaters of some borehole locations at Middle Banks. The dilution effect within the dredge hopper will make concentrations of toluene in the Bay itself negligible.
- While the concentration of suspended solids may be very low, an observable plume will be present due to increased turbidity.
- While the model predicts a small increase in concentrations of suspended solids within a portion of the HEV area for the duration of the dredging, it is likely to be undetectable above background concentrations due to the increases being very small.
- An observable plume may be present within the HEV area even though concentrations of suspended solids in the plume are similar to existing, background concentrations.
- There are unlikely to be any cumulative effects from the dredging operations outside the areas of actual dredging.
- It is expected that impacts to seagrass beds beyond the zone of active dredging are likely to be negligible.
- On completion of all dredging at Middle Banks, it is expected that concentrations of TSS, TN and TP will return to ambient concentrations within a very short time (approximately 1 dredge cycle).

4.1 Proposed Development and Receiving Waters

The receiving waters of Eastern Moreton Bay are where potential impacts from the construction phase of the NPR project will have to be managed. Specifically, dredging of sands in the Middle Banks area will be required as part of the surcharge and filling of the runway area to promote compaction of the marine sediments. This dredging has the potential to liberate fine sediment, nutrients (on both the surface of the banks and in porewaters extracted) and other contaminants which may be associated with the dredging operation. The management of the waterways surrounding Middle Banks is under the jurisdiction of the Queensland Environmental Protection Agency (EPA). In managing these waters, the EPA has specified water quality objectives that if achieved will protect the environmental values of the receiving waters.

4.2 Policies and Guidelines - Environmental Values and Water Quality Objectives

Environmental Values (EVs) and Water Quality Objectives (WQOs) have been identified for those receiving waters above and immediately surrounding the Middle Banks. In documenting these, the process outlined within the Queensland *Environmental Protection (Water) Policy 1997* was followed, where a hierarchy of documents was used to derive which EVs and WQOs take precedence. The Policy states:

> The following documents are used to decide the water quality guidelines for an environmental value for a water.
>
> (a) Site specific documents;
>
> (b) The AWQ guidelines;
>
> (c) Documents published by a recognised entity; and
>
> (d) To the extent of any inconsistency between the documents for a particular water quality guideline, the documents are to be used in the order in which they are listed in subsection (2).

In the case of the above, the Queensland EPA's Environmental Values and Water Quality Objectives were used and defined as being site specific documents. It should be noted that the EV's and WQO's discussed above reflect several different legislative instruments and local policies including the South East Queensland Regional Water Quality Management Strategy, and the requirements of the *Environmental Protection (Water) Policy 1997.*

4.2.1 Environmental Values and Water Quality Objectives

The Middle Banks area of Moreton Bay falls within the Eastern Moreton Bay zone as defined in the EPA's WQOs document. Environmental Values and Water Quality Objectives for the Middle Banks as defined by the Schedule 1 Document for Moreton Bay and Islands, are listed in **Table 4.2**. The Middle Banks' aquatic ecosystem protection level is defined as Level 2, which is slightly to moderately disturbed and is defined as an open coastal water type.

Table 4.2 Environmental Values and WQOs for Middle Banks.

Environmental Value	Water Quality Objectives Open Coastal Waters, Aquatic Ecosystem Level 2
Aquatic Ecosystem	• Annual median turbidity <1 NTU, suspended solids < 10 mg/L • Annual median chlorophyll a < 1 µg/L • Annual median total nitrogen <140 µg/L, oxidised N < 3 µg/L, Amm N < 6 µg/L, Org N <130 µg/L • Annual median total phosphorus <20 µg/L, FRP < 6 µg/L • Annual median dissolved oxygen between 95 - 105 percent saturation • Annual median pH between 8.0 and 8.4 • Annual Median Secchi depth >5 m
Human consumer	Objectives as per Australian Water Quality Guidelines (AWQG) 2000 and Food Standards Code, Australia New Zealand Food Authority, 1996 and updates
Primary Recreation	Objectives as per AWQG including; • Median faecal coliforms <150 organisms per 100 mL or Median enterococci organisms <35 per 100 mL • Secchi depth > 1.2 m
Secondary Recreation	Objectives as per AWQG including; • Median faecal coliforms <1,000 organisms per 100 mL or Median enterococci organisms <230 per 100 mL
Visual Recreation	Objectives as per AWQG including water being free from: • Floating debris, oil, grease and other objectionable matter • Substances that produce undesirable colour, odour, taste or foaming • Undesirable aquatic life such as algal blooms, or dense growths of attached plants or insects.
Cultural Heritage	Protect or restore indigenous and non-indigenous cultural heritage consistent with relevant policies and plans.
Oystering	Objectives as per AWQG 2000 and Food Standards Code, Australia New Zealand Food Authority, 1996 and updates, including median faecal coliforms <14 MPN per 100 mL with no more than 10 percent of samples exceeding 43 MPN per 100 mL.
Seagrass	The minimum WQOs required to restore seagrass to areas where it has been lost are: • Annual median suspended solids <10 mg/L • Annual median Secchi depth > 1.7 m • Light Attenuation coefficient >0.9

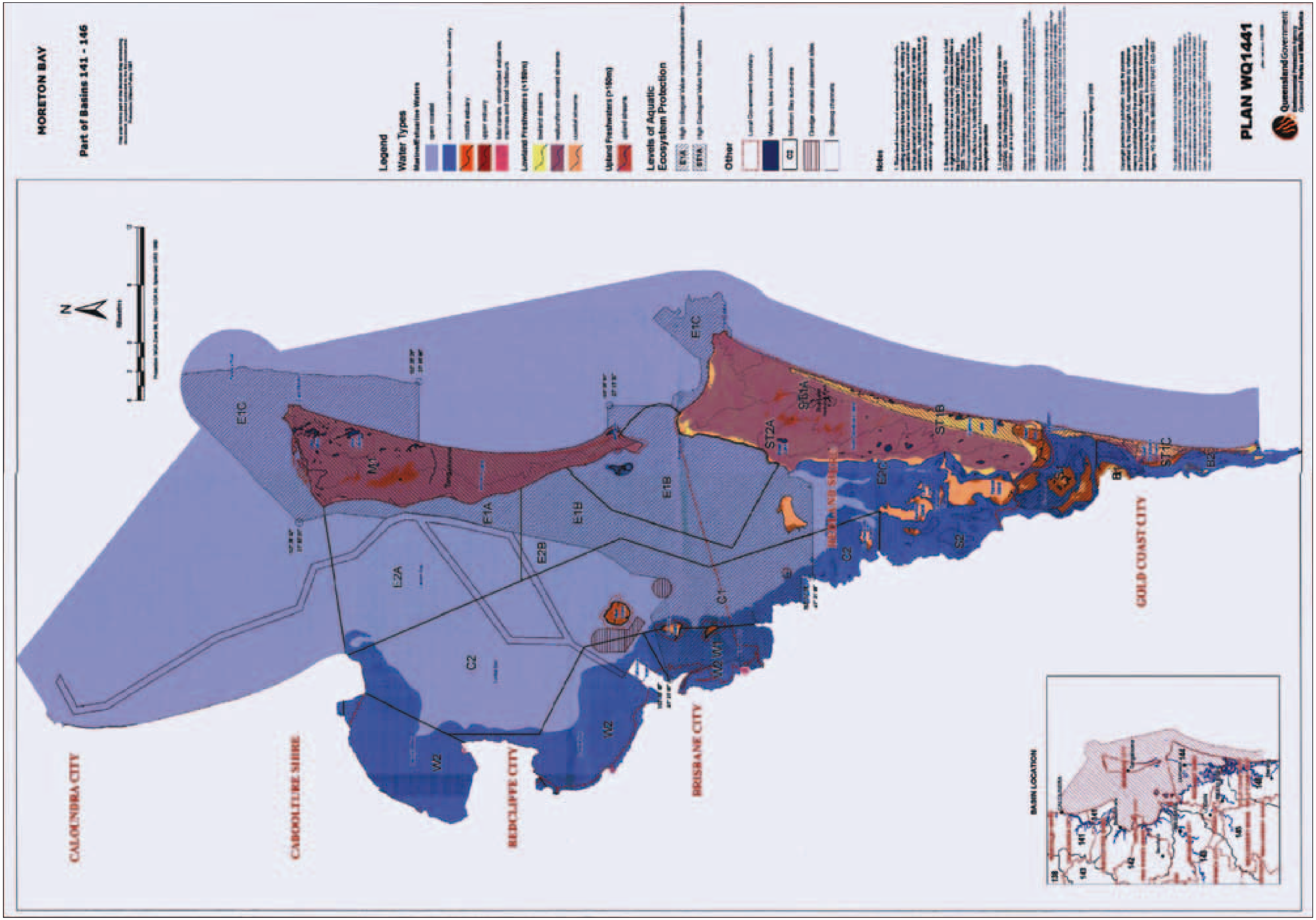
Of relevance in this area is the location of the High Ecological Value (HEV) areas near to the Middle Banks (see **Figure 4.2**). Explanatory Notes to the recently released Environmental Protection (Water) Amendment Policy 2006 provide the following management intent for HEV areas in Moreton Bay relevant to sand extraction activities:

"Marine activities such as sand extraction, capital and maintenance dredging and the sub-tidal placement of dredged material, which is acceptable for ocean disposal, are environmentally relevant activities requiring development approval under the Integrated Planning Act 1997, according to the Environmental Protection Act 1994.

Approvals for these activities stipulate the use of best practice measures, including minimising the dispersal of sediment and turbidity plumes to adjacent waters. Where activities such as dredging are conducted near waters of high ecological value, the natural action of winds and tides could carry transient suspended sediment plumes into these adjacent waters even with best practice management for the activity in accord with approval conditions.

However, the transient impacts of temporary sediment plumes from the above mentioned activities are not considered to be detrimental to the maintenance of the values of adjacent high ecological waters and their long term natural physico-chemical and biological variability. The existence of intact high ecological values in waters adjacent to areas where such activities have been conducted in Moreton Bay for many years, confirms the transient nature of the impacts."

Figure 4.2: High Ecological Value Areas in Moreton Bay.



4.3 Methodology

This baseline assessment was conducted by a review of the datasets available from the Ecosystem Health Monitoring Program.

4.4 Ambient Water Quality

Water quality in close vicinity to the Middle Banks in Moreton Bay has been monitored as part of the Ecosystem Health Monitoring Program (EHMP).

Monitoring results of three key locations within close vicinity of the Middle Banks were examined to determine ambient water quality in the Middle Banks region. **Figure 4.4a** details the location of these monitoring sites. The combined median annual concentration at these sites for all measured parameters are displayed in **Table 4.4a**.

Figure 4.4a *Middle Banks Monitoring Locations.*

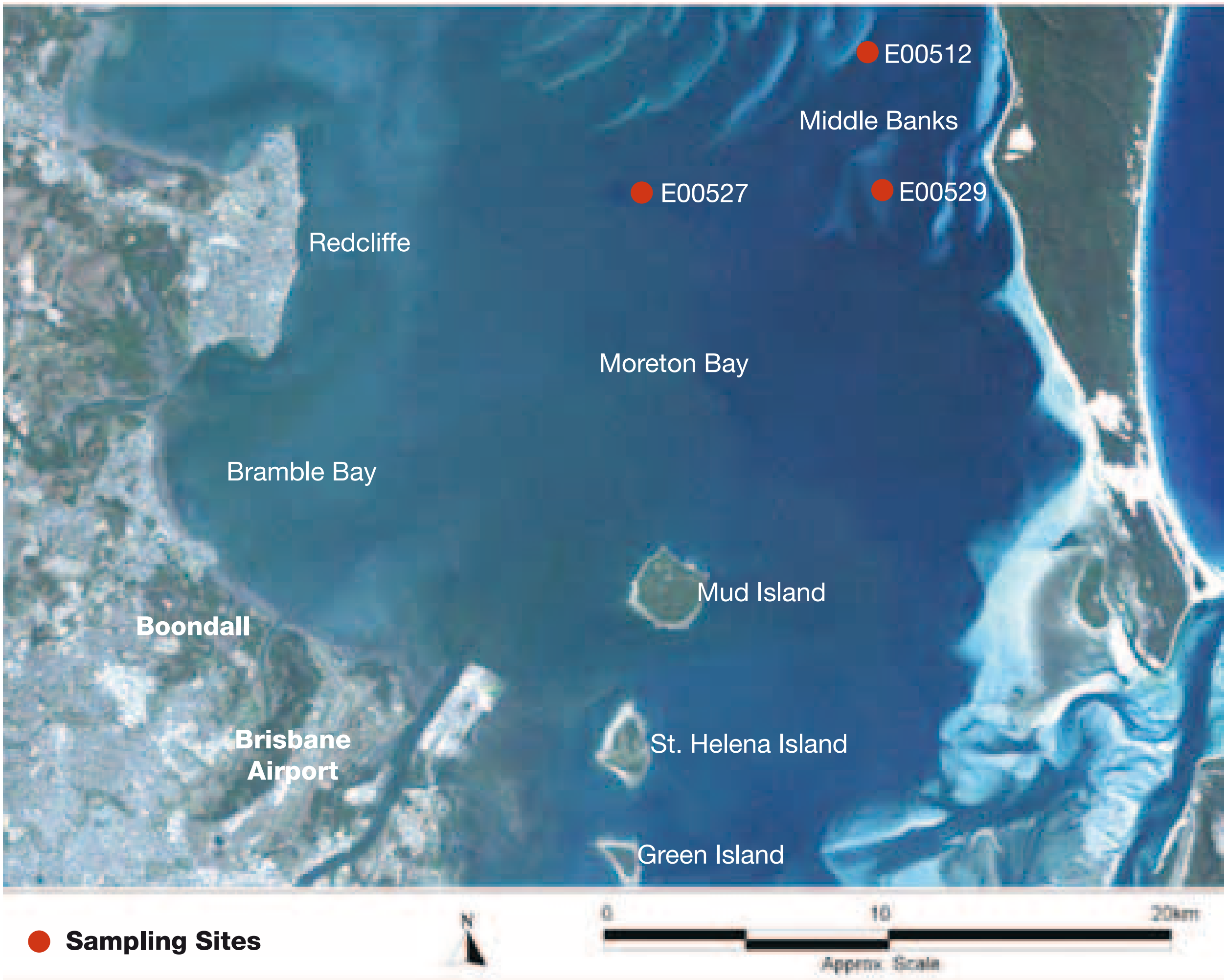


Table 4.4a Ambient Water Quality Near Middle Banks.

Parameter	Median Values			
	2002	2003	2004	2005
Conductivity at 25 deg C (mS/cm)	53.52	52.74	53.96	53.39
Salinity (ppt)	35.35	34.78	35.69	35.26
Temperature (°C)	23.61	21.39	22.55	23.07
Turbidity (NTU)	0	0	0	0
Light penetration (Secchi depth) (m)	7.00	6.60	7.20	6.20
Chlorophyll-a (µg/L)	0.90	0.67	0.53	0.77
Nitrogen (ammonia) as N (mg/L)	0.003	0.003	0.002	0.002
Nitrogen (organic) as N (mg/L)	0.12	0.11	0.14	0.09
Nitrogen (oxidised) as N (mg/L)	0.002	0.002	0.002	0.002
Nitrogen (total) as N (mg/L)	0.12	0.11	0.15	0.09
Oxygen per cent saturation (%sat)	102.60	98.90	100.90	99.00
Oxygen (dissolved) (mg/L)	7.22	7.05	6.99	6.87
pH	8.22	8.25	8.24	8.25
Phosphorus (total) as P (mg/L)	0.011	0.013	0.015	0.011
Phosphorus (dissolved reactive) as P (mg/L)	0.002	0.002	0.003	0.004

Results exceeding WQOs have been highlighted in red for easy identification, however it should be noted that not all parameters have recommended WQOs for comparison. **Table 4.4a** shows that existing water quality in the Moreton Bay Middle Banks region complies with Water Quality Objectives, apart from slightly elevated levels of organic and total nitrogen in 2004, though no reason for this slight increase is given in the EHMP report for 2004.

Figures 4.4b, 4.4c and 4.4d show median annual concentrations of turbidity, TN and TP respectively at monitoring locations adjacent to the Middle Banks. These figures are described as "box and whisker plots" and are commonly used to show the characteristics of the water quality parameter monitored. Each box represents 50 percent of the data with the median value of the water quality parameter displayed as a line. The top and bottom of the box mark the limits of ± 25 percent of all the data (also called the upper and lower quartiles). The lines extending from the top and bottom of each box mark the minimum and maximum values within the data set that fall within an acceptable range. Any value outside of this range, called an outlier, is displayed as an individual point. This is shown in the legend.

Figure 4.4b *Turbidity in Middle Banks EHMP Sites 527, 529 and 512.*

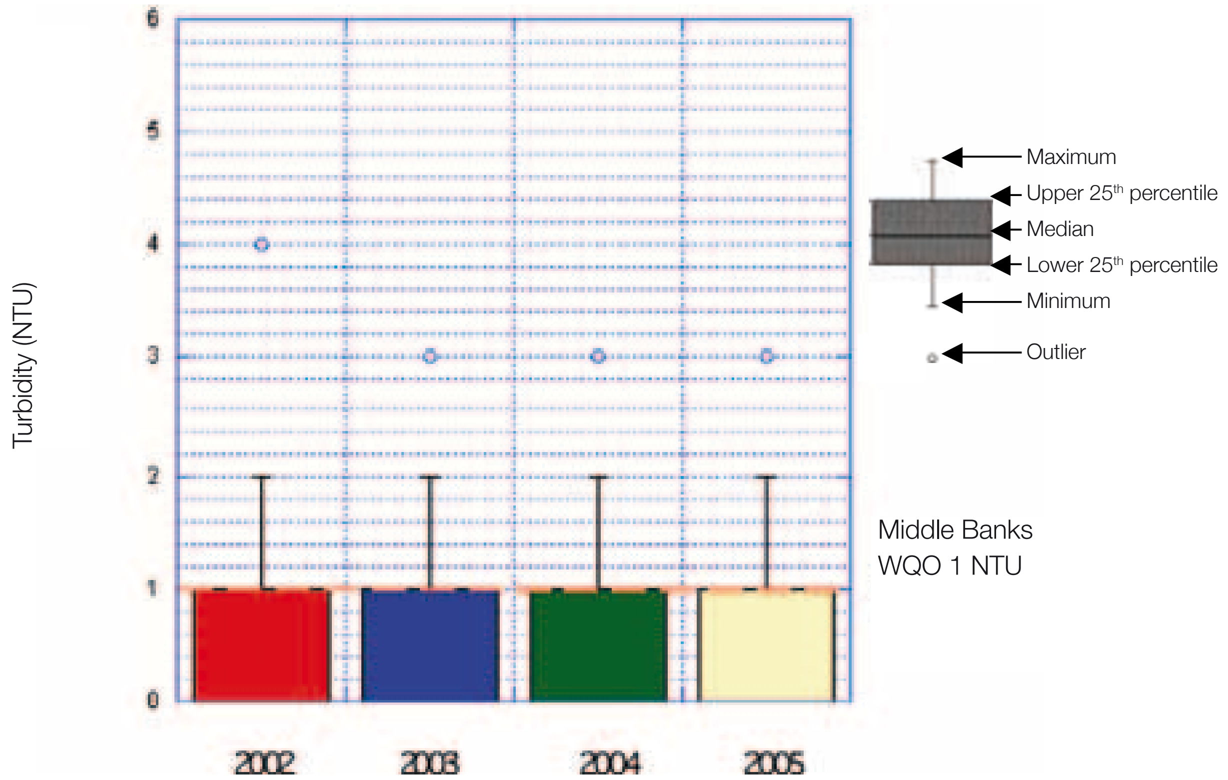


Figure 4.4c *TN in Middle Banks EHMP Sites 527, 529 and 512.*

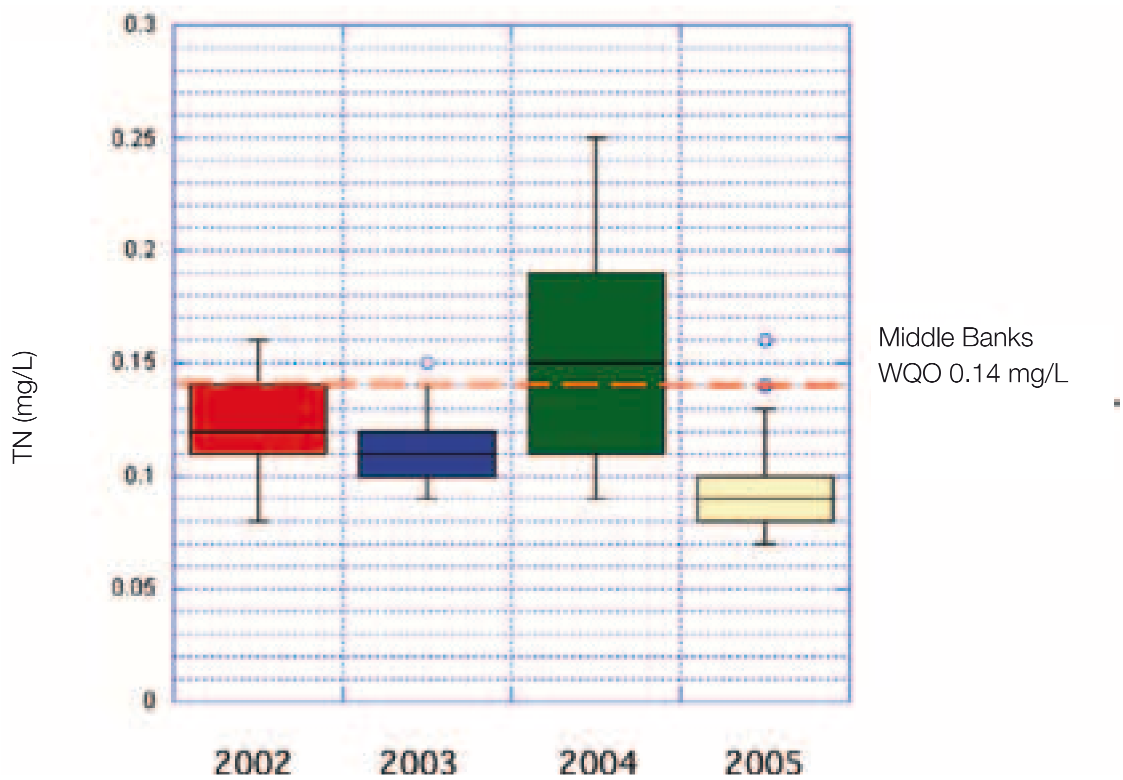
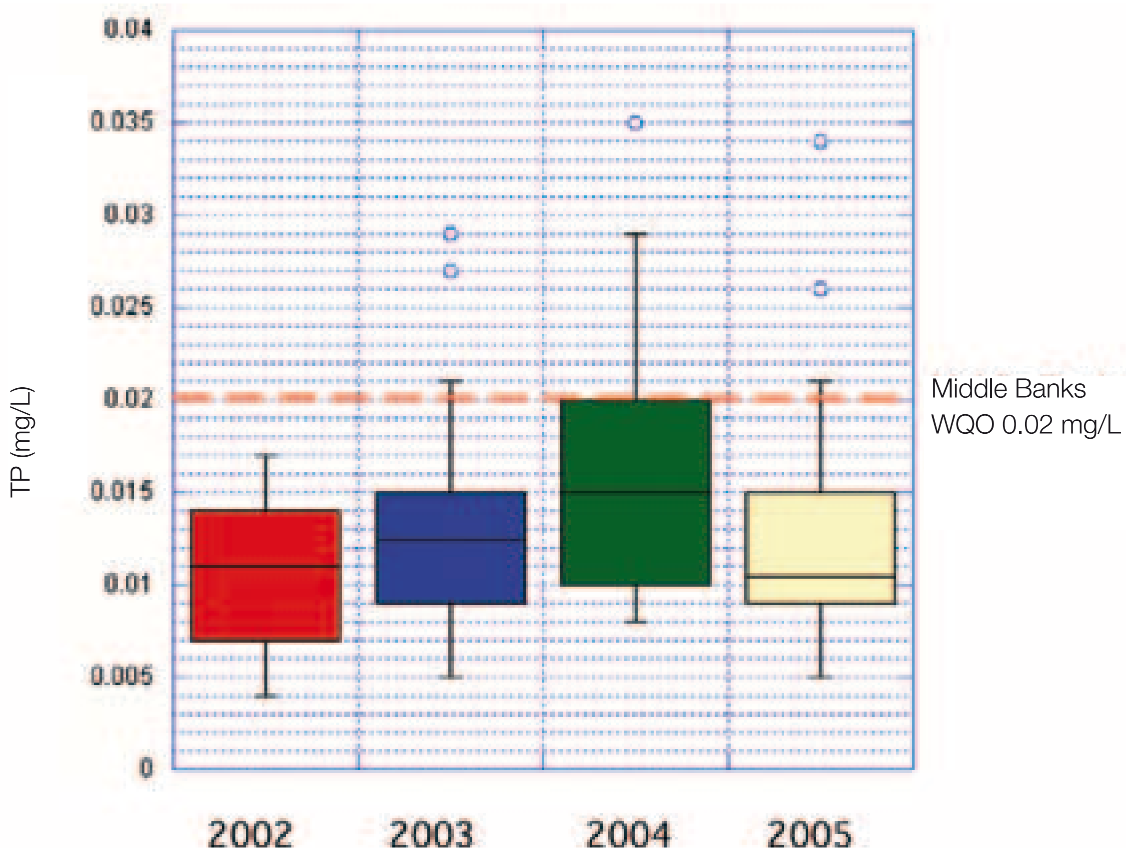


Figure 4.4d *TP in Middle Banks EHMP Sites 527, 529 and 512.*



From the figures, it is apparent that water quality within the Middle Banks and vicinity is extremely good, hence any dredging operations within this area will require careful management to ensure that these water quality objectives are not exceeded. Of particular concern in this area is the zone defined as "High Ecological Value".

4.5 Consultation

Refer to Chapter B8 for agencies consulted as part of the water quality assessment.

4.6 Assessment of Impacts Methodology

4.6.1 General Considerations

This assessment has modeled the dredging operations to determine any impacts from the activity.

It is intended that the dredge vessel will transit the Middle Banks locations in several passes, sufficient to fill the hopper to capacity over a two hour dredging period, then travel to a mooring point at Luggage Point, from where dredged material will be pumped ashore and associated excess water discharged into Bramble Bay after passage through sediment ponds. The discharge of this water is addressed in the Volume B, Chapter B8 of the Impact Assessment.

The Middle Banks area, while containing several other sand extraction leases, is also adjacent to an area defined by the EPA as having a High Ecological Value (EPA 2006).

To assess the impacts of dredging on the water quality of Moreton Bay, a regional two-dimensional hydrodynamic and water quality model, with enhanced/refined detail around the proposed dredging location, was constructed. This model was based on a previous Moreton Bay Receiving Water Quality Model (RWQM) developed for previous studies of the Bay on behalf of the Moreton Bay Waterways and Catchments Partnership (WBM 2005-6).

Results of the modelling have been used to predict likely sediment and nutrient plume extents and the overall impacts of these plumes on compliance with pre-defined water quality objectives for the site. The operation of the dredge is likely to discharge both sediment and potentially nutrients (associated with the porewaters of the extracted material) from three possible sources:

- Operation of the dredge cutter head, including disturbance of the existing and/or exposed bed sediments through movement of the cutter and the extraction of the material;
- Disturbance of the existing and/or exposed bed sediments through turbulence associated with the propellers of the dredging vessel; and
- Discharge of water entrained during the extraction process into the storage hopper on the vessel, which is then expelled during the dredging process.

For the purposes of modelling, these three sources have been combined as one discharge, as separation of these individual processes is not possible due to insufficient data on the relative magnitude of each of these sources.

4.6.2 Previous Studies

Several studies have been previously conducted on sand extraction at the Middle Banks. Most recently, this has been through the Moreton Bay Sand Extraction Study (Phase 1 and Phase 2) commissioned by the Queensland Environmental Protection Agency and conducted between 2002 and 2005. Phase 1 consisted of a detailed examination of the major issues associated with extraction at the most likely locations of sand extraction, namely Central, Middle, Spitfire and Yule Banks (WBM, 2002). From a water quality perspective, the major conclusion drawn from these earlier studies was that there was likely to be limited, if any, long term impacts associated from dredging activities and that these could be managed through the design of the dredging operations. This report also documented recommendations for further studies to be conducted under the Phase 2 investigations.

Within Phase 2, a separate report investigating sediment geochemistry and water quality was prepared (NIWA 2004), examining existing nutrient concentrations within the sediments at the proposed extraction areas and the potential nutrient generation from the release of sediment porewaters during dredging operations. The report states that porewater nutrient concentrations in sediment from the Middle Banks were relatively low (e.g. Total Nitrogen <10 mg/L) and stable throughout the sand core. This is consistent with recent pore water sampling undertaken by Golder Associates as part of the NPR Impact Assessment, which also showed low nutrient concentrations in the porewater (e.g. total nitrogen (average over 5 samples) 5.8 mg/L) as detailed in Chapter C2.

The Phase 2 report also examined the contribution of nutrients from dredging operations in comparison to overall nutrient inputs in Moreton Bay. Typical nutrient inputs in the Bay are derived from various sources, including catchment runoff from forested, urban, agricultural and industrial sources and point source contributions such as wastewater treatment plants, industrial processing facilities and intensive agricultural practices such as dairying and aquaculture, and benthic fluxes from sediment resuspension, algal production and respiration and sediment nutrient release. In terms of these inputs, a comparison was made to the dredging inputs likely from liberated nutrients in the porewaters of the extracted material. A conservative estimate was then made using an extrapolated dredging intensity of 18 Mm^3/year. This calculation was based on the nutrient concentrations measured during actual dredging and scaled up to the proposed maximum annual dredging intensity. From this, it was found that the potential total contribution of nitrogen from dredging operations was estimated to be of the order of 3 percent of the total nitrogen released through sediment nutrient release in Moreton Bay and would be equivalent to the total nitrogen estimated to come from natural resuspension processes such as tidal currents and wind mixing. **Table 4.6a** presents these loads for dredging operations in comparison to total nutrient inputs within Moreton Bay. The report stated that it considered the comparison of dredging inputs to that of the nutrient fluxes in the whole of Moreton Bay was appropriate considering that any plumes generated by dredging would be mixed into the whole of the Bay in a relatively short time frame.

As part of the construction of the new Brisbane Airport in the early 1980s, 16 Mm^3 of sand fill were extracted from the Middle Banks in 1982 by the 10,000 m^3 capacity dredge "Humber River". During dredging, monitoring of the activities were undertaken by the Water Research Laboratory of the University of New South Wales as documented in Foster and Higgs (1987) and Willoughby and Crabb (1983). From aerial photographs taken at the time, they observed a small plume generated by the dredge heads upon commencement of the dredging, however the dominant plume began once the dredge hopper overflowed, approximately 15 minutes after commencement. This is consistent with observations in the NIWA report which monitored dredging by the suction dredge "Darra" in 2003, where the dominant plume was that generated by discharge from the dredge hopper, with no observable (from the surface) plume from the dredge head. The monitoring in 1982 showed that suspended solids concentrations reduced to at or just above background levels within approximately 1 hour of plume age, with 90 percent of the reduction occurring in the first 20 minutes. With current velocities during dredging of between 0.57 – 0.63 m/s, it was reported that the major proportion of the dredge suspended material would have settled within 600m down current from the dredge. This is also consistent with the monitoring of the dredge "Darra" in 2003 in which it was found the concentrations of suspended solids, Total (Kjeldahl) Nitrogen and Total Phosphorus were not significantly different from background within a short distance of the dredge due to a lack of fines, rapid dilution in the fast moving water (0.5-0.6 m/s), dispersion and (possibly) settling.

4.6.3 Dredging operations

The actual amount of suspended solids and nutrients generated will be dependent upon the forces acting upon the sand bed and on the dredged material being removed by the extraction process. From cores obtained from the dredging locations, the amount of fine material present in the sand has been assumed to be that passing through the smallest sieve (in this case 75 μm) of the sieve particle sizing analysis undertaken by Golder and Associates. This is probably conservative, as it would likely be material less than 50 μm (Willoughby and Crabb 1983) that is likely to generate plumes. Nutrients in the porewaters have been assumed to be completely liberated by the extraction process, given that it is anticipated that the ratio of water entrained through suction to extracted material is approximately 3.5, such that the material is effectively "washed" by the extraction process.

Table 4.6a Comparative Inputs of Nutrients in Moreton Bay (from NIWA 2004).

Source	Nitrogen (t/yr)	Phosphorus (t/yr)
River Influx		
Diffuse Loads	222	85
Point Sources	3383	1182
Benthic Sources		
Efflux	21000	2885
Resuspension	268	201
Dredging		
1 Mm^3/yr	7 - 33	0.15 - 0.96
18 Mm^3/yr	132 - 586	3 - 17

As part of the development of the impact assessment, Significance Criteria have been developed to quantify the magnitude of potential impact from the proposed activities. These criteria are shown below in **Table 4.6b**.

Table 4.6b Significance Criteria: Marine Water Quality.

Significance	Criteria: Water Quality
Major Adverse	Permanent change in the Annual Ecosystem Health Report Card for Eastern Moreton Bay resulting from changes to water quality due to direct impacts of dredging or as a result of changed hydrodynamics post dredging.
High Adverse	Temporary change in the Annual Ecosystem Health Report Card for Eastern Moreton Bay resulting from changes to water quality due to direct impacts of dredging or as a result of changed hydrodynamics post dredging, but return to predredging status once dredging is completed.
Moderate Adverse	Water quality within the defined High Ecological Areas of Moreton Bay are permanently impacted such that the scheduled Environmental Values and Water Quality Objectives cannot be achieved during and after the dredging process even with mitigation measures.
Minor Adverse	Water quality within the defined High Ecological Areas of Moreton Bay are temporarily impacted such that the scheduled Environmental Values and Water Quality Objectives cannot be achieved during the dredging process even with mitigation measures but will be achieved post dredging.
Negligible	No perceptible impacts on regional Moreton Bay water quality in any areas through the use of effective mitigation measures during dredging operations.
Beneficial	Existing water quality is improved in areas of Moreton Bay due to hydrodynamic changes as a result of dredging.

4.6.4 Model Development

Water quality modelling of the proposed dredging operations at Middle Banks was undertaken using the two-dimensional RWQM modelling software. This software is a derivative of the RMA suite of models. It is a coupled two-dimensional (depth averaged) finite element model that is configured to consecutively simulate the evolution of hydrodynamic and water quality variations in a water body subject to external forcing. Whilst the RWQM has its origins in the RMA suite of models, it has undergone further development over recent years, such that it is now markedly distinct from, and incompatible with, the standard RMA suite. Much of this development has involved the inclusion of additional algorithms and processes deemed as being necessary for the reliable simulation of water quality processes in Moreton Bay.

To provide adequate resolution in the vicinity of Middle Banks, WBM's model mesh was selected over the original RWQM mesh. The WBM mesh incorporates the most up to date bathymetric data and had already been extensively refined at Middle Banks and adjacent areas for Coastal Process assessments undertaken for this project. Element widths in the study area are predominantly in the range of 200 to 400 m. **Figure 4.6a** shows the extent of the WBM mesh. The refined mesh representing the Middle Banks area is shown in **Figure 4.6b**.

Figure 4.6a *WBM Mesh of Moreton Bay.*

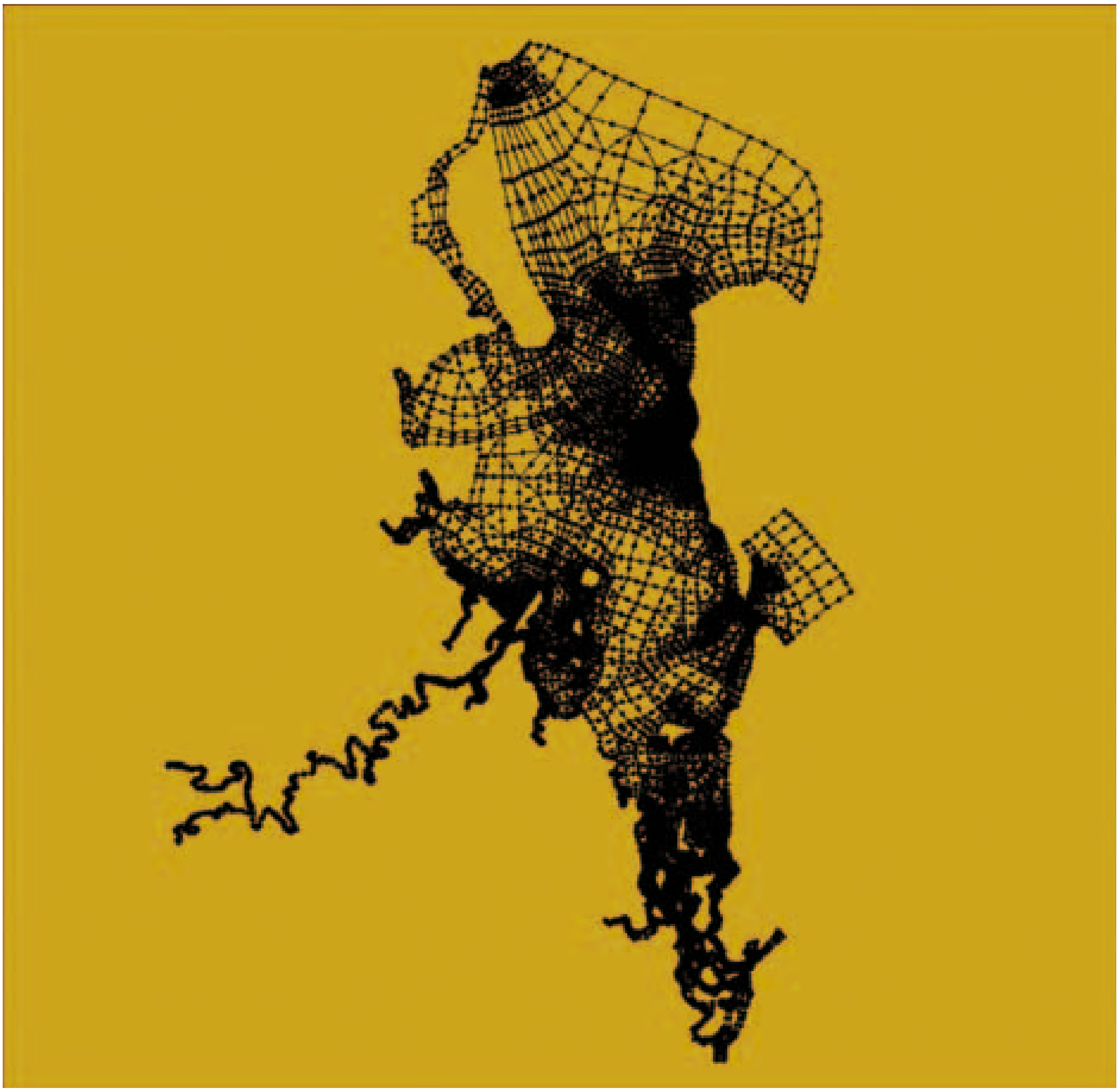
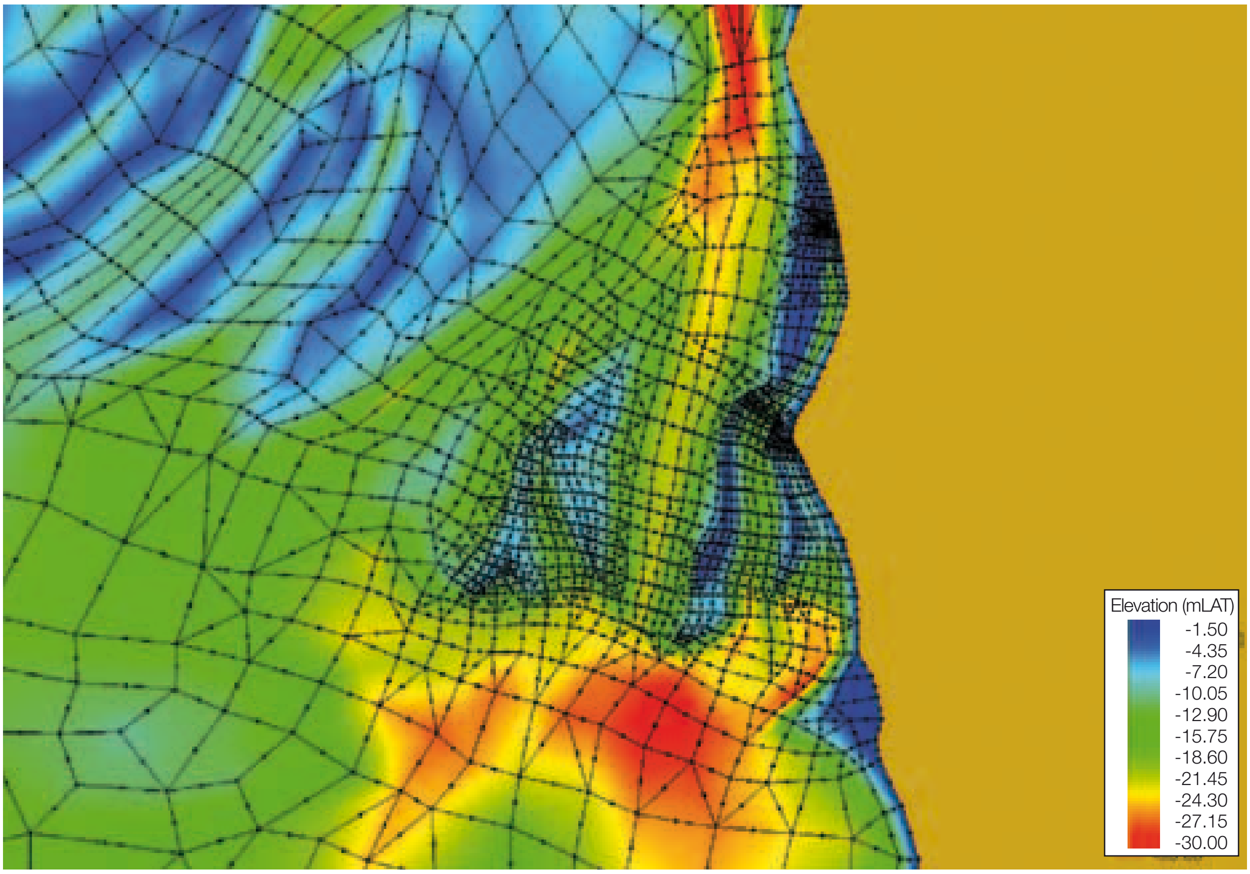


Figure 4.6b *WBM Mesh near Middle Banks showing Bathymetric Data.*



The hydrodynamic model was driven by tidal boundary conditions derived from 10 minute interval water elevation data supplied by Maritime Safety Queensland for Mooloolaba and Gold Coast Seaway.

The time step adopted was 15 minutes for the hydrodynamic modelling and 1.5 minutes for the water quality modelling of the dredge plume.

4.6.5 Hydrodynamic Validation

The model used in the present investigation has been established and progressively refined and upgraded over several years (WBM, 2005). It has been calibrated and verified previously against a range of measured data to confirm its suitability as an assessment tool for various previous investigations (WBM, 2005).

For the present application, representation of the characteristics of the Middle Banks region was of particular significance. As such, the bathymetry and model grid mesh resolution was reviewed and significantly refined at Middle Banks and surrounds. Further validation of the model's capability to simulate the hydrodynamic processes was undertaken as part of the Coastal Processes section of this project. This validation is described in Chapter C3 and as such is not repeated here.

4.6.6 Advection Dispersion and Water Quality Application

No further validation of advection dispersion or water quality model capabilities was undertaken for this study. However parameterisation of the model with respect to these processes was guided by recent extensive work performed by WBM for the Moreton Bay Waterways and Catchments Partnership, which was also favourably reviewed in an external assessment undertaken by CSIRO (WBM, 2005).

Key parameters simulated for this assessment were total nitrogen (TN), total phosphorus (TP) and total suspended sediment (TSS).

4.6.7 Model Assumptions

The following assumptions were made, in consultation with the project design and dredging consultants, for all dredging simulations:

- Volume of fill material to be dredged per run = 14,000 m^3.[1]
- Duration of typical dredge run = 2 hrs.[1]
- Dredge speed = 1.5 knots (~2.8 km/h).
- Bay water:sand ratio = 3.5:1 [1]
- Pore water:sand ratio = 0.3:1[2]
- Dilution of porewater concentrations ~ 13:1 [1]
- Discharge rate of water during a typical dredge run = 24,500 m3/hr. [1]
- Water in dredge hopper considered to be fully mixed.
- Plume commences 15 minutes after commencement of dredge run.
- Track of dredge vessel is approximately central in the dredge footprint. The resolution of the model mesh was initially not sufficient (though was refined considerably as part of this project) to obtain a suitable eastern and western dredge path, however based on peer review comments, the model mesh was refined and sensitivity analysis undertaken to determine if the centre dredge track was a robust predictor of plume extent and duration.

For the TSS assessments, the following assumptions were also made:

- Predominant source from discharge of fine sediment (fines) from vessel's hopper during dredging.
- Median percentage of fines (<75 microns) in dredged fill material = 2 percent.
- Settling velocity of fines = 0.1 mm/s.
- Discharge rate of fines during a typical dredge run = 260 t/hr. [3]
- Ambient concentrations at Middle Banks ~ 1 to 3 mg/L. Ambient concentrations were not modelled in order to remove any confusion in the interpretation of the results. Discharge from the dredge vessel was therefore the only TSS source considered.

For nutrient assessments, the following assumptions were made:

- Predominant source was from the porewaters of the dredged material. Median concentrations = 3.8 mg/L and 0.19 mg/L for TN and TP respectively. [4]
- Ambient concentrations at Middle Banks ~ 0.12 mg/L and 0.01 mg/L for TN and TP respectively from EHMP monitoring. Ambient concentrations of TN and TP were modelled.
- Discharge rate of TN and TP during a typical dredge run = 10 kg/hr and 0.6 kg/hr.[5]

4.6.8 Scenario Descriptions

Twelve scenarios were selected to assess the extent of impacts from the dredge plumes. The scenarios were run for a 10 hour period with the dredge run timed to commence after 2 hours of simulation. In all cases, this length of simulation was shown to be adequate for the concentration of TN, TP and TSS to fall to ambient levels. Combinations of the following conditions were simulated:

- Direction of dredge vessel (Northerly or Southerly);
- Tidal ranges (Spring, Neap and King tidal cycles); and
- State of tide (Mid Neap and Mid Spring).

The matrix shown in **Table 4.6c** provides details on the combination of conditions simulated by each scenario.

1 *Based on proposed dredge assumed in design calculations.*
2 *From borehole investigations*
3 *Based on proposed dredge assumed in design calculations.*
4 *From borehole investigations – refer Chapter C2*
5 *Calculated*

Table 4.6c Scenario Details.

Scenario Number	Northerly Path	Southerly Path	Spring Ebb Tide	Spring Flood Tide	Neap Ebb Tide	Neap Flood Tide
1	x		x			
2	x			x		
3	x				x	
4	x					x
5		x	x			
6		x		x		
7		x			x	
8		x				x
9	x		king			
10	x			king		
11		x	king			
12		x		king		

Model results were extracted from three monitoring points within both the areas of seagrass as defined in Chapter C5, and in the area of High Ecological Value. These areas are shown in the following figures.

4.7 Dredge Plume Impacts – Total Suspended Solids

The results of the dredge plume modelling show that the behaviour of the plume is consistent with previous monitoring of dredging in the Middle Banks (Foster and Higgens 1987, Willoughby and Crabb 1983, NIWA 2004) in that the dredge plume is confined locally to the dredge area and dissipates rapidly. Plots of the suspended solids plume extent (based on maximum concentrations) show how the plumes vary for the different scenarios modelled. In each of the extents shown in **Figure 4.7 to Figure 4.7u**, the direction of both the tide and dredge are shown indicatively for clarity and the extent represents the maximum area likely to be affected by the plume.

Figure 4.7a *Scenario 1 North Dredge Path – Spring Ebb Tide - TSS.*

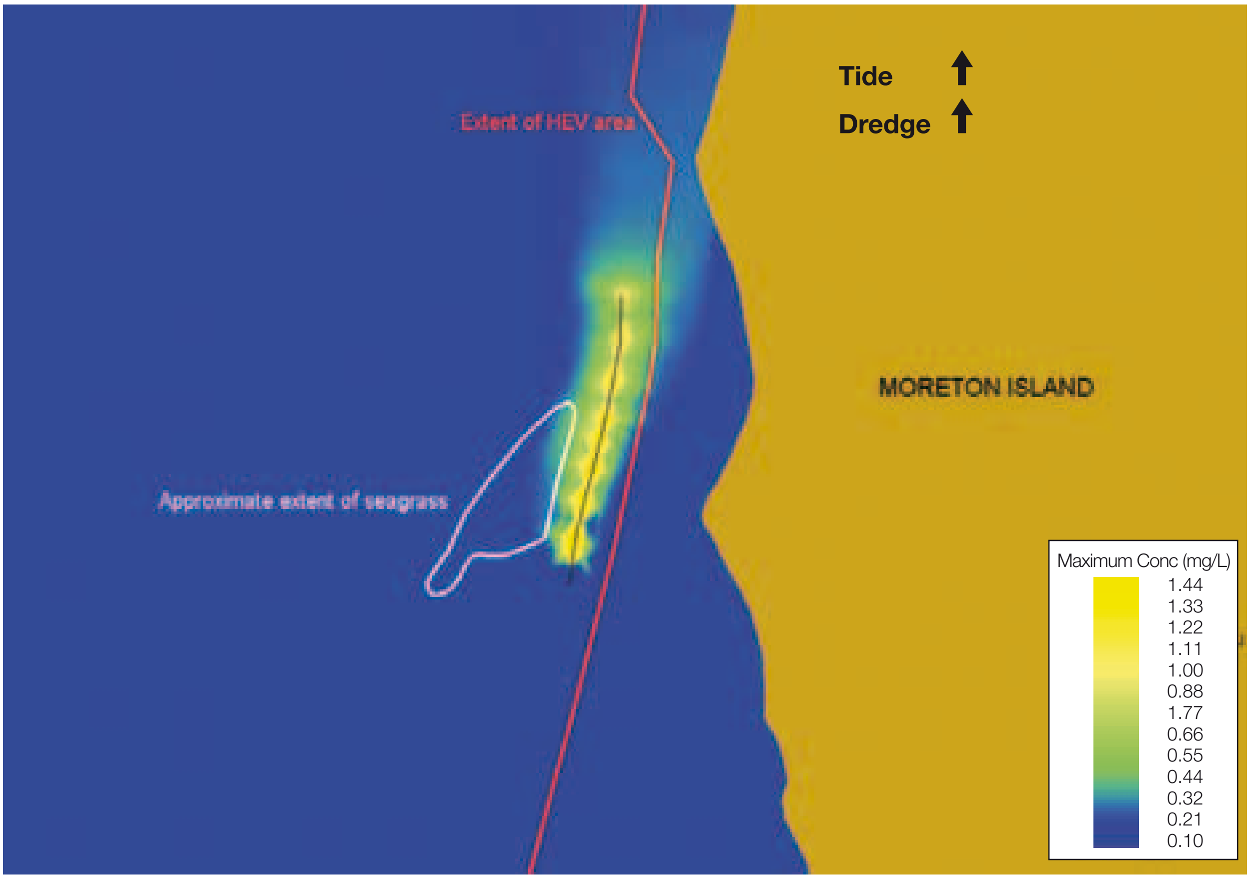


Figure 4.7b Scenario 2 North Dredge Path – Spring Flood Tide - TSS.

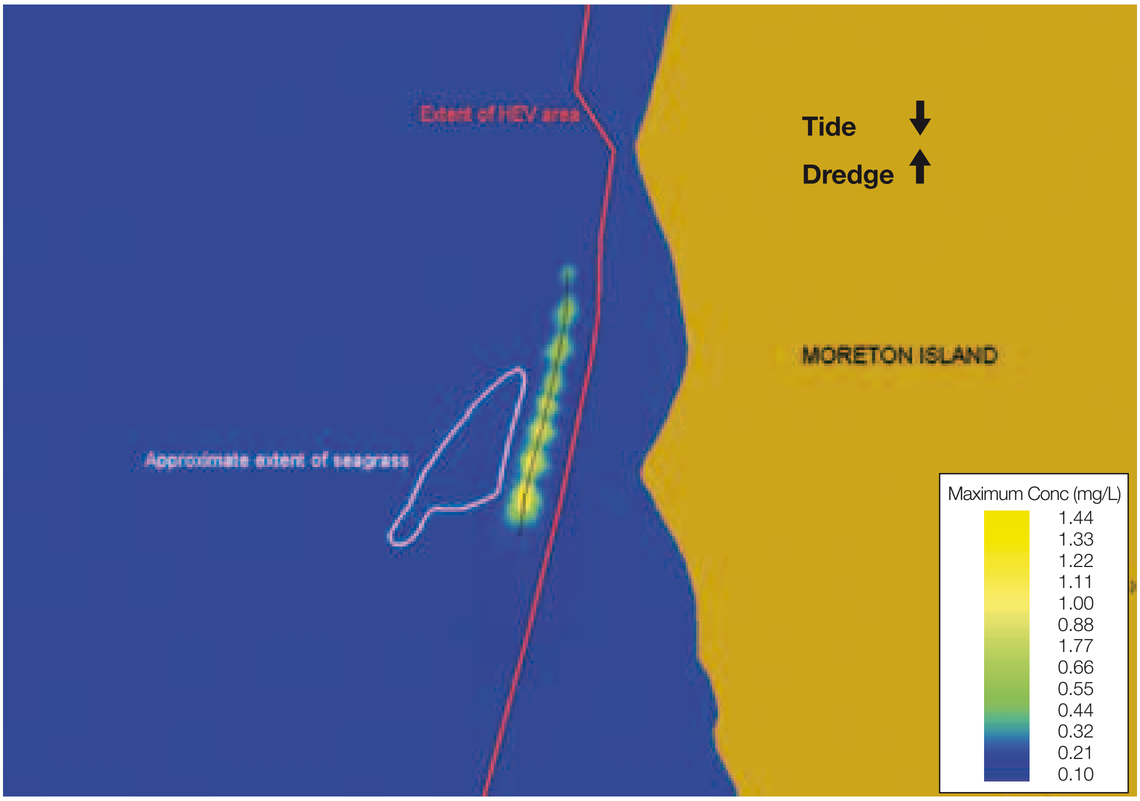


Figure 4.7c Scenario 3 North Dredge Path – Neap Ebb Tide - TSS.

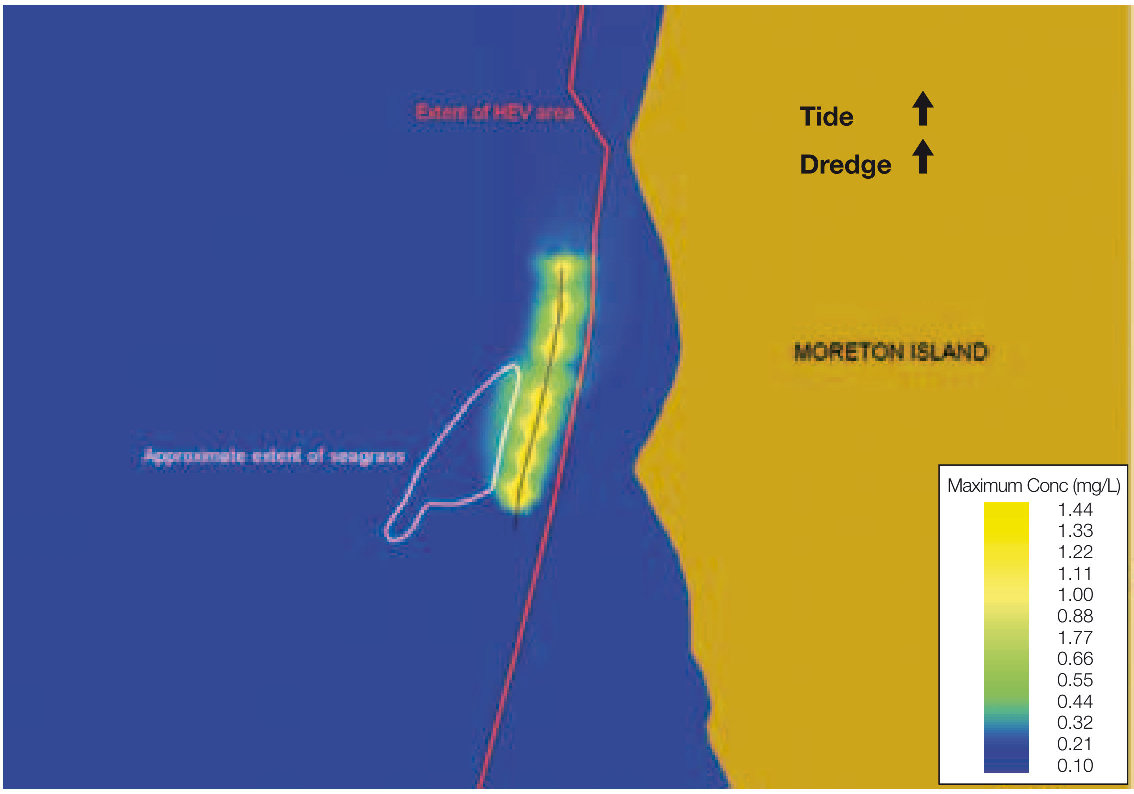


__Figure 4.7d__ Scenario 4 North Dredge Path – Neap Spring Tide - TSS.

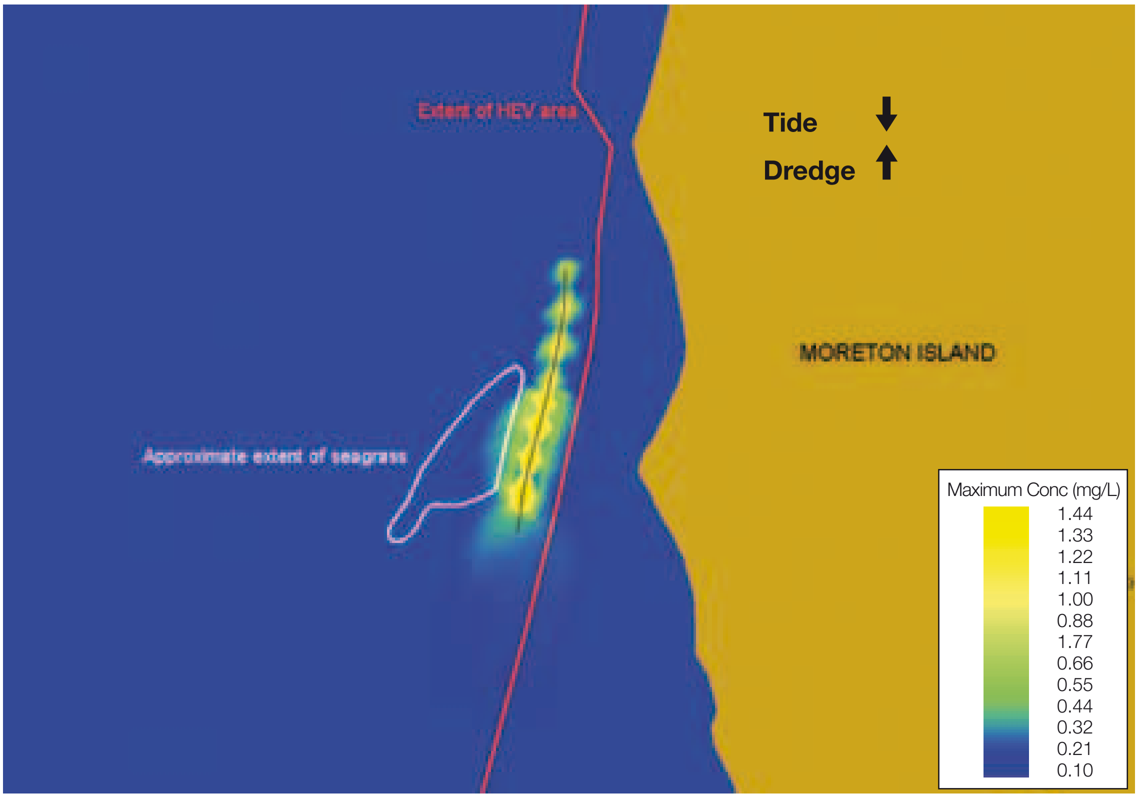


__Figure 4.7e__ Scenario 5 South Dredge Path – Spring Ebb Tide - TSS.

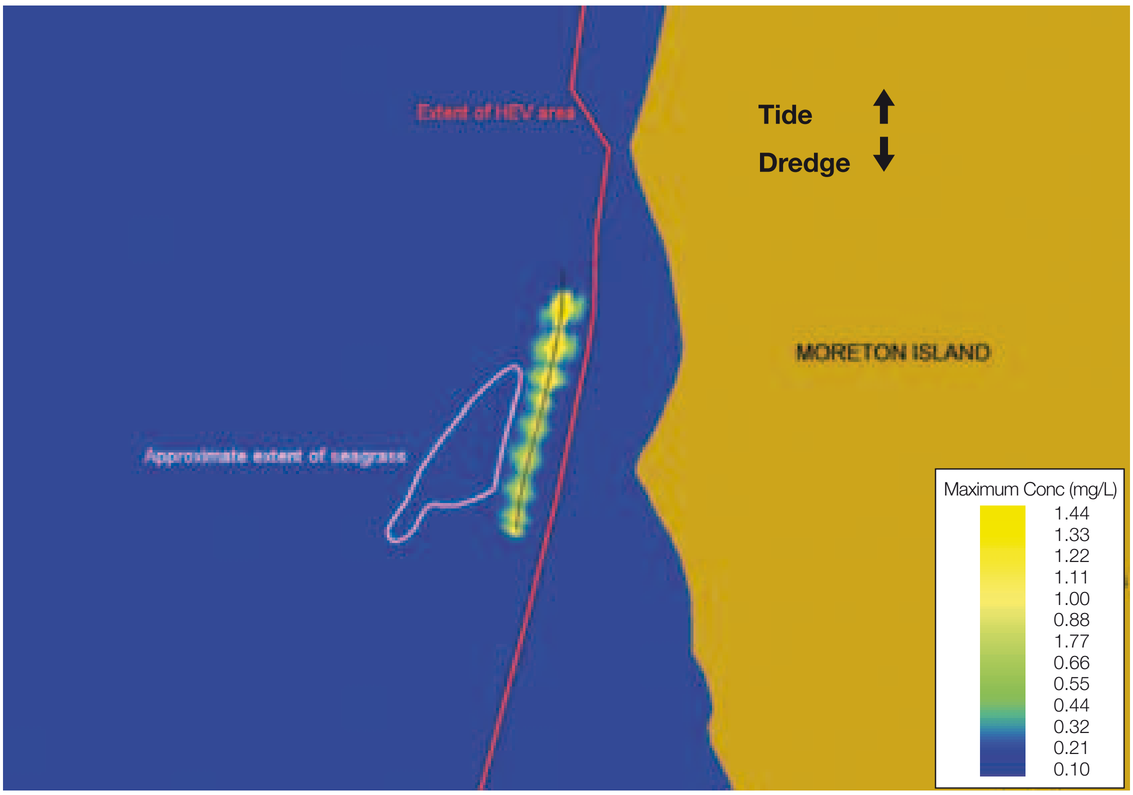


Figure 4.7f *Scenario 6 South Dredge Path – Spring Flood Tide - TSS.*

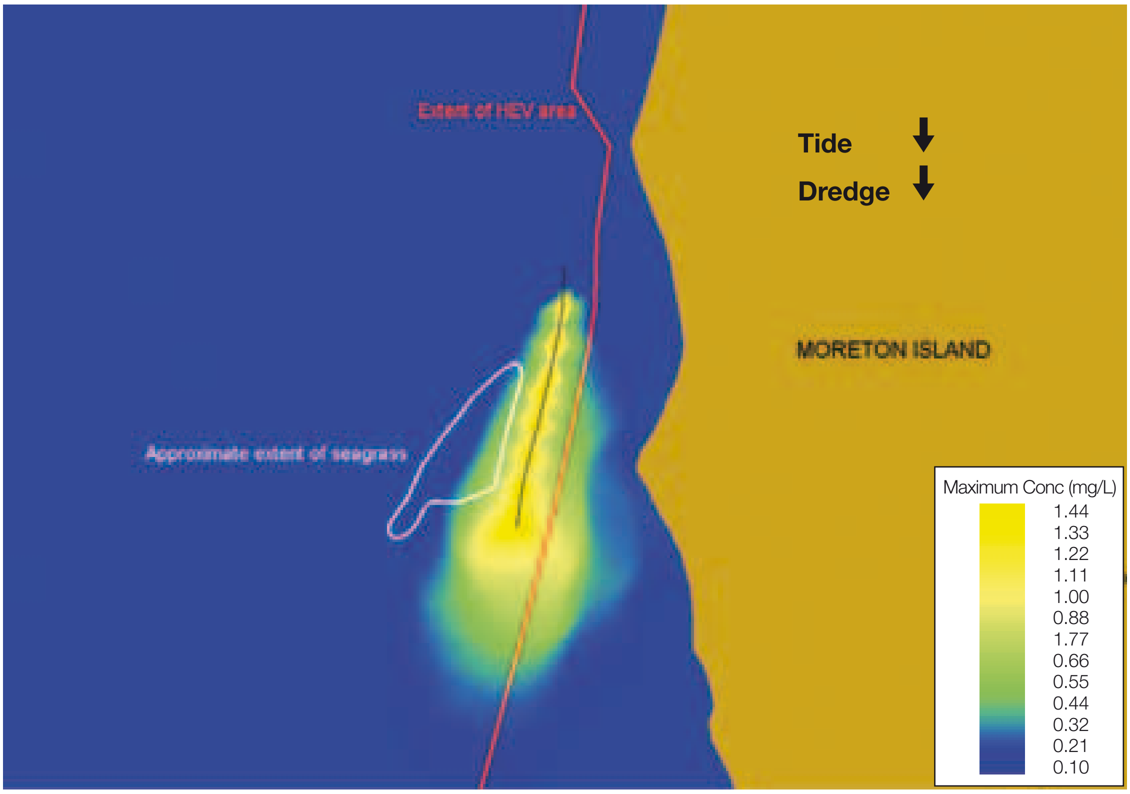


Figure 4.7g *Scenario 7 South Dredge Path – Neap Ebb Tide - TSS.*

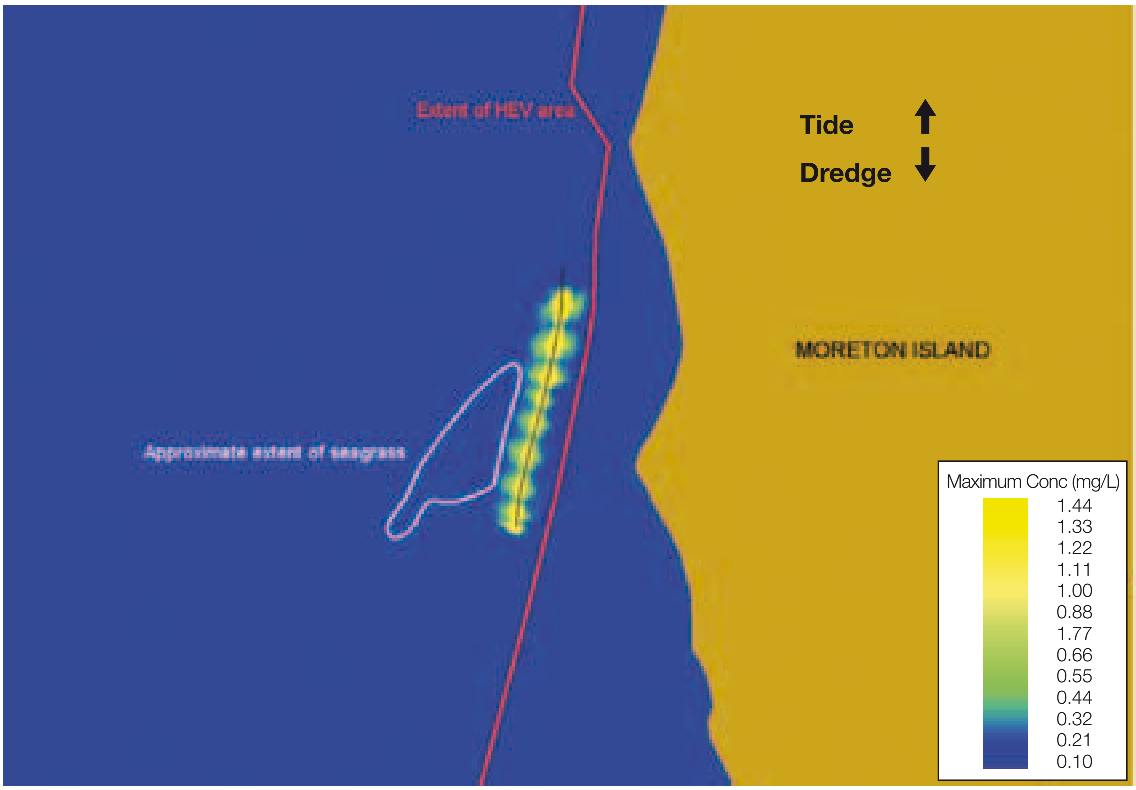


Figure4.7h *Scenario 8 South Dredge Path – Neap Flood Tide - TSS.*

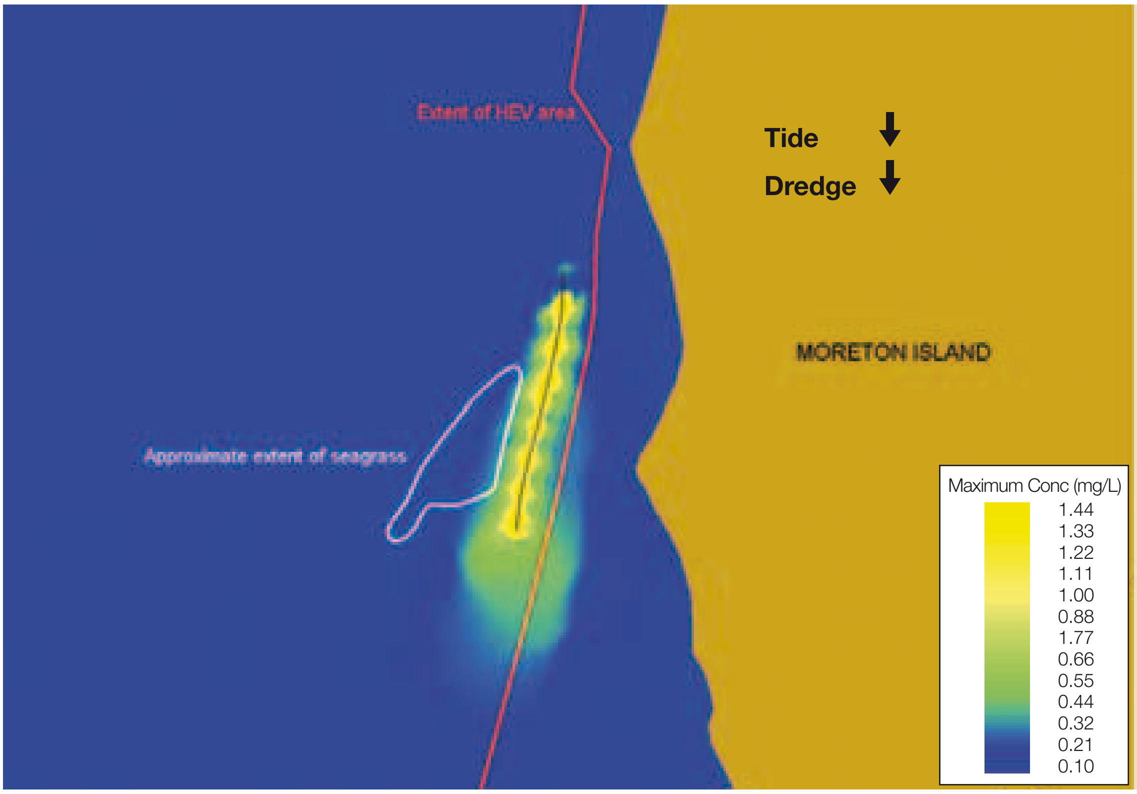


Figure 4.7i *Scenario 9 North Dredge Path – King Ebb Tide - TSS.*

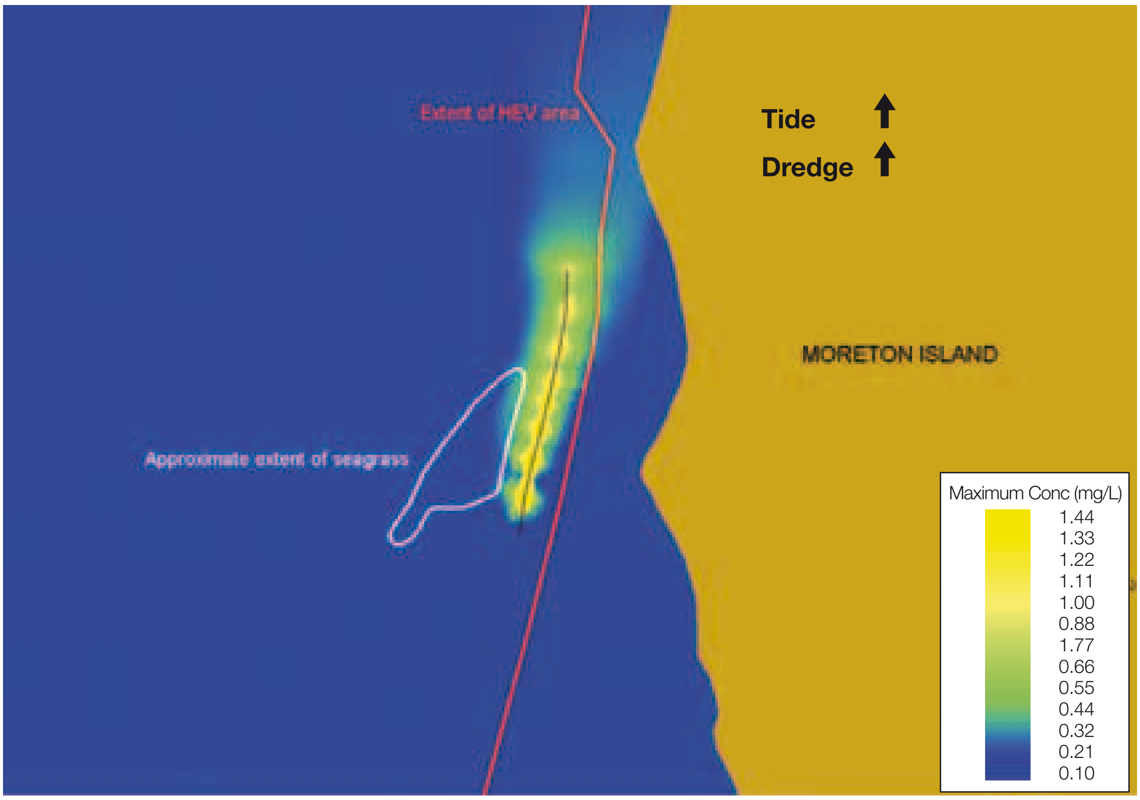


Figure 4.7j *Scenario 10 North Dredge Path – King Flood Tide - TSS.*

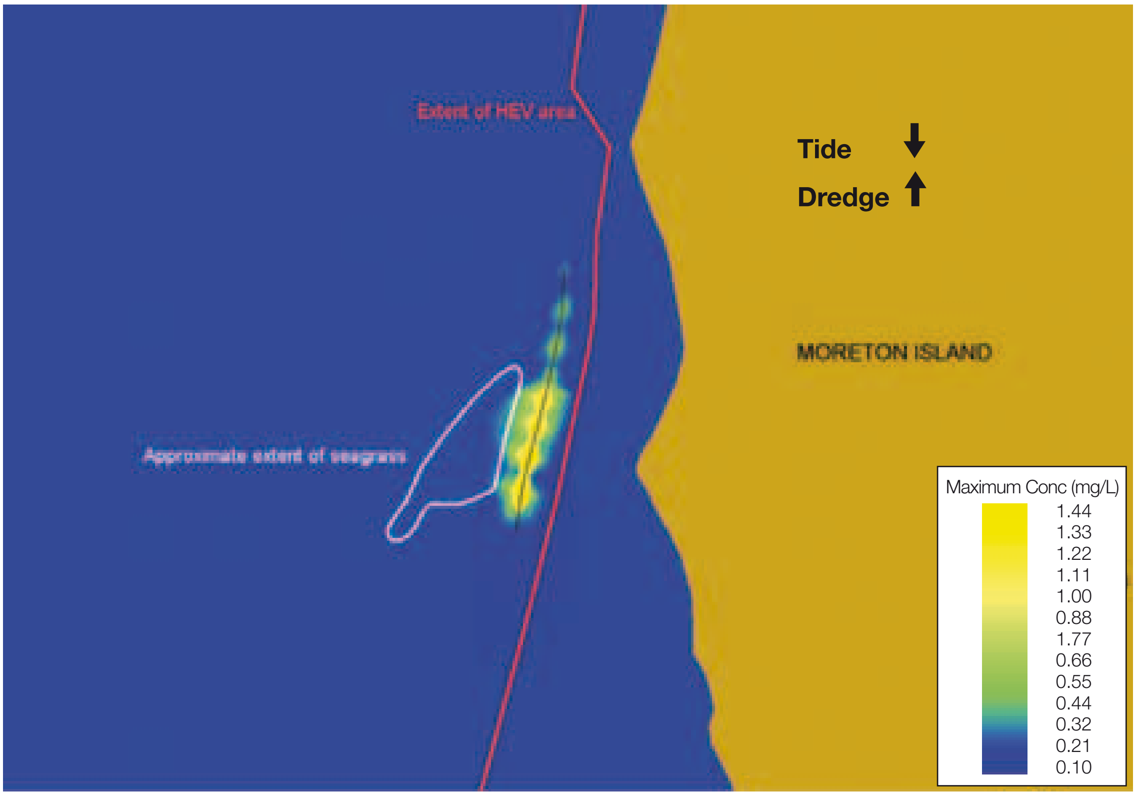


Figure 4.7k *Scenario 11 South Dredge Path – King Ebb Tide - TSS.*

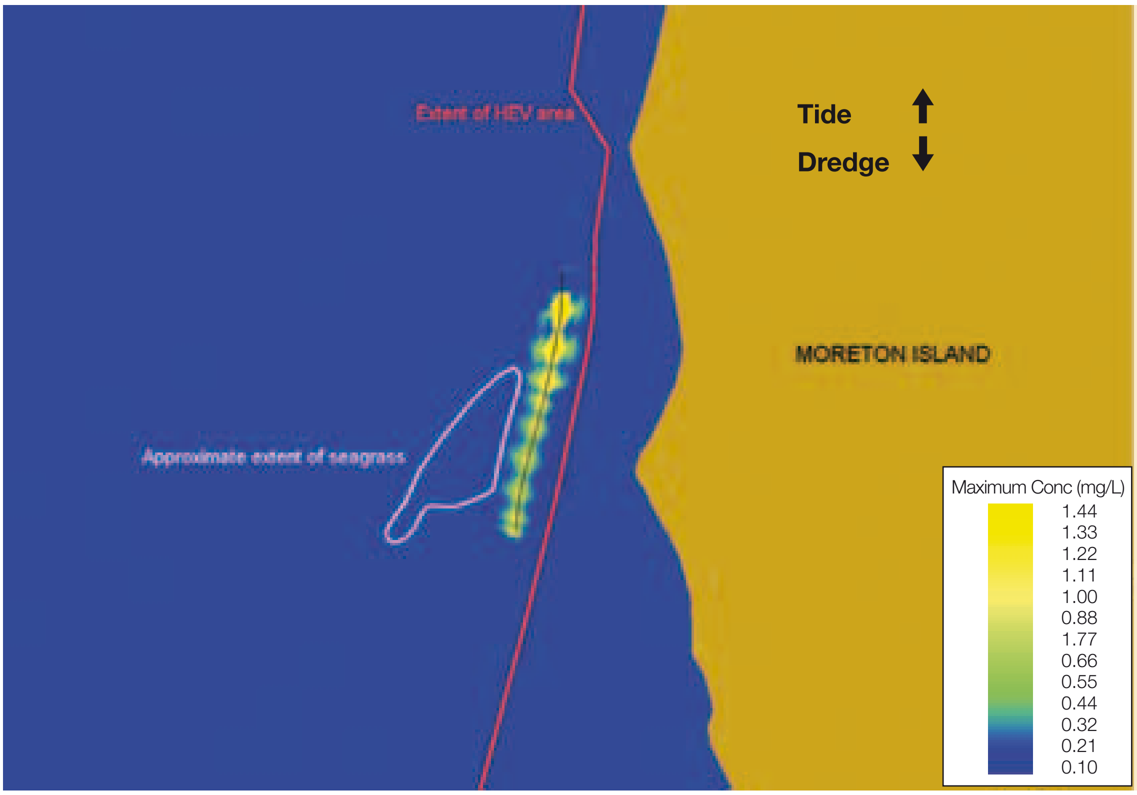
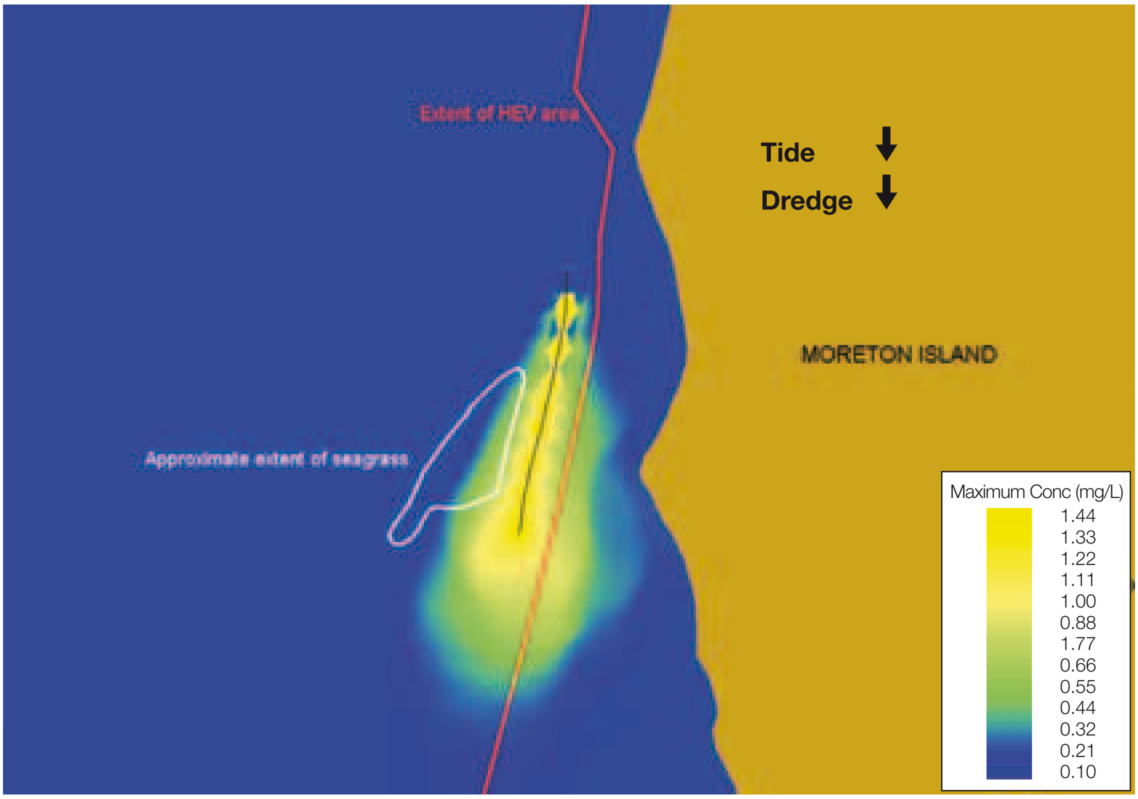


__Figure 4.7l__ Scenario 12 South Dredge Path – King Flood Tide - TSS.



The scale is identical for each of the figures and represents concentrations above background. In this area, the background or baseline suspended solids concentration has not been monitored by the Ecosystem Health Monitoring Program (EHMP) and has been reported separately as being <5 mg/L (NIWA 2004) and 3 mg/L (Willoughby and Crabb 1983), though it was noted with the latter result that background concentrations were expected to vary considerably. Turbidity results for the EHMP sites in the vicinity of Middle Banks have median turbidities <1 NTU which are extremely low and hence suspended solids concentrations would also be expected to be in a similar range. For the purposes of defining a background value, a conservative approach has been taken of assuming that the suspended solids concentration is identical to the turbidity (i.e. 1 mg/L) given the lack of suspended solids results for the location. Given this, the concentrations of suspended solids above background are relatively low, with maximums (post vertical mixing) only 1.5 times greater than background in the highest areas. It should be noted that immediately adjacent to the dredge, concentrations would be much higher, however the model assumes full vertical mixing has occurred at discharge. From Willoughby and Crabb (1983), it was observed that over scales of 100 m (which is approximately ¼ of the distance between nodes in the model used in this study), the plume was well mixed both vertically and laterally. The actual observable plume is difficult to predict without knowing an exact conversion between TSS and turbidity for the materials actually causing the plume, however the coloured areas indicated in the legend on the plume extents are intended to show those areas greater than 10 percent above background concentrations and hence are likely to be representative of those areas where a visible plume are likely to be observable.

What the figures show is that the extent of maximum concentrations is governed by the direction of the dredge relative to tidal movements. This is to be expected in that the spread of the plume will be dictated by current speed relative to the dredge, hence when the dredge is moving in the same direction as the tidal movement, the effective 'relative' speed will be very low. The plume in this case would be expected to drift with the dredge and concentrations would therefore be higher due to reduced mixing with surrounding waters and continued discharging of turbid waters 'into' the plume. It is suggested that if minimizing the extent of the plume is necessary, dredging operations should be confined to those where the vessel is moving against the tide as this will result in lower overall suspended solids concentrations.

While the plots show the total area that may be affected at any time by the plume during the entire 8 hour dredging cycle (i.e. 2 hours dredging, 2 hours transit to the discharge point, 2 hours discharging and 2 hours transit to return to Middle Banks), the observable plume at one particular time would be vastly different and will vary during the dredge and tidal cycle. To represent this, several "snapshots" of model output at varying times through the dredge cycle are shown for Scenario 12, which has the maximum spatial impact extent of all scenarios run. The time shown is the time elapsed from first plume generation.

Figure 4.7m *t = 2 mins (i.e. approximately 15+2 minutes after commencement of dredging).*

Figure 4.7n *t = 30 mins.*

Figure 4.7o *t = 60 mins.*

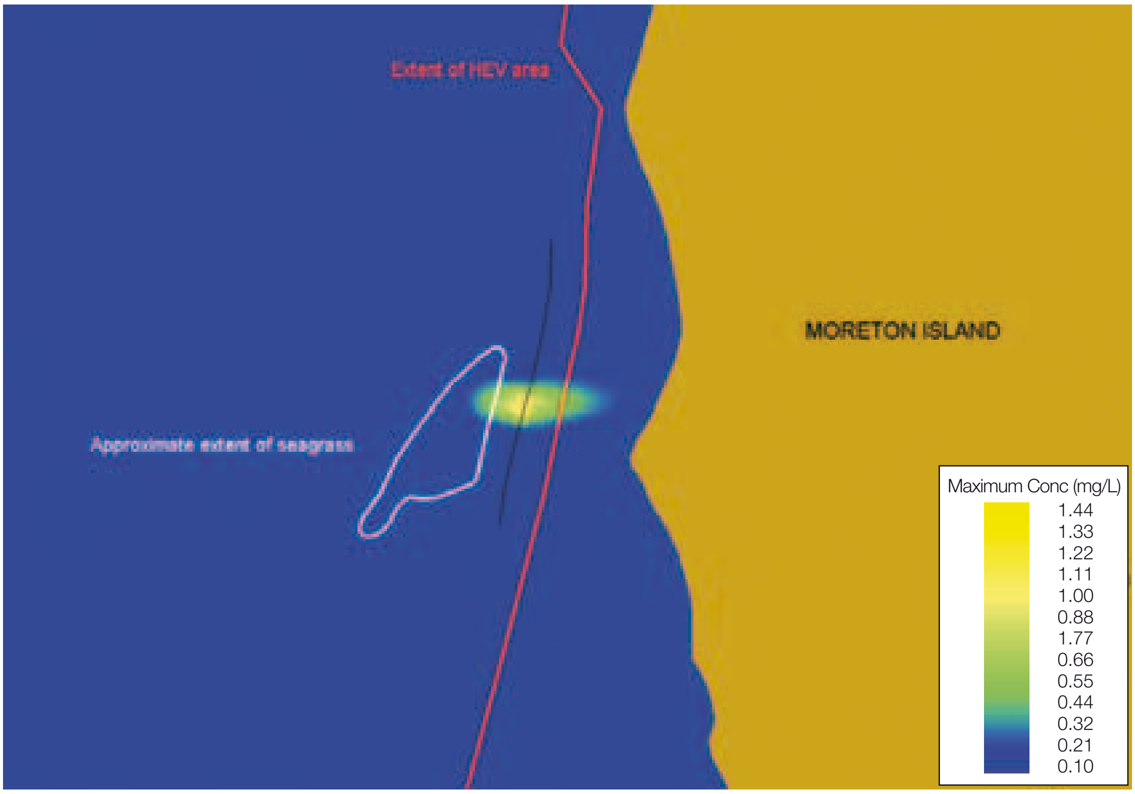


Figure 4.7p t = 90 mins.

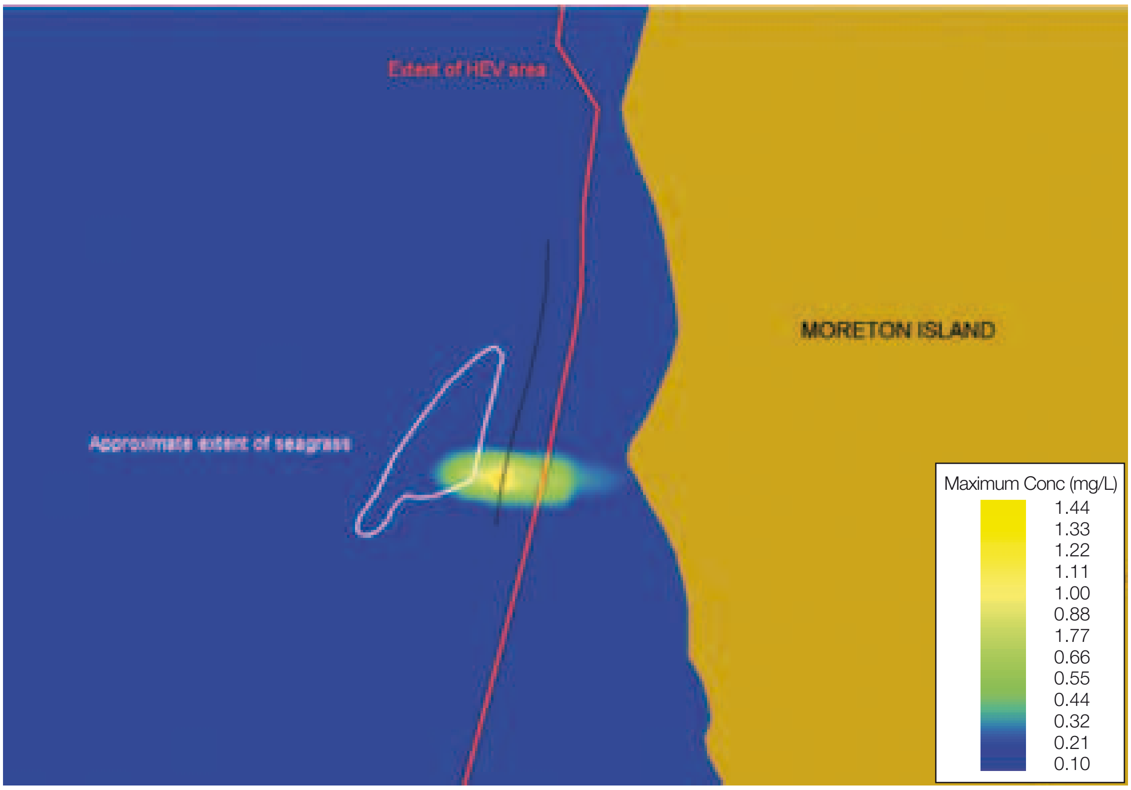


Figure 4.7q t = 120 mins (approx 15 minutes after completion of dredging).

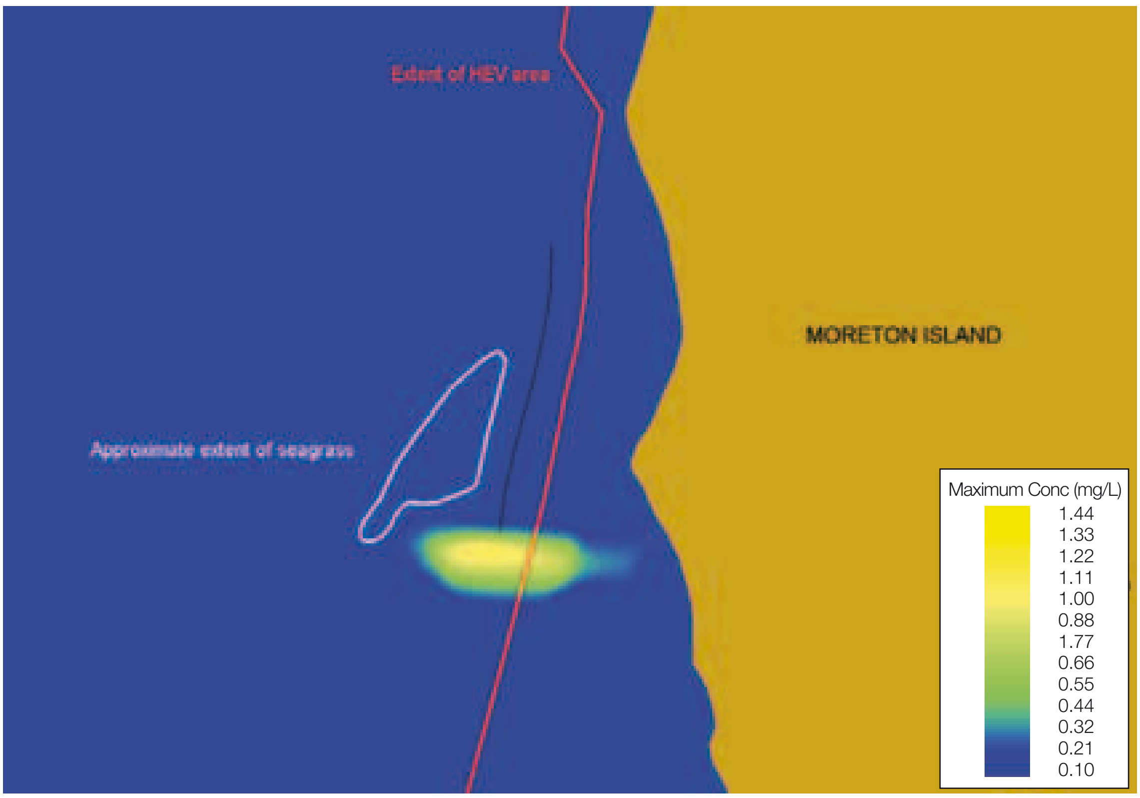


Figure 4.7r *t = 150 mins.*

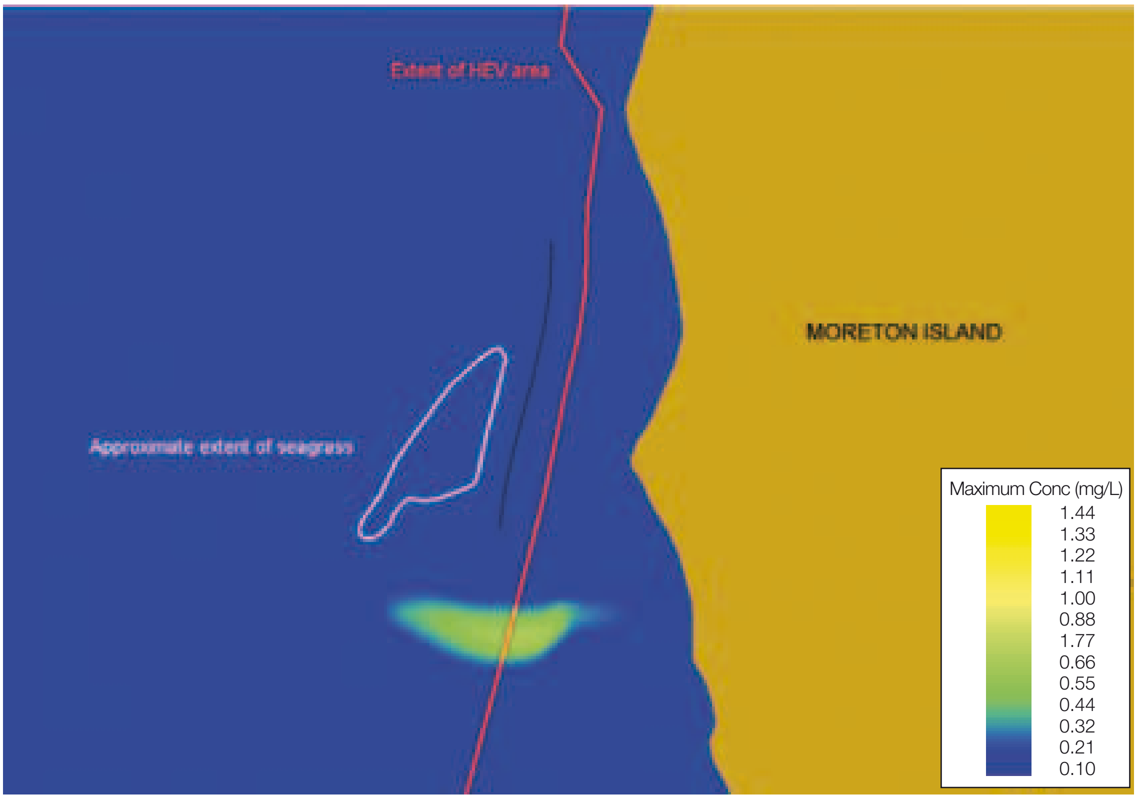


Figure 4.7s *t = 180 mins.*

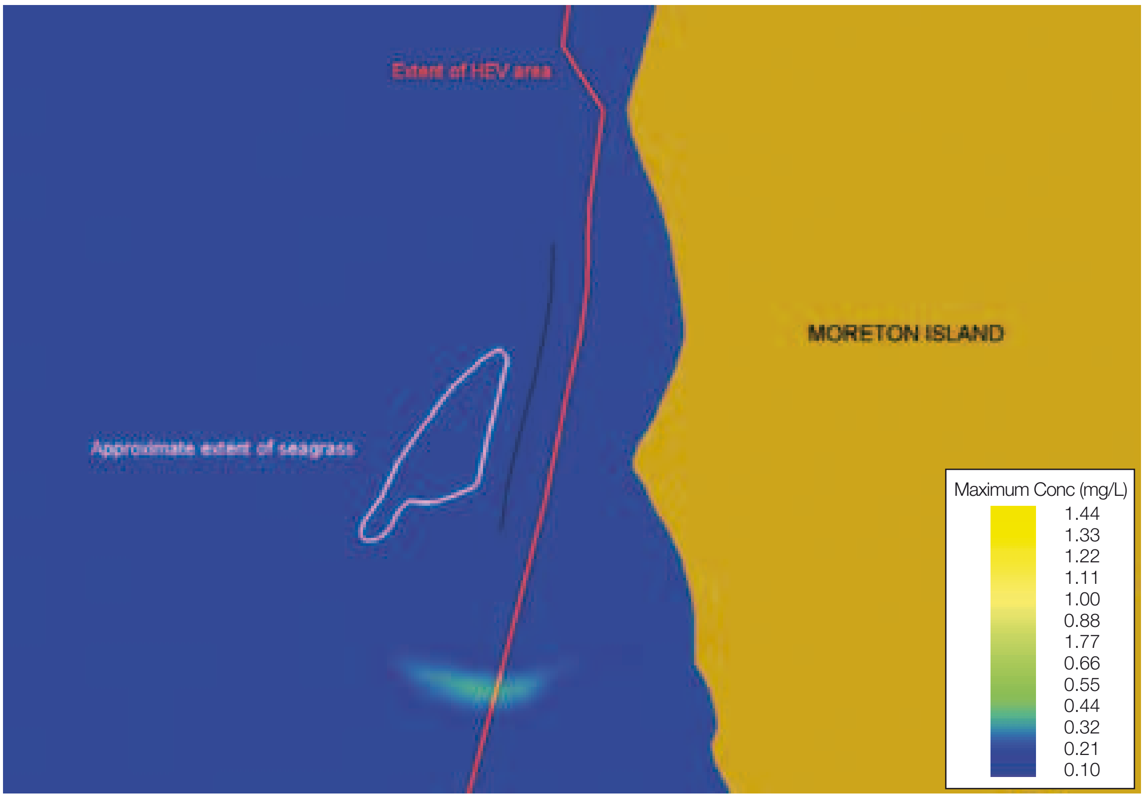


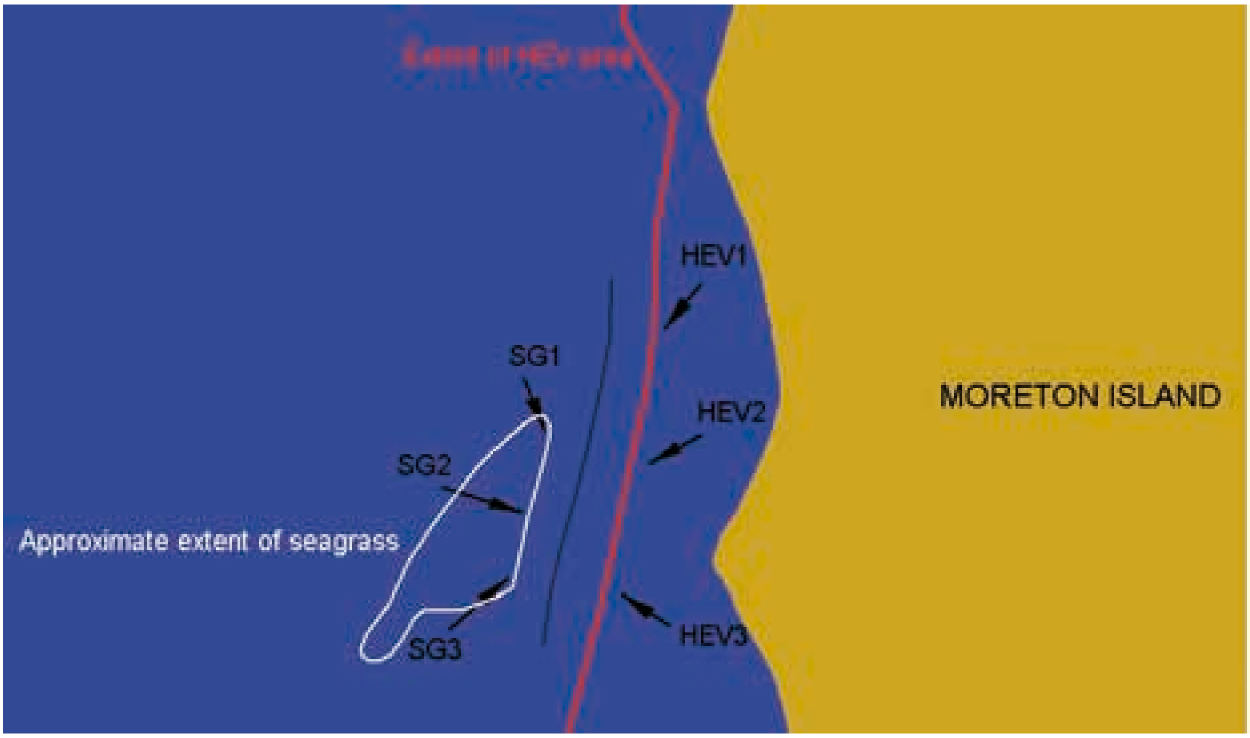
Figure 4.7t t = 240 mins.

Figure 4.7u *t = 480 mins (end of dredge cycle).*

From **Figure 4.7m** to **Figure 4.7u**, it can be seen that the plume remains localised around the dredge during extraction activities, and then dissipates rapidly once extraction has been completed and returns to background concentrations prior to the commencement of the next dredge cycle. It also shows that the area of maximum concentration passes through any given point in a short period when the dredge is moving with the current.

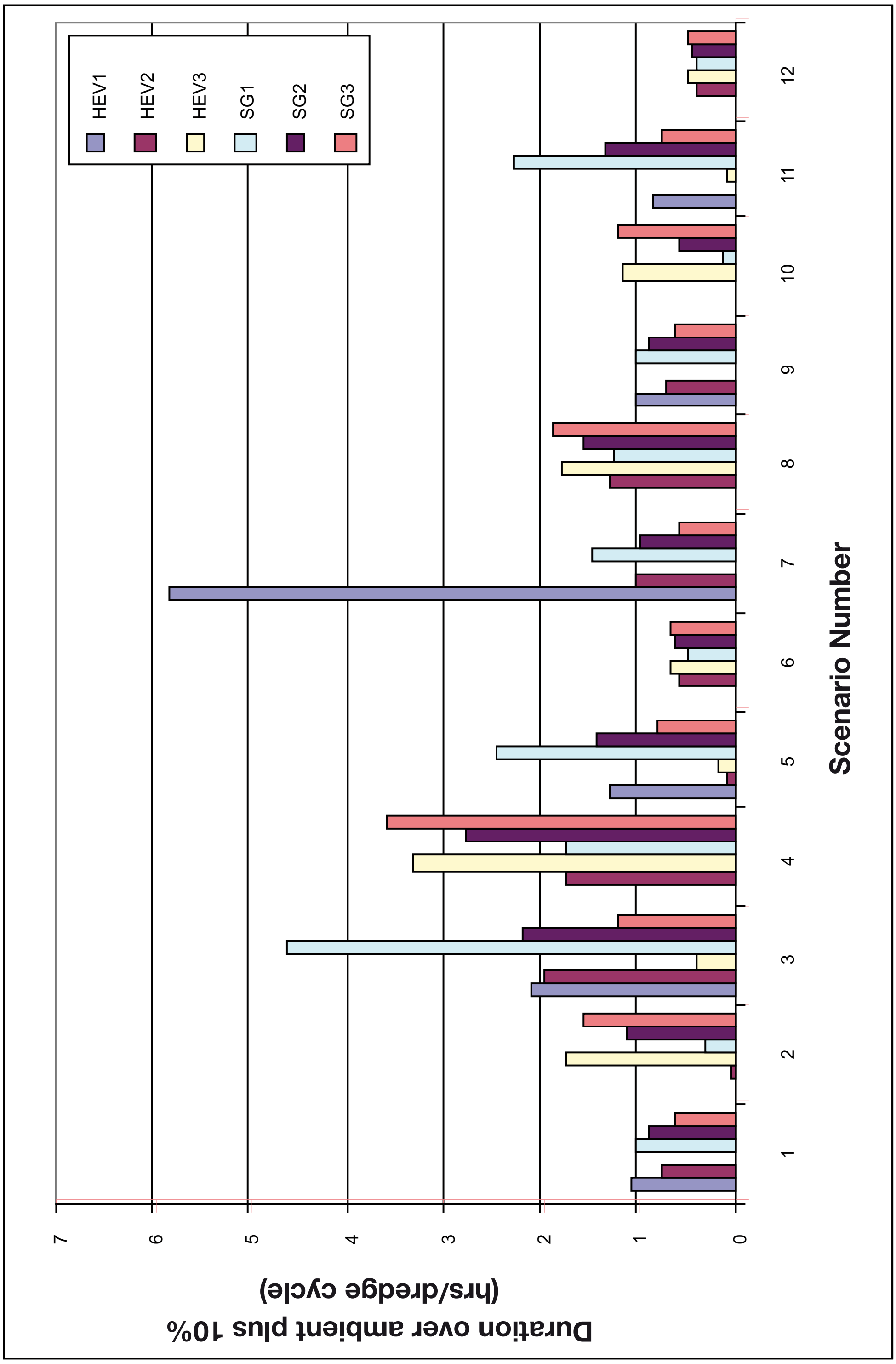
Hence, while concentrations may be elevated compared to those times when the dredge is moving against the current, the actual duration of maximum concentration at sample points SG 1 - 3 and HEV 1 - 3 (see **Figure 4.7v**) is minimised. These locations were selected as representing locations in the seagrass and High Ecological Value areas and being closest to the northern most, centre and southern most points of the dredging track.

Figure 4.7v *Model Sample Points.*



In order to investigate the extent of duration of maximum concentration further, time series were extracted at each of the sample points SG1-3 and HEV1-3 for all scenarios and compiled into one bar chart (see **Figure 4.7w**).

Figure 4.7w *Duration > 10% Above Background TSS.*



This shows that in spring and king tides where the dredge is operating with the prevailing tide (Runs 1, 6, 9 and 12 highlighted in green above), both in the ebb and flood cycles, the period when the TSS concentration is greater than 10 percent above background is lowest. This is of interest for minimising impact from light attenuation on seagrass, though it must also be understood that the concentrations being considered are relatively small (<0.8 mg/L TSS above background).

4.8 Dredge Plume Impacts - Sensitivity Analysis

Sensitivity analysis of the impacts of using a western or eastern dredging track were examined to determine if the variation in location of the dredge path may have a noticeable influence on the extent of the plume and/or duration of the plume at the HEV and sea grass areas. To test this hypothesis, best and worst case scenarios were re-run using an eastern and western dredge track. Results of these analyses are presented in the following **Figure 4.8a to Figure 4.7m:**

Figure 4.8a *Scenario 2 (West) North Dredge Path (West Track) – Spring Flood Tide – TSS.*

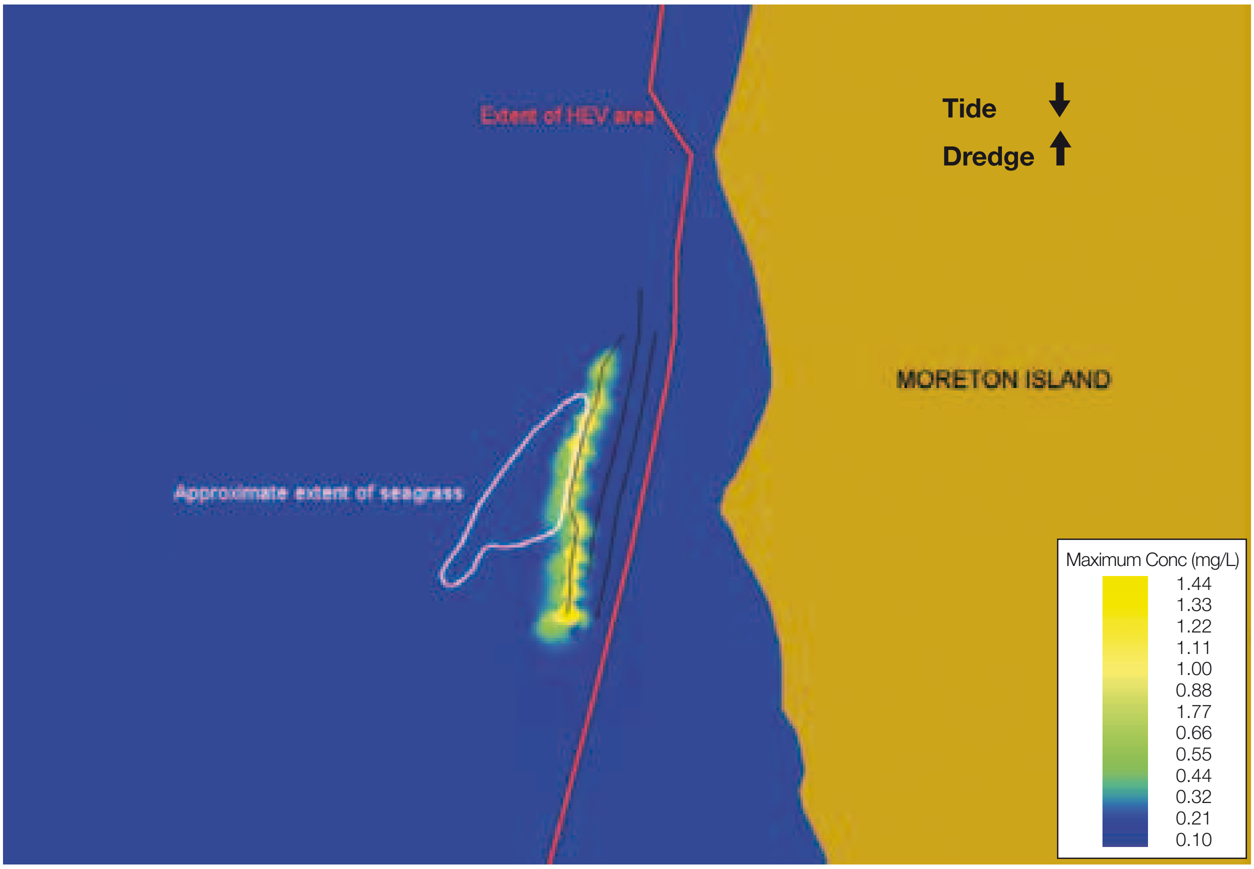


Figure 4.8b *Scenario 2 (East) North Dredge Path (East Track) – Spring Flood Tide – TSS.*

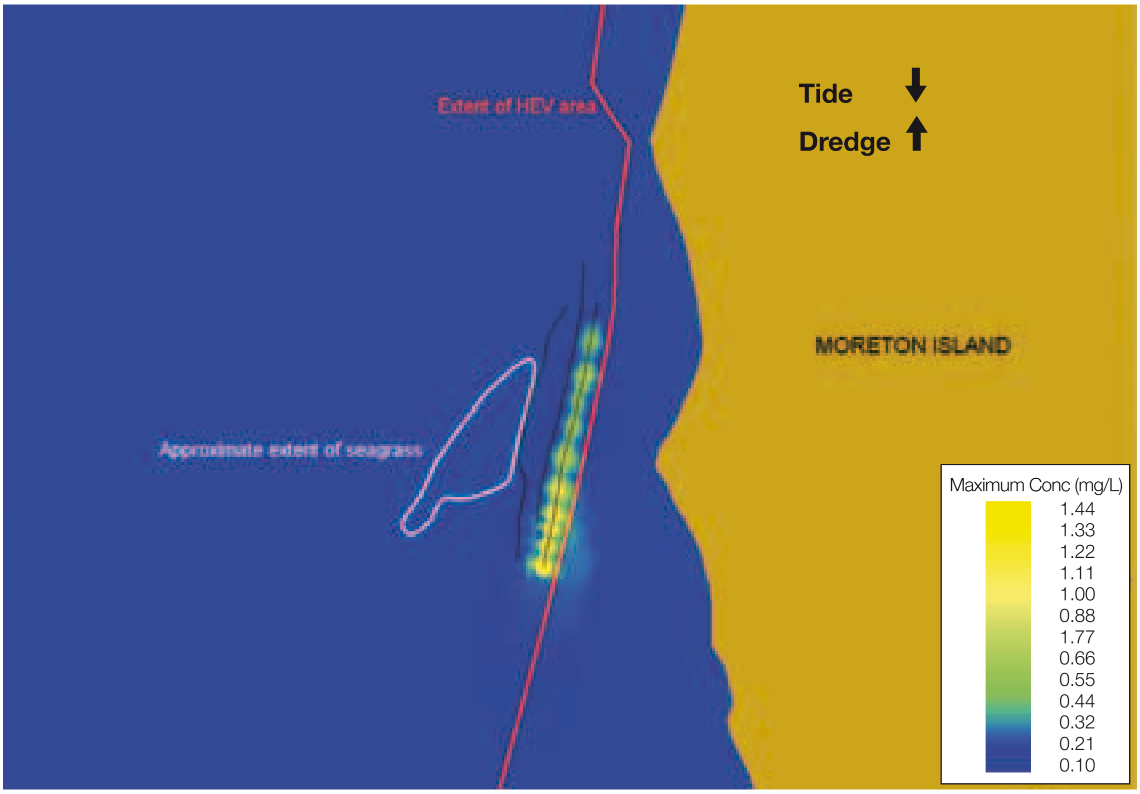


Figure 4.8c *Scenario 6 (West) South Dredge Path (West Track) – Spring Flood Tide – TSS.*

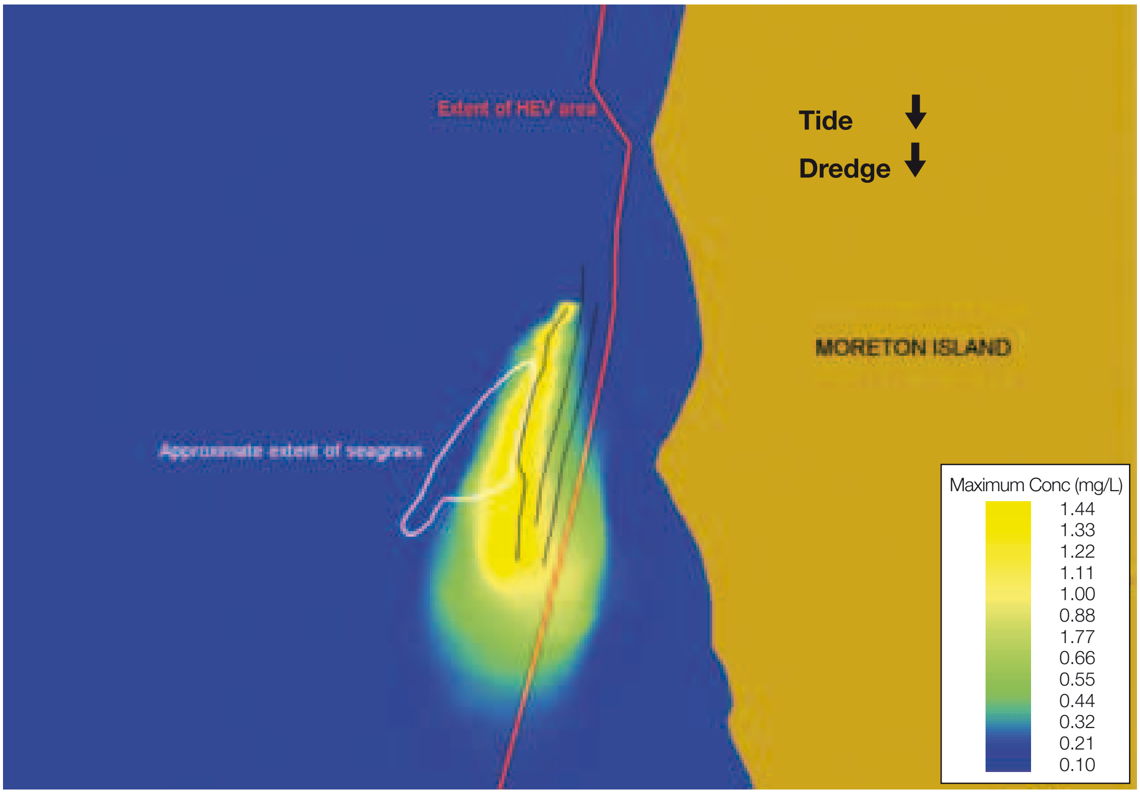
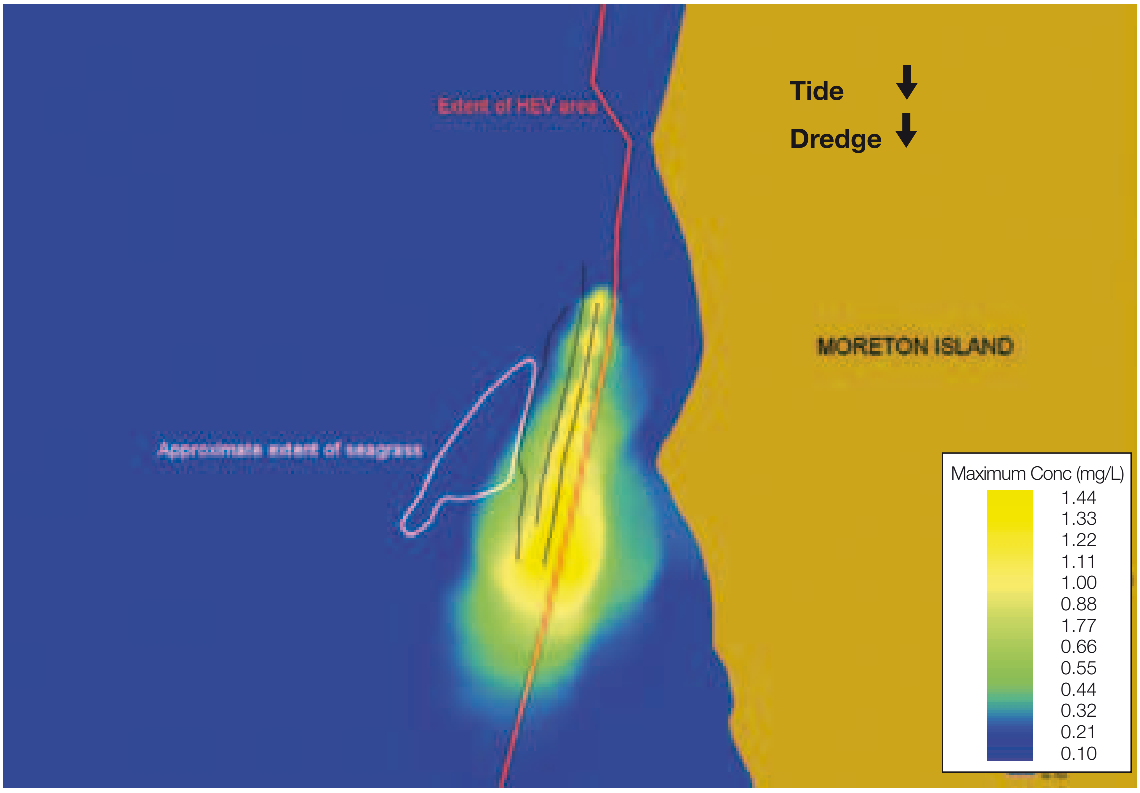
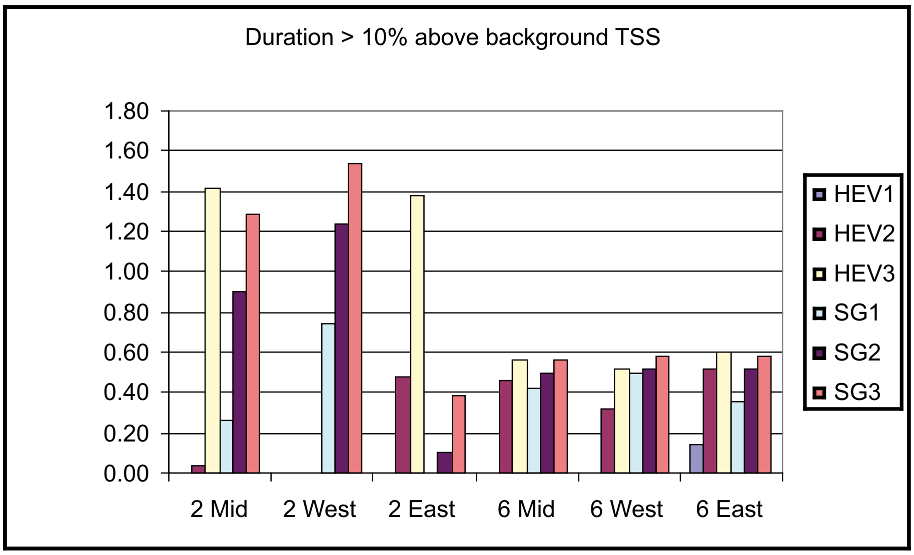


Figure 4.8d *Scenario 6 (East) South Dredge Path (East Track) – Spring Flood Tide – TSS.*



As can be seen, the maximum plume extents do not change significantly compared to the centre track scenarios, however it is apparent that for the western track, higher concentrations are observable over the seagrass area and correspondingly, for the eastern track, higher concentrations are observed in the HEV area. Given the similarity of the plume extents to the central track, it is not anticipated that impacts will be significantly different from those for the central track. In terms of duration above background, data was extracted from each of the model runs and compiled as shown in **Figure 4.8e**.

Figure 4.8e *Duration >10 percent Above Background TSS.*



Once again this shows that while dredging against the current limits overall plume extents, durations at the seagrass, and to a lesser extent, the HEV areas are minimised when dredging with the current. This shows that the results obtained using the centre dredge track are relatively robust in terms of predicting likely duration and extents of the plume.

Further sensitivity analyses were conducted on settling velocities used with 4 further model runs conducted at a settling velocity of 0.05 mm/s rather than 0.1 mm/s originally used. The plume extent plots derived from the model for these runs are shown in comparison with the original model runs at 0.1 mm/s.

Figure 4.8f *Scenario 9 0.05 mm/s SV.*

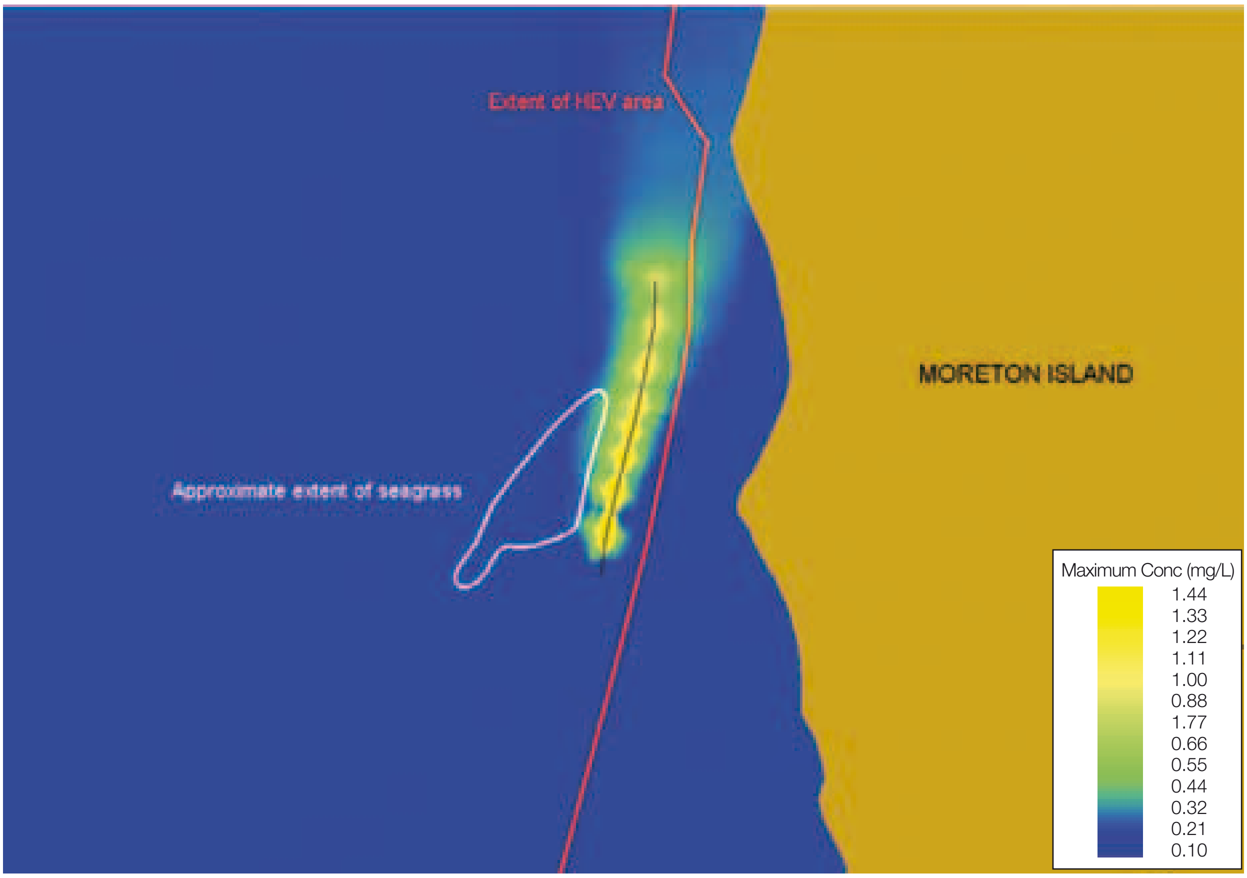


Figure 4.8g Scenario 9 0.1 mm/s SV.

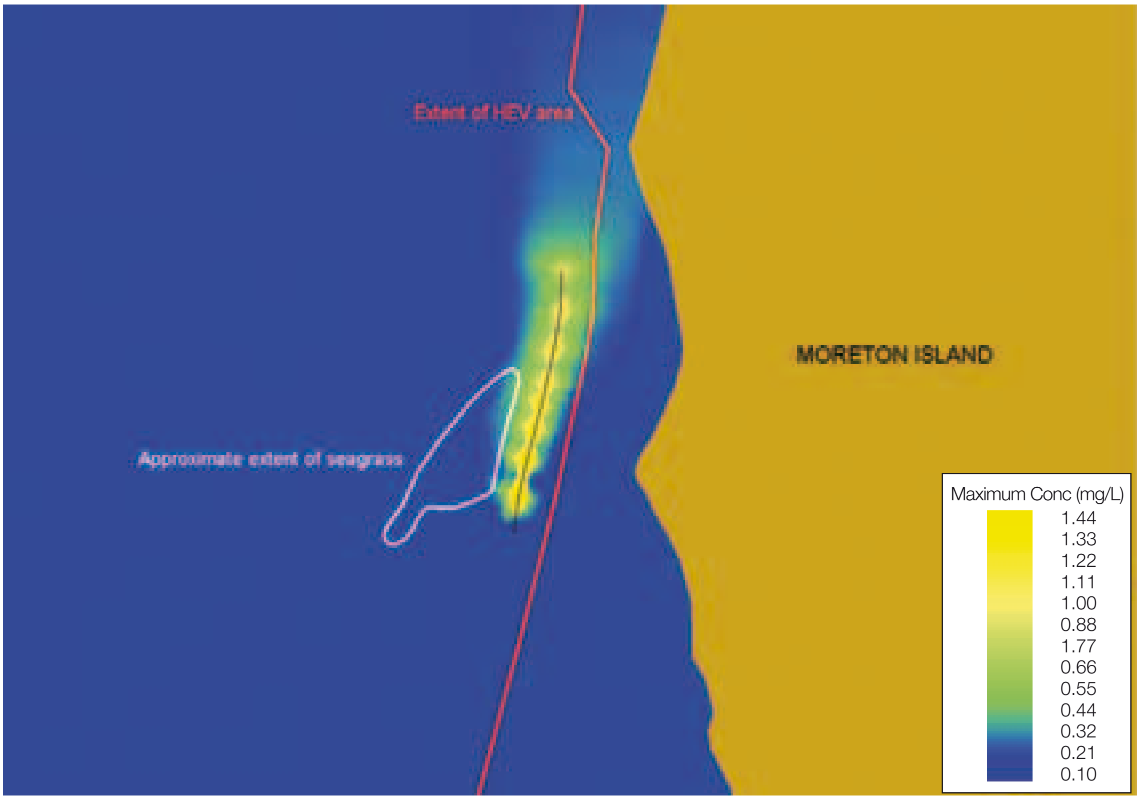


Figure 4.8h Scenario 10 0.05 mm/s SV.

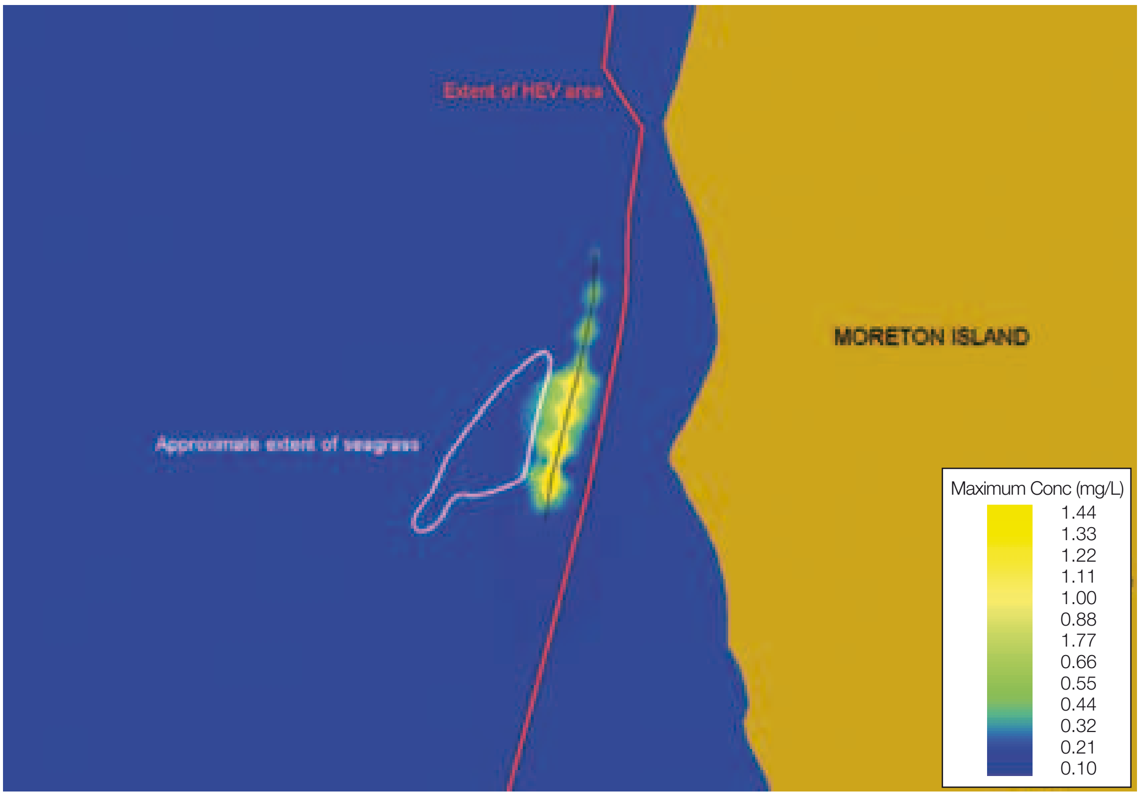


Figure 4.8i *Scenario 10 0.1 mm/s SV.*

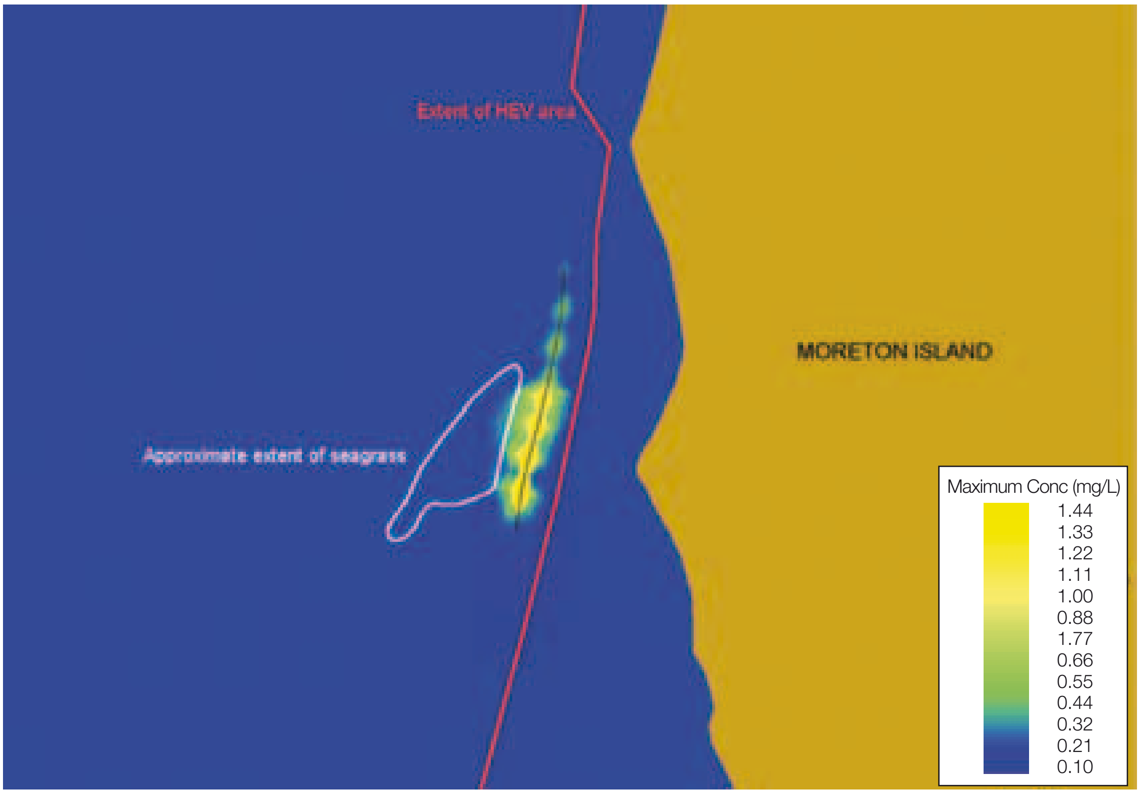


Figure 4.8j *Scenario 11 0.05 mm/s SV.*

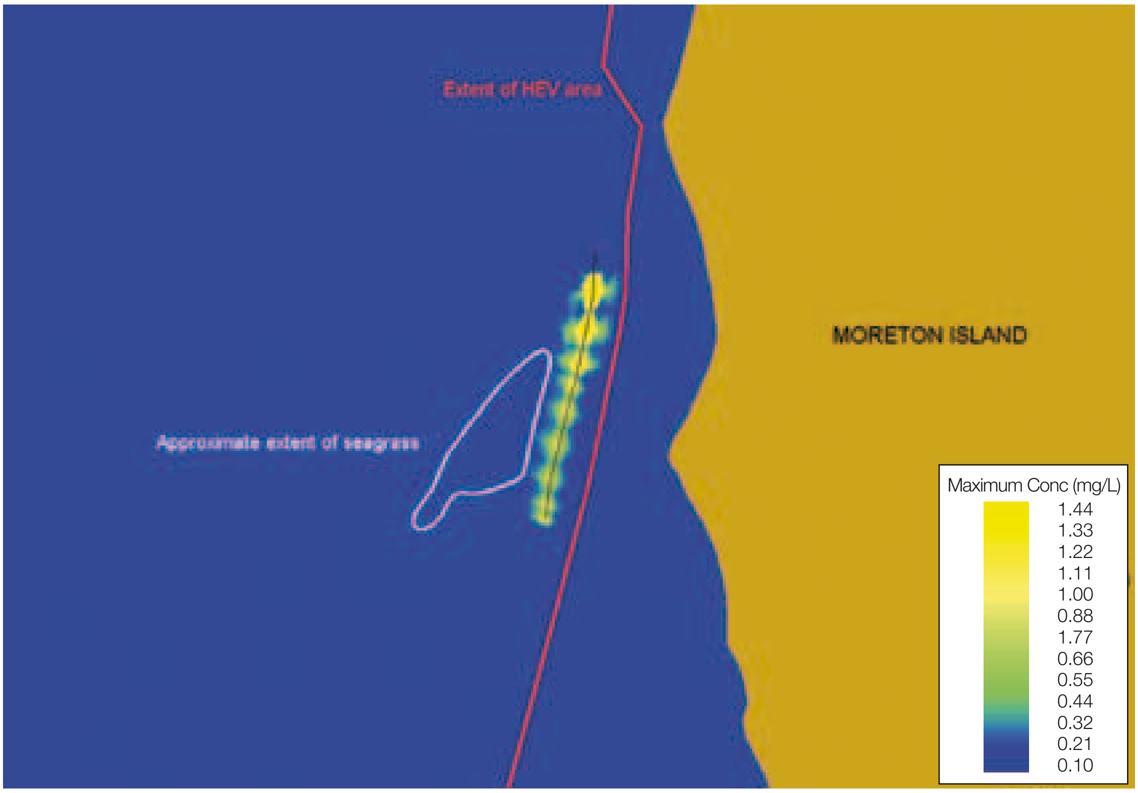


Figure 4.8k *Scenario 11 0.1 mm/s SV.*

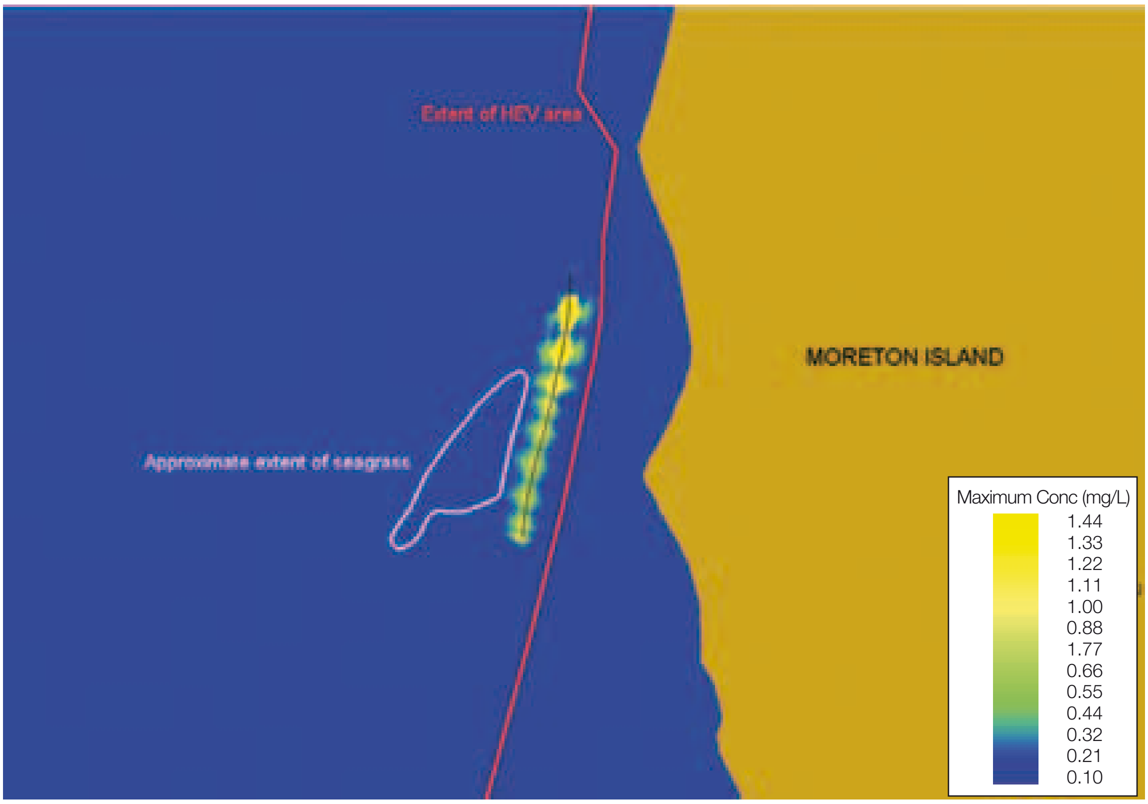


Figure 4.8l *Scenario 12 0.05 mm/s SV.*

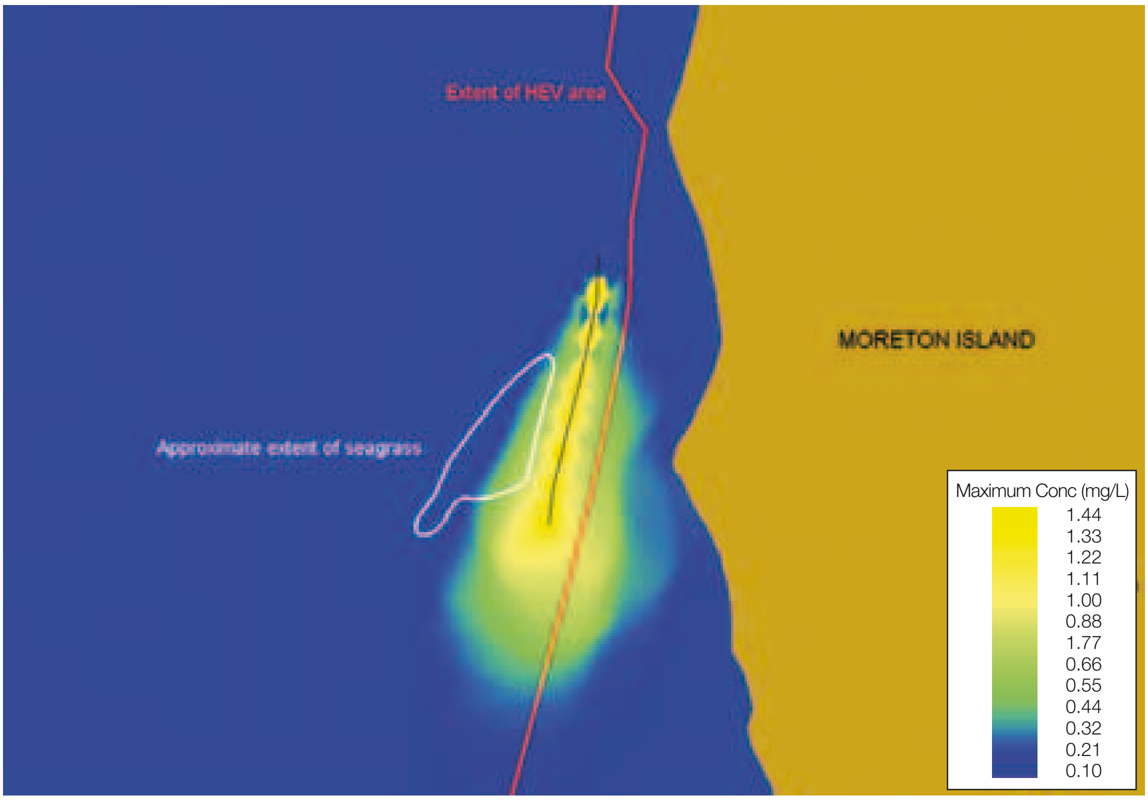
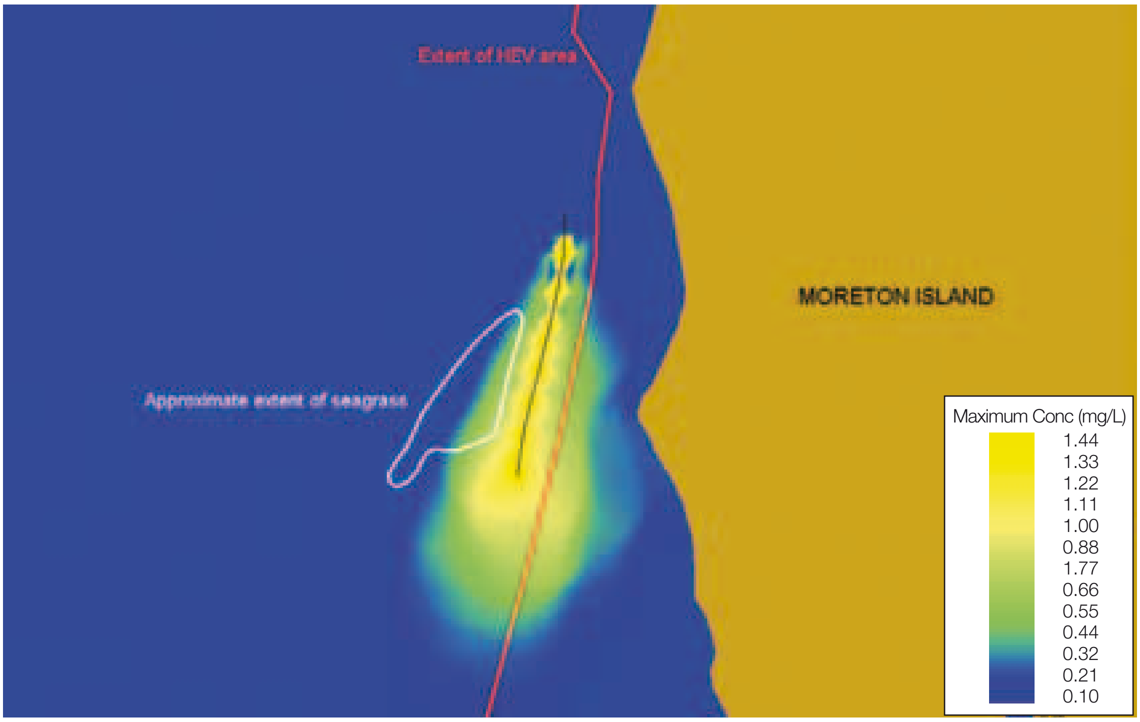


Figure 4.8m *Scenario 12 0.1 mm/s SV.*



These plume extent maps show almost imperceptible differences which indicates that the model is relatively insensitive to changes in settling velocity at these low values and hence would again suggest that the results obtained are a reasonably robust prediction of the likely plume extents at the dredging location.

4.9 Dredge Plume Impacts – Other Parameters

4.9.1 Introduction

While the dominant pollutant from dredging operations is likely to be the suspended solids as outlined above, the material being extracted also has the potential to contain nutrients and other contaminants within its porewaters. Sampling and analysis of those porewaters (refer to Chapter C2) indicated that total nitrogen and total phosphorus were present and detectable concentrations of toluene were also observed in some boreholes. As such, any consideration of potential impact must also consider the effect of nutrients generated by release of these porewaters into the surrounding environment. From the discussion of modelling methodology above, it can be seen that dilution of the porewaters within the hopper with water entrained during extraction will result in a large reduction in the concentrations of nutrients prior to discharge. As such, the modelling has shown that the extent of nutrient plumes are considerably smaller than that for total suspended solids due to the dilution effect noted above. The actual extent of the plumes are in **Figure 4.9a** and **Figure 4.9b**.

From the concentrations shown in the nutrient plume extent maps (which are actual concentrations, not above background concentrations), it can be seen that the overall maximum concentration range is very low, and is very close to the background values of 0.12 mg/L and 0.012 mg/L for TN and TP respectively (see **Figure 4.4c** and **Figure 4.4d**). These also show that, in comparison to suspended solids, the plume extent for nitrogen and phosphorus is constrained to the immediate area of dredging. As such, it is expected that the overall impact from dredging on nutrient concentrations within the vicinity of the Middle Banks, and for the whole of Eastern Moreton Bay, is insignificant.

Toluene was also detected in the porewaters of some of the borehole locations at Middle Banks (refer to Chapter C2). For the same reasons as given above for nutrients, the dilution effect within the hopper is such that the concentrations of toluene are reduced from a maximum of 0.27 mg/L in the porewater, to 0.021 mg/L being discharged from the dredge. Once vertically mixed, the concentrations of toluene then become negligible (<0.0001 mg/L) and are unable to be modeled with any degree of certainty.

Figure 4.9a *Total Nitrogen Plume Extent – Scenario 12.*

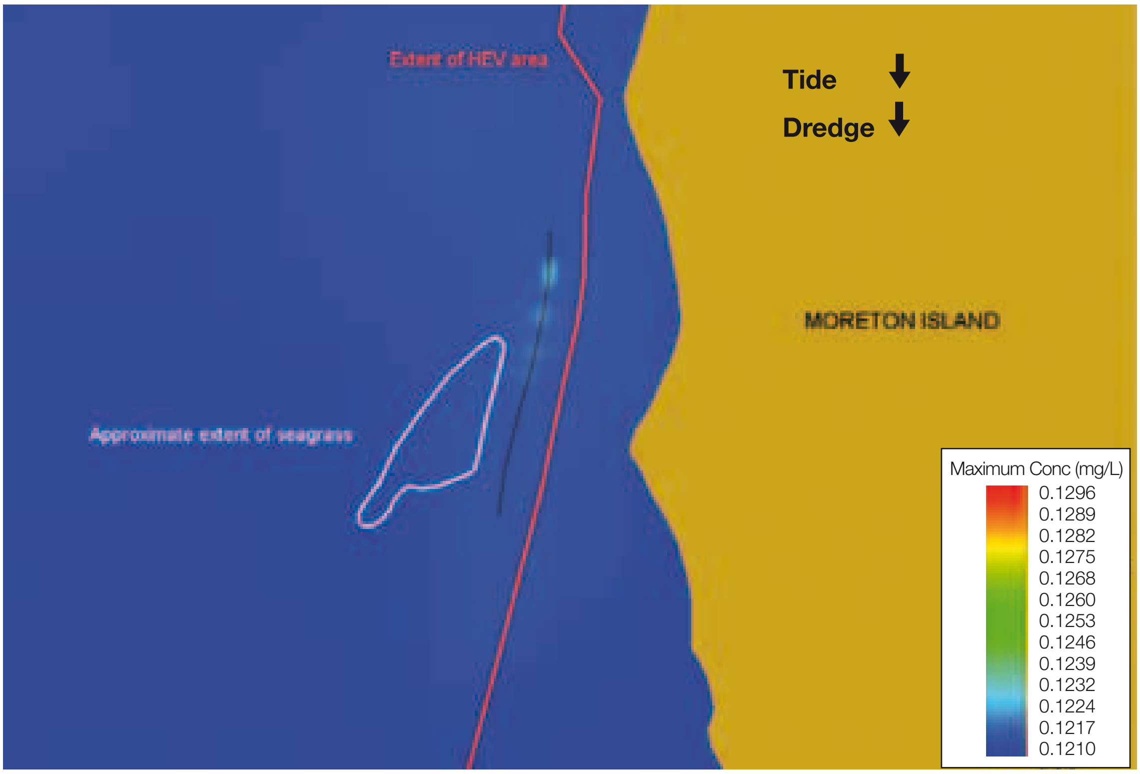
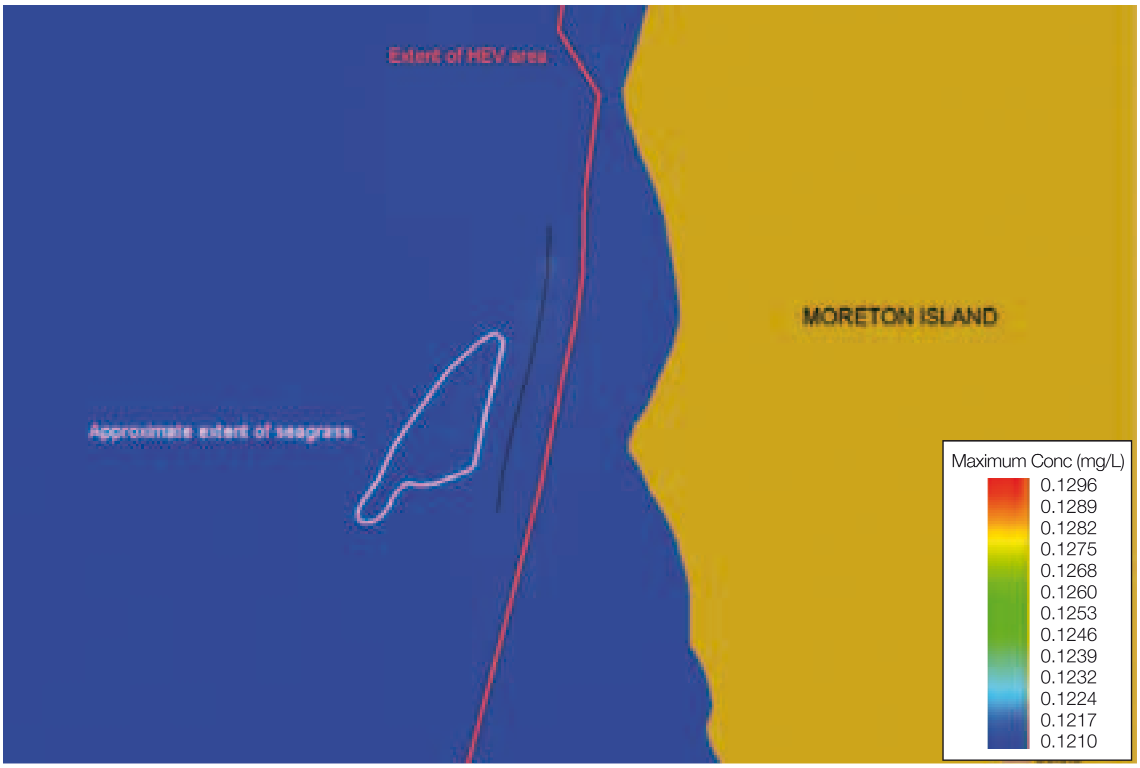


Figure 4.9b *Total Phosphorus Plume Extent – Scenario 12.*



4.9.2 Compliance with WQOs

Compliance with Water Quality Objectives is necessary for those locations outside of the High Ecological Value (HEV) area to demonstrate that the Environmental Values for the area are being met. The area immediately to the west of the HEV area is within the Moreton Bay sub-zone E2A and the Water Quality Objectives for this location are defined in Schedule 1 of the *Environmental Protection (Water) Policy 1997* under "Environmental Values and Water Quality Objectives for Waters of Moreton Bay and Bay Islands". To determine compliance with the WQOs, median values (50th percentiles) were obtained through extraction of model results at the locations immediately west of the dredging location, at sample points SG1-3. The results for all 12 dredging model scenarios were used to derive the 50th percentiles as being representative of the typical mix of tidal ranges to be found at the Middle Banks area. This approach was used rather than running the model over an extended time series as it was anticipated that this may not give the best indication of impacts if the full range of tidal scenarios were not considered. As such the 50th percentiles derived are indicative of the median values likely to be obtained through a full range of tidal cycles, rather than a median value over a certain time period. These results are shown in **Table 4.9a** to **Table 4.9c**, in addition to the relevant WQO.

Table 4.9a Total Nitrogen Compliance (mg/L).

	SG1	SG2	SG3
WQO	0.12	0.12	0.12
50%	0.12	0.12	0.12
max	0.12	0.12	0.12

Table 4.9b Total Phosphorus Compliance (mg/L)

	SG1	SG2	SG3
WQO	0.012	0.012	00.12
50%	0.012	0.012	0.012
max	0.012	0.012	0.012

Table 4.9c Total Suspended Solids Compliance (mg/L above background)

	SG1	SG2	SG3
WQO	No data available	No data available	No data available
50%	0.12	0.012	0.079
max	0.48	0.64	0.80

From these tables, it can be seen that both Nitrogen and Phosphorus concentrations show no variation (i.e. 50th percentiles compared to maximums using two significant figures) and are at the Water Quality Objective for each parameter as extracted at each of the sampling points. Once again, this would appear to indicate that there is likely to be negligible impact on nutrient concentrations in the Eastern Bay from dredging at Middle Banks based on the modelling undertaken. This is consistent with the EPA's Moreton Bay Sand Extraction Study – Phase 2 which states that only minimal effects are likely beyond the visible plume and may be minimal even within the zone of the visible plume (NIWA 2004).

The suspended solids results indicate that there may be a slight increase in concentrations at monitoring points SG1 – 3, at very low concentrations. The increases suggested by the modelling are not likely to be detectable via current monitoring techniques for suspended solids, which usually have detection limits between 1 - 5 mg/L. Of note though is that while suspended solids concentrations may be very low, it is still possible that an observable plume may be present due to increased turbidity associated with the fines from the material being extracted, though once again, the previous reports state that the turbidity plume post-dredging was within 10 percent of background levels within 40 m of the dredge (WBM 2002) and that a plume from a dredging pass 4 hours earlier was still visible, even though concentrations were effectively down to background levels (Willoughby and Crabb 1983).

4.9.3 Compliance within HEV Area

Demonstrating compliance in the HEV area has only recently been outlined comprehensively in the final release of the Queensland Water Quality Guidelines (March 2006) where it is recommended that compliance be assessed in terms of no change of 20th, 50th and 80th percentile concentrations for the parameter of concern. It should be noted that in the explanatory notes issued with the Environmental Protection (Water) Amendment Policy No. 1 2006 (being the policy that scheduled the Environmental Values and Water Quality Objectives of the Queensland Water Quality Guidelines), it is anticipated that the HEV areas are able to assimilate some minor transient impacts such as those associated with dredging.

For this assessment, all 12 dredging model scenarios were used to derive the 20th, 50th and 80th percentiles as being representative of the typical mix of tidal ranges to be found at the Middle Banks area. As such the percentiles derived are indicative of the values likely to be obtained through a full range of tidal cycles, rather than the percentile over a certain time period.

These results are shown in **Table 4.9d** to **Table 4.9f**. The concentrations to be maintained for these values are also given in Schedule 1 of the *Environmental Protection (Water) Policy 1997* under "Environmental Values and Water Quality Objectives for Waters of Moreton Bay and Bay Islands".

Table 4.9d Total Nitrogen Compliance (mg/L).

	HEV1	HEV2	HEV3
WQO 20%	0.10	0.10	0.10
20%	0.12	0.12	0.12
WQO 50%	0.12	0.12	0.12
50%	0.12	0.12	0.12
WQO 80%	0.16	0.16	0.16
80%	0.12	0.12	0.12
max	0.12	0.12	0.12

Table 4.9e Total Phosphorus Compliance (mg/L).

	HEV1	HEV2	HEV3
WQO 20%	0.009	0.009	0.009
20%	0.012	0.012	0.012
WQO 50%	0.012	0.012	0.012
50%	0.012	0.012	0.012
WQO 80%	0.016	0.016	0.016
80%	0.0121	0.0121	0.0121
max	0.0121	0.0121	0.0121

Table 4.9f Total Suspended Solids Compliance (mg/L above background).

	HEV1	HEV2	HEV3
WQO 20%	No data available	No data available	No data available
20%	0.076	0.001	0.003
WQO 50%	No data available	No data available	No data available
50%	0.11	0.032	0.067
WQO 80%	No data available	No data available	No data available
80%	0.18	0.10	0.16
max	0.33	0.43	0.73

The total nitrogen and total phosphorus results shown above are very similar to those presented for the monitoring locations HEV1 - 3, in that there is no appreciable variation in nutrient concentrations at these locations due to the dredging activities as shown by the outputs of the water quality model. While the 20th and 80th percentiles are different to the WQOs given in Schedule 1, this simply reflects that the water quality model does not contain the inherent natural variability in water quality expected at these sites but is based on the boundary, or forcing conditions of the model, one of which is ambient water quality. Hence the results suggest little, if any, variation in ambient water quality due to dredging activities and would likely be consistent with the 20th and 80th percentiles of the distribution of ambient concentrations at the monitoring locations.

For total suspended solids, as for locations SG1 - 3, the model predicts a small increase in concentrations within a portion of the HEV area for the duration of dredging, however this is likely to be undetectable by conventional monitoring due to the very low concentration change anticipated. As stated in the WQO compliance section above, it may be possible that an observable plume may be present within the HEV area even though concentrations are at background concentrations. This is consistent with the Water Amendment Policy Explanatory Notes as stated above, where it is expected that some short term impacts may be present, however they are likely to be transitory in nature and "are not considered to be detrimental to the maintenance of the values of adjacent high ecological waters and their long term natural physico-chemical and biological variability".

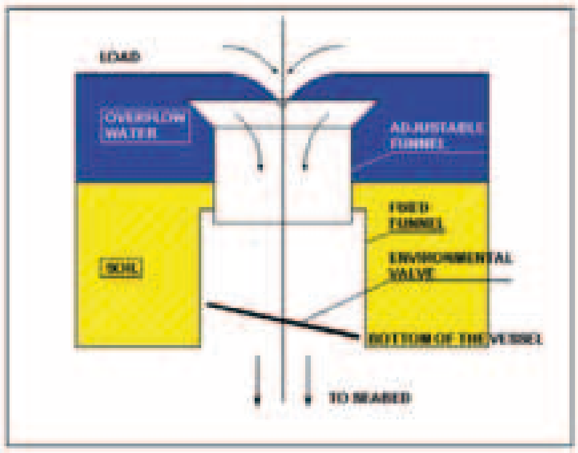
4.10 Cumulative and Interactive Effects

From this assessment, the modelling has shown that it is unlikely there will be cumulative effects from the dredging operations outside of the areas of actual dredging due to the plume from the previous dredge cycle reducing to concentrations indistinguishable from ambient concentrations for the parameters evaluated. Within the dredge footprint, it is likely that the heavier material will resettle close to the extraction point, possibly within 40 m (WBM 2002), or more conservatively within 100 m (Willoughby and Crabb 1983). It is anticipated that this would cover the bed to a depth of between 10 - 25 mm (Willoughby and Crabb 1983) within this zone, though this will be dependent on the final size of dredge used, quantity extracted per run and the amount of material actually discharged while the hopper is filling. It is therefore expected that impacts to seagrass beds beyond the zone of active dredging (i.e. beyond those at Middle Banks) are likely to be negligible.

4.11 Mitigation Measures

It is obvious from the plume extent plots that the direction of travel of the dredge relative to the prevailing tide has a noticeable influence on the extent of the plume and concentrations within it, however there are competing objectives of minimising both the extent of the plume (which would require the dredge to travel against the prevailing tide) and the duration of the plume over any one point (which would require the dredge to travel with the prevailing tide). As such, and given the very low concentrations of suspended solids, nitrogen and phosphorus likely to be present as suggested by the modelling, changing the direction of the dredge dependent upon the prevailing tide direction is not considered necessary. To further reduce possible effects of the dredge plume, large trailer suction hopper dredges can be fitted with an environmental valve.

Figure 4.11 *Conceptual Diagram Showing Operation of the Environmental Valve in a Dredger.*



As shown in **Figure 4.11**, the environmental or ‘green’ valve is an adjustable valve that chokes the flow in such a way, that no air is taken down with process water leaving the hopper. The result is a density stream, causing a minimum of turbulence, taking the excessive material back to the sea bottom and significantly reducing turbidity plumes. Use of a green valve will be further investigated as part of the tendering process for a dredge vessel following completion of the EIS/MDP process.

4.12 Residual Effects

On the completion of all dredging at Middle Banks, it is expected, based on the modelling results, that concentrations of total suspended solids, total nitrogen and total phosphorus would all return to ambient concentrations within a very short time (approximately 1 dredge cycle). It may be possible that some fine material deposited on the bed may be redisturbed by tidal currents in the future, however given the low concentrations anticipated from the dredge plume, it is considered unlikely that these would be detectable.

4.13 Assessment Summary Matrix

Based on the above assessments, a summary of potential impacts is provided in the following matrix.

Table 4.13 Water Quality Assessment Summary Matrix.

EIS/MDP Area: Water Quality Feature/ description	Current Value + Substitutable Y:N	Description of Impact			Additional Compensation (beyond standard practice)	Residual Impact
		Impact	Mitigation inherent in design/standard practice amelioration	Significance Criteria		
Moreton Bay water quality	Impacts would affect other parts of Moreton Bay. Not substitutable	Water quality within the defined High Ecological Areas of Moreton Bay are temporarily impacted such that the scheduled Environmental Values and Water Quality Objectives cannot be achieved during the dredging process even with mitigation measures but will be achieved post dredging.	Dredge footprint avoids direct impacts on areas of seagrass and HEV area. Turbidity plumes from the dredge may occur in these area depending on the position of the dredge in the footprint and wind and wave conditions but will be temporary and at very low concentrations. Dredge vessel may be fitted with a green valve to further reduce turbidity impacts from hopper overflow.	Minor to Negligible -ve, D, T	Nil	Minor to Negligible-ve, D, T

Key:

Significance Criteria:
Major, High, Moderate, Minor Negligible

+ve positive; **-ve** negative
D – direct; **I** – indirect
C – cumulative; **P** – permanent; **T** – temporary

ST – short term; **MT** – medium term;
LT long term

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