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Gladstone Ports Corporation

Report for Western Basin Dredging and Disposal Project

Coastal Processes Assessment

September 2009

INFRASTRUCTURE | MINING & INDUSTRY | DEFENCE | PROPERTY & BUILDINGS | ENVIRONMENT

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1. Introduction

The Fisherman's Landing area is located on the western side of the northern end of the estuary known as Port Curtis around 10km north-west of the centre of Gladstone. The proposed Western Basin reclamation is immediately adjacent to the existing Fisherman's Landing reclamation and proposed Fisherman's Landing Northern Expansion (FLNE). The development of the Western Basin will incorporate dredging associated with the deepening and widening of existing channels and swing basins, and the creation of new channels, swing basins, and berth pockets. The location of the proposed Western Basin Dredging Stages and Western Basin Reclamation is shown on Figure 2-1.

In this report the terms Western Basin and Project Area have been used to describe particular areas of interest. These terms are defined as follows:

Western Basin: The area in Gladstone harbour generally to the north and west of the existing Fisherman's Landing reclamation. The area includes the FLNE, the proposed Western Basin reclamation area, the embayment to the north of the proposed reclamation, and the proposed dredged channels to the east of the reclamation. The entrance to The Narrows between Friend Point and Laird Point forms the northern boundary to the Western Basin area.

Project Area: The area of Gladstone Harbour from the Clinton Swing Basin to the entrance to The Narrows.

1.1 Purpose and Scope of this Report

The purpose and scope of this report is drawn from those parts of the Terms of Reference for the EIS that relate to coastal processes.

The purpose of the report is to:

- » Describe the physical coastal processes operating at the site;
- » Describe the changes to the physical coastal processes as a result of the Project;
- » Assess the effects of changes to the tidal hydrodynamics on the physical coastal environment;
- » Describe the wave climate in the vicinity of the Project area including a description of inter-annual variability and details of predicted extreme wave conditions generated by tropical cyclones or other severe storm events;
- » Discuss the impacts on siltation, particularly in terms of maintenance dredging requirements;
- » Assess the effects of changes to the propagation of storm surge on the physical coastal environment; and
- » Describe any measures that might be considered to mitigate against detrimental effects on coastal resources and processes.

Related matters that are included in the Terms of Reference but have not been addressed, or have not been addressed in detail, in this report, are covered elsewhere in the EIS as indicated below:

- » Storm surges and sea level rise - Chapter 4 (Climate and Climate Change);
- » The flushing efficiency is discussed in Chapter 7 (Coastal Environment);

- The relationship of physical processes to marine flora and fauna and biological processes within the study area - Chapter 9 (Nature Conservation);
- Acid Sulphate Soils - Chapter 7 (Coastal Environment);
- The role of buffer zones in sustaining fisheries resources through maintaining connectivity between coastal and riparian vegetation and estuarine and freshwater reaches of catchments - Chapter 9 (Nature Conservation).
- Hydrology – Chapter 8 (Water Resources);
- Sediment quality – Chapter 7 (Coastal Environment);
- Water quality – Chapter 7 (Coastal Environment);
- Dredge spoil plumes – Chapter 7 (Coastal Environment) and Chapter 6 (Hydrodynamic Modelling); and
- Statutory requirements for the proposed works – Chapter 1 (Introduction).

2. Methodology

2.1 Overview

The assessment methodology involves an investigation of the existing physical coastal processes and hydrodynamics in the vicinity of the proposed reclamation and associated dredging and an examination of the effects of the reclamation and dredging on those processes. For the assessment, extensive use is made of the results from the numerical modelling carried out by WBM (WBM 2009b). The modelling included the hydrodynamics of Gladstone Harbour, ambient and extreme waves, sedimentation, and plume flushing. Through this assessment, potential impacts on coastal processes are identified and comments provided on the need for mitigation measures. The Numerical Modelling Report prepared by WBM is located in Appendix J of the main EIS.

2.2 Data Extraction Points

This report makes use of the data extraction points at which results from the numerical modelling have been made available. The available points are listed in Table 2-1 Subsets of these points have been used in this report to assess the impact of the proposed development on particular parameters or locations and these are also listed in Table 2-1

Table 2-1 Data Extraction Points

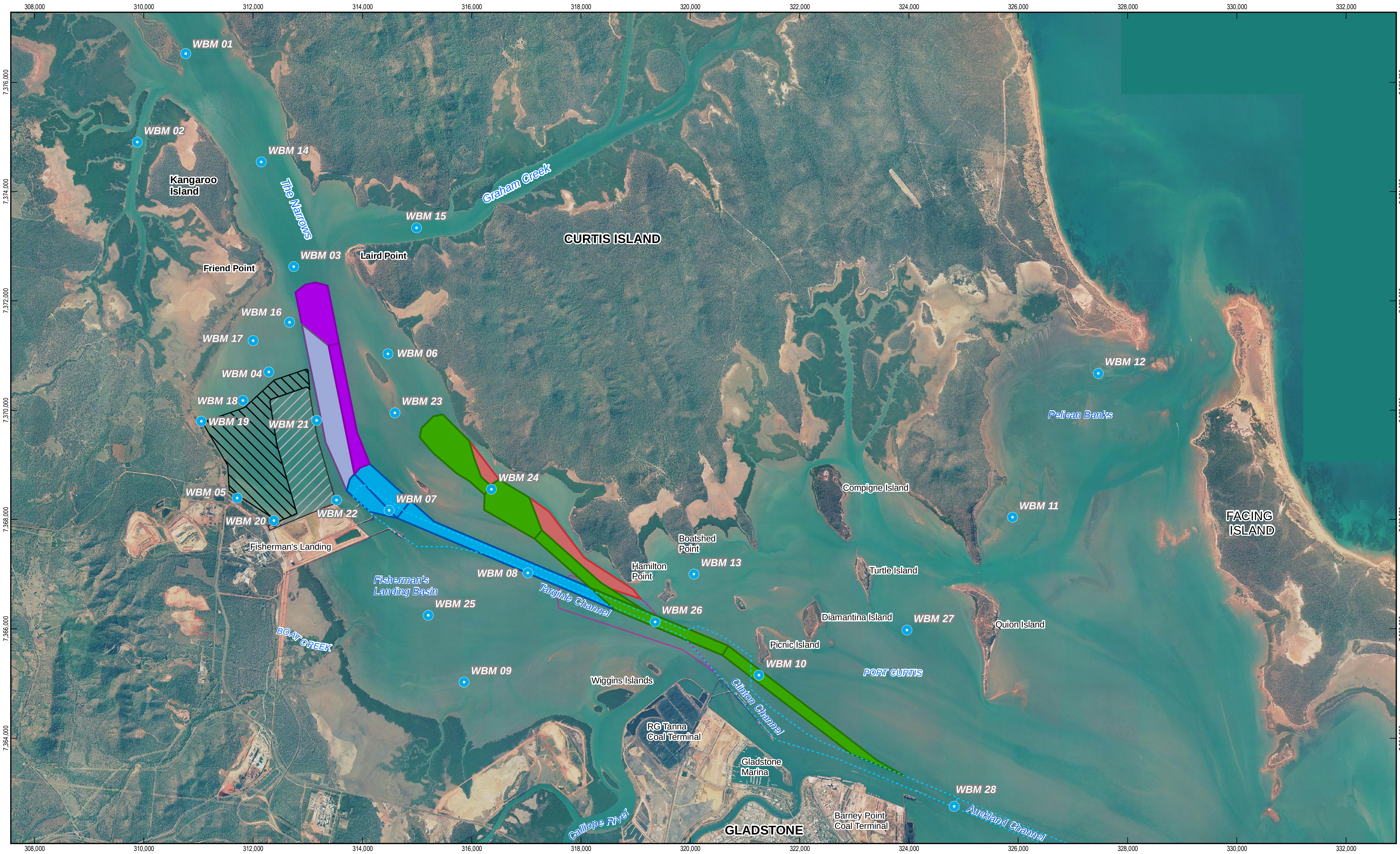
Data Point	Short Description	Detailed Description	Water Levels and Tidal Currents[1]	Wave Climate[2]	Reclam-ation[3]
WBM01	Black Swan Island	Adjacent to southern end of Black Swan Island in The Narrows	√		
WBM02	Kangaroo Island Creek	In creek west of Kangaroo Island	√		
WBM03	Entrance to Narrows	Southern entrance to The Narrows between Laird Point on the Curtis Island and Friend Point on the mainland.	√	√	
WBM04	Western Basin	In the undeveloped part of the Western Basin adjacent to the northern boundary of the proposed reclamation.	√	√	√
WBM05	Mid Western Channel	Half-way along tidal channel between reclamation and western shoreline	√		√

Data Point	Short Description	Detailed Description	Water Levels and Tidal Currents[1]	Wave Climate[2]	Reclam-ation[3]
WBM06	North Passage Island	Directly east of the northern extremity of the proposed reclamation in the channel between North Passage Island and Curtis Island.	√	√	
WBM07	Fisherman's Landing Berths	Adjacent to the existing berths in an easterly direction	√	√	
WBM08	Targinie Channel	Half-way along Targinie Channel	√		
WBM09	Tidal Flats West of Wiggins Island	Southern end of bay between Wiggins Island and Fisherman's Island	√		
WBM10	Clinton Bypass Channel	Adjacent to the existing Clinton Swing Basin	√		
WBM11	Tail Point	North-east of Tail Point at southern end of Curtis Island	√		
WBM12	South End	South-west of South End township on Curtis Island	√		
WBM13	Boatshed Point	Directly south of Boatshed Point on Curtis Island	√		
WBM14	Kangaroo Island	In The Narrows opposite Kangaroo Island	√		
WBM15	Graham Creek	East of where Graham Creek enters The Narrows	√		
WBM16	North East Western Basin	North-eastern edge of Western Basin embayment	√	√	√
WBM17	North Western Basin	Northern end of embayment north of reclamation	√		√
WBM18	West Western Basin	Adjacent to northern extent of reclamation	√		√
WBM19	North Western Channel	Entrance to tidal channel between the reclamation and western shoreline	√		√

Data Point	Short Description	Detailed Description	Water Levels and Tidal Currents[1]	Wave Climate[2]	Reclam-ation[3]
WBM20	South Western Channel	Southern end of tidal channel between the reclamation and western shoreline	√		√
WBM21	Eastern Edge of Reclamation	Half way along the eastern edge of the reclamation footprint	√	√	
WBM22	Fisherman's Landing Reclamation	Northern Corner Fisherman's Landing Reclamation	√		
WBM23	Mid Passage Islands	Between North and South Passage Islands	√		
WBM24	China Bay	Directly east of Fisherman's Landing in the channel between the Passage Islands and Curtis Island	√	√	
WBM25	Tidal Flats opp Boat Creek	On the tidal flats east of the entrance to Boat Creek south of Fisherman's Landing	√		
WBM26	Wiggins Island Channel	In channel opposite Wiggins Island	√		
WBM27	Turtle Island Reef	South of Turtle Island and West of Quoin Island	√		
WBM28	Barney Point	In channel south-east of Barney Point	√		

1. Points used in the assessment of impact on water levels and tidal currents
2. Points used in the assessment of the impacts on wave climate
3. Points used in the assessment of the impact of the reclamation and dredging scenarios on the area immediately north and west of the reclamation.

The location of all of the above points is shown on Figure 2-1 which also includes an outline of the dredging scenarios and the proposed reclamation area



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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 56

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LEGEND

- Output Location
- Stage 1A - North China Bay LNG
- Stage 1B - Fisherman's Landing LNG
- Stage 2 - Laird Point LNG
- Stage 3 - Fisherman's Landing
- Stage 4 - Hamilton Point
- Western Basin Reclamation Area
- Fisherman's Landing Northern Expansion
- Existing Channels, Swing Basins and Berths
- Wiggins Island Coal Terminal (Approved)

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Port of Gladstone
Western Basin Dredging and Disposal Project

Job Number 42-15386
Revision A
Date 30 Aug 2009

Data Extraction Points from Numerical Model

Figure 2-1

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3. Existing Conditions

3.1 Description of Existing Physical Processes

The physical processes of the adjacent marine environment are predominantly characterised by tidal flows with effects from locally generated waves and storm events which can cause extreme waves and elevated water levels (storm surge).

Surface sediments range from unconsolidated silts and clays in the shallow tidal flats north and west of the reclamation area to coarse sands and gravel in the deeper areas. The processes that transport sediment around the area are dominated by tidal currents driven by the relatively large spring tides, coupled with a mild wave climate that stirs up sediments in the shallower areas at times of low tide. Important but infrequent drivers are extreme events like cyclones which can generate high waves and water levels that can have major effects on the environment and affect areas that would not normally be affected under prevailing conditions.

3.1.1 Tides

The characteristics of the tides in Gladstone Harbour in terms of the standard tidal planes are described in the Tidal Hydraulics section of the Numerical Modelling Report (WBM 2009b). Due to amplification of the tidal wave as it propagates up the estuary, the tidal planes at Fisherman's Landing are higher than at Auckland Point. For example, the HAT level at Auckland Point is 2.42m AHD and at Fisherman's Landing it is 2.54m AHD. Tidal planes for both locations are detailed in Table 3-1.

The tidal times, heights, and planes used for this study are those published by Maritime Safety Queensland (MSQ) for the Standard Port of Gladstone harbour at Auckland Point in their publication of the 2009 Tide tables (MSQ 2008) and as provided by MSQ directly for Fisherman's Landing. It should be noted that MSQ have now published updated tidal planes for Standard Ports and Secondary Places in Queensland based on recent measurements and updates for the current Tidal Epoch 1992-2011 (MSQ 2009) which show that while the mean tidal ranges are similar to the previous analysis, the absolute values including that of HAT have increased. However, as the numerical modelling simulations carried out for this study are based on measured data (which are compatible with the new tidal planes), the assessments derived from the modelling are considered to be up to date and unaffected by this new information.

Table 3-1 Gladstone Region Tidal Planes

Tidal Plane	Gladstone (Auckland Point)		Fisherman's Landing	
	m LAT	m AHD	m LAT	m AHD
Highest Astronomical Tide (HAT)	4.69	2.42	4.97	2.54
Mean High Water Springs (MHWS)	3.91	1.64	4.14	1.71
Mean High Water Neaps (MHWN)	3.06	0.79	3.24	0.81
Mean Level (ML)	2.35	0.08	2.44	0.01
Australian Height Datum (AHD)	2.268	0.0	2.429	0.0
Mean Low Water Neaps (MLWN)	1.52	-0.75	1.61	-0.82
Mean Low Water Springs (MLWS)	0.67	-1.6	0.71	-1.72
Lowest Astronomical Tide (LAT)	0.0	-2.27	0.0	-2.43
Port Datum (PD)	0.0	-2.268	0.0	-2.43

Gladstone Harbour is located in the Port Curtis estuary that experiences large tides with ranges up to almost 5 metres. The tide propagates into the estuary through the wide opening between Facing Island and the mainland to the south, the narrow channel between Curtis Island and Facing Island to the east, and through The Narrows, the waterway separating Curtis Island from the mainland in the north.

These large tides generate strong tidal currents up to 1.5m/s in the main channels and up to 0.35m/s on the shallower areas of the estuary. Tides in this area go through a neap-spring cycle over a period of approximately 14 days, with ranges of around 4m at the spring and 1m during the neap (Connell Hatch 2006). The estuary has extensive intertidal banks, mangrove, and saltpan areas that are inundated to various degrees depending on the tidal range. These changes to the available storage areas with tide height mean that the relationship between tidal velocities, the rate of rise and fall of the water level, and the tide range is non-linear, particularly for tides of large range.

The large tide range and associated high tidal currents means that the estuary waters are well mixed with only minor variation in density of dissolved or suspended material through the water column.

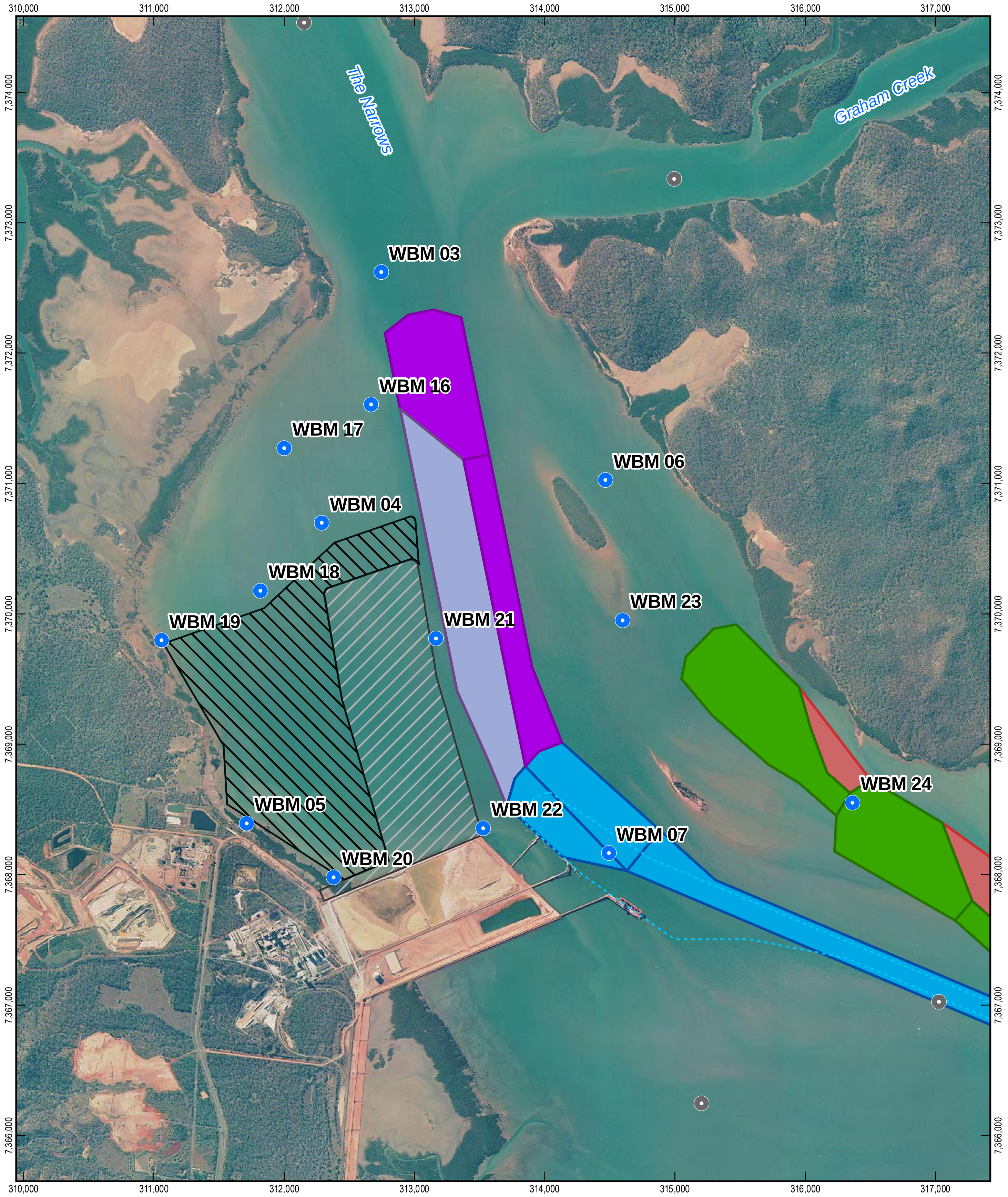
The tidal hydrodynamics have been modelled by WBM for this study and the results for the base case (representing existing conditions) and the developed scenarios are provided in Appendix J of the main

EIS. The model results and the impact of the proposed development are discussed in Section 4 of this report.

Selected results for a number of locations in the vicinity of the Western Basin for the base case for water level and tidal currents are presented in Figure 3-2. The locations of the points at which the results were extracted are shown on Figure 3-1. The results presented are over a two month period in February / March 2009 and includes four spring tides and four neap tides. The modelled period was chosen by WBM to coincide with the data acquisition campaign for this EIS.

Tidal currents vary from a maximum of 1.0 m/s at Fisherman's Landing berths, China Bay, and the Entrance to The Narrows, to 0.9 m/s at North Passage Island (all of which are in the tidal stream leading up to The Narrows), to 0.35 m/s in the Western Basin where it is more sheltered and much shallower. Higher tidal currents up to 1.5m/s occur in the main channels downstream of the Western Basin.

Water levels at each of the points are very similar with maximum levels of 2.8m AHD in the second spring tidal cycle and minimum levels of -2.3m AHD in the first spring tidal cycle.



LEGEND

- Results Extraction Points - Western Basin
- Western Basin Reclamation Area
- Fisherman's Landing Northern Expansion
- Stage 1A - North China Bay LNG
- Stage 1B - Fisherman's Landing LNG
- Stage 2 - Laird Point LNG
- Stage 3 - Fisherman's Landing
- Stage 4 - Hamilton Point
- Existing Channels, Swing Basins and Berths

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Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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Western Basin Dredging and Disposal Project

Results Extraction Points - Project Area

Job Number	42-15386
Revision	A
Date	01 Sept 2009

Figure 3-1

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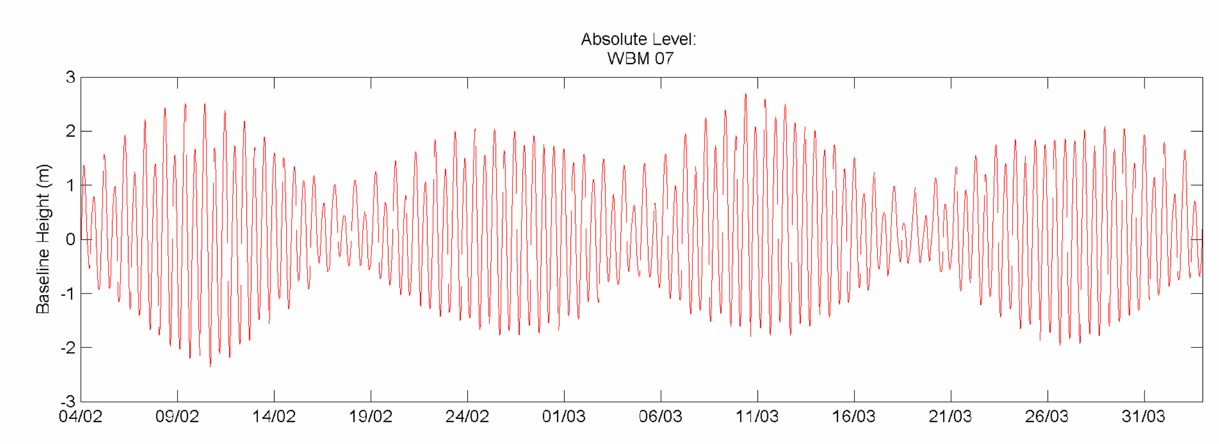
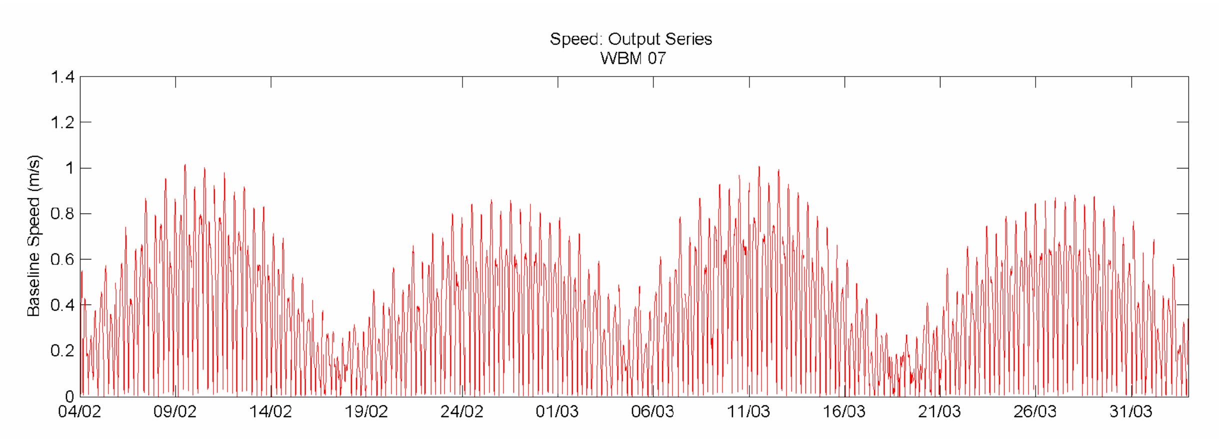
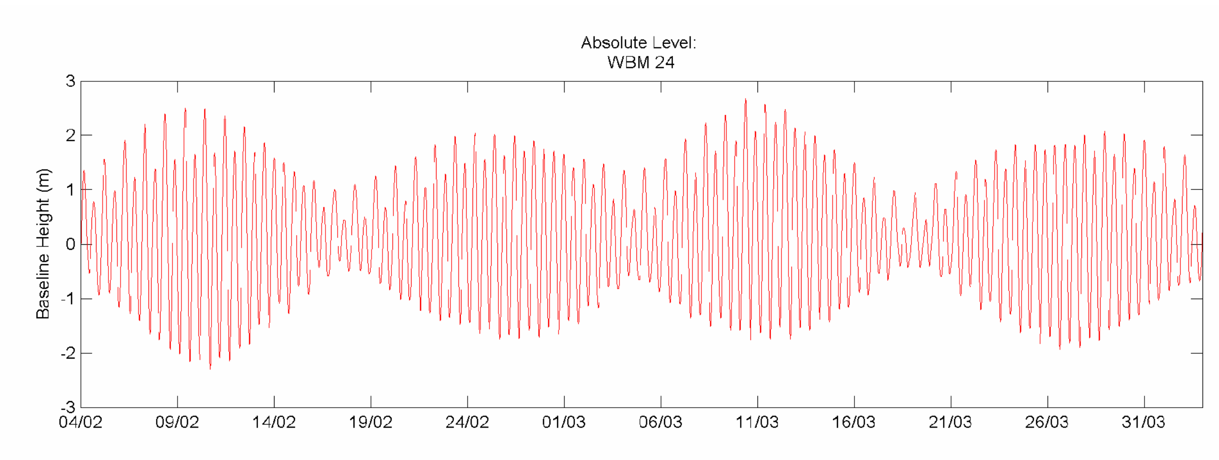
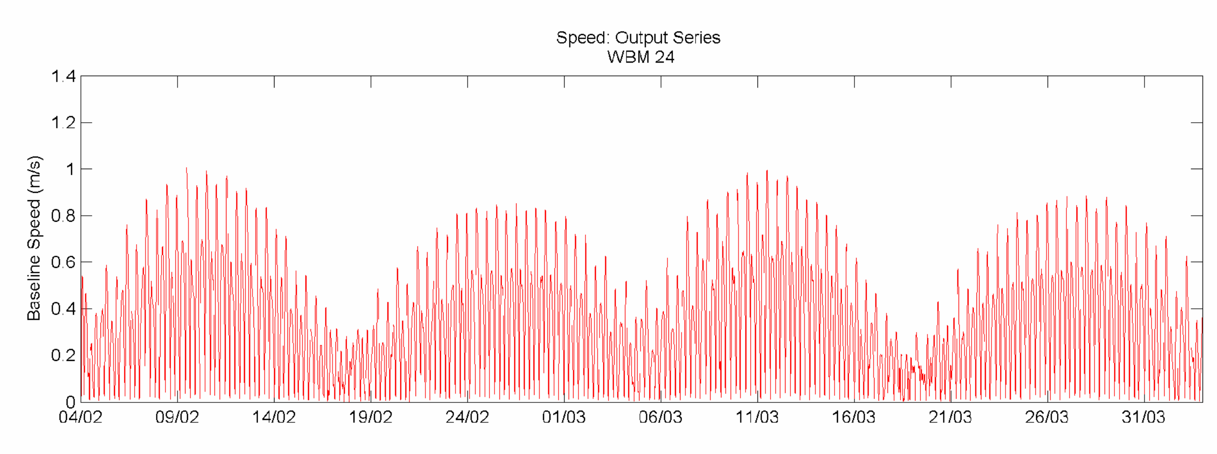
WBM07 – Fisherman's Landing Berths



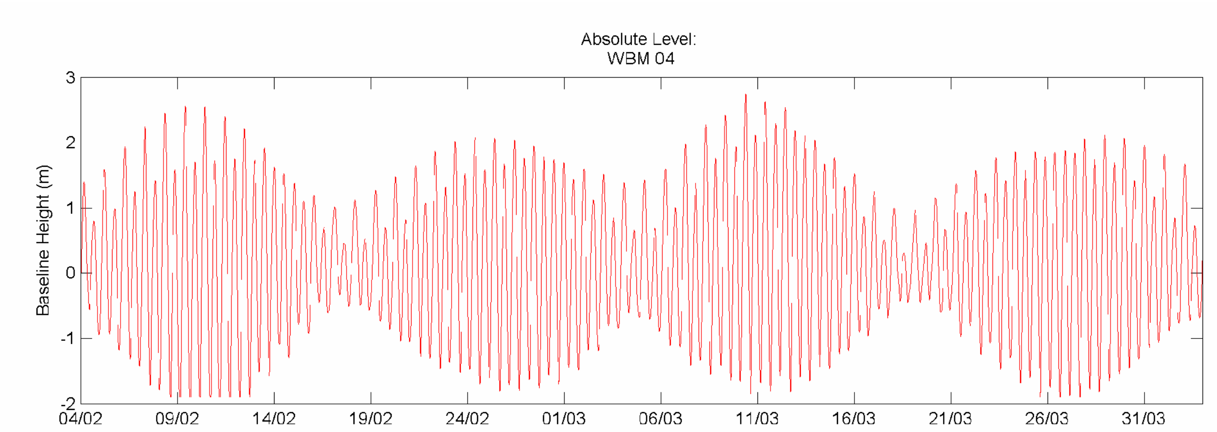


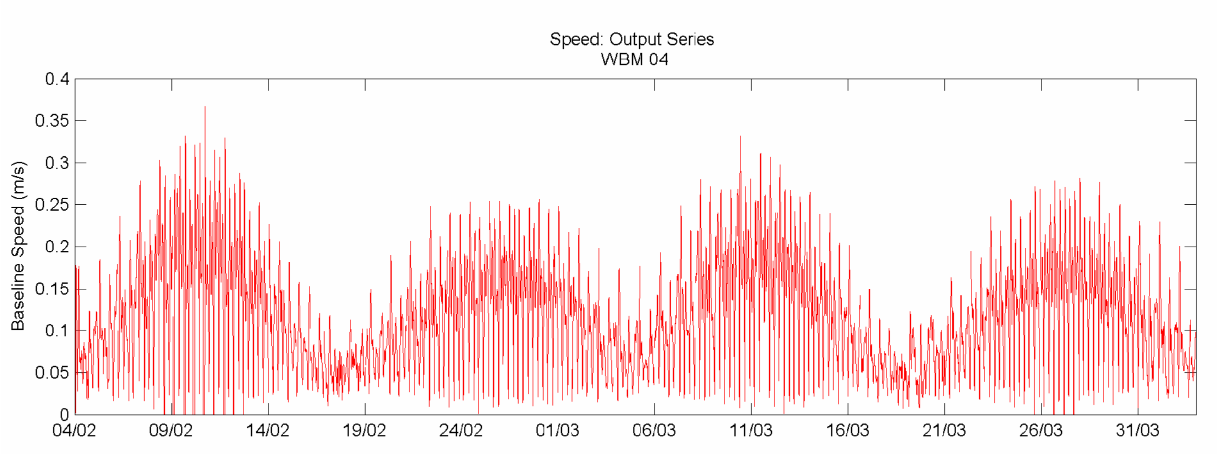
WBM24 – China Bay



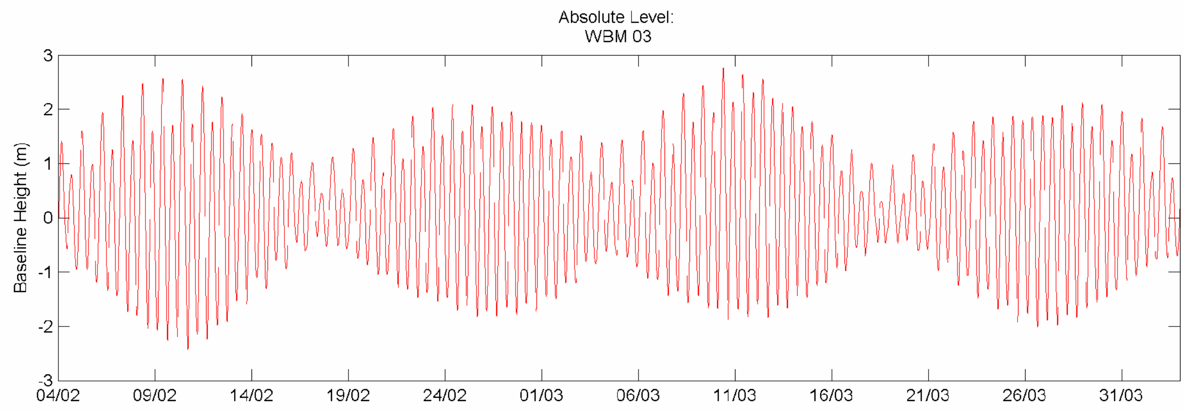


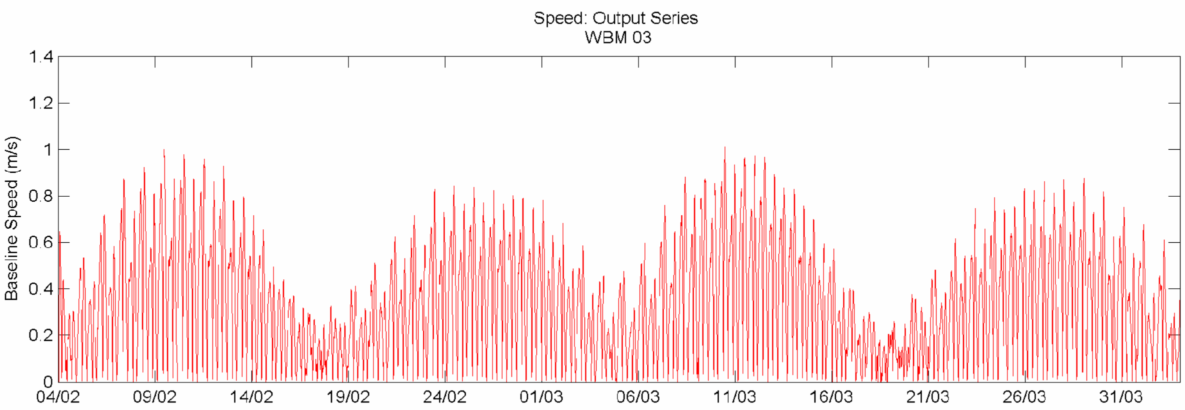
WBM04 – Western Basin



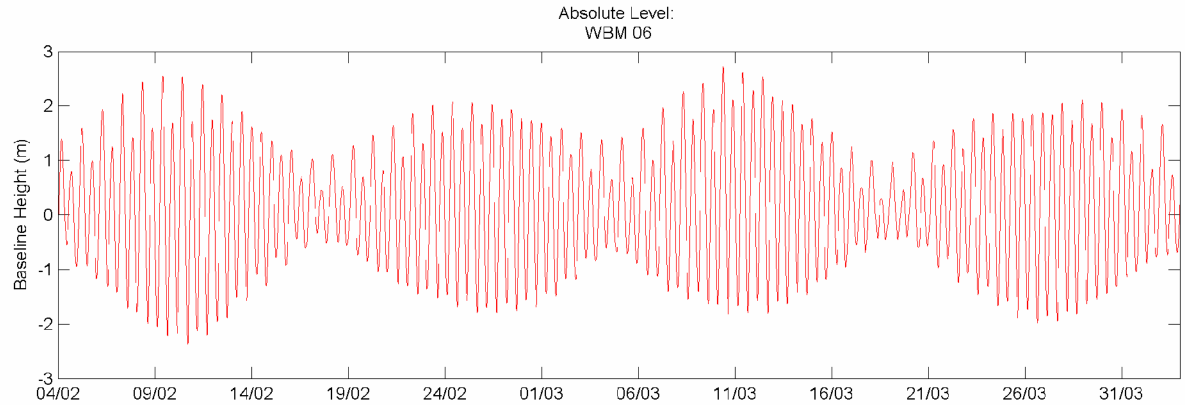


WBM03 – Entrance to Narrows





WBM06 – North Passage Island



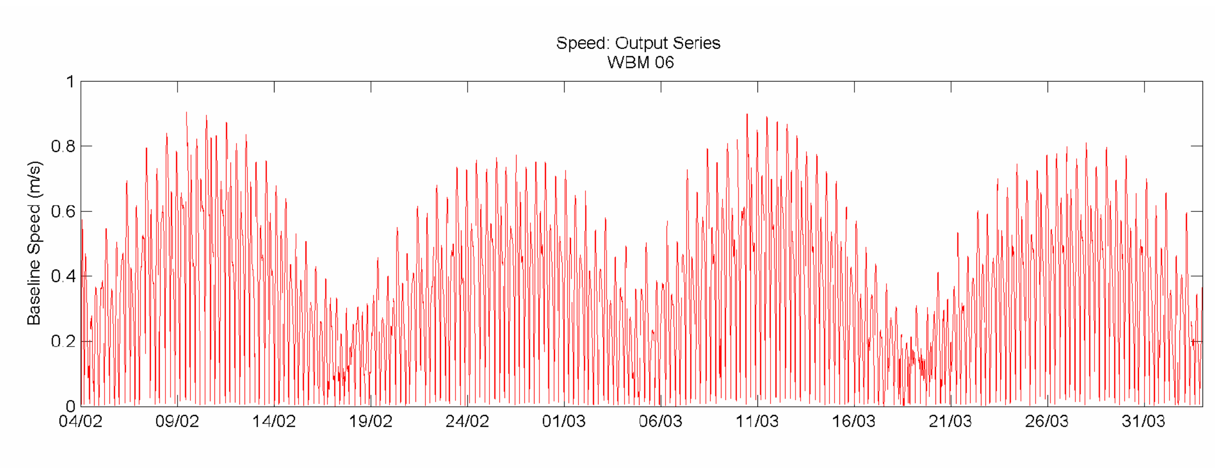


Figure 3-2 Water Level and Tidal Current Plots – Base Case

3.1.2 Wave Climate

The site is protected from ocean-generated sea and swell waves by Curtis and Facing Islands to the east and hence the wave action at the site is relatively mild although there is a substantial fetch for the generation of waves to the east south-east. The site is subject to locally generated seas waves under the influence of local wind conditions and to higher waves, principally from the east south-east, during cyclonic conditions.

Details of the wind climate in Gladstone Harbour are discussed in detail in Chapter 4 of the main EIS. Wind roses showing the average annual wind speed and direction for 9am and 3pm observations at Gladstone airport are shown in Figure 3-3 [1].

[1] Prepared by National Climate Centre of the Bureau of Meteorology 31 July 2008. Copyright © Commonwealth of Australia 2008

Observation period: 26 October 1993 to 30 June 2008

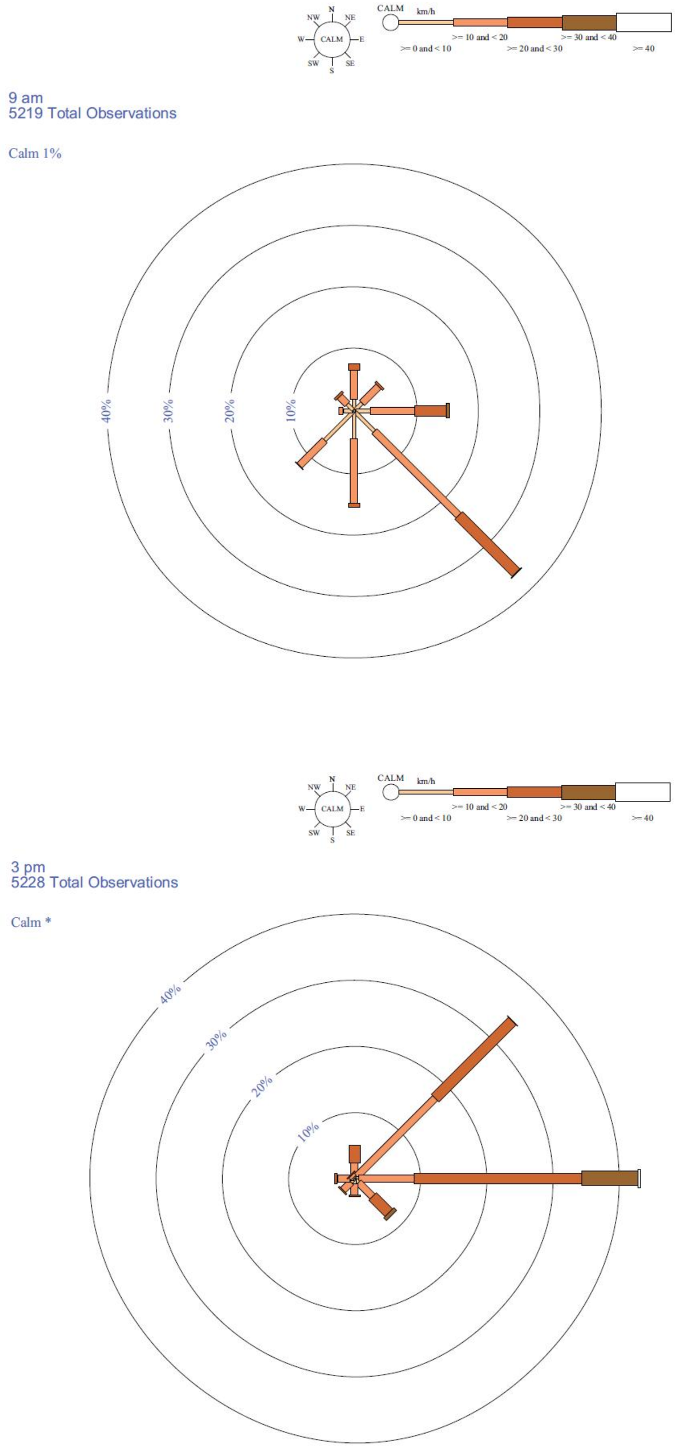


Figure 3-3 Wind Roses for Gladstone Airport – 9am and 3pm

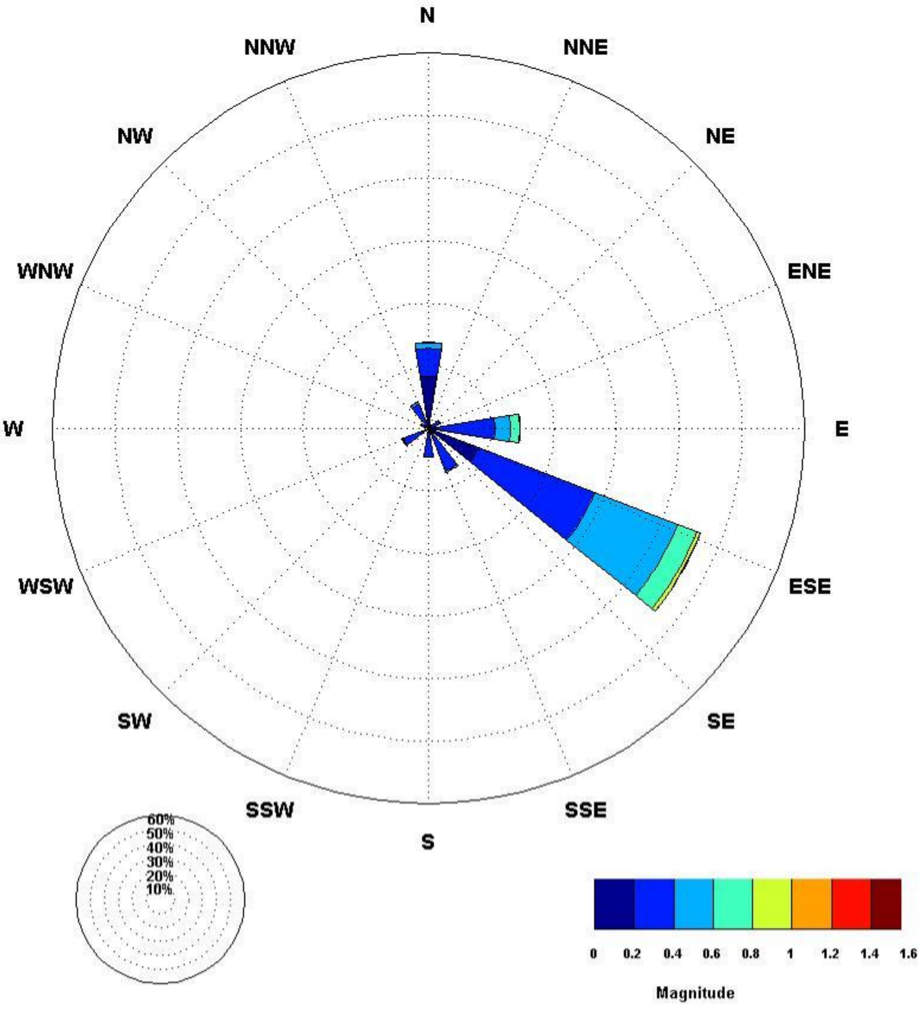
The wave climate is characterised by a predominance of south-easterly wind in the morning swinging to the east and north-east in the afternoon. However, the south-easterly winds in the morning are not as strong (20-30 km/hr for 10% of time) as the easterly winds in the afternoon (30-40 km/hr for 10% of time).

In addition, easterly winds in the afternoon at 20-30 km/hr occur for a further 25% of time. Wave height modelling for these conditions shows that the maximum wave height would rarely exceed 0.5m from any direction as illustrated in Figure 3-4 containing wave roses for a six locations in the vicinity of the Western Basin site. These results have been derived from the wave modelling by WBM and are discussed in detail in Section 4.2 of this report. The locations where the results of the wave modelling have been extracted are shown on Figure 3-1 and are listed in Table 3-2 below with a short description for reference.

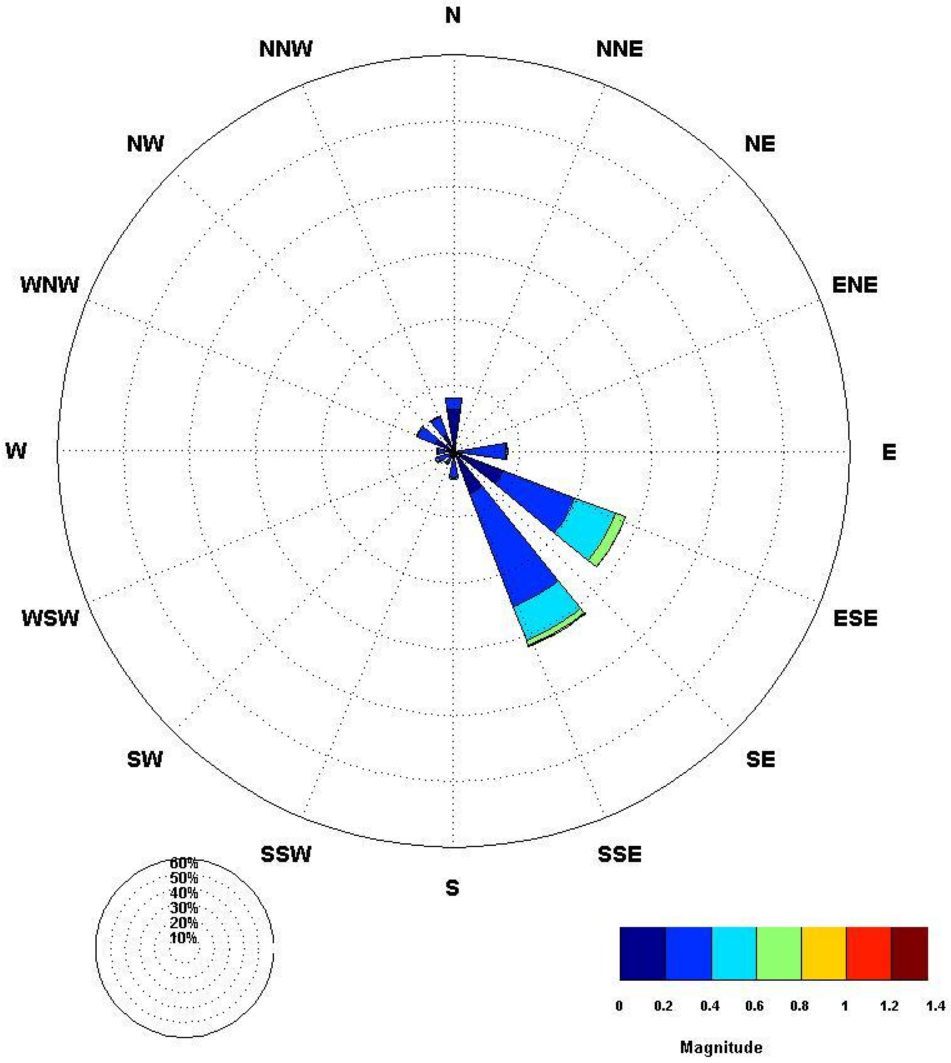
Table 3-2 Points of Interest for Wave Modelling

Point of Interest	Description	Notes
WBM07	Fisherman's Landing Berths	Adjacent to the existing berths in an easterly direction
WBM21	Eastern Edge of Reclamation	Half way along the eastern edge of the reclamation footprint
WBM24	China Bay	Directly east of Fisherman's Landing in the channel between the Passage Islands and Curtis Island.
WBM04	Western Basin	In the undeveloped part of the Western Basin adjacent to the northern boundary of the proposed reclamation.
WBM16	Western Basin North	North-eastern edge of Western Basin embayment
WBM03	Entrance to Narrows	Southern entrance to The Narrows between Laird Point on the Curtis Island and Friend Point on the mainland.
WBM06	North Passage Island	Directly east of the northern extremity of the proposed reclamation in the channel between North Passage Island and Curtis Island.

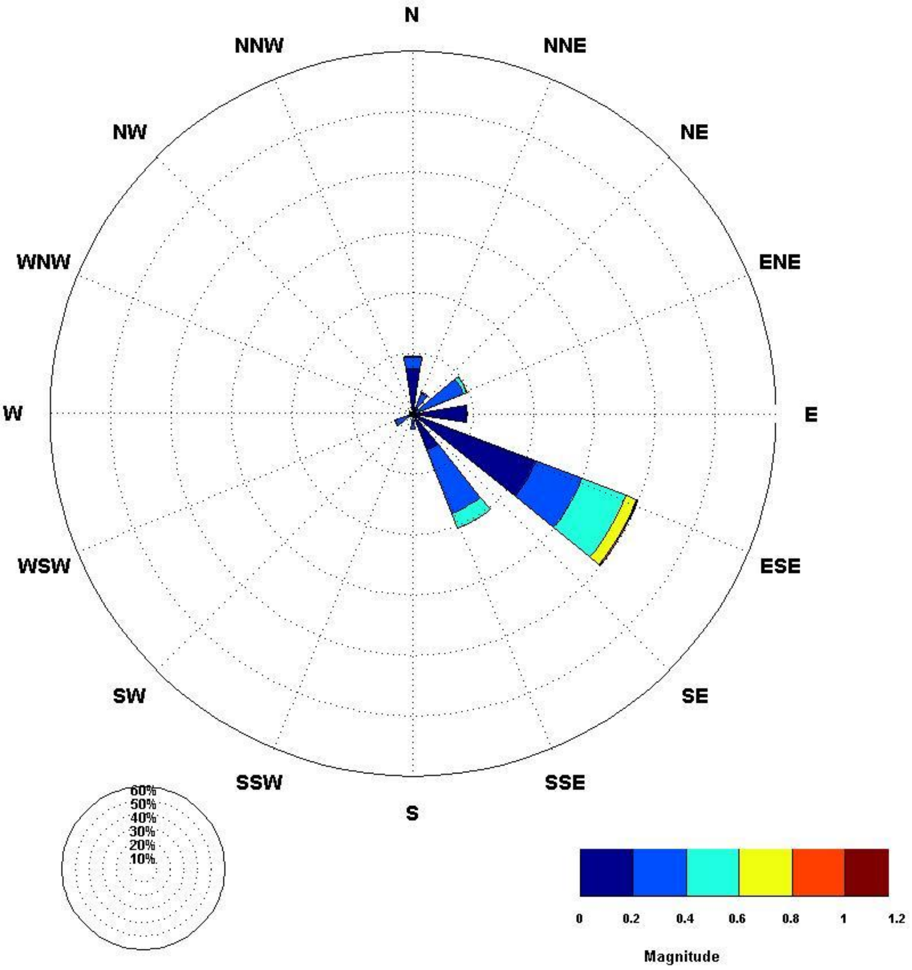
WBM07 – Fisherman's Landing Berths



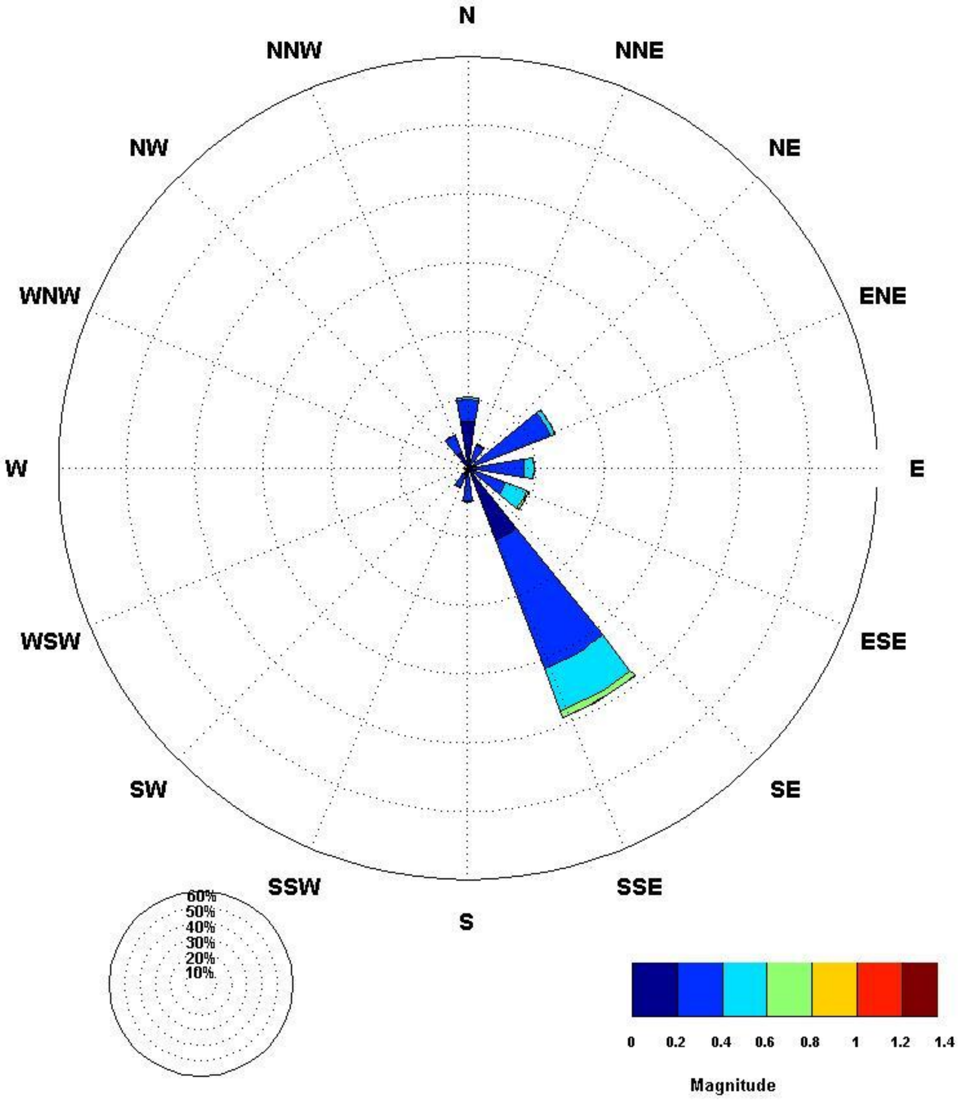
WBM24 – China Bay



WBM04 – Western Basin



WBM03 – Entrance to Narrows



WBM06 – North Passage Island

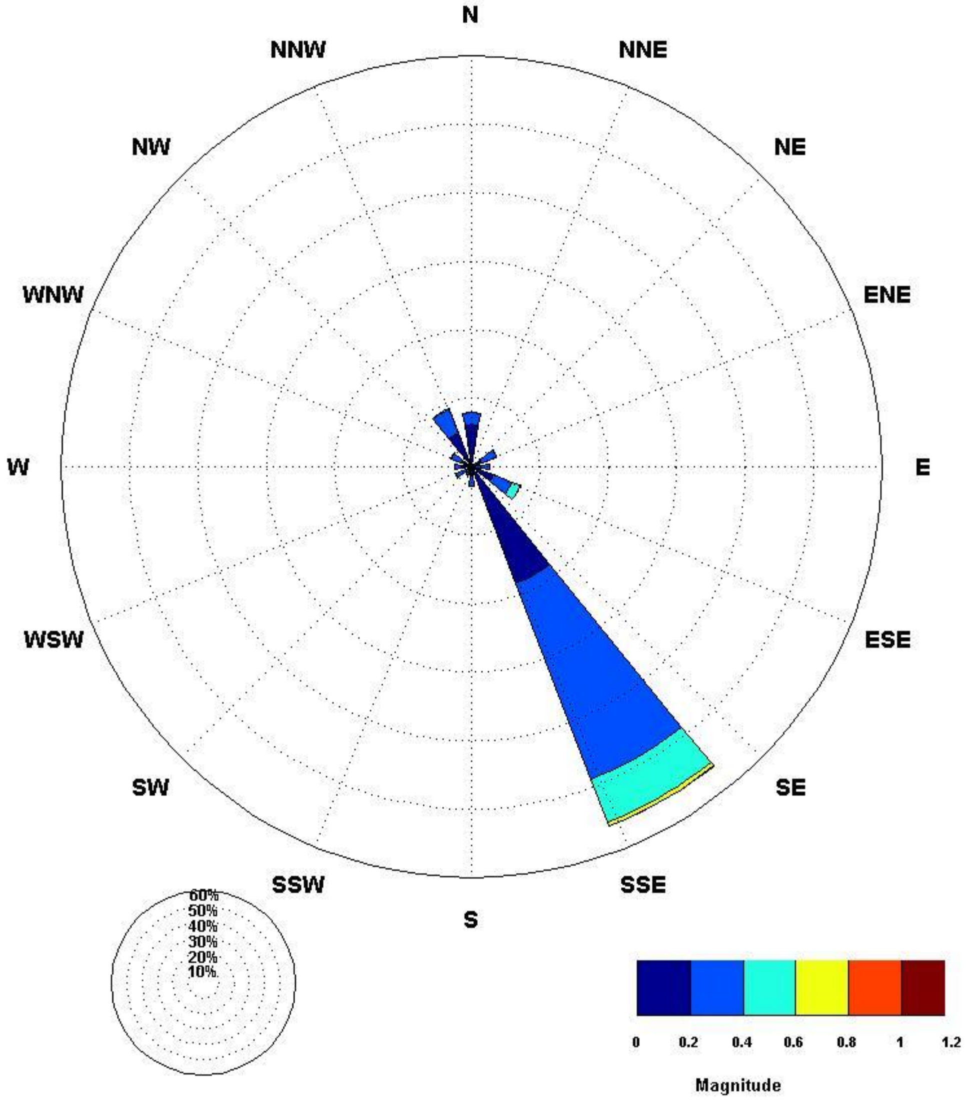


Figure 3-4 Wave Roses - Ambient Conditions

The above calculations are representative of the average ambient wave climate for the site. A separate analysis of extreme events was carried out by WBM and during cyclonic conditions waves up to 2.5m could occur in the dredged channel adjacent to the Fisherman's Landing site and depending on their duration and the time of occurrence in relation to the tide could cause substantial movement of the sediments in the shallower areas and along the western foreshore (WBM 2009b).

Figure 3-5 shows the spatial variation of wave height and direction for the base case and winds from a 1:100 year cyclone. The water level for this simulation was RL 3.53m AHD which included allowances for storm surge and sea level rise. Cyclones by their very nature are unpredictable in their intensity, track, and coastline crossing point. However, they are most likely to either follow a south-east track parallel to the coast or approach and cross the coast at an angle, usually between north-east and east. Either of these scenarios will generate very strong winds from the sector extending from the east to the south. The longest fetch affecting the Western Basin site is aligned approximately east south-east and hence cyclones will have a significant effect on the wave climate. Cyclonic waves from other directions are likely to be lower due to the lower effective wind speeds, wind duration, and fetch, and the chance of occurrence is less given the most likely tracks are as described above. Plots for waves from the north and east are available in the Wave Climate section of the Numerical Modelling Report (WBM 2009b).

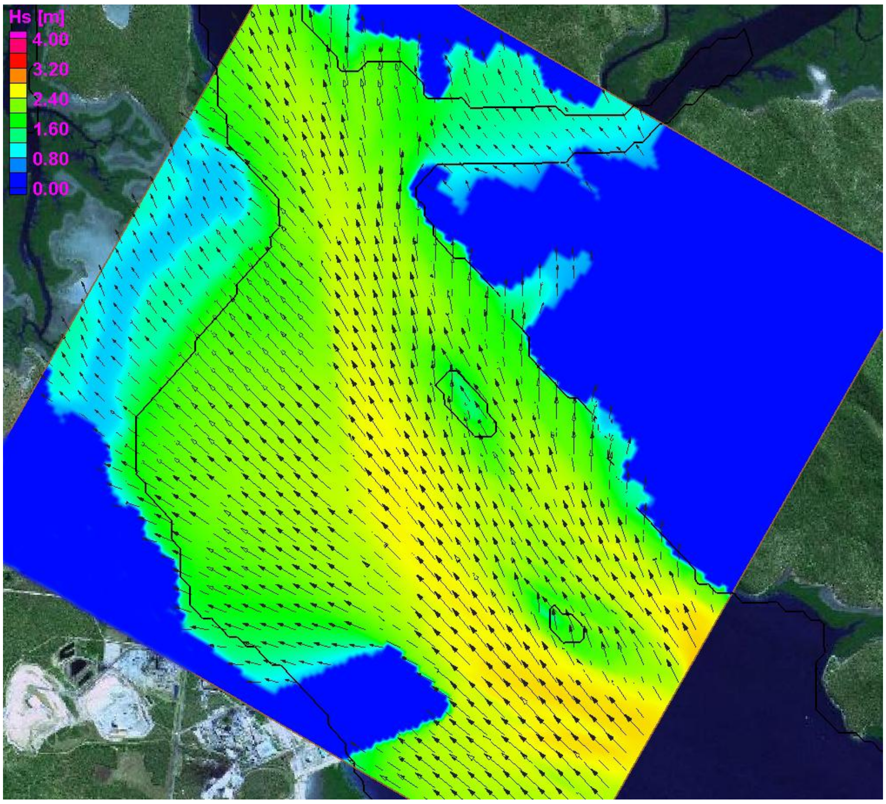


Figure 3-5 Wave Plot for South Easterly Waves generated by a 1:100 year cyclone

South easterly waves generated by a cyclone penetrate to all parts of the project area. The highest waves are adjacent to the existing Fisherman's Landing Reclamation and along the channel to the north towards the entrance to The Narrows. In the Western Basin embayment north of Fisherman's Landing, the wave action is reduced due to the shallower water and diffraction around the existing reclamation.

Figure 3-6 shows the variation in wave height and direction against the wind direction for extraction point WBM07 at the Fisherman's Landing berth for a 1:100 year cyclone. The maximum wave height is 2.54m from the east-south-east and there is a spread of wave heights around 2.5m covering the directions from east to south-south-east as a consequence of the longer fetches from these directions.

For a body of water of uniform depth, the wave direction would be the same as the wind direction and the wave direction line on Figure 3-6 would be a straight line with a unit slope. In addition to the influence of wind direction, the variation in the wave direction plot illustrates the effects of refraction of the waves over the variable depths in the harbour and around the prominent features of the harbour coastline, such as the existing Fisherman's Landing Reclamation. For example, waves generated by a wind from 180 degrees (south) will reach Fisherman's Landing berth from 164 degrees (approximately south-south-east).

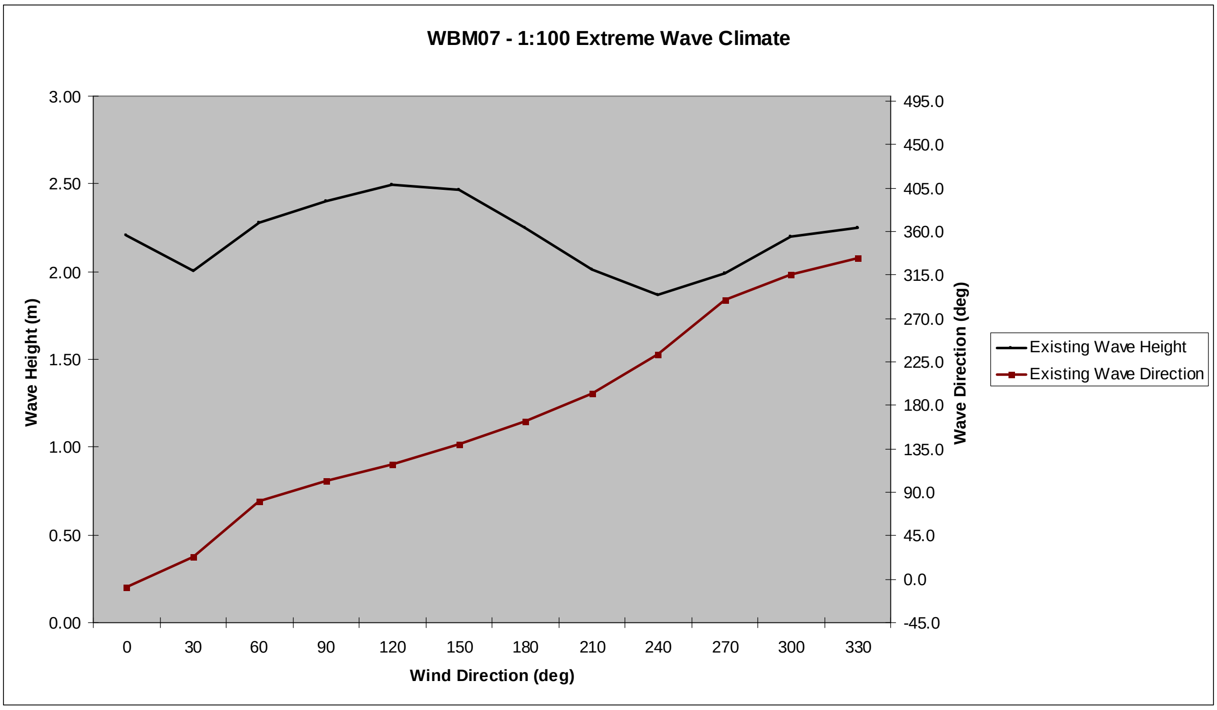


Figure 3-6 Wave Height and Direction at Fisherman's Landing (WBM07) for 1:100 year cyclone

3.1.3 Storm Tides

The Climate and Climate Change Assessment report (Appendix H of the main EIS) provides a detailed assessment of the storm tide level risk at Fisherman's Landing.

The storm tide level is a combination of the storm surge from a cyclone approaching the coast and the astronomical tide level and is presented in terms of the risk of occurrence while considering the independence of the two components. Table 3-3 presents the storm tide level for the 1 in 50, 100, 500, and 1000 year return periods, or, in terms of Annual Exceedance Probabilities (AEP), 2%, 1%, 0.2%, and 0.1% and includes an allowance for sea level rise, and expected changes to cyclonic behaviour (number and intensity). The values presented in Table 3-3 are derived from Hardy *et al*. 2004 updated with the current assessment for sea level rise (refer Climate and Climate Change Assessment report for details). The values are presented for Fisherman's Landing, derived by amplifying the levels for Gladstone at

Auckland Point by 6%, using the amplification of the tide wave as it travels from Auckland Point to Fisherman's Landing as the basis. Tidal plane levels are based on the levels in the 2009 Tide Tables (MSQ 2009) and supplementary information provided by MSQ.

Any of these events can occur during the lifetime of a structure, however there is much less chance of the 1 in 1000 year event occurring than the 1 in 50 year event. By way of an example there is a 10% chance that a 1:500 year event will occur sometime during a 50 year lifetime. For comparison the Highest Astronomical Tide (HAT) level is also presented in the table.

These storm tide levels include a 0.3m allowance for sea level rise. However, it should be noted that this will apply progressively over the life of the development with most of the rise occurring towards the end of the project.

Table 3-3 Storm Tide Levels in Gladstone (Hardy *et al*. 2004)

Location	Highest Astronomical Tide (HAT) m AHD	Storm Tide Level (Storm Surge + Tide + 0.3m Sea Level Rise) m AHD			
Return Period (years)		50	100	500	1000
Gladstone (Auckland Point)	2.42	3.05	3.33	4.18	4.51
Fisherman's Landing	2.54	3.33	3.58	4.43	4.78

3.2 Sediment Transport

Sediment transport under the action of tidal currents has two principal components – bed load and suspended load. Bed load generally consists of the coarser fractions of the bed material with the finer silts being suspended in the water column by the turbulence from the relatively high tidal velocities.

The transport potential for both types of sediment can be estimated from the results of the hydrodynamic modelling. The actual transport that occurs depends on the characteristics of the bed material at each location and on the amount of material that is available for transport. The relationship between the potential and actual transport can be assessed by comparing the transport potential with historical sedimentation records, usually in the form of maintenance dredging records of the adjacent channels and swing basins.

3.2.1 Sand Transport

The potential for sand transport under tidal current action has been estimated by applying the Meyer-Peter-Muller bed load formula to the simulated hydrodynamic model results (WBM 2009b). These calculations provide an estimate of the sediment transport potential assuming that the bed is uniformly mobile with a sand sized sediment grain size of 1mm and do not account for the presence of non-erodible areas such as rocky outcrops.

During large spring tides, the strong ebb tide currents generate a high sediment transport potential to the south-east while the flood tide currents, being somewhat weaker, generate less sediment transport potential (WBM 2009b). The potential for sand transport in the vicinity of the Fisherman's Landing swing basin area is considerably lower than experienced at the Clinton Wharves, further to the south-east, where currents are constricted between Hamilton Point and the Calliope River mouth.

Net sand transport potential was estimated by averaging the results over two consecutive spring-neap tidal cycles. The results for the base case are shown in Figure 3-7. The net sand transport is generally in the ebb tide direction due to the asymmetry in the tidal currents. Potential sand transport is confined to the channels, where current speeds are sufficient to mobilise coarse sand deposits. The magnitude of the net transport potential generally increases with distance downstream and is at a maximum around the Clinton Wharves. Within the Western Basin, the net sand transport is generally higher within the Targinie Channel to the west of the Passage Islands than in the “Curtis” channel to the east (WBM 2009b).

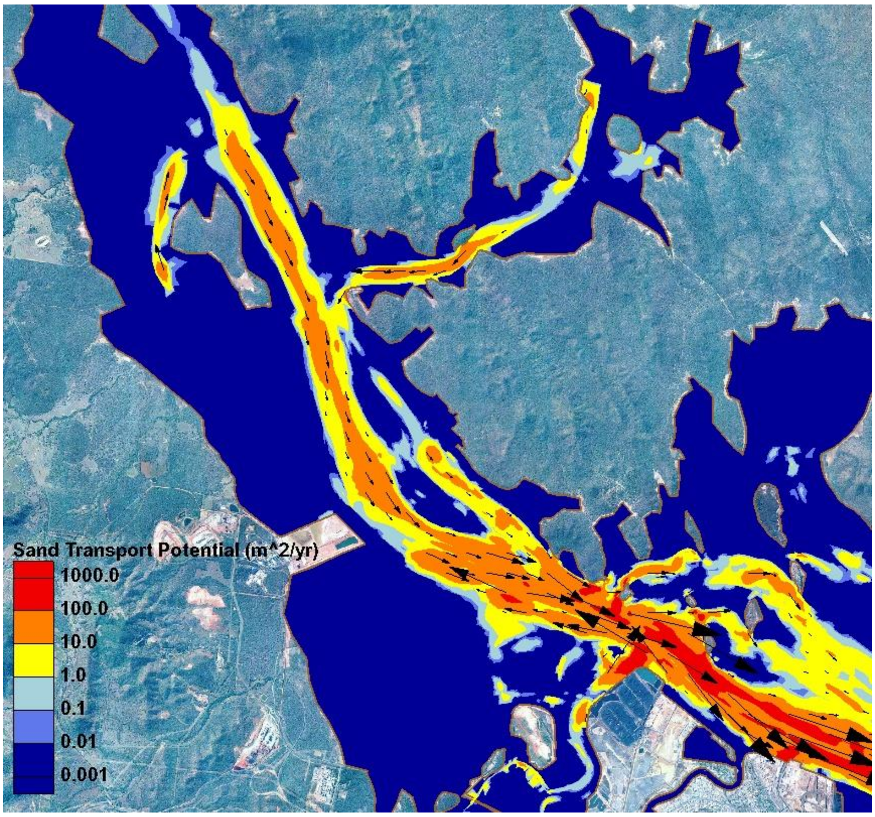


Figure 3-7 Existing Net Sediment Transport Potential

The modelled sedimentation (sand-sized material only) of a number of existing dredged areas has been summarised in Table 3-4. The net sedimentation volumes for the existing Targinie Channel and Fisherman’s Landing berths are generally consistent with the annual dredging volumes shown in Table 3-5 in the following section.

Table 3-4 Net Sedimentation Volumes for the Base Case

Location	Sedimentation m^3/year	2007 Maintenance Dredging m^3 (Refer Table 3-5)
Clinton Swing Basin	40,000 (20,000 – 80,000)	4,200
Targinie Channel	2,400 (1,200 – 4,800)	14,600
Fisherman's Landing	7,200 (3,600 – 14,400)	1,900

The estimate for the Clinton Swing Basin illustrates the difference between the potential transport and the actual transport represented by the dredging maintenance quantities. At Clinton the presence of coarser material and/or immobile reef structure means that the actual transport will be lower than what the hydrodynamic conditions might indicate. The results at Targinie Channel show the opposite trend but may be influenced by the fact that recent dredging in this location has been associated with capital dredging. The difference at Fisherman's Landing is likely to be due to the lack of material available for transport compared with the potential calculated transport volume. In addition, as the sediment transport model was not calibrated to provide actual quantities, there will be some inherent difference between predicted and actual transport rates.

Nevertheless, the potential sediment transport calculations provide an indication of the likely transport and allow comparisons to be made between different points in the harbour and between development scenarios.

3.2.2 Silt Movement and Deposition

Silt movement and deposition is assessed through an examination of bed shear stresses that can be derived from the hydrodynamic modelling results. Bed shear stresses less than about 0.2N/m^2 will generally result in deposition of fine silts that are in suspension in the water column while higher stresses will resuspend deposited material and keep it in suspension (WBM 2009b).

During neap tides, the bed shear stresses in the channel are typically at or below the threshold for deposition. However during spring tides, the stresses are much greater and as such the fine sediments will not be stable in the long term (WBM 2009b). This is consistent with observations of limited fine material in the main channel. As could be expected, in the shallower less dynamic areas where velocities are lower, the bed shear stresses are typically low and this is consistent with the natural deposition of fine material in these areas. This is illustrated in Figure 3-8 which shows the bed shear plots for WBM04 in the Western Basin northern embayment and WBM07 in the Fisherman's Landing berth. The plot period is over several large spring tides and shows that the base case bed shear stress at WBM04 (a low dynamic area) at less than 0.2N/m^2, is much less than the base case bed shear stress at WBM07 (in the main channel) at a maximum of 0.9N/m^2.

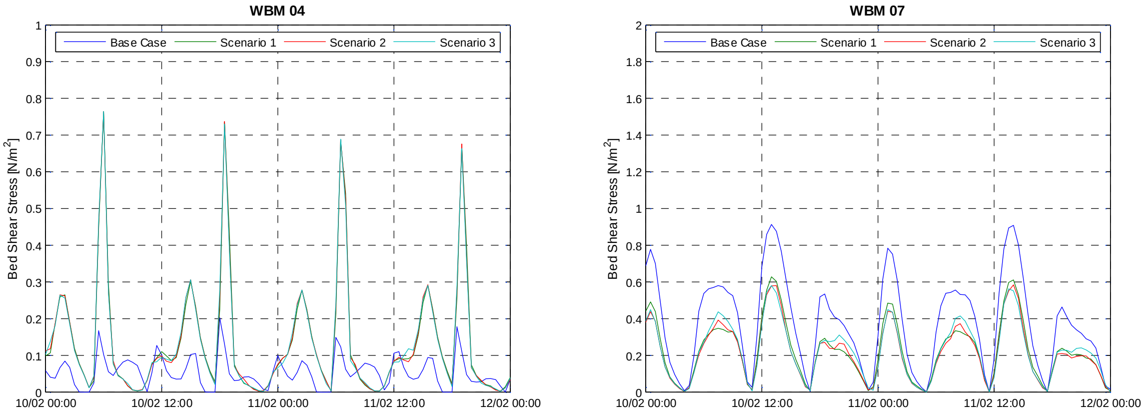


Figure 3-8 Existing bed Shear Stresses at WBM04 and WBM07

In an earlier report WBM reported that sediment density sampling on the inter-tidal flats in the vicinity of the proposed reclamation has shown that the *in-situ* material is made up of relatively unconsolidated silt material with bulk densities in the range 1200-1500 kg/m^3 in the top 0.5 metres (WBM 2009a). This material will be prone to erosion when subjected to shear stresses in excess of 0.5-1.0 N/m^2.

To assess the potential for silt erosion and deposition, bed shear stresses were calculated throughout the hydrodynamic model domain over the full two month simulation period. Maximum bed shear stresses due to tidal currents will correlate inversely with the likelihood of silt deposition. For the base case the spatial distribution of the 5% exceedance (of the modelled period) bed shear stress is illustrated in Figure 3-9 and time series plots of bed shear stress at each location in the project area is shown in Figure 3-10.

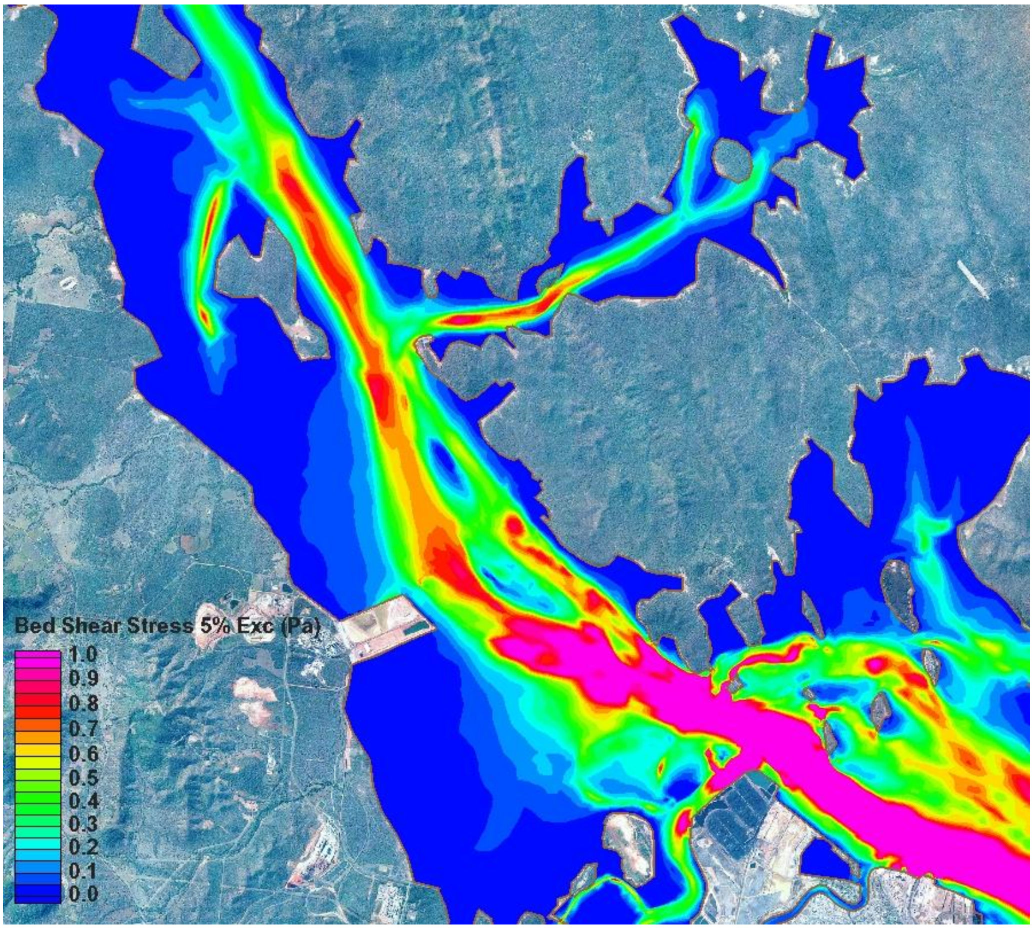
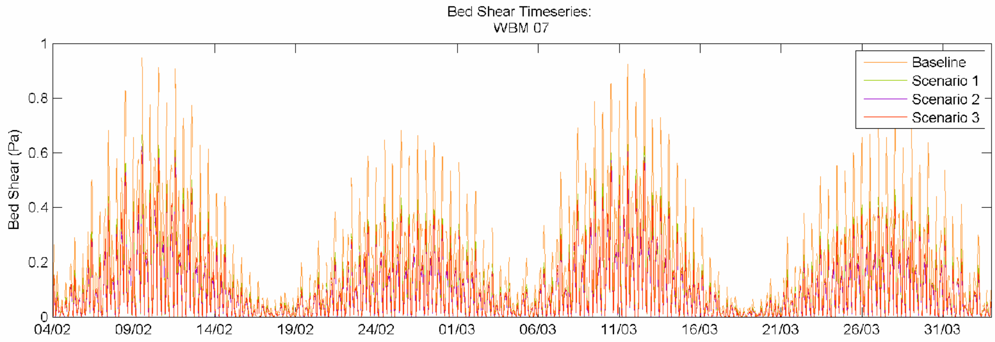
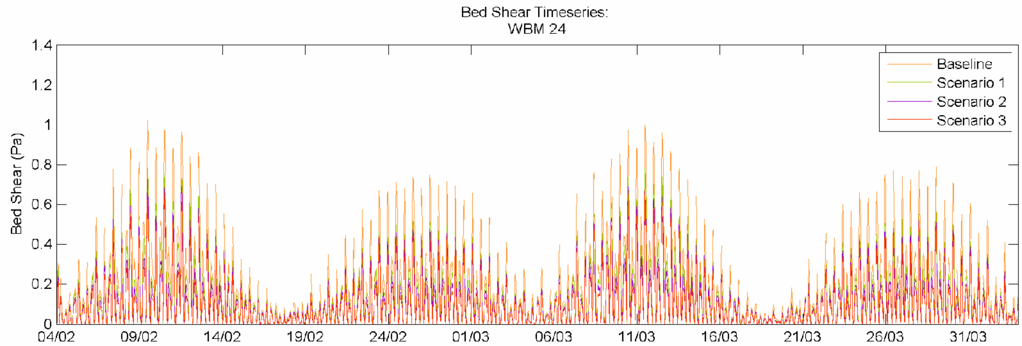


Figure 3-9 Base Case Bed Shear Stresses

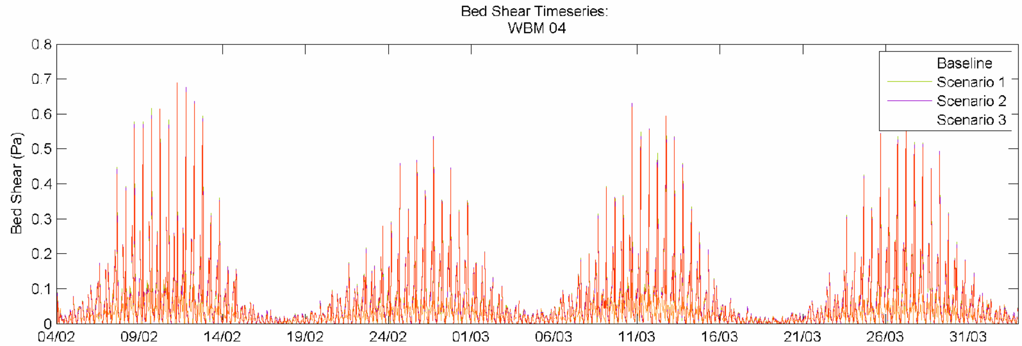
WBM07 - Fisherman's Landing Berths



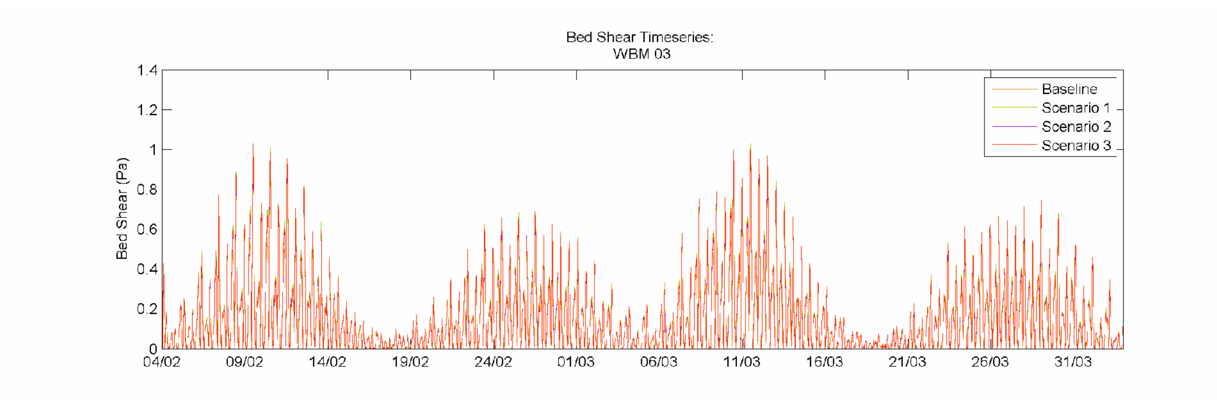
WBM24 - China Bay



WBM04 - Western Basin



WBM03 - Entrance to Narrows



WBM06 - North Passage Island

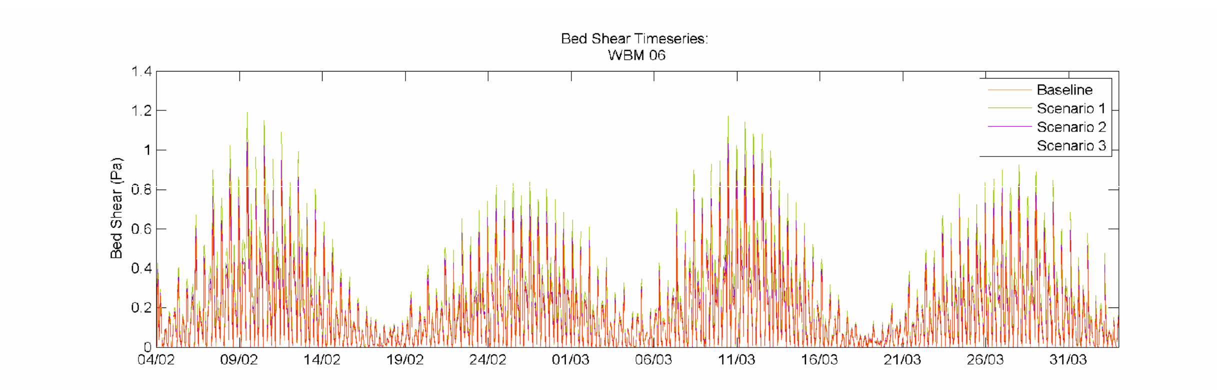


Figure 3-10 Time History Bed Shear Stresses

3.3 Description of Morphology and Integrity of Existing Landforms

The Fisherman's Landing area forms part of a large macro tidal estuary of Port Curtis. This part of the estuary is located between a low lying coastal plain backed by low hills to the west rising to the 500m high Mount Larcom range 8km distant and the southern part of Curtis Island to the east. Fisherman's Landing is on the western side of the estuary that is characterised by a mangrove foreshore, wide intertidal flats extending into a shallow water environment as far as the edge of the main channel that forms the basis of the access to the existing wharves at Fisherman's Landing. There are no sandy beach / dune formations within the western basin area.

3.3.1 Existing Reclamation

The existing reclamation at Fisherman's Landing was constructed in the early 1980's (Harbours & Marine 1986) and consists of a perimeter bund armoured on the outside with a widely graded rock. It is likely that the existing armour layer has been modified from the originally placed material by the prevailing wave conditions that have washed out much of the finer material. From site inspections and as shown in the photographs in Figure 3-11, the perimeter bund has formed a stable revetment for the existing reclamation that is 116.5ha in area.

Northern bund **Eastern bund**

Figure 3-11 Existing Reclamation

3.3.2 Intertidal Flats

The intertidal flats of Gladstone Harbour have high environmental values, in terms of the individual flora and fauna they support, the ecosystems they represent, and their community values. As a physical feature they are relatively stable unless affected directly by engineering works. The environmental values of the intertidal flats are examined in detail in Chapter 9 in the EIS report.

3.3.3 The Narrows

The southern end of The Narrows is located approximately 2 km north of the proposed reclamation at Fisherman's Landing. The Narrows is part of the Great Barrier Reef Coast Marine Park and was listed on the National Estate Register on 26 October 1999. The Narrows was listed as it represents an "uncommon passage landscape", being only one of five narrow tidal passages separating large continental islands from mainland Australia (DEWHA 2009b). The environmental values of The Narrows are discussed in Chapter 9 in the EIS report.

3.3.4 Existing Channel and Swing Basin

The closest channel to Fisherman's Landing is the Targinie Channel that provides shipping access to the four berths that utilise the existing reclamation for their connecting infrastructure (conveyors, pipelines, services, access) (Port of Gladstone 2008). Currently, the Targinie Channel is 120 metres wide and is maintained to a depth of RL10.6m LWD through maintenance dredging (Port of Gladstone 2008). The Wiggins Island Coal Terminal Environmental Impact Statement 2006 (Connell Hatch 2006) provides information on the maintenance dredging quantities between 2000 and 2005. This information has been updated in the Sediment Transport section of the Numerical Modelling Report (WBM 2009b) and the details for the Fisherman's Landing Berth, Targinie Swing Basin, the Targinie Channel, and the Clinton Swing Basin at the southern end of the channel are provided in Table 3-5.

Table 3-5 Historical Dredging Quantities (WBM 2009b)

Location	Dredging Quantities (m^3)						
	2007	2006	2005	2004	2003	2002	2000
Clinton Swing Basin	4,200	4,300	5,300	7,800	400	-	1,000
Targinie Channel	14,600	17,600	12,300	42,500	DEV[1]	DEV[2]	3,600
Targinie Swing Basin	4,400	3,900	1,900	-	-	-	-
Fisherman's Landing Berth	-	1,900	-	-	1,400	6,500	600

Source: Port of Brisbane Corporation 1) 95,000 2) 380,000
Table Notes: Development is extra to maintenance
All volumes are in-situ cubic metres (tons dry/1.3)

These are relatively small quantities of maintenance dredging and reflect the minimal siltation regime in the harbour. This in turn indicates that there is limited sediment transport and/or that the currents/ship movements are sufficient to keep the sediments in suspension, preventing them from settling out in the dredged areas (Connell Hatch 2006). Analysis of historical hydrographic surveys indicates that the general siltation of the channels and swing basins occurs at a rate of around 1 to 5 cm/annum with some areas such as where the Targinie Channel crosses the Passage Island shoals the rate is up to 10 cm/annum (WBM 2009b).

3.4 Description of Sediment Properties (physical)

The Fisherman's Landing area is located within a coastal plain setting lying to the east of Mount Larcom along the shores of an inlet known as The Narrows. The geology and the soils of the area are described in detail in the GHD Preliminary Design of Bunds report (GHD 2009b) and a summary of the characteristics relevant to the coastal processes is provided below:

» The local geology at the site comprises estuarine clay overlying marine and residual clays with the estuarine clay varying in thickness from 0.5m to approximately 5.0m across the site. The underlying soil varies from clay, silty clay or residual clay and some areas may contain gravel and/or sand layers, more commonly in the first 10m below seabed.

» The shallow inter tidal areas consist of a mixture of sands and silts with fine soft silts dominating in the lower current and wave energy areas. Sediment density sampling on the inter-tidal flats in the vicinity of the proposed reclamation extension shows that the in-situ material consists of relatively unconsolidated silt material with bulk densities in the range 1200-1500 kg/m^3 in the top 0.5m (WBM 2009a). The thickness of this soft estuarine sediment across the proposed development varies generally between 0.5 and 2m with deeper pockets of up to 5m (Marine & Earth Sciences 2008).

» In the main channel and berthing areas on the eastern side of the proposed reclamation, there is a mixture of gravels, sands, silts and soft clays. High current areas occur in the vicinity of the main channel and typically consist of the coarser fractions as the finer particles have been swept away (WBM 2009b).

3.5 Coastal Process Relationships

The study of coastal processes is essentially a study of sediment movements in the coastal environment and the forcing mechanisms that drive that movement. Within Gladstone Harbour and at Fisherman's Landing, the principal drivers of sediment movement are tidal currents and locally generated waves. Important but infrequent drivers are extreme events like cyclones which can generate high waves and water levels that can have major effects on the environment and affect areas that would not normally be affected under prevailing conditions.

Port Curtis is subject to a relatively high tidal range and has a large tidal compartment being the area of waterway into which the tide propagates. This produces tidal currents up to 1.5m/s in the main channels and up to 0.35m/s on some of the shallower areas (WBM 2009b). These velocities are capable of moving large amounts of sediment depending on the water depth and wave action.

Wave action will not move sediment over long distances except where waves break at an angle on a sandy beach. However, the oscillatory currents under an unbroken wave are capable of mobilising the bottom sediments. The degree to which this occurs depends mainly on the wave height / water depth combination and the wave period. Once mobilised, sediments may then be transported by tidal currents which in themselves may not be strong enough to cause the initial movement of the sediment.

Therefore, in deep areas, tidal currents are the dominant motive force for sediment movement, and in shallower areas, where tidal currents are smaller; it is the combination of wave action and tidal currents that are important. In this report the impact of the proposed reclamation in the Western Basin and the various dredging scenarios on the coastal processes in the harbour and adjacent areas will be examined through an assessment of the changes to water levels, tidal currents, ambient and extreme wave climates, and transport of sand and silts as a result of the development.

4. Potential Impacts

4.1 Western Basin Development Scenarios

For the purposes of modelling impacts on hydrodynamics, plumes, flushing and other coastal processes, the Western Basin development scenarios presented in Table 4-1 have been considered.

Table 4-1 Development Scenarios

Scenario	Dredging	Reclamation
Base Case	Existing Channels Wiggins Island Coal Terminal	Existing Fisherman's Landing reclamation (no FLNE)
Scenario 1	Stage 1A Stage 1B (Stage 1)	Western Basin Reclamation and FLNE fully constructed
Scenario 2	Stage 1A Stage 1B (fully developed) Stage 2	Western Basin Reclamation and FLNE fully constructed
Scenario 3	All stages (1 – 4) fully dredged	Western Basin Reclamation and FLNE fully constructed

A full description of the development scenarios and the details of the dredging proposed at each stage are provided in Chapter 2 of the main EIS. The three development scenarios are shown on Figure 2-1, which also shows the data extraction points for the hydrodynamic and wave models.

It is noted that for many of the locations in the model domain, the results for Scenario 1, 2, and 3 are very similar. In the discussion that follows, reference will be made to the base case (representing the existing conditions) as defined in Table 4-1 and the developed case which will use results from Scenario 3 to illustrate changes and impacts. Particular locations where there are significant differences in the impacts from the three developed scenarios will be noted separately.

4.2 Wave Climate

The existing wave climate, in terms of both ambient conditions and extreme events, has been described in section 3.1.2. The same modelling package has been used to determine the wave climate for each of the developed cases and by comparing the results at each point of interest, the impact of the development can be assessed.

The points of interest at which wave data has been extracted from the model are shown on Figure 3-1 above and are described in Table 3-2

4.2.1 Ambient Wave Climate

The ambient wave climate at each point has been presented as percentage frequency of occurrence of combinations of wave height and wind direction. The development will cause changes in the percentage frequency of occurrence due to the blocking effect of the reclamation and changes in wave refraction patterns caused by the reclamation and the dredging of the navigation channels, swing basins, and berth pockets.

Comparisons of the wave climate at each point for the existing and developed cases are presented in Figure 4-1 to Figure 4-7 as three dimensional plots for the existing case and the developed case (Scenario 3) and separate plots of Wave Direction and Wave Height against percentage occurrence. Commentary on the impacts of the development scenarios on the ambient wave climate for each point is as follows:

WBM07 Fisherman's Landing Berths (*Figure 4-1*)

As expected, the wave directions at the Fisherman's Landing Berths are not affected from the highest occurrence directions from the east to the south-south-east. There are some minor variations in directions from the western sector due to the reclamation but these are not considered significant given their low occurrence.

There is a small reduction in the occurrence of the most common wave height (0.2m) due to the blocking effect of the reclamation on waves from the western sector.

WBM21 Eastern Edge of Reclamation (*Figure 4-2*)

The relative percentage occurrence of waves from the 120 degree sector increases at the eastern edge of the reclamation with the reclamation in place due to a decrease in the occurrence of waves from the westerly sectors and some refocussing of waves from the 150 degree sector by the dredged channels to the south of this location.

In terms of wave height there is a decrease in the occurrence of the predominant 0.2m wave height and an increase in the occurrence of waves 0.1m or less at the eastern edge of the reclamation.

WBM24 China Bay (*Figure 4-3*)

There is a small shift in the direction of the highest occurring waves at China Bay with a reduced occurrence from 120 degrees (2.7%) and an increased occurrence from 150 degrees (1.9%). This is caused by the dredged channel to the North China Bay LNG Precinct effectively funnelling the larger waves from the 120 sector around to the 150 sector. The same effect does not occur for waves from the equivalent sector to the east of sector 120 as they are blocked by Curtis Island.

This is mirrored by a small reduction in the occurrence of 0.2m waves and a small increase in the occurrence of 0.4m waves as the dredged channel will allow higher waves to be transmitted to the site due to the increased water depth.

WBM04 Western Basin (*Figure 4-4*)

There is a significant change in the direction of the waves at this location in the Western Basin due to the blocking effect of the reclamation reducing the influence of waves from the south-east and southerly sectors, for instance, the highest occurrence of waves changes from 120 degrees to 90 degrees. Waves from the southerly sectors still occur through refraction around the eastern extremity of the reclamation but with a much smaller occurrence (27% compared to 66%).

In keeping with the reduction in waves from the predominant southerly sector, the predominant wave height is reduced with a significant decrease in the occurrence of 0.4m waves and a significant increase in the occurrence of waves less than 0.1m (effectively calm conditions).

WBM16 Western Basin North (*Figure 4-5)***

This location in the north of the Western Basin dries at the lower stages of the tide and the plotted data point on the far right of the plots for this point represents the occurrence of dry conditions at this location.

A 4.2% reduction occurs in the occurrence of waves from the southerly sectors (120 to 180) due to the reclamation is mirrored by an increase in the occurrence of waves from the westerly sectors.

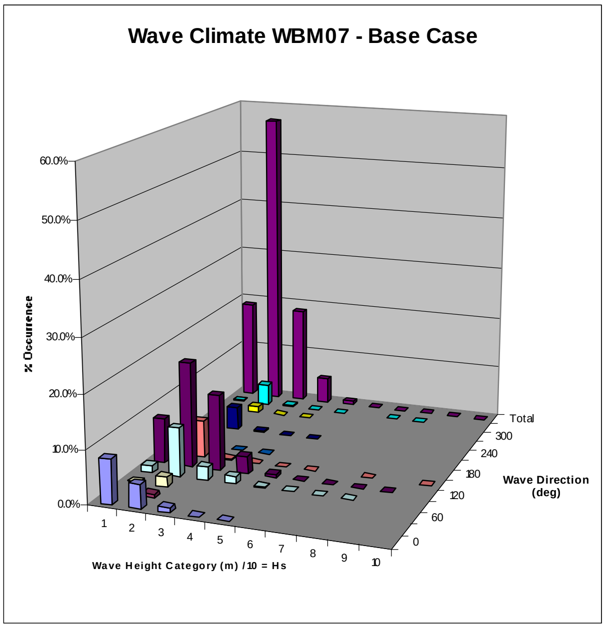
There is very little change in the wave height occurrence across the development scenarios compared with the existing case at this location.

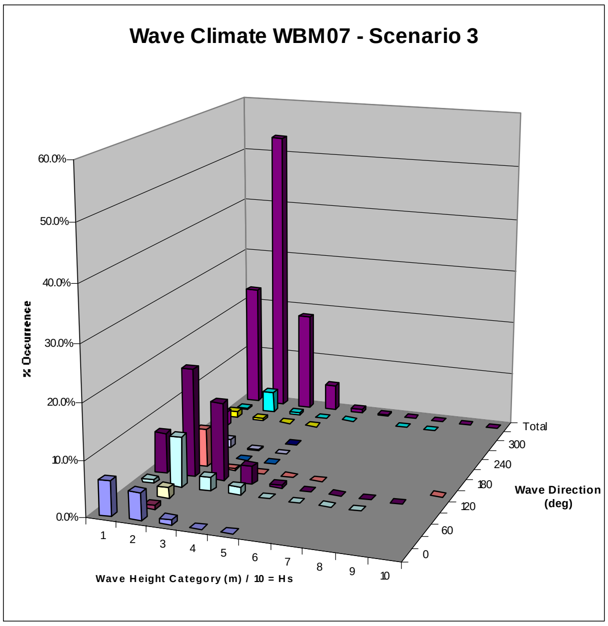
WBM03 Entrance to Narrows (*Figure 4-6)***

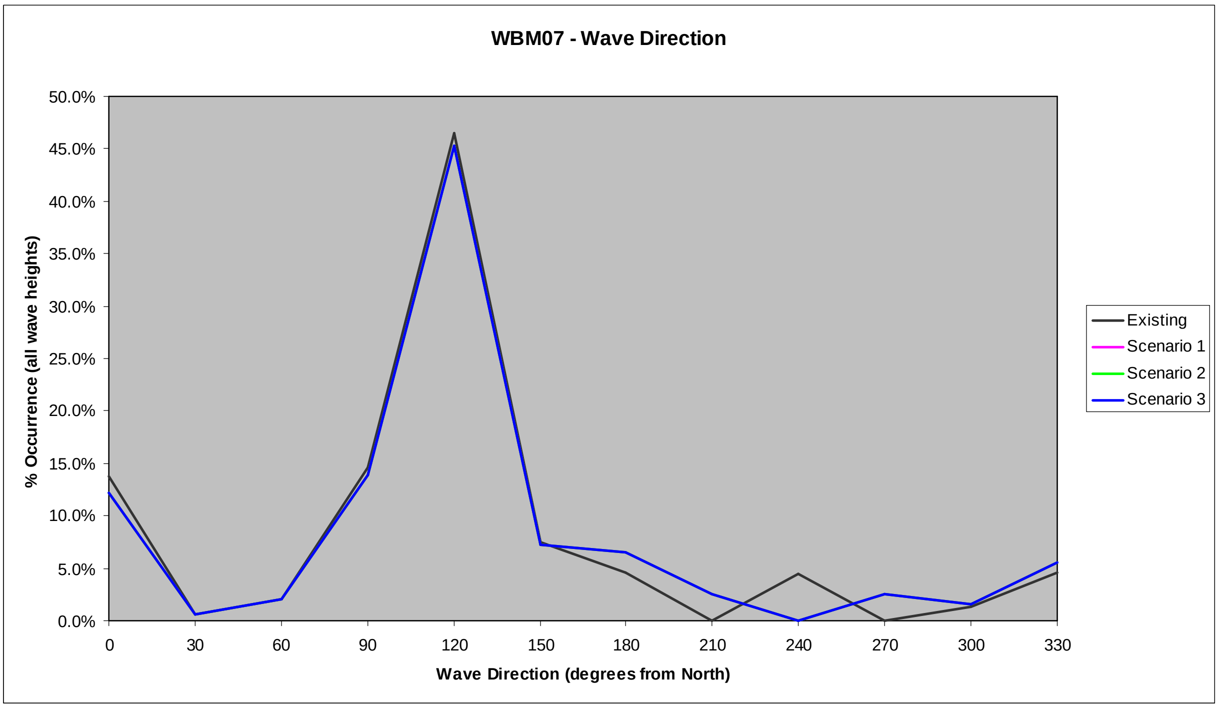
There are some minor changes (generally < 2%) to wave direction at the entrance to The Narrows due to the influence of the dredged channels in the developed scenarios. The development has no effect on the ambient wave height at the entrance to The Narrows.

WBM06 North Passage Island (*Figure 4-7)***

The results indicate only minor variations in wave direction at North Passage Island due to the dredged channels. The development has no effect on the ambient wave height at this location.


Wave Climate WBM07 - Base Case
% Occurrence
Wave Height Category (m) / 10 = Hs
Wave Direction (deg)
Total


Wave Climate WBM07 - Scenario 3
% Occurrence
Wave Height Category (m) / 10 = Hs
Wave Direction (deg)
Total


WBM07 - Wave Direction
% Occurrence (all wave heights)
Wave Direction (degrees from North)
Existing
Scenario 1
Scenario 2
Scenario 3

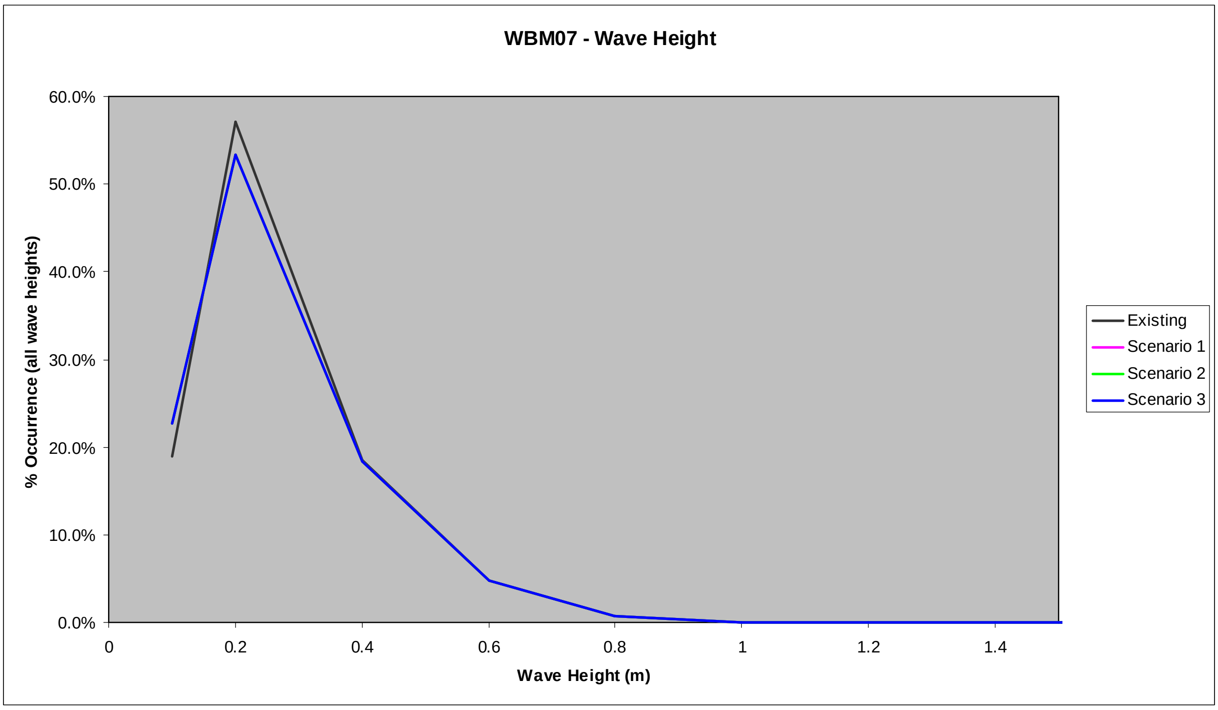
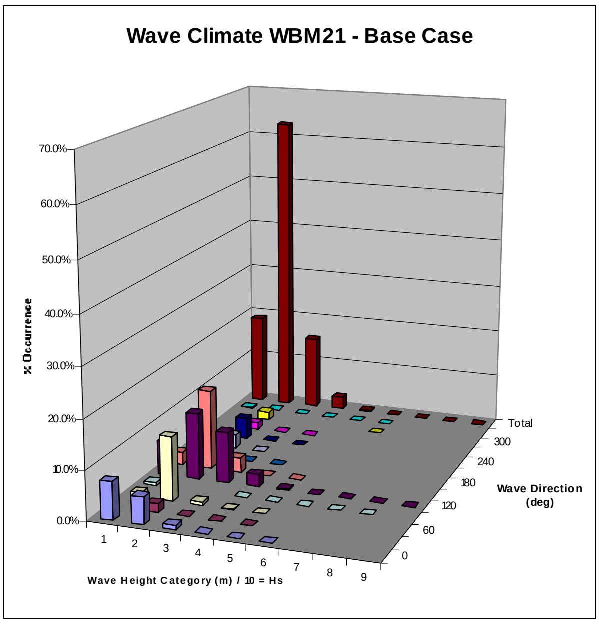
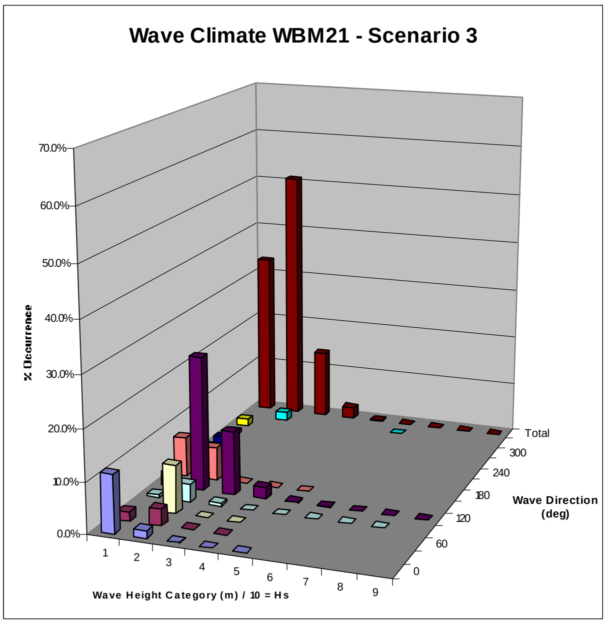
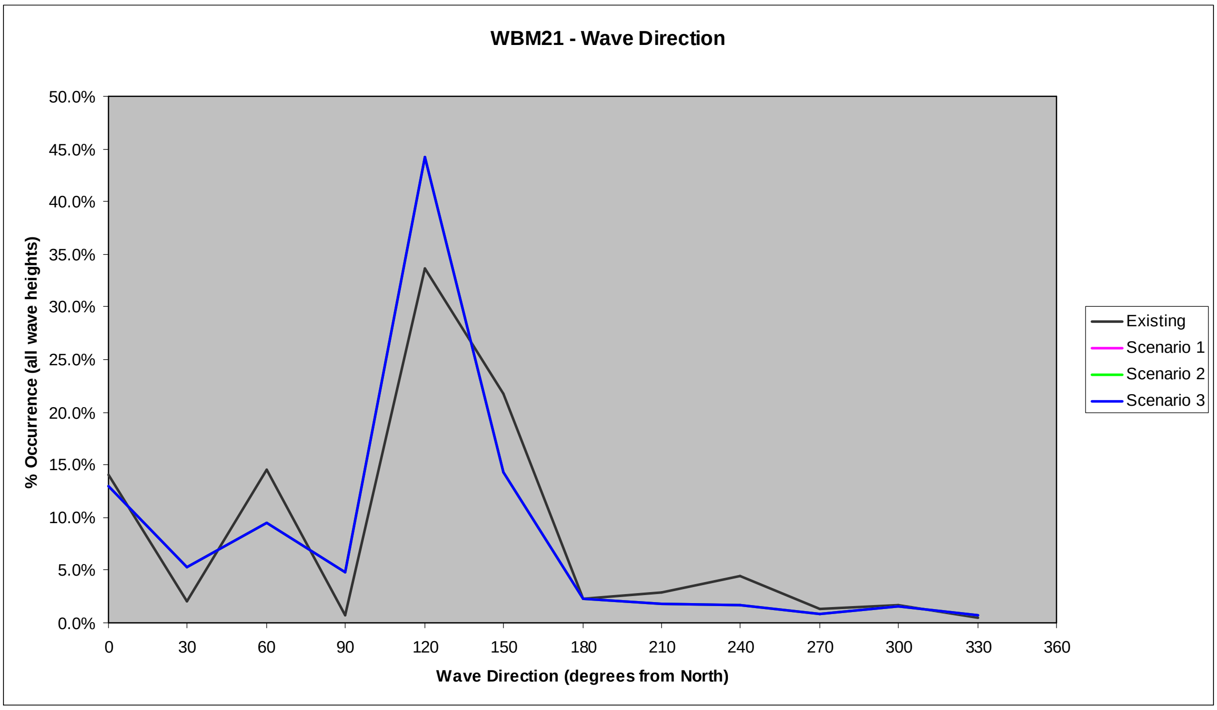


Figure 4-1 Ambient Wave Climate – WBM07 Fisherman's Landing Berths







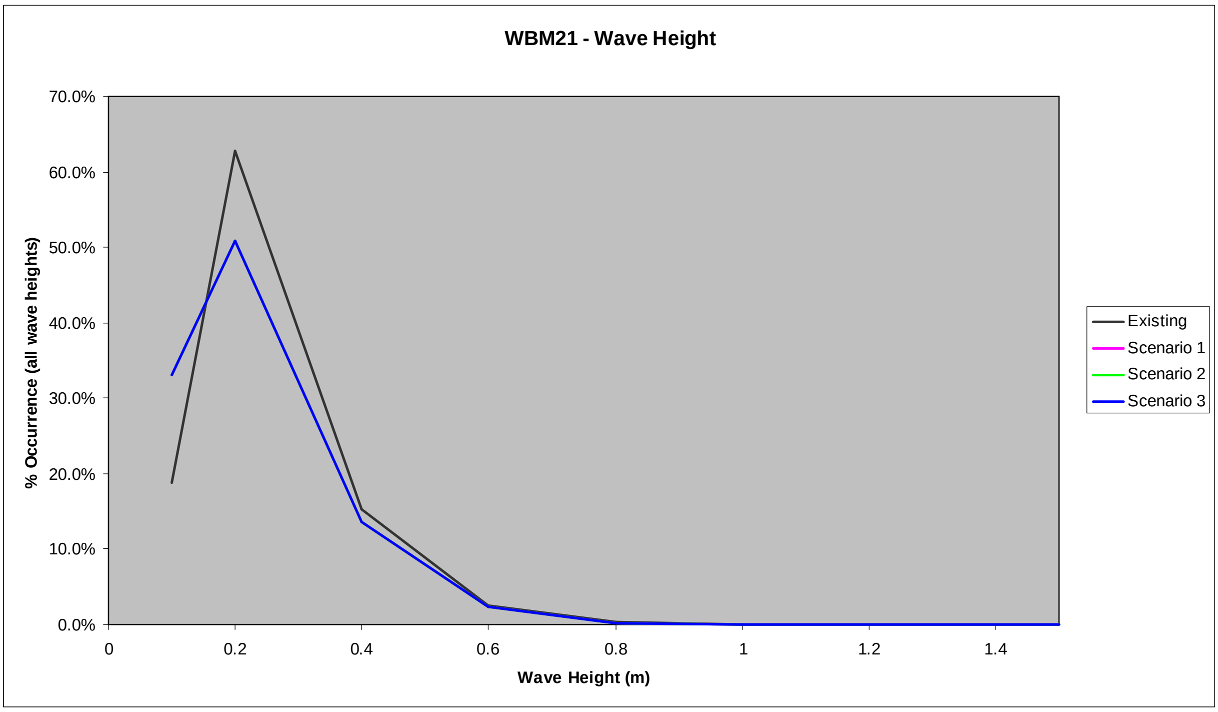
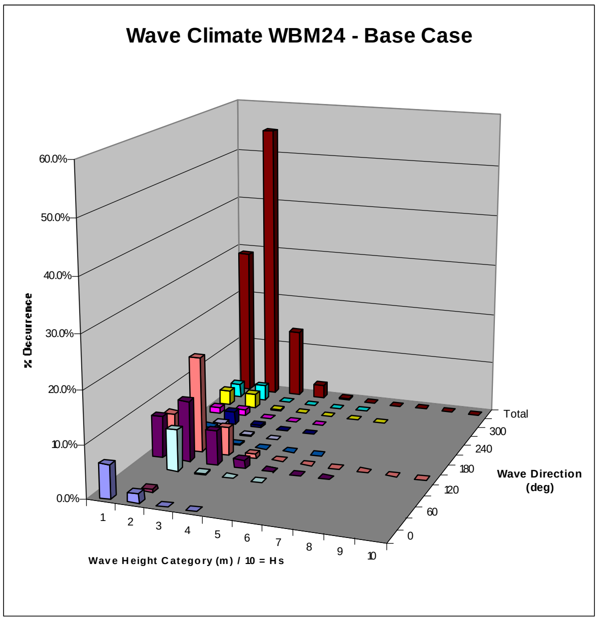
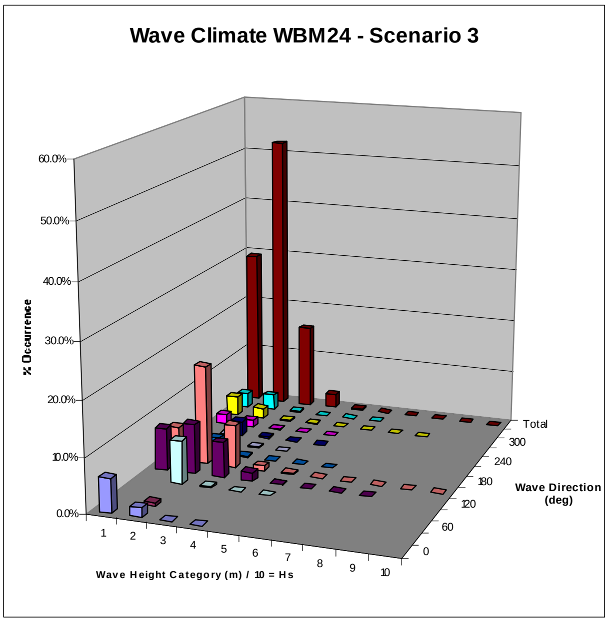
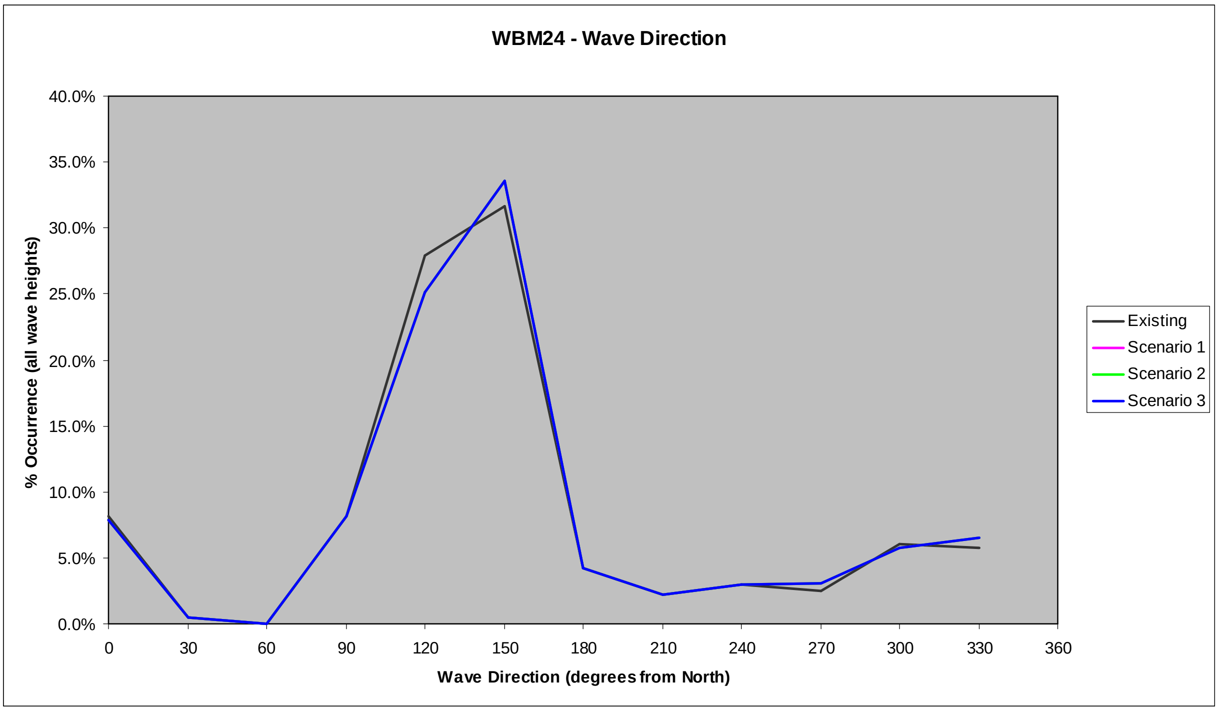


Figure 4-2 Ambient Wave Climate – WBM21 Eastern Edge of Reclamation


Wave Climate WBM24 - Base Case
% Occurrence
0.0%
10.0%
20.0%
30.0%
40.0%
50.0%
60.0%
Wave Height Category (m) / 10 = Hs
1 2 3 4 5 6 7 8 9 10
Wave Direction (deg)
0 60 120 180 240 300 Total


Wave Climate WBM24 - Scenario 3
% Occurrence
0.0%
10.0%
20.0%
30.0%
40.0%
50.0%
60.0%
Wave Height Category (m) / 10 = Hs
1 2 3 4 5 6 7 8 9 10
Wave Direction (deg)
0 60 120 180 240 300 Total


WBM24 - Wave Direction
% Occurrence (all wave heights)
0.0%
5.0%
10.0%
15.0%
20.0%
25.0%
30.0%
35.0%
40.0%
Wave Direction (degrees from North)
0 30 60 90 120 150 180 210 240 270 300 330 360
Existing
Scenario 1
Scenario 2
Scenario 3

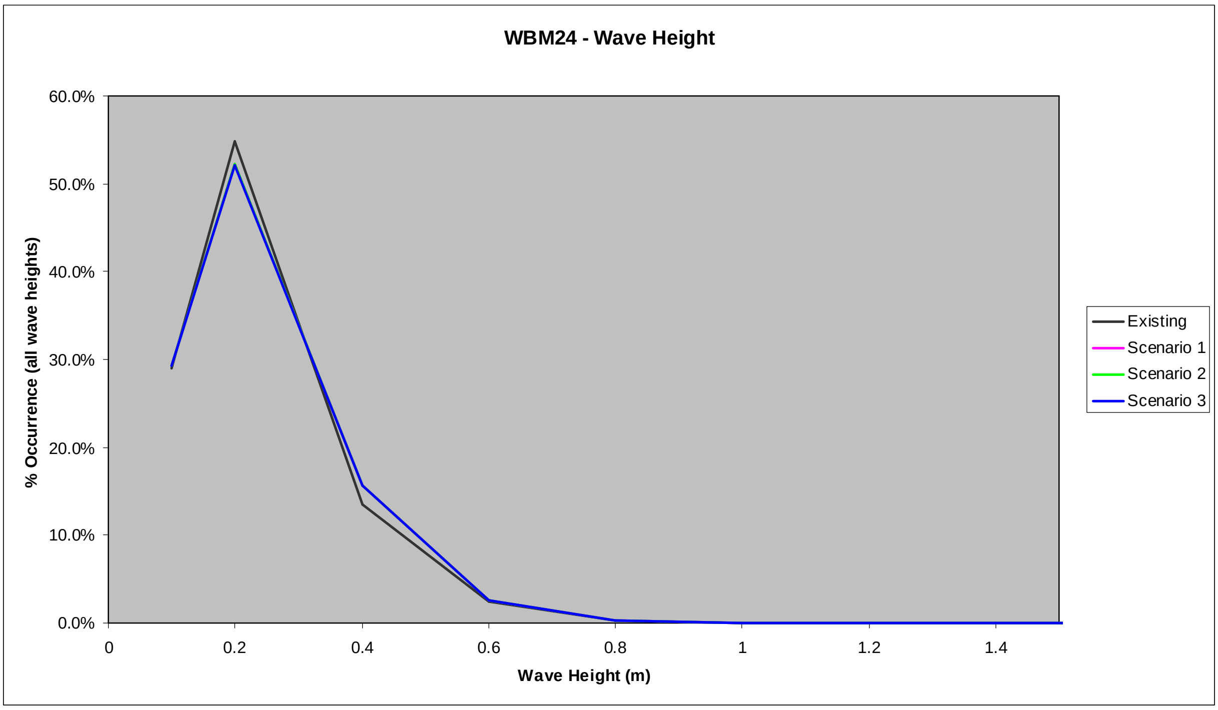
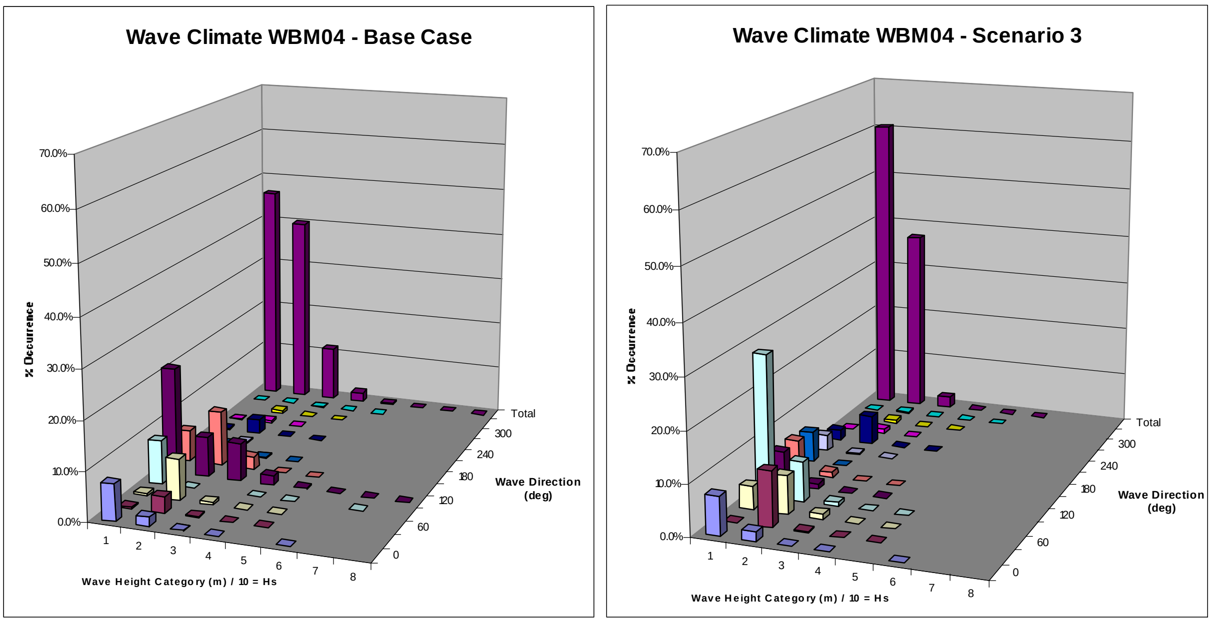
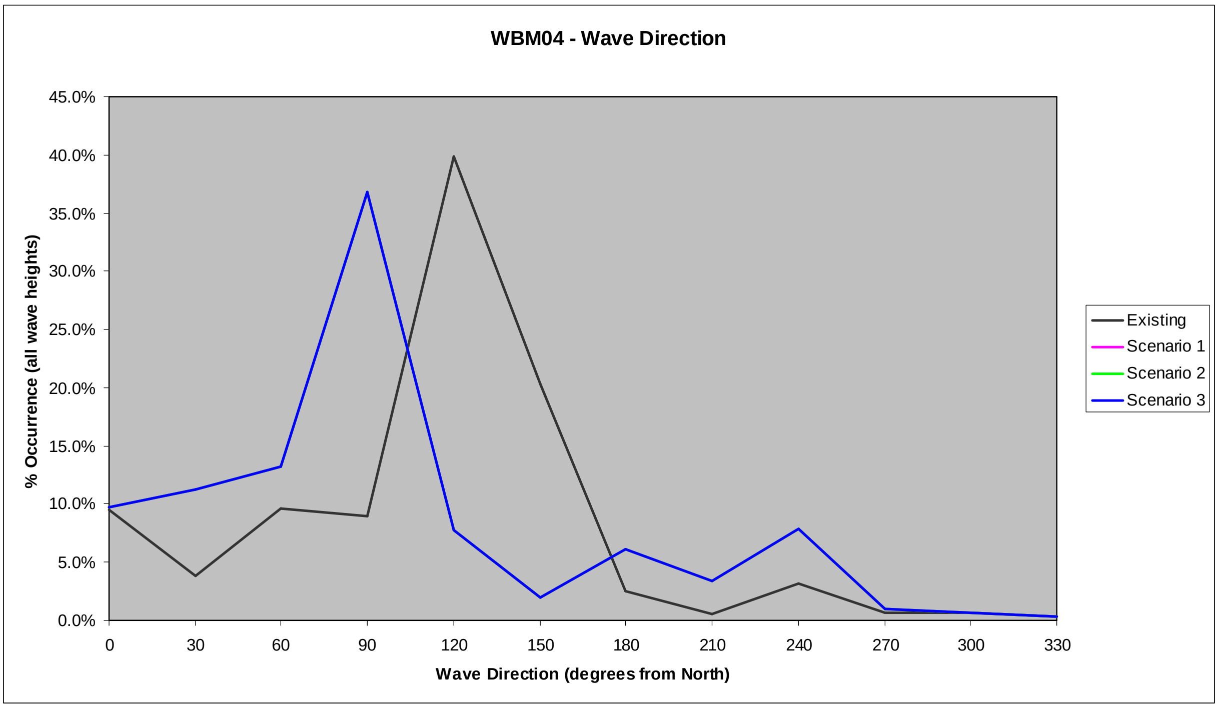


Figure 4-3 Ambient Wave Climate – WBM24 China Bay





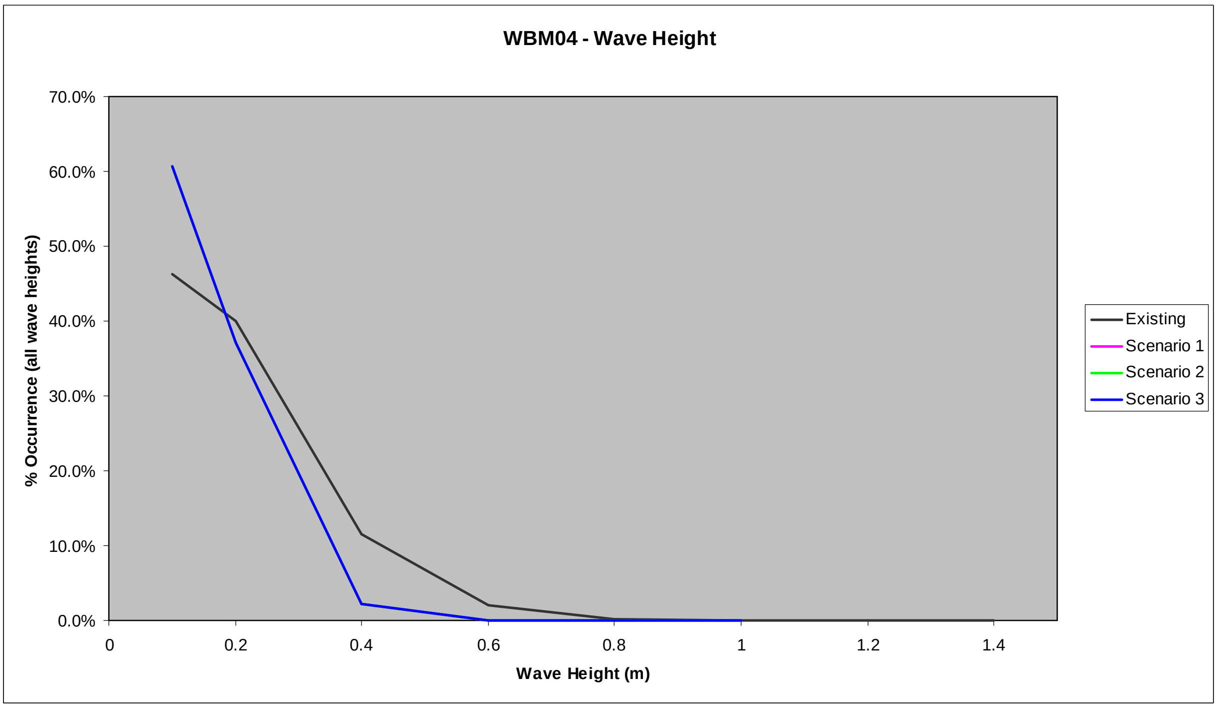
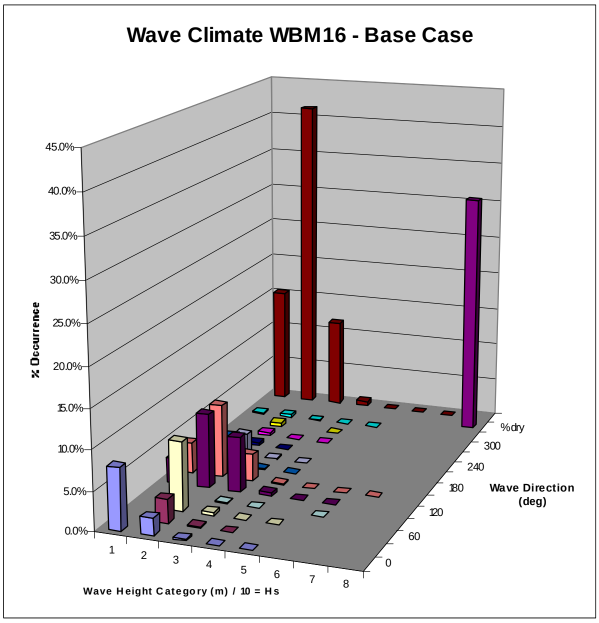
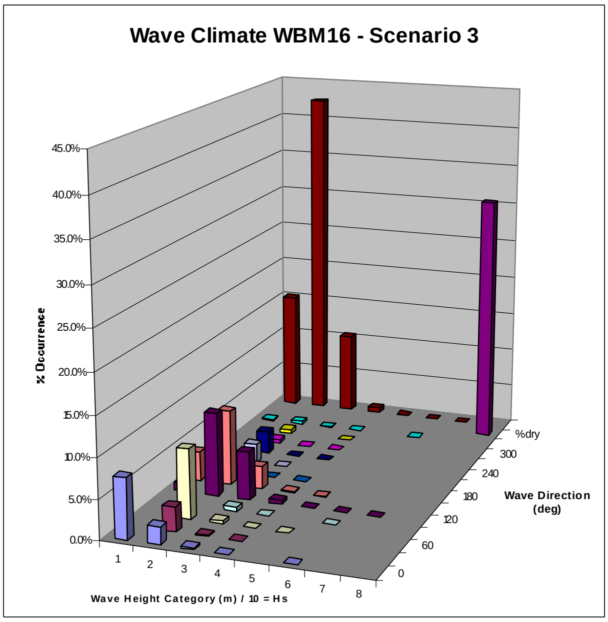


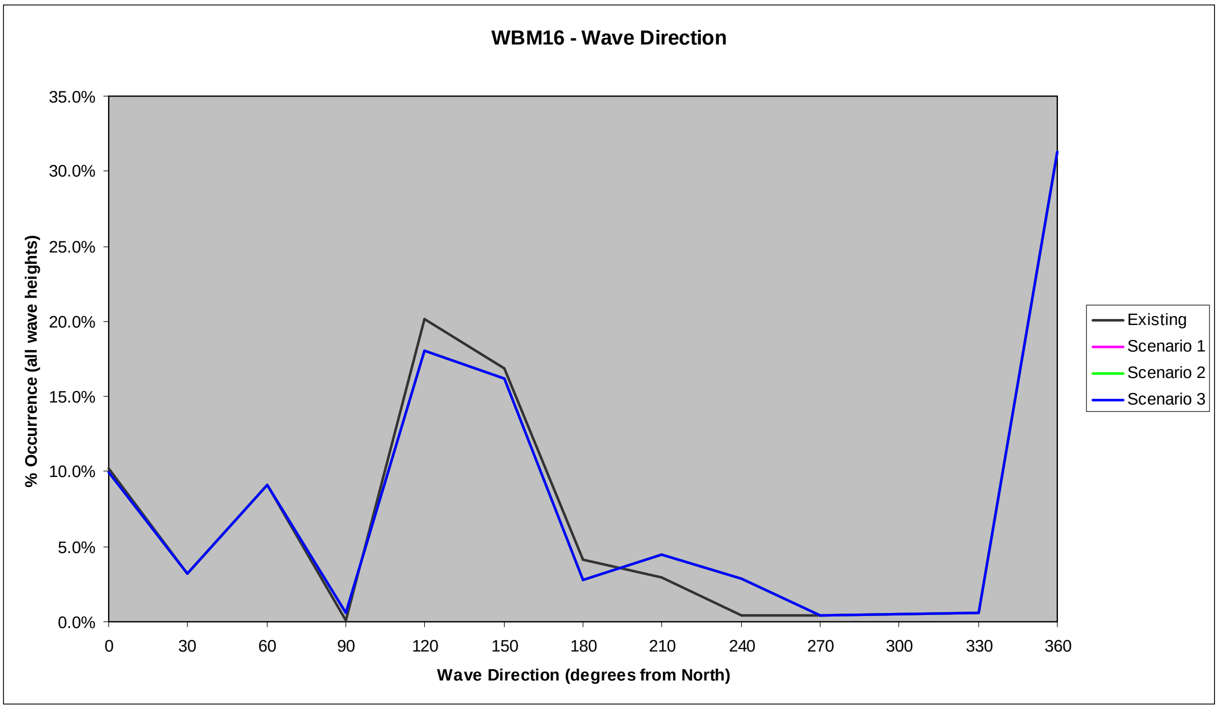
Figure 4-4 Ambient Wave Climate – WBM04 Western Basin



Wave Climate WBM16 - Base Case
% Occurrence
Wave Height Category (m) / 10 = Hs
Wave Direction (deg)
%dry



Wave Climate WBM16 - Scenario 3
% Occurrence
Wave Height Category (m) / 10 = Hs
Wave Direction (deg)
%dry



WBM16 - Wave Direction
% Occurrence (all wave heights)
Wave Direction (degrees from North)
Existing
Scenario 1
Scenario 2
Scenario 3

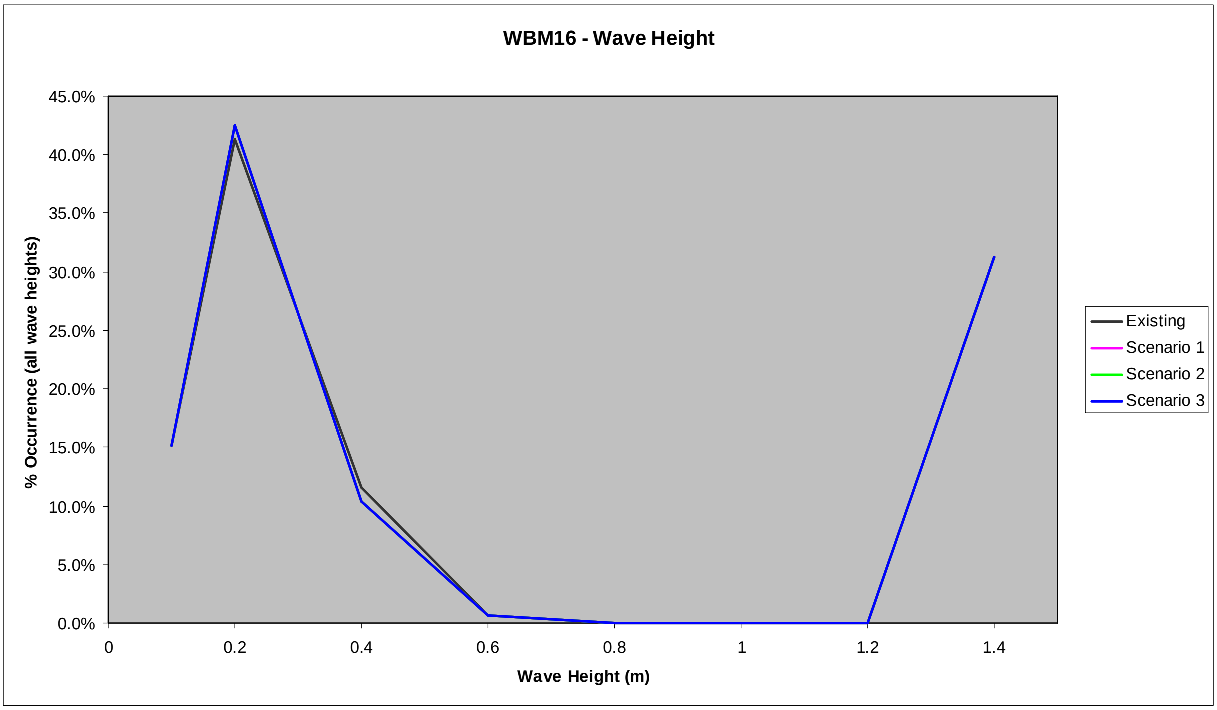
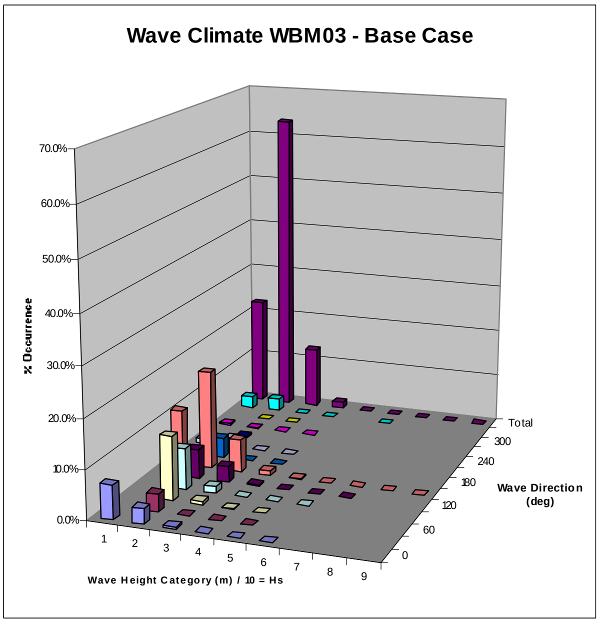
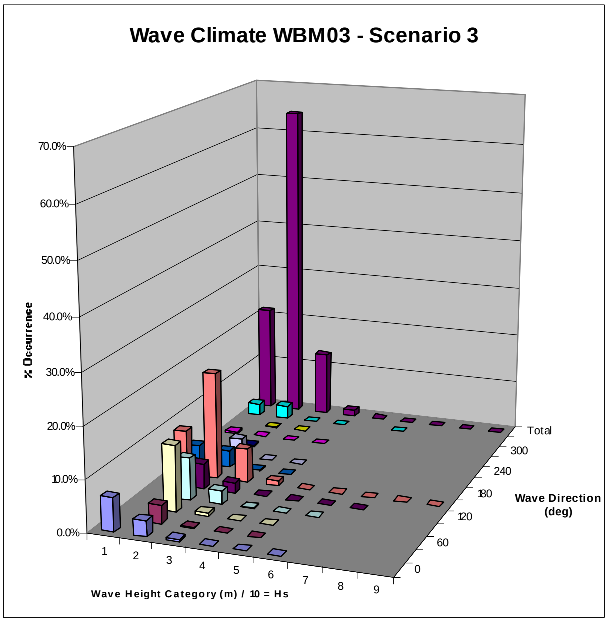
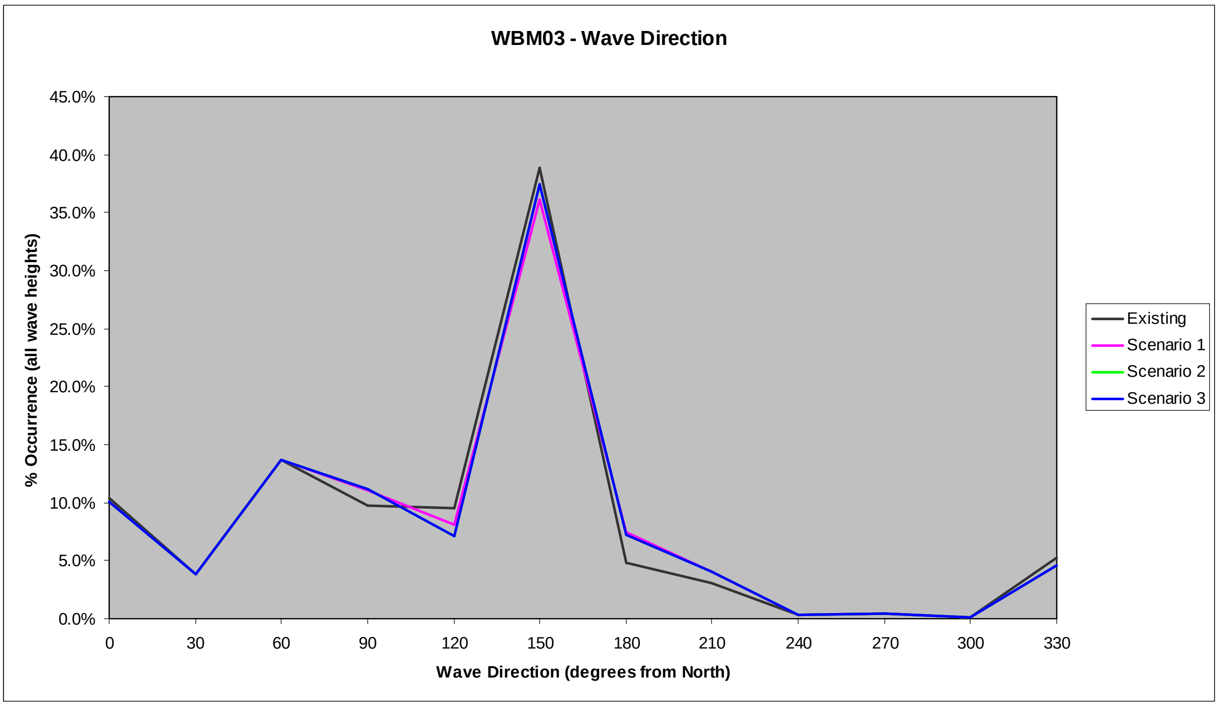


Figure 4-5 Ambient Wave Climate – WBM16 Western Basin North







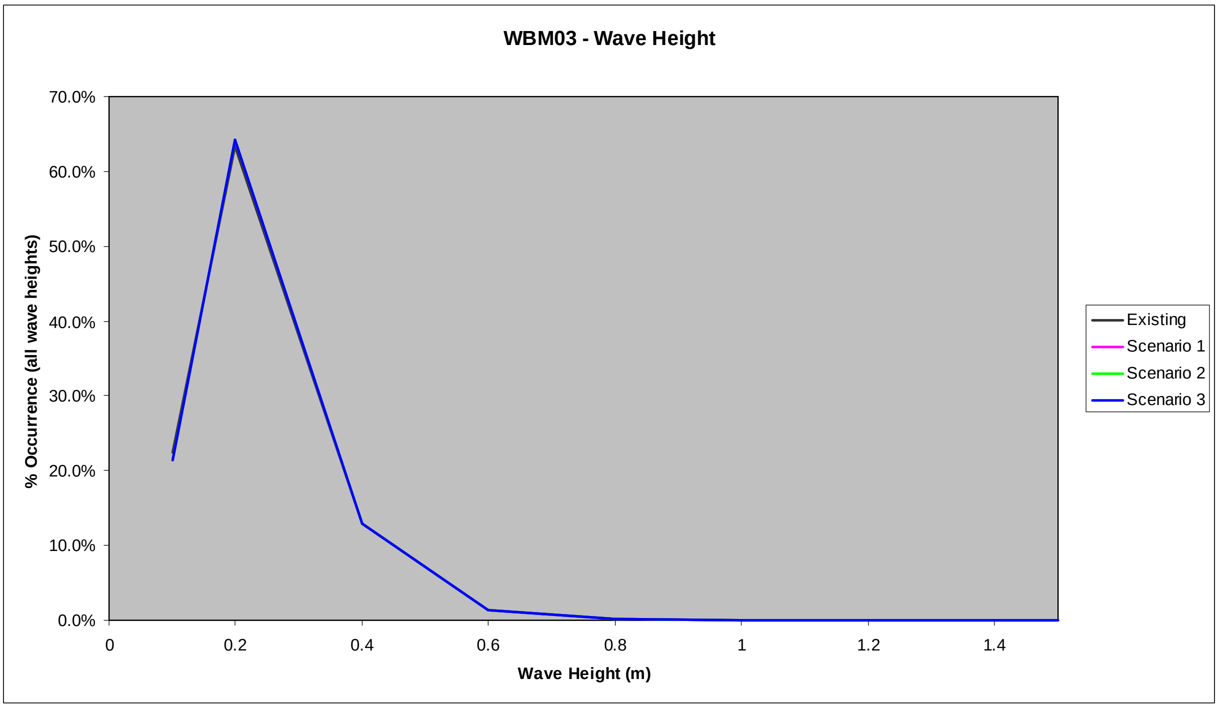
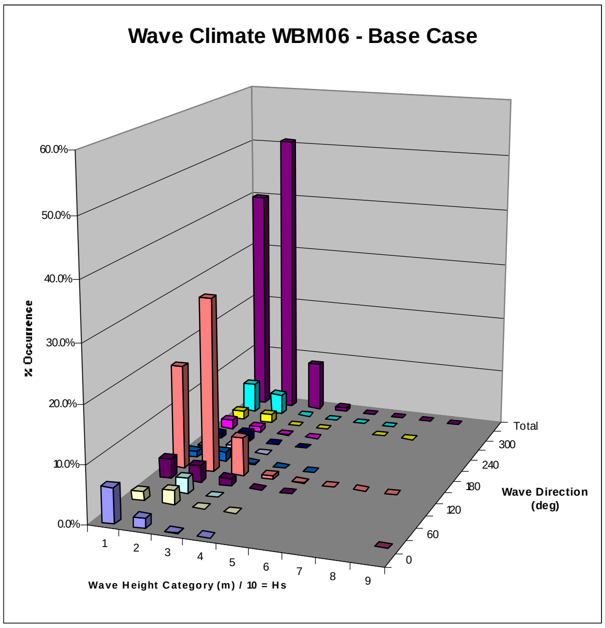
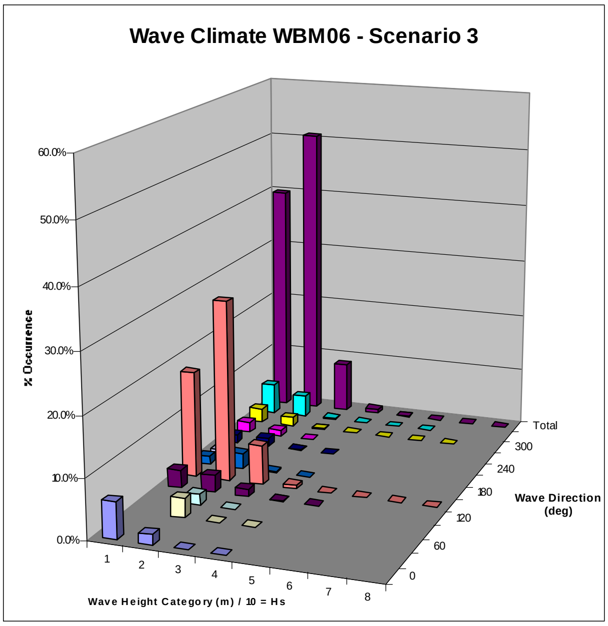
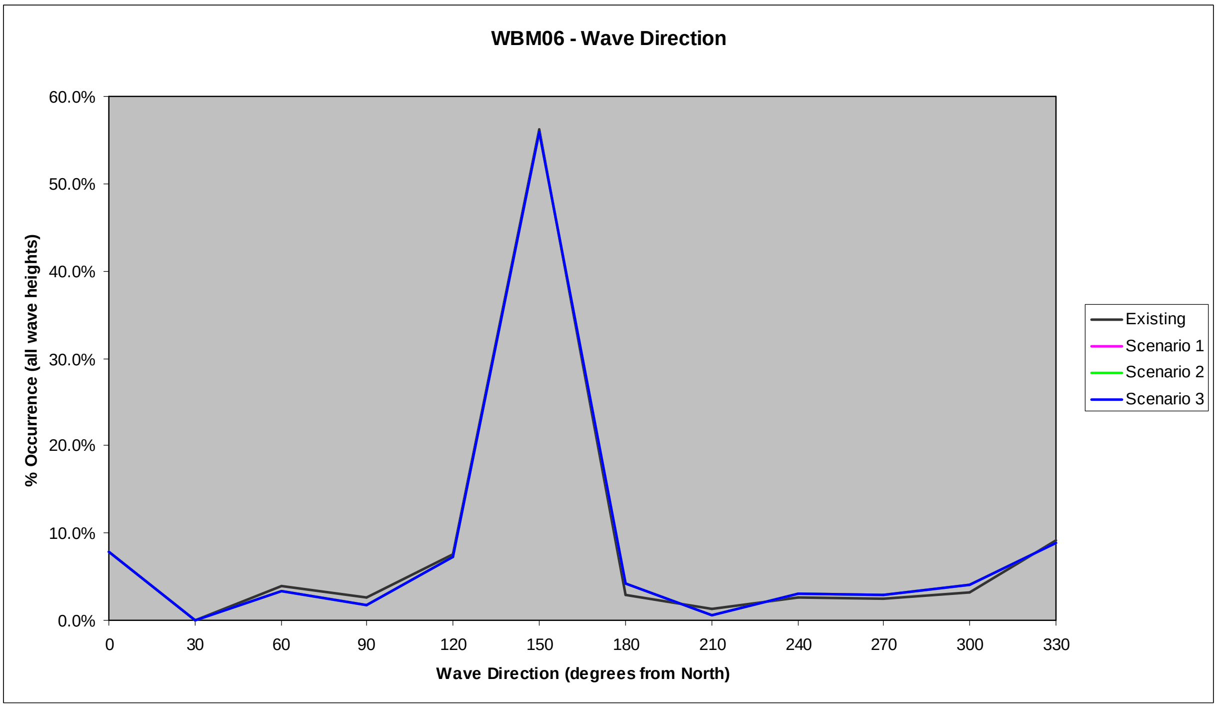


Figure 4-6 Ambient Wave Climate – WBM03 Entrance to Narrows


Wave Climate WBM06 - Base Case
% Occurrence
Wave Height Category (m) / 10 = Hs
Wave Direction (deg)
Total


Wave Climate WBM06 - Scenario 3
% Occurrence
Wave Height Category (m) / 10 = Hs
Wave Direction (deg)
Total


WBM06 - Wave Direction
% Occurrence (all wave heights)
Wave Direction (degrees from North)
Existing
Scenario 1
Scenario 2
Scenario 3

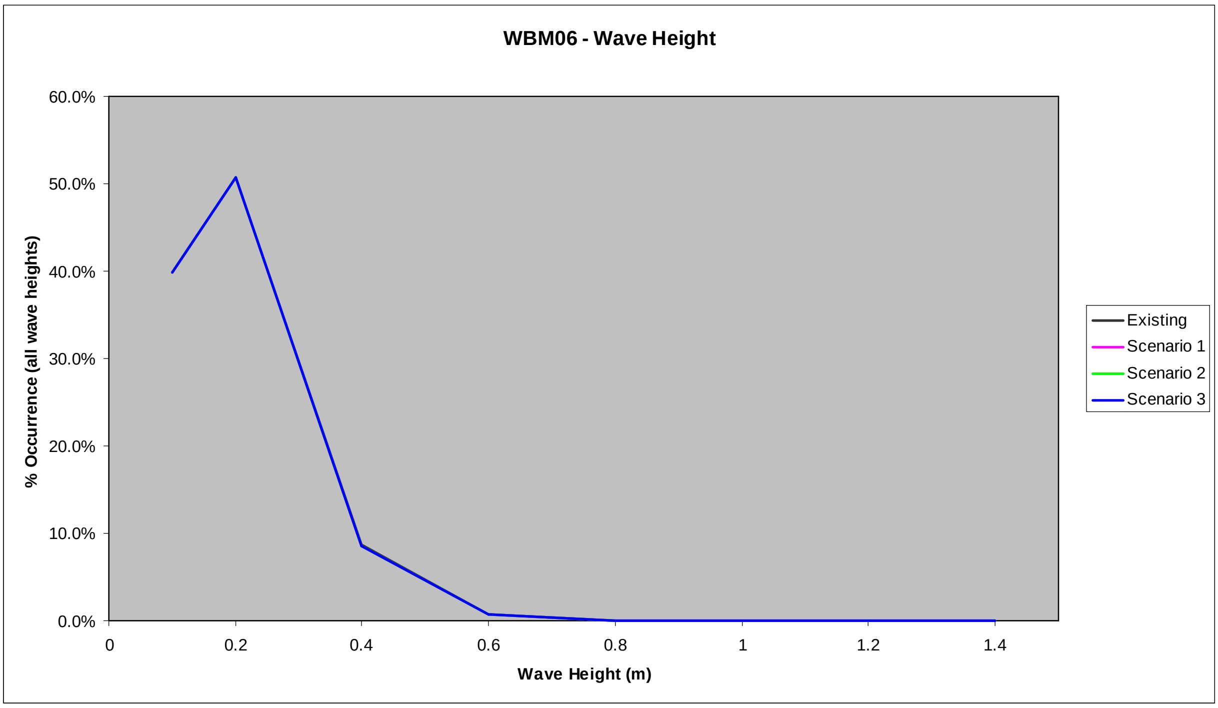


Figure 4-7 Ambient Wave Climate – WBM06 North Passage Island

Ambient Wave Climate Summary

The ambient wave height in the Project Area rarely exceeds 0.6m (less than 1% of time) and the predominant direction of the ambient waves is from the south-east with over 50% occurrence from the 120 and 150 degree sectors.

Except for the area immediately north of the reclamation (WBM04), the proposed reclamation and dredging has only minor effects on the wave climate in that part of the harbour between Fisherman's Landing and The Narrows. Given the low wave heights, the changes will not be significant in terms of the effects on coastal processes.

North of the reclamation footprint, wave heights will decrease and the predominant wave direction will move from south-east to east. This area will become more quiescent in terms of wave action and will be prone to increased siltation.

4.2.2 Extreme Wave Climate

The extreme wave climate has been assessed using the numerical spectral wave model SWAN for a 1 in 50 year (AEP 2%) event and a 1 in 100 year (AEP 1%) event (WBM 2009b). Wind speeds for this analysis were determined from an analysis of tropical cyclones that could affect the Gladstone Region (GHD 2009a) and were coupled with a water level appropriate for the risk level as determined in the Climate and Climate Change Assessment report (Appendix H of the main EIS). The parameters used are summarised in Table 4-2.

Table 4-2   Extreme Wave Climate Parameters

Return Period (AEP)	1:50 (2%)	1:100 (1%)
Wind Speed (m/sec)	31.3	34.5
Water level (m AHD)	3.33	3.53

For each design storm, twelve combinations of wind (direction and speed) and water levels were modelled using SWAN models (WBM 2009b). The twelve directions were from 0 degrees around the compass in 30 degree sectors. The models were run for the base case and each of the development scenarios and the results are presented in the Wave Climate section of the Numerical Modelling Report (WBM 2009b) as spatial plots showing the distribution of significant wave heights and directions and as tables detailing the wave height, wave period, and wave direction for each wind direction for each case and design storm.

The spatial plots showing significant wave heights and directions throughout the western basin for waves from the north, east, and south-east are available in the Numerical Modelling Report (WBM 2009b). The spatial plot for the south-easterly wind direction for the base case is shown in Figure 3-5 in Section 3.1.2. The same plot for the developed case for the 1:100 wind event is provided in Figure 4-8.

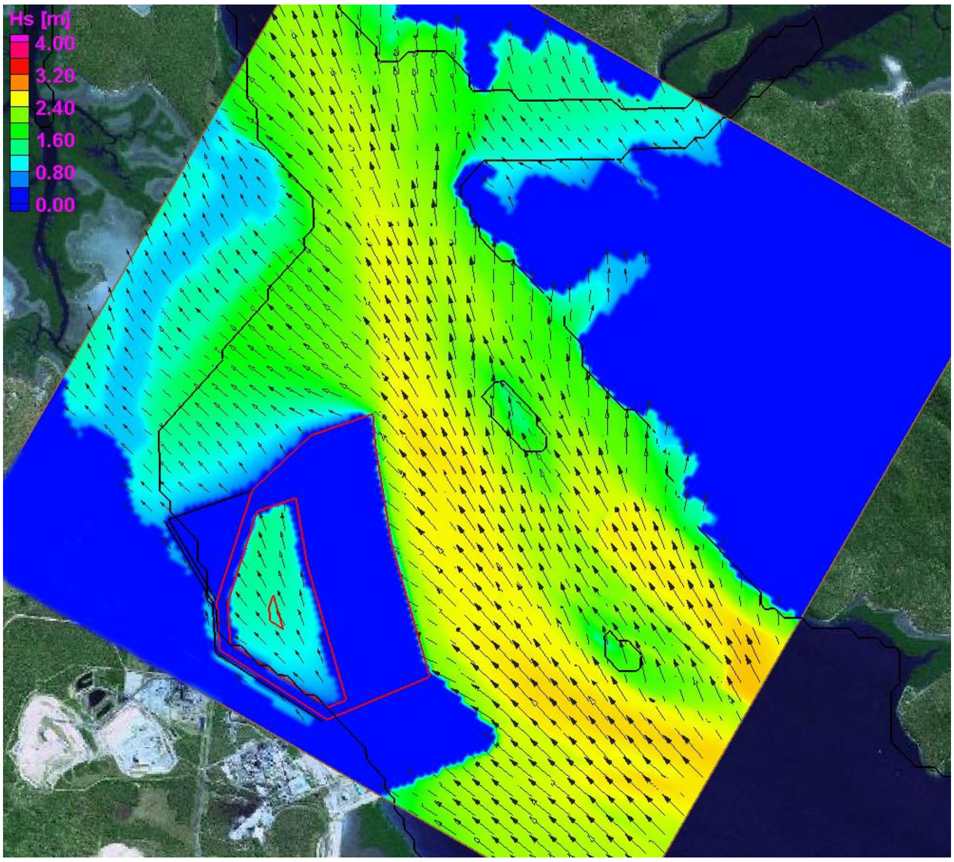
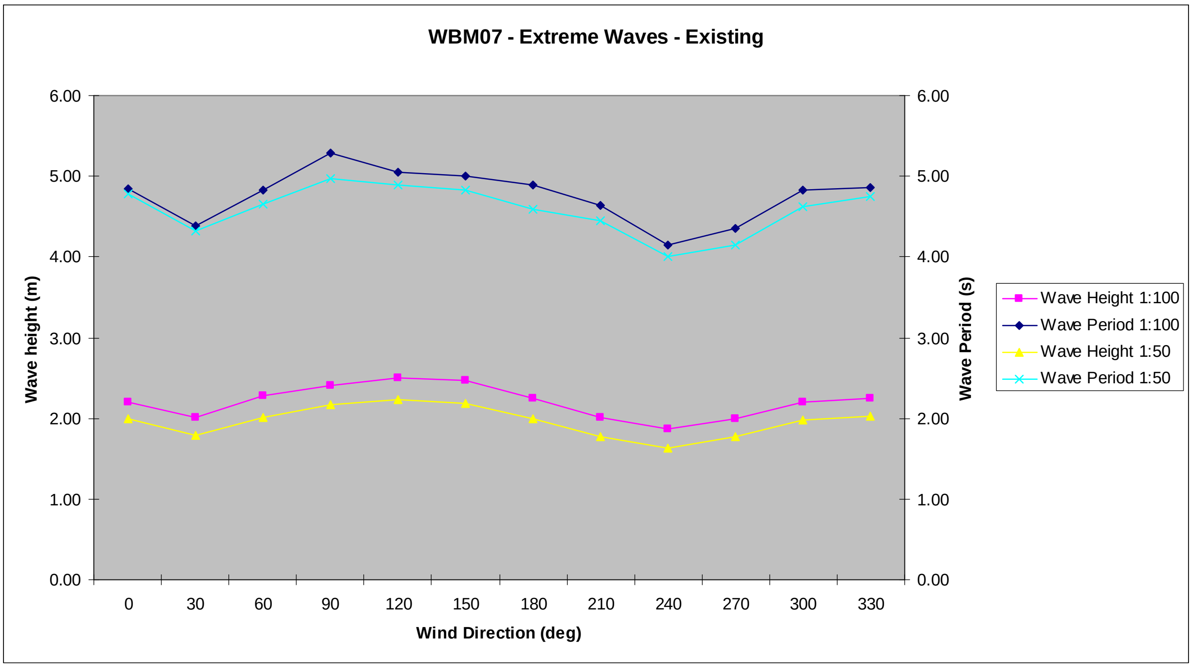


Figure 4-8   Extreme Wave Climate – Modelled Significant Wave Height for South-easterly Wind – Development Scenario 3

The results of the extreme wave climate have been analysed at each point of interest in the Western Basin taking account of the wave height, wave period, and wave direction for each wind direction, for each case and design storm. In order to assess the impact of the development on the extreme wave climate, plots comparing the modelled existing and developed conditions for each point of interest are presented in Figure 4-10 to Figure 4-7.

All results are available for both the 1:50 year event and the 1:100 year event. The two extreme event scenarios produce very similar results in terms of wave heights, period, and direction. The 1:50 results show smaller wave heights and shorter wave periods but similar wave directions and these trends are consistent across all the points of interest in the Western Basin area. To illustrate the typical differences between the 1:50 and 1:100 year scenarios, comparison plots for WBM07 Fisherman's Landing Berths and WBM03 Entrance to Narrows are shown in Figure 4-9.

WBM07 Fisherman's Landing Berths



WBM03 Entrance to Narrows

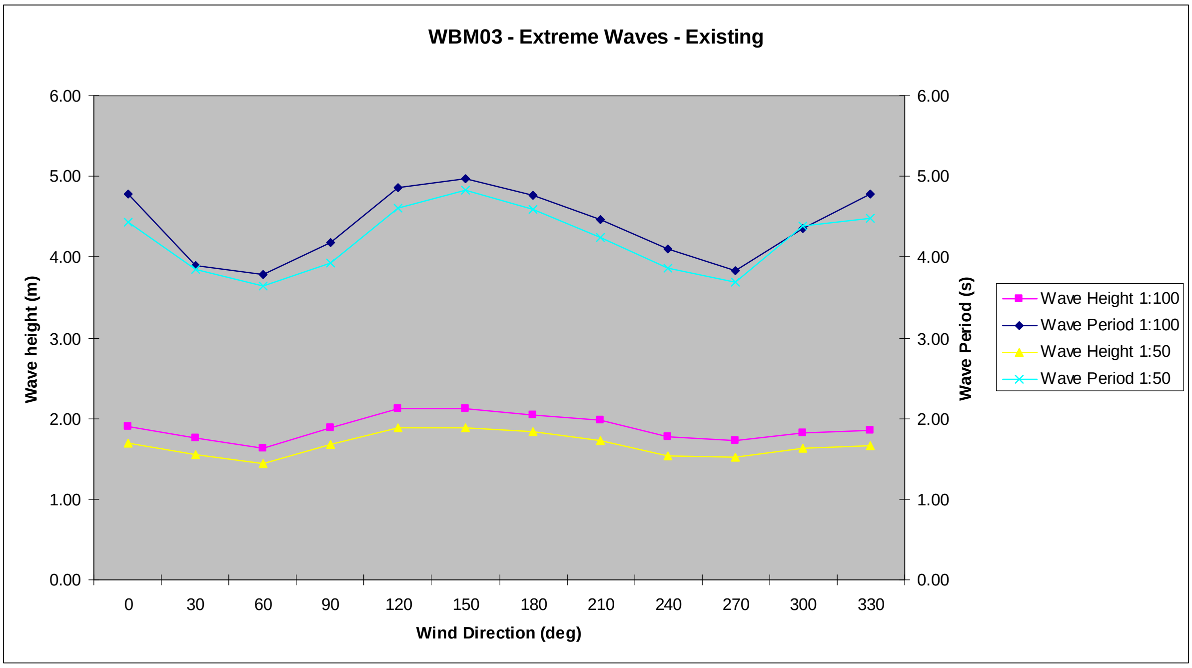


Figure 4-9 Wave Height and Period Comparison – 1:50 and 1:100 Events for the Base Case

Figure 4-9 shows that the results follow the same pattern in relation to the wind direction. Therefore, the 1:100 extreme event has been adopted for further analysis of the impact of the development on the wave climate under these conditions.

Figure 4-10 to Figure 4-16 show the impact of the three development scenarios on the extreme wave climate at each of the points of interest in the Western Basin area compared to the base case. For each point the significant wave height and wave direction is plotted against the wind direction for the 1:100 extreme wind event.

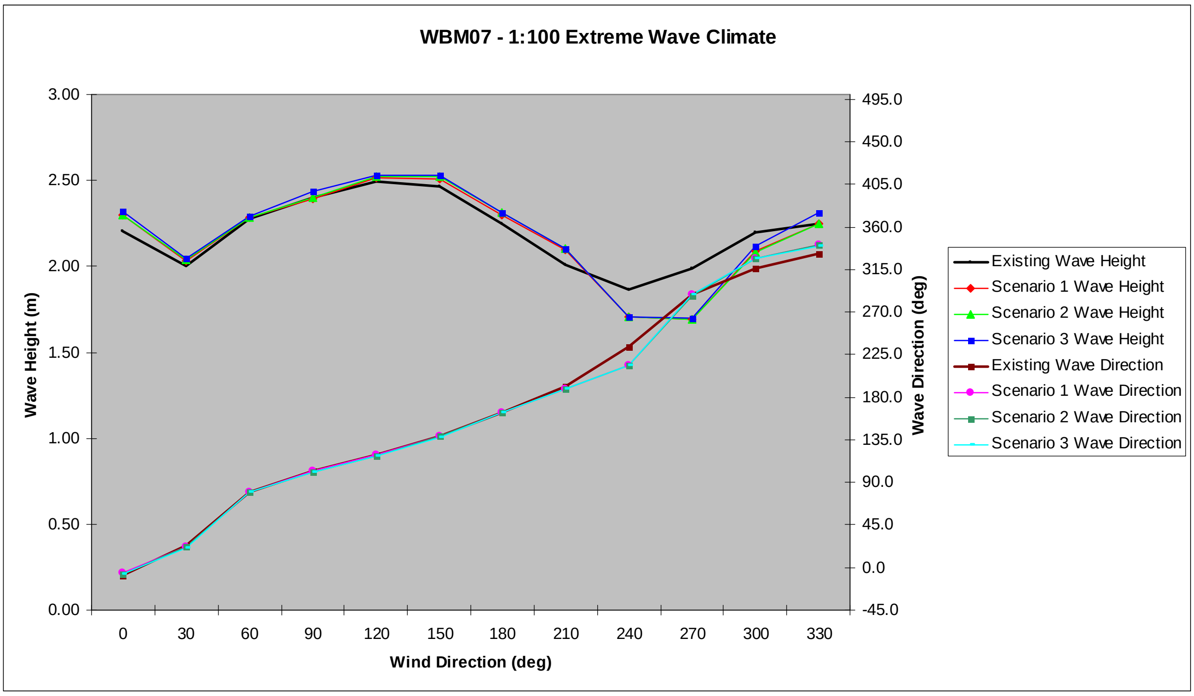


Figure 4-10 Extreme Wave Climate at WBM07 Fisherman's Landing Berths

Figure 4-10 shows the following:

- Marginal increases in wave height from the southerly sector due to the dredged channels.
- Marked reduction in wave height from the west due to the blocking effect of the reclamation.
- Minor changes in wave direction from the west and north due to the influence of the reclamation.

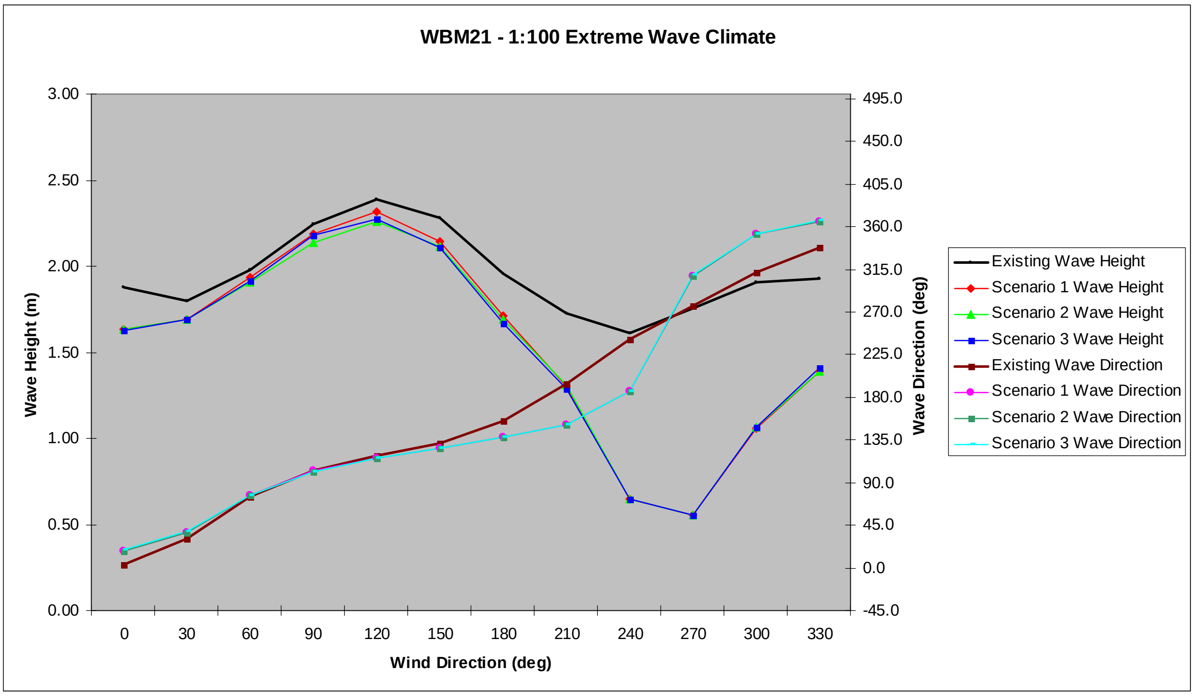


Figure 4-11 Extreme Wave Climate at WBM21 Eastern Edge of Reclamation

Figure 4-12 shows the following:

» Minor reduction in wave height from the east and south due to interaction with the eastern boundary of the reclamation.

» Major reduction in wave height from the west (270 degrees) due to blocking effect of the reclamation (1.76m existing to 0.55m for developed case).

» Significant reduction in wave height from the north due to interaction with the eastern boundary of the reclamation.

» Significant change in wave directions (up to 55 degrees) for winds from the west and north, but changes are related to relatively low wave heights (0.5m to 1.0m) from directions that will have a low chance of occurrence.

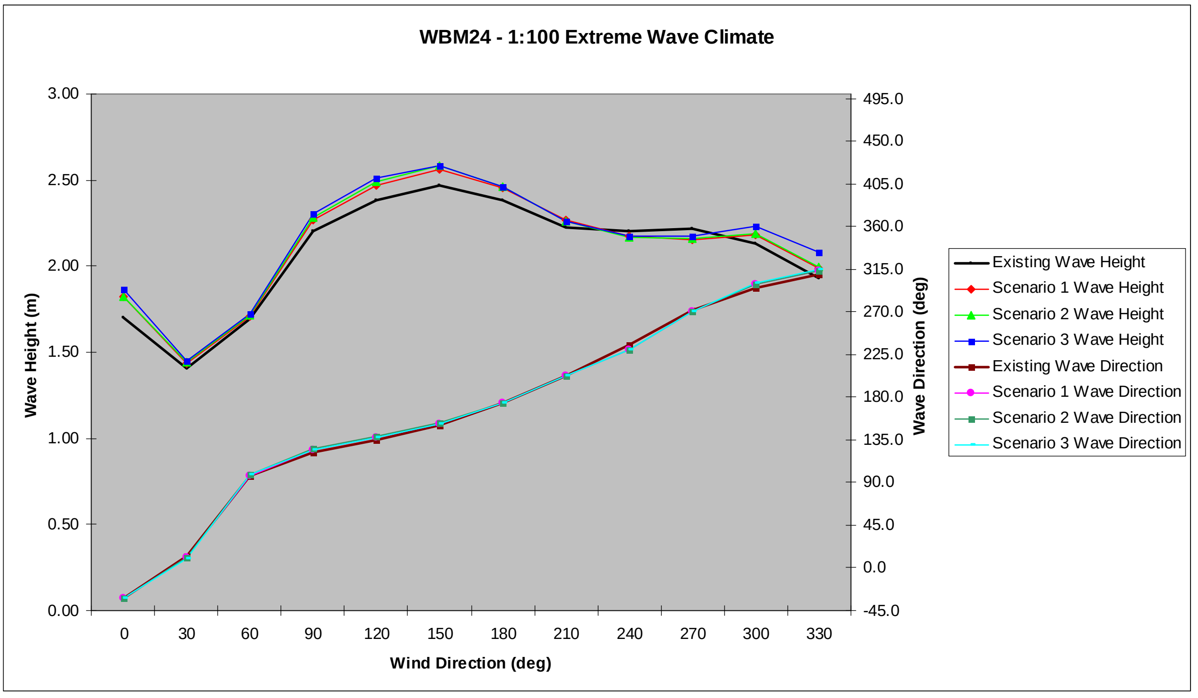


Figure 4-12 Extreme Wave Climate at WBM24 China Bay

Figure 4-12 shows the following:

» Minor increases in wave height from the southern and northern sectors due to the influence of the dredged channels.

» No changes in wave direction as a result of the development.

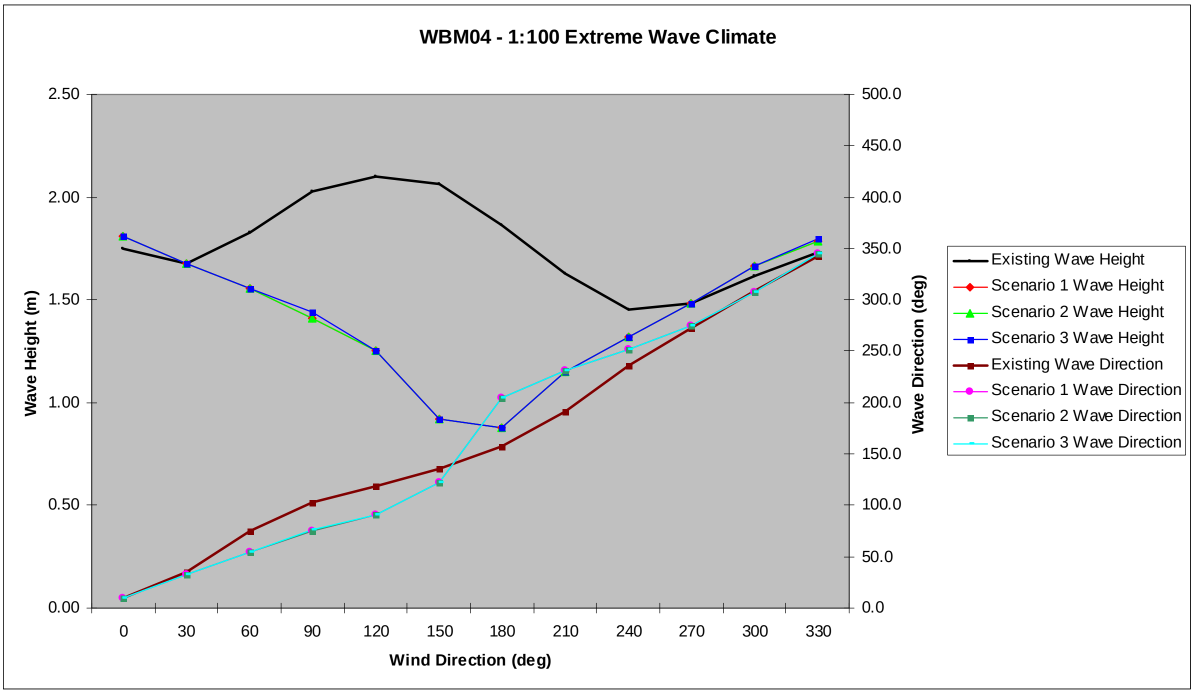


Figure 4-13 Extreme Wave Climate at WBM04 Western Basin

Figure 4-13 shows the following:

» Significant to major reductions in wave height from all sectors between north-east to south-west due to sheltering effect of the reclamation.

» Significant changes in wave direction for winds from the east and south-east as waves refract around the northern limit of the reclamation.

» Significant changes in wave direction for winds from the south-west and west due to changes to the available fetch caused by the reclamation.

WBM16 Western Basin North

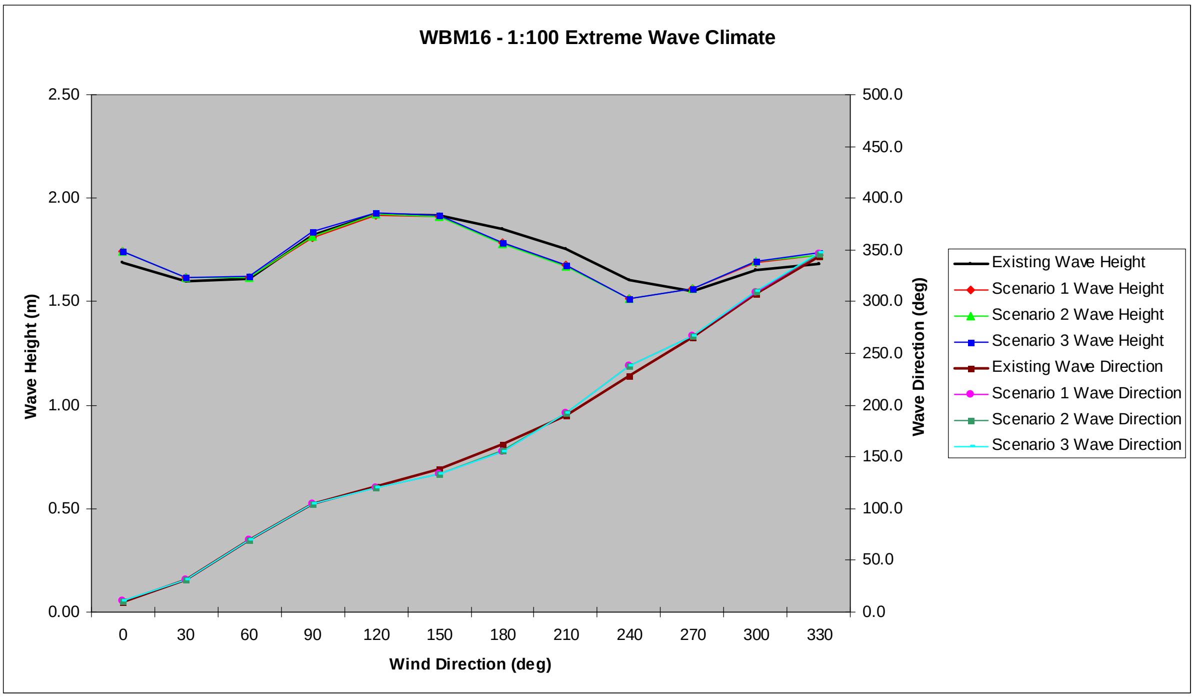


Figure 4-14 Extreme Wave Climate at WBM16 Western Basin North

Figure 4-14 shows the following:

» Minor reductions in wave heights from the southerly sector due to partial shadowing by the reclamation.

» Minor changes to wave direction for winds from the south and west due to the presence of the reclamation.

WBM03 Entrance to Narrows

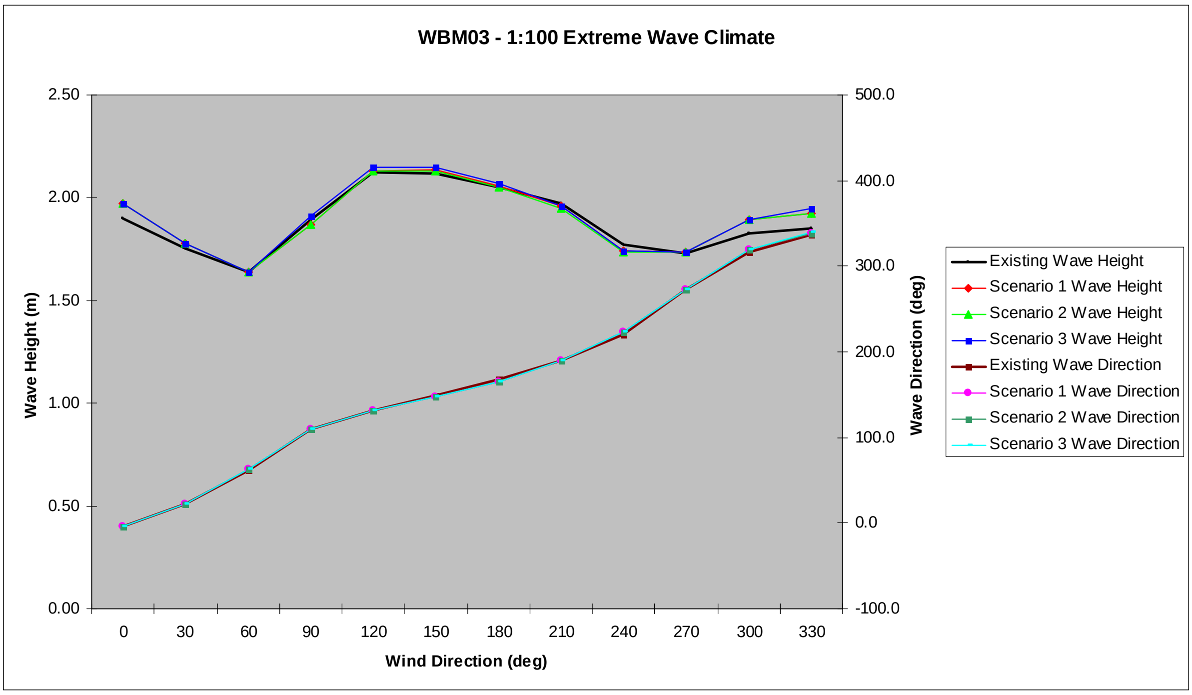


Figure 4-15 Extreme Wave Climate at WBM03 Entrance to Narrows

Figure 4-15 shows the following:

» Minor increases in wave height from the north and north-west. This is somewhat counter- intuitive given that the reclamation is downstream of this wind direction. It is likely that the minor increases are the result of changes to the model required to incorporate the large reclamation area and are probably not real.

» No changes in wave direction as a result of the development

WBM06 North Passage Island

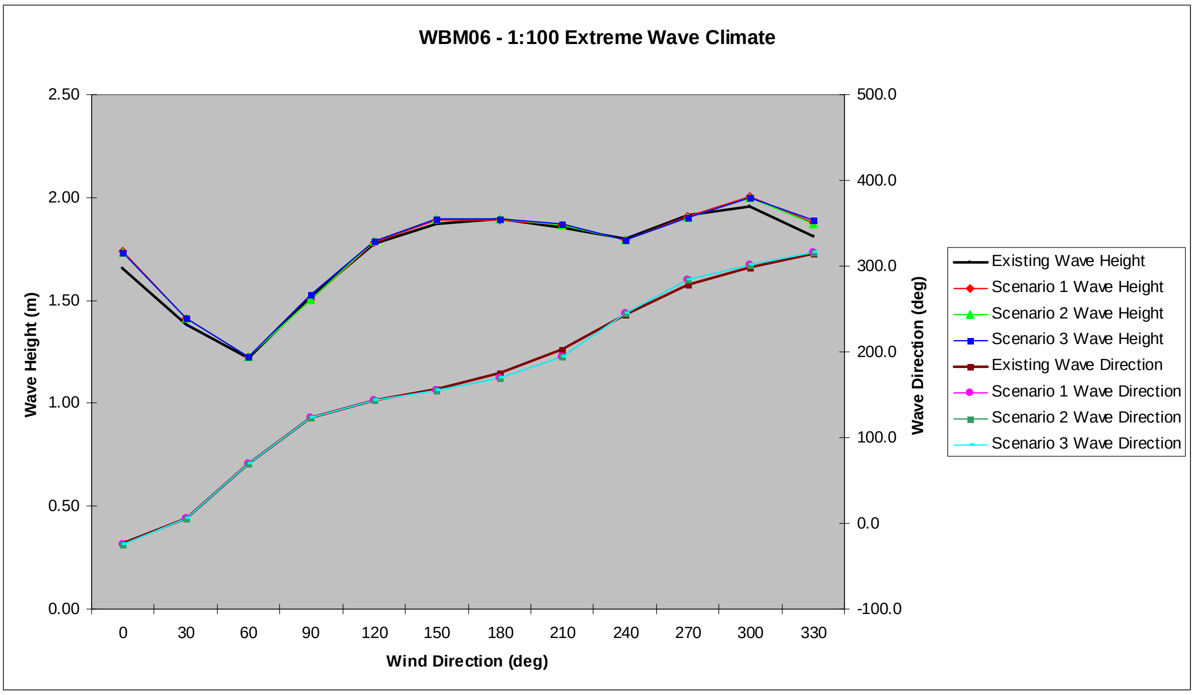


Figure 4-16 Extreme Wave Climate at WBM06 North Passage Island

Figure 4-16 shows the following:

- Minor increases in wave height from the north and north-west.
- Minor changes to wave direction for wind from the south due to the influence of the dredged channels.

Extreme Wave Climate Summary

The wave height generated by extreme events (1 in 100 year) in the vicinity of the Western Basin can be up to a maximum of 2.54m. The maximum wave height is generated from a few degrees south of east around to the south-south-east as a consequence of the fetch lengths in these directions. This is also the most likely wind direction from a cyclone crossing the coast north of Gladstone and therefore this combination of extreme wave and direction is a realistic component of the overall wave climate for the Western Basin area.

Except for the area immediately north of the reclamation (WBM04) and along the eastern margins of the reclamation (WBM21), the proposed reclamation and dredging has only minor effects on the extreme wave climate in the Western Basin area. The most significant impact of the proposed development is a reduction in the extreme wave energy north of the reclamation and hence, in an extreme event, increased siltation may occur in this area. However, this is unlikely to be significant in terms of the overall impacts that such an extreme event would have in other areas in the harbour.

4.3 Water Levels

The potential impacts of the proposed works represented in the three development scenarios, have been assessed with the calibrated and validated TUFLOW-FV model of Port Curtis. The results from the modelling have been used to assess the impact of the development scenarios and a Numerical Modelling Report (WBM 2009b) that provides the model details and a complete set of results is located in Appendix J of the main EIS.

The dredging and reclamation works introduce various inter-related, additive and sometimes compensating effects to modify water levels and tidal currents. The stage of works also adds to the complexities with some impacts in early stages being mitigated in certain areas by subsequent works while others increase (WBM 2009b).

The proposed reclamation reduces the inter-tidal storage area by 408.5ha, which causes a reduction in the tidal prism that subtly alters the tidal propagation dynamics within the system (WBM 2009b).

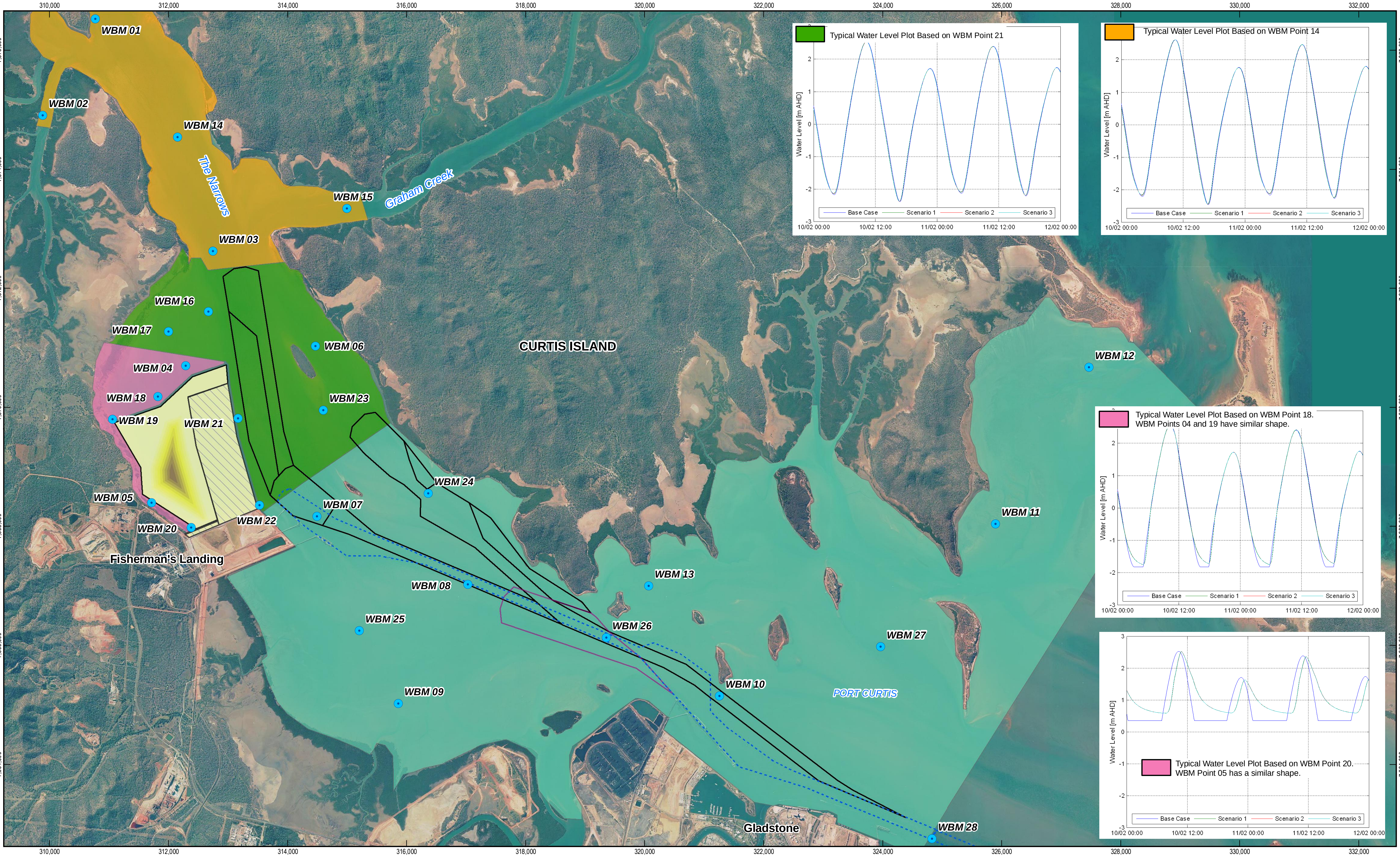
4.3.1 Results from Time Series

Time series of water levels for the base case and the three development scenarios were extracted at the 28 locations throughout the model as shown on Figure 2-1. On examination of the results across the model, it is clear that different impacts are apparent in different parts of the harbour and can generally be characterised by one of the points in those areas. This is illustrated for water level impact in Figure 4-17. Water level changes are categorised as No Change, Very Minor Phase Change, Very Minor Phase Change with Small Change to Low Water (LW) Level, and major Changes to LW and Phase Shifts and are further described as follows:

1. The area where there is no change (light green) covers all points down-harbour of Fisherman's Landing.
2. Very minor phase changes (dark green) occur at points adjacent to the reclamation in main harbour i.e. to the east of the reclamation. Typically the phase change is less than 10 minutes.
3. North of the entrance to The Narrows, a small change to the low water (LW) occurs (< 0.05m) in addition to very minor phase changes.
4. The only location where there are noticeable changes in water level is in the immediate vicinity of the reclamation (north and west) (pink). Here it is evident that major changes to LW and phase shifts will occur resulting in a more gradual drop in the tide to LW and the LW level generally being marginally higher.

The relative impact of the various staged scenarios is much smaller than the impacts relative to the base case, which indicates that the reclamation and the associated loss of inter-tidal storage is a more significant influence on the hydrodynamics of the area than the dredging works.

The most noticeable differences in water level occur in the western channel between the proposed reclamation and the western foreshore. At WBM20, the model predicts a shallow depth (<0.3m) of water pondage due to a high spot in the drainage path along the western side of the reclamation.



1:60,000 (at A3)

0 500 1,000 1,500 2,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 56

N

LEGEND

- Output Locations
- Western Basin Reclamation
- Fisherman's Landing Northern Expansion
- Proposed Dredging Stages
- Existing Channels, Swing Basins and Berths
- Wiggins Island Coal Terminal (Approved)

Water Level Change

- No Change
- Very Minor Phase Change
- Very Minor Phase Change - Small Change to LW Level
- Major Changes to LW and Phase Shifts

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Predicted Changes in Water Levels

Figure 4-17

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4.3.2 Water Levels Summary

The water level time series results indicate that the reclamation and dredging works will have negligible impacts on high tide levels and relatively minor impacts on low tide levels except in the channel on the western side of the reclamation.

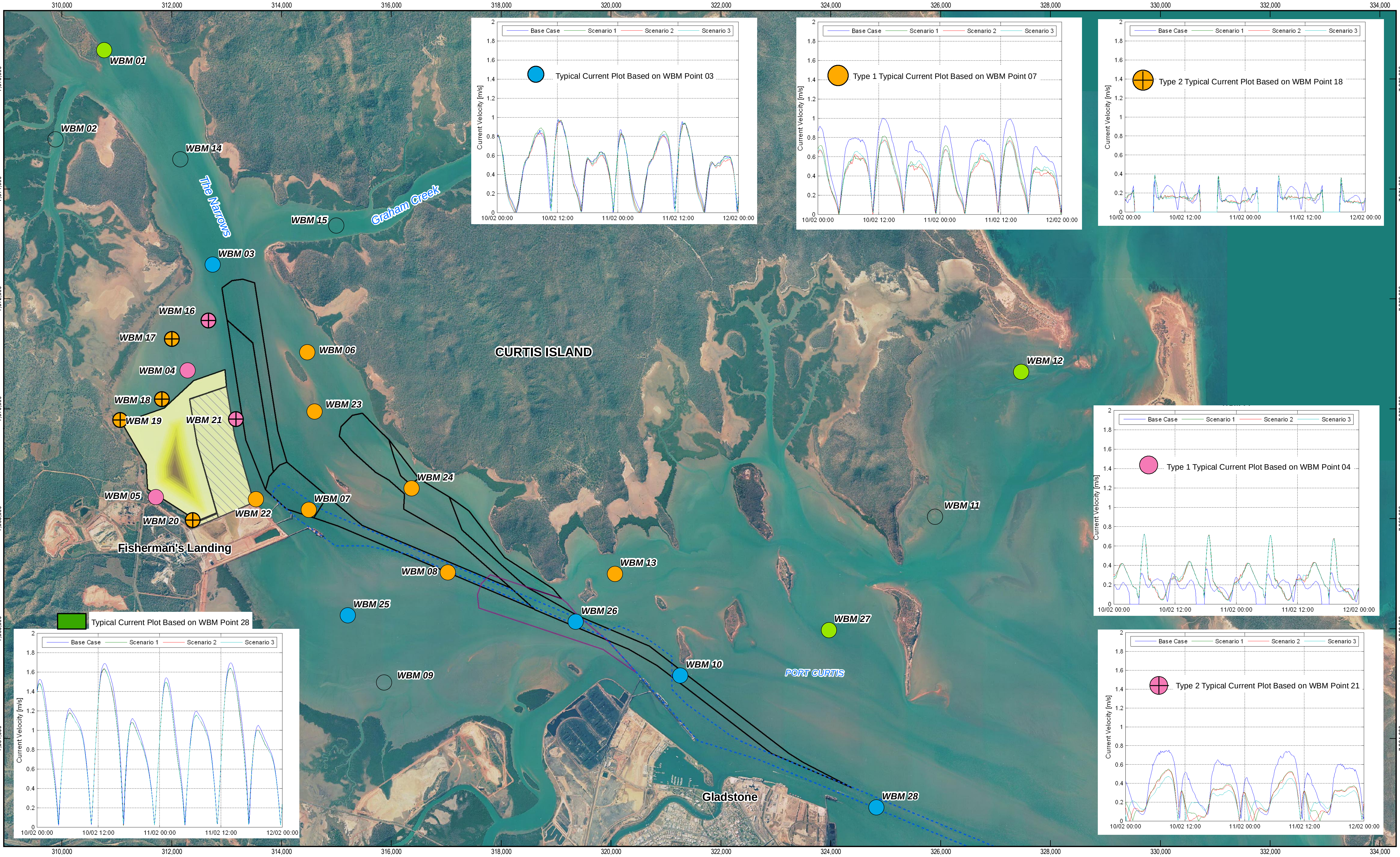
4.4 Tidal Currents

As stated previously, the proposed reclamation reduces the inter-tidal storage area by 408.5ha, which causes a reduction in the tidal prism that subtly alters the tidal propagation dynamics within the system (WBM 2009b). While these changes did not have significant effects on water levels except in the area immediately adjacent to the reclamation, the reduction in the tidal prism and the changes to flow paths as a result of the reclamation cause much more significant effects on current velocities.

4.4.1 Results from Time Series

Time series of current velocities for the base case and the three development scenarios were extracted at the 28 locations throughout the model as shown on Figure 2-1. Characterisation of the results into typical responses is more complicated than the same analysis of water levels as there are more significant differences to assess and the there are more typical response types. The results are illustrated on Figure 4-18 and are further described as follows:

1. No change (no colour) – at four points only, two upstream in The Narrows, and two downstream in "quiet" areas of the harbour (west of Wiggins Island and east of Compigne Island)
2. Very minor changes (light green) – at three points only, located the furtherest from the reclamation, upstream in The Narrows and downstream in the harbour away from the main channels. The changes are typically a very minor reduction in peak currents.
3. Minor changes (blue) occur upstream and downstream of Fisherman's Landing adjacent to and in the dredged channels and typically consist of a minor change (both up and down) in peak currents and some minor phase changes.
4. In the immediate vicinity of Fisherman's Landing east to Curtis Island and downstream to Hamilton Point, there are substantial differences (orange - Type 1) that show up as changes (both up and down) in peak currents up to 25% and some minor phase changes. For this group, the current plot for WBM07 is typical.
5. In the area to the west and north of the reclamation, there are also substantial differences (orange - Type 2) of the same general description but the typical plot is quite different (WBM18).
6. Major Changes (pink - Type 1) occur close to the reclamation at points WBM 04 and 05 and involve large velocity increases and decreases and major phase shifts, but on a low velocity base. The plot for WBM04 is typical of this group.
7. Major Changes (pink – Type 2) occur north of the reclamation at WBM16 and along the eastern edge of the reclamation at WBM21. The plot for WBM21 is typical of this group.



1:65,000 (at A3)

0 500 1,000 1,500 2,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 56

N

LEGEND

- No Change
- Very Minor Changes
- Minor Changes
- Substantial Differences - Type 1
- Substantial Differences - Type 2
- Major Changes - Type 1
- Major Changes - Type 2
- Western Basin Reclamation
- Fisherman's Landing Northern Expansion
- Existing Channels, Swing Basins and Berths
- Wiggins Island Coal Terminal (Approved)

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Western Basin Dredging and Disposal Project

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Predicted Changes in Current Velocities Figure 4-18

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The above observations are consistent with the summary provided in the Numerical Modelling Report (WBM 2009b) which states that, in general, current velocities tend to decrease in dredged areas as well as those areas laterally adjacent to the dredging (e.g. WBM07, 08, 24, 22, and 13). Increases in velocity are typically evident in adjacent un-dredged areas upstream and downstream of the newly dredged areas (e.g. WBM03, 06, and 23). The reclamation can also act to modify velocities in the immediate adjacent channel and inter-tidal areas by confining and redirecting the flow (e.g. all points in the Western Basin).

4.4.2 Impact Plots

Aerial plots of maximum ebb and flood tide velocities for the base case are shown in Figure 4-19 and Figure 4-21 and the changes to those velocities for Scenario 3 are shown in Figure 4-20 and Figure 4-22.

Only Scenario 3 is shown here as it generally represents the worst case scenario in terms of impacts outside the new dredged channel areas, for example, the ultimate dredging configuration associated with Scenario 3 causes the footprint of increased velocities to extend further north into The Narrows, and ebb tide velocity increases at Hamilton Point are accentuated and extend through to Boatshed Point.

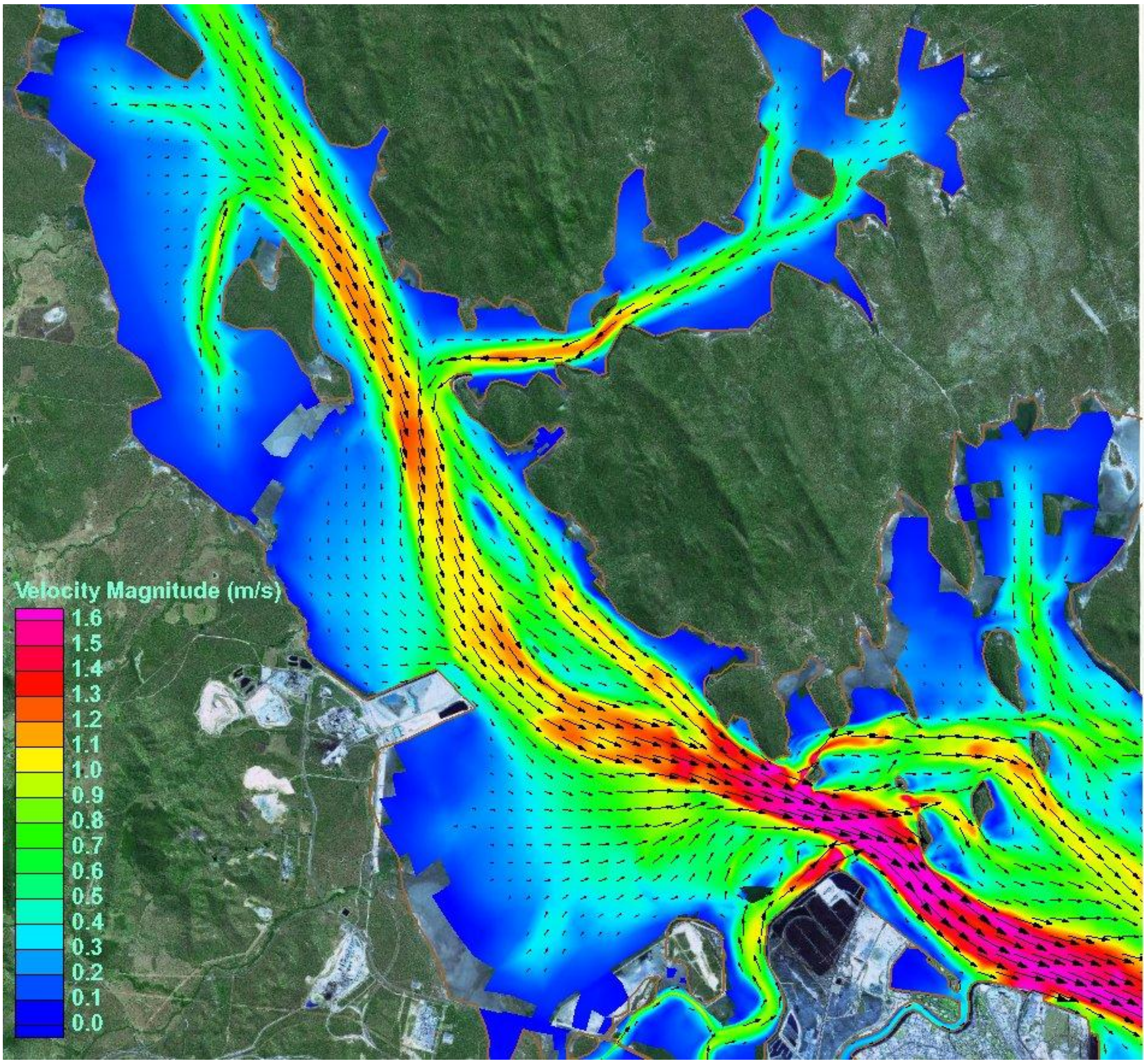
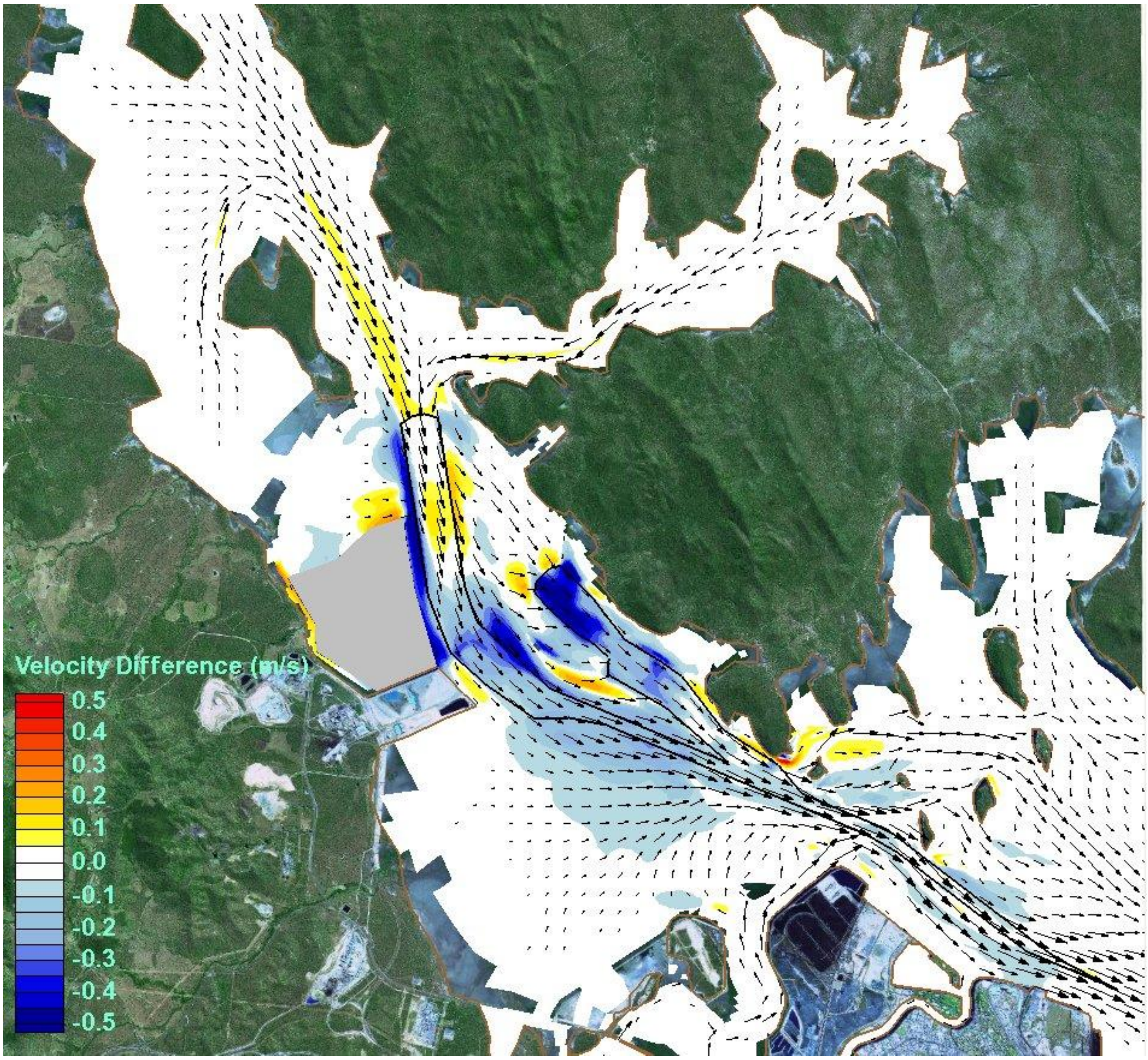


Figure 4-19 Maximum Ebb Currents – Base Case



Developed Scenario 3

Figure 4-20 Impact of Development on Maximum Ebb Currents

The results for the ebb tide show:

1. There is a small overall reduction in velocity downstream of the western basin due to the presence of the reclamation reducing the tidal prism.
2. Current velocity increases opposite the northern end of the reclamation are evident due to the reduction in the available waterway width.
3. Small area of increased velocities adjacent to Curtis Island (opposite the reclamation) due to "weir effect"[2] as water drops into dredged channel.
4. Around the northern edge of reclamation there is a small area of increased velocities as the tide flows out of the embayment north of the reclamation.

[2] "weir effect" refers to the analogy of the increase in flow upstream of a broad crested weir as the water approaches the weir crest

5. Current velocities east of the reclamation reduce progressively from Scenario 1 to Scenario 2 and 3 due to the increasing capacity of the channel.
6. For Scenario 3 there is an area of increased velocities extending up into The Narrows from the Laird Point channel due to the “weir effect” of the final stage of the dredging of the channel parallel to the reclamation.
7. Erosion of the bed may occur in areas of increased velocity depending on the bed material. Any eroded material will settle in the bottom of the channel and will need to be removed by maintenance dredging. Given the low magnitude of the velocity increase, the volume of material is expected to be similar to existing maintenance dredging commitments (refer also Section 4.5)
8. Some scour of and redistribution of fine sediments at the northern corner of the reclamation can be expected. Some of this material may also settle in the dredged channel. There is potential for the finer material to form a plume until the fine material in this area is removed or the bed deepens such that the velocities are reduced (refer also Section 4.9). The expected scour will also need to be considered in the design of the reclamation bund walls in this area, particularly with respect to the stability of the toe of the wall.

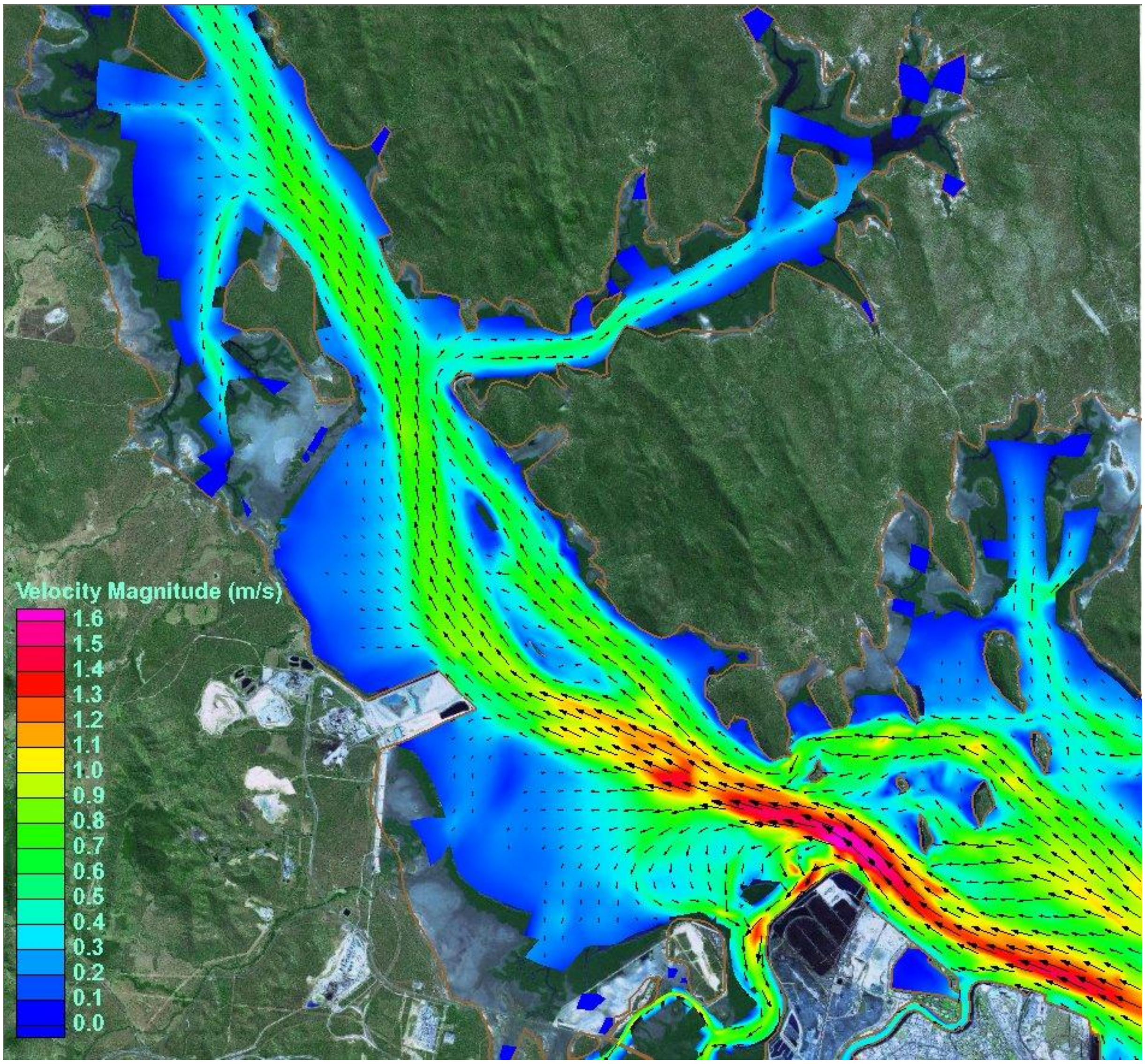
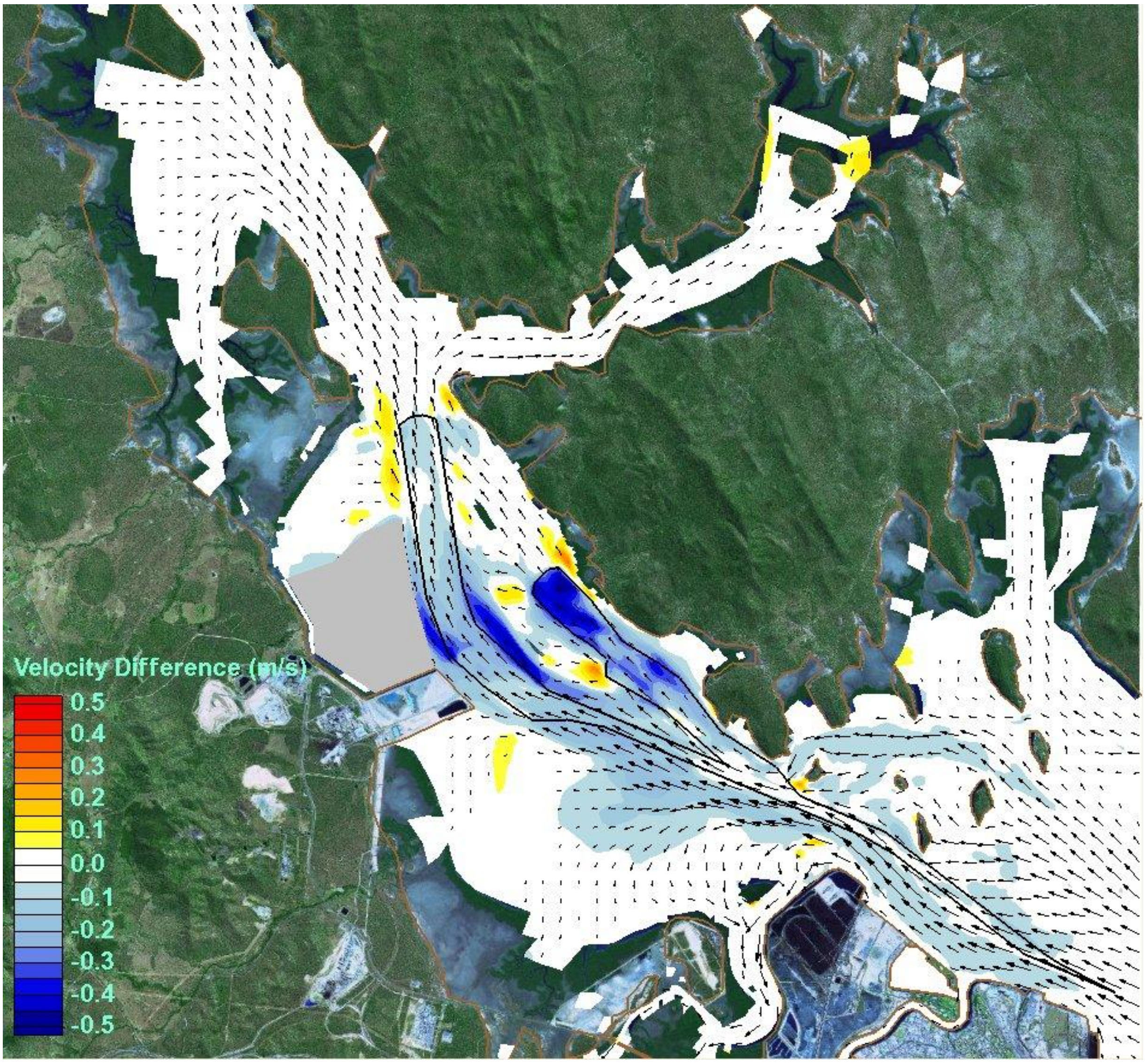


Figure 4-21 Maximum Flood Currents – Base Case



Developed Scenario 3

Figure 4-22 Impact of Development on Maximum Flood Currents

The results for the flood tide show:

1. Small increases in current velocity upstream of dredged channels as flow progresses from the deep dredged channel to shallower un-dredged areas. This phenomenon fades by the time the flow enters The Narrows.
2. General reductions in current velocities in the dredged channels due to their larger cross sectional area for similar flows
3. Current velocity increases generally are highest for Scenario 1, reducing for Scenarios 2 and 3 due to the increased capacity provided by the dredged channels.

4.4.3 Integrated Flow Summary

The integrated flow results from the hydrodynamic model indicate a slight reduction in the total flow entering and leaving the Western Basin at the southern (downstream) end between Mud Island and Hamilton Point as a result of the loss of storage volume (tidal prism) associated with the reclamation (WBM 2009b).

For The Narrows, there are negligible changes to the flood tide flows into this area while ebb tide flows indicate a small increase in flow in line with the small increases in ebb tide velocities in this area (WBM 2009b).

4.5 Sediment Transport

As introduced in Section 3.2, sediment transport under the action of tidal currents has two principal components – bed load and suspended load. Bed load generally consists of the coarser fractions of the bed material with the finer silts being taken into the water column by the turbulence from the relatively high tidal velocities.

The coarser fractions are characterised by sand and the impacts on the sand transport potential are discussed in Section 4.5.1. Silt movement and deposition is assessed through an examination of bed shear stresses and a semi-quantitative / qualitative assessment of silt deposition. The impacts of the development on bed shear stresses are discussed in Section 4.5.2 and the results of the silt deposition analysis are in Section 4.5.3.

4.5.1 Sand Sedimentation Impacts

The net sand transport potential for the Base Case is shown in Figure 4-23 and the net sand transport potential impacts relative to the Base Case for the three developed scenarios are shown in Figure 4-24.

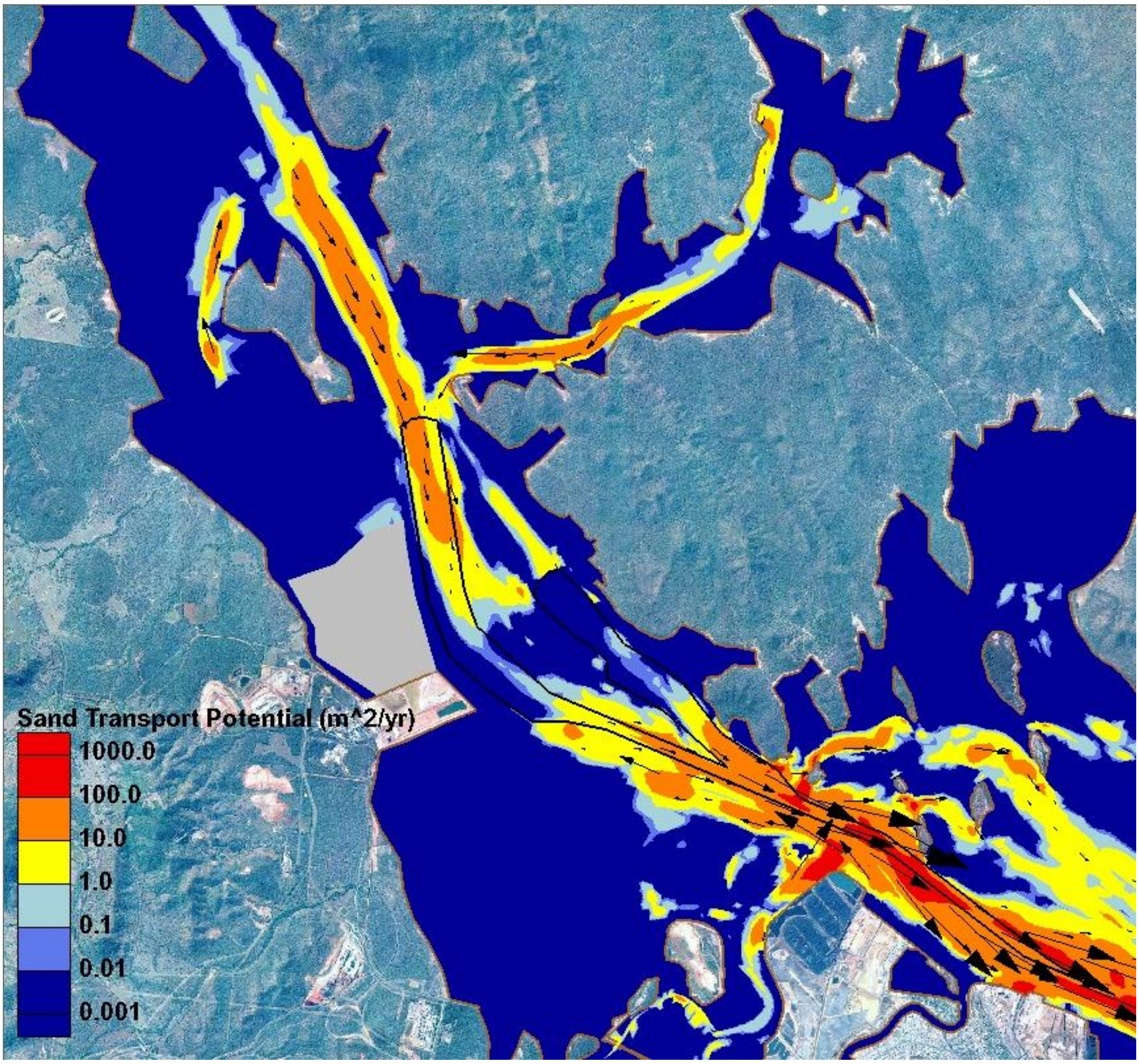
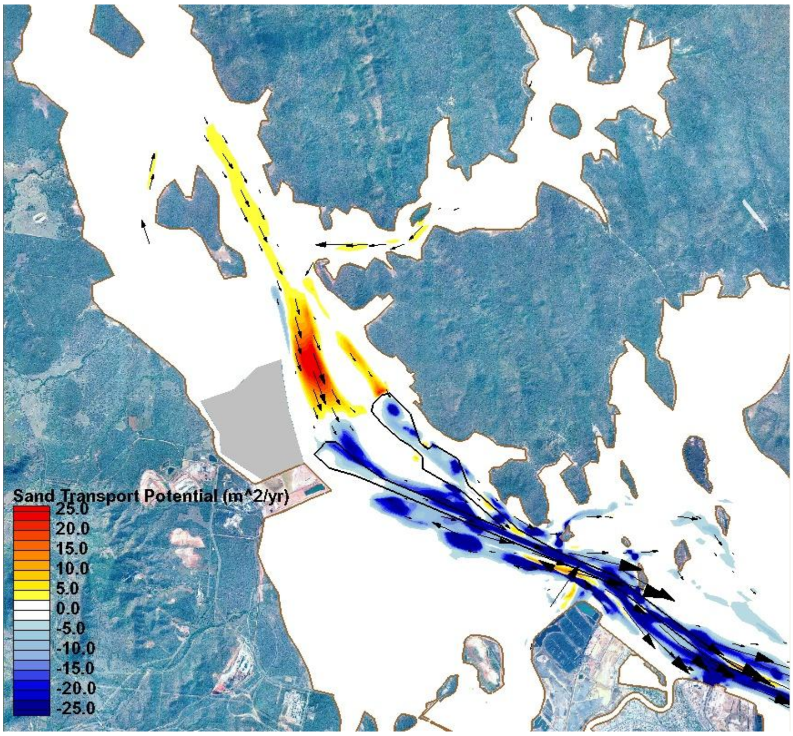
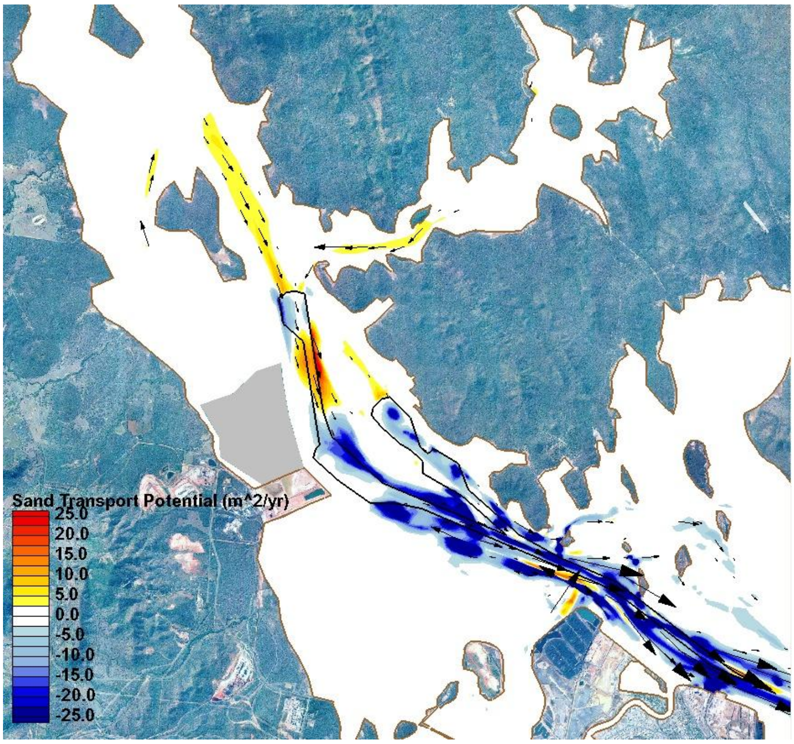


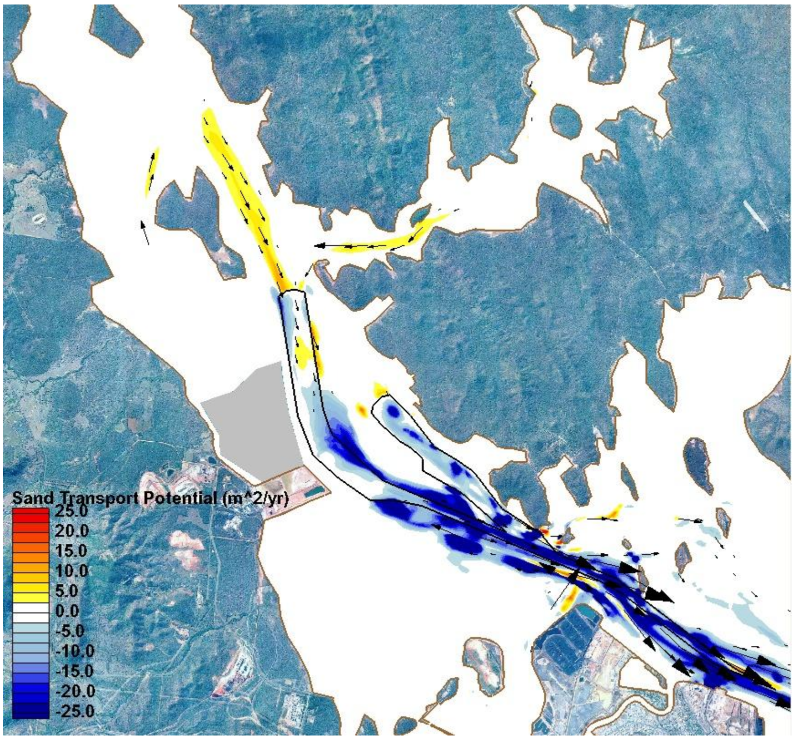
Figure 4-23 Net Sand Transport – Base Case (Existing Conditions)



Impact of Scenario 1



Impact of Scenario 2



Impact of Scenario 3

Figure 4-24 Impact on Net Sand Transport

Scenario 1 impacts on net sand transport potential include an increase in the ebb-dominant transport in the channels upstream of the dredging to Fisherman's Landing (red areas opposite the northern end of the reclamation). Downstream of Fisherman's Landing (blue areas) the net sand transport potential is generally reduced because of the reduced current speeds and bed shear stresses caused by the reclamation / dredging development.

While there appear to be some substantial reductions in the net transport potential in the downstream swing basins (Clinton and Wiggins Coal Terminal), it is likely that the transport potential in those areas may be overstated by the assumption of 100%-mobile uniformly-graded sand being available for transport and hence the predicted reductions may likewise be over-estimated. Nevertheless, there will be reduction in the transport potential in this area due to the reduction in current speeds and hence bed shear stresses due to the combined effects of reclamation and dredging on the hydrodynamics. This is most evident in Scenario 1 indicating that the loss of tidal compartment to the reclamation has the most impact.

Other results of note are:

1. An increase in the net sand transport potential into Targinie Channel in Scenario 1. This is slightly reduced in Scenarios 2 and 3, but remains higher than the Base Case;
2. A reduction in potential sand siltation into the Fisherman's Landing swing basin in Scenario 1 with further reductions in Scenarios 2 and 3 on the ebb tide, due to the general reduction in transport potential upstream of this location and, for Scenarios 2 and 3, due to the additional dredging upstream;

3. An increase in coarse material siltation in the proposed dredged areas along Curtis Island for Scenario 1, with subsequent reductions in the siltation rate for Scenarios 2 and 3; and
4. Overall, additional sand-sized siltation from around 10,000m^3/yr for the base case to 25,000m^3/yr for the developed case is predicted to occur in the Western Basin because of the expanded dredge footprint.

Relative sedimentation hotspots can be qualitatively identified by inspection of the sand transport potential patterns and include:

» Northern end of Fisherman's Landing swing basin;

» Northern end of both swing basins adjacent to Curtis Island; and

» Northern end of Laird Point swing basin.

At these locations sand is transported from the shallower upstream areas and is expected to be deposited near the bottom of the dredged batter, under the influence of the net transport in the ebb tide direction. The peak sedimentation rates are expected to be similar to those experience in current port operation areas, that is 1 to 5cm/annum and up to 10cm/annum at localised "hotspots.

4.5.2 Bed Shear Stress Impacts

The hydrodynamic model results have been used to calculate bed shear stresses throughout the model domain over a two month period. Plots of selected points in the Western Basin area are provided in Figure 3-10 in Section 3.2. Plots of bed shear stress time series are also available for the 28 model data extraction points for 4 days of the largest spring tide period in Appendix I of the Numerical Modelling Report (WBM 2009b). The results for those points adjacent to the reclamation are discussed in detail in Section 4.9.

Spatial plots of 5% Exceedance bed shear stresses for the Base Case are shown on Figure 4-25 and the impacts of each development scenario are presented in Figure 4-26.

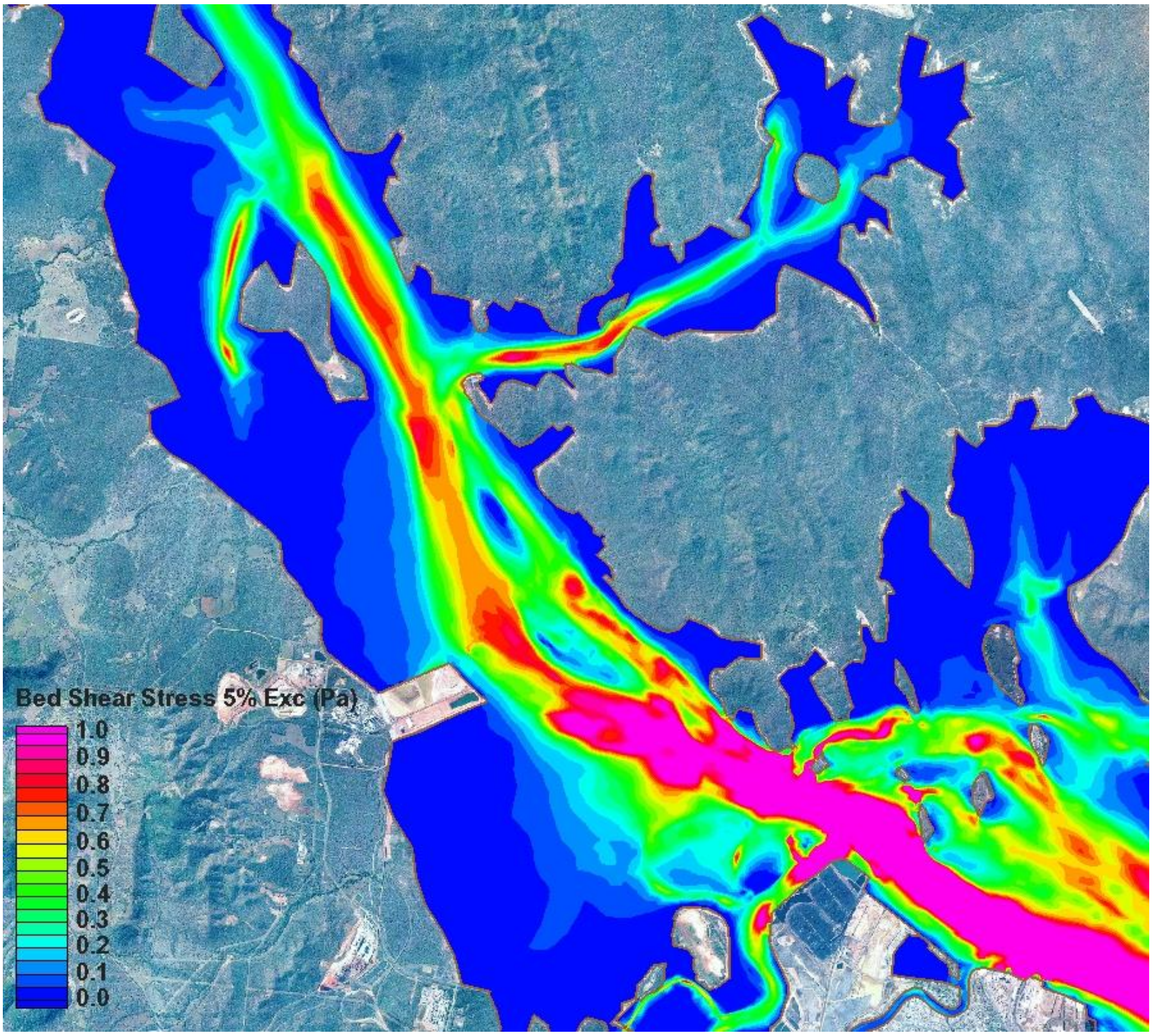
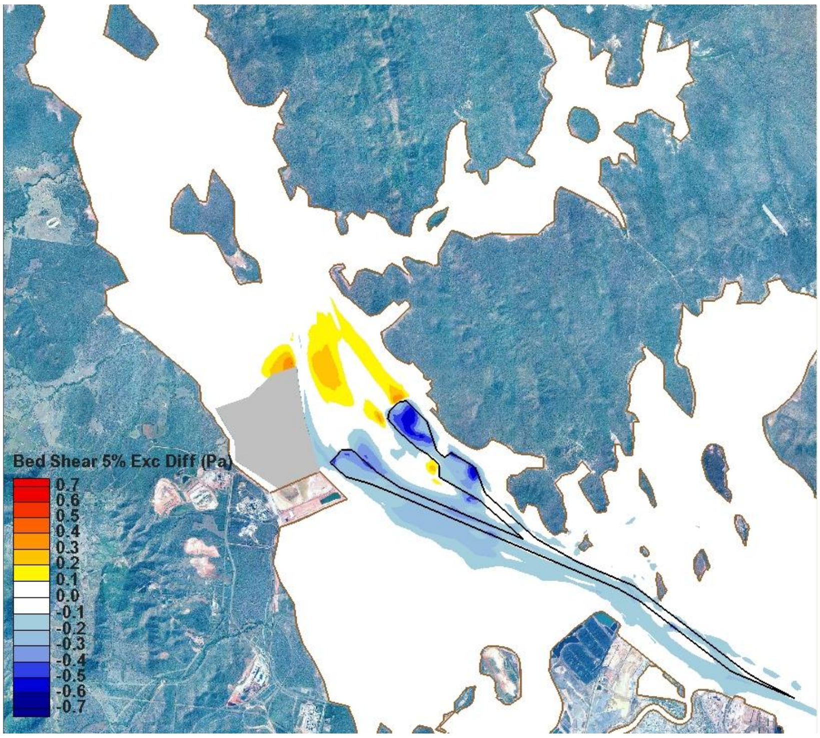
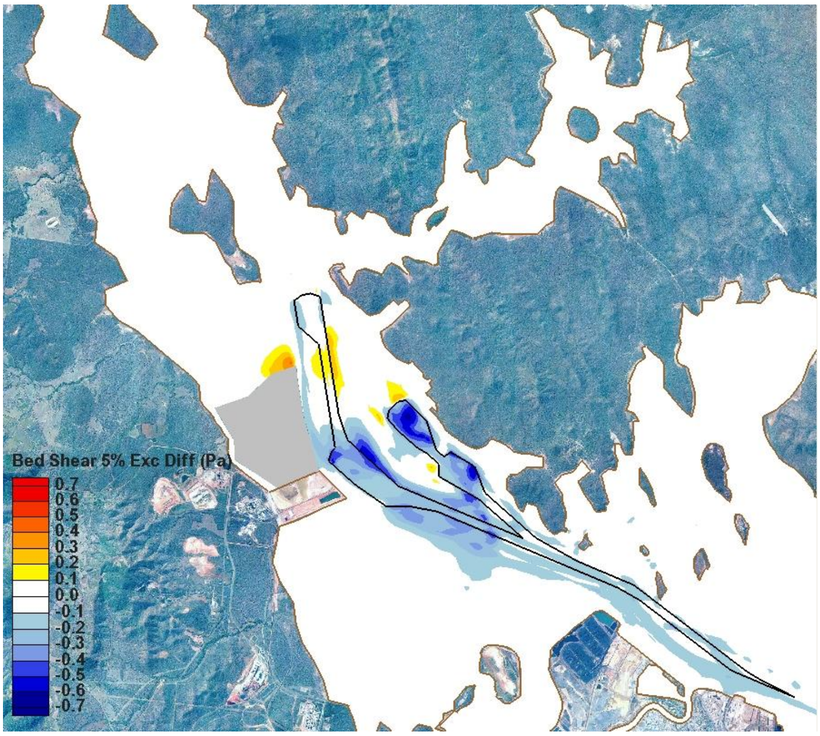


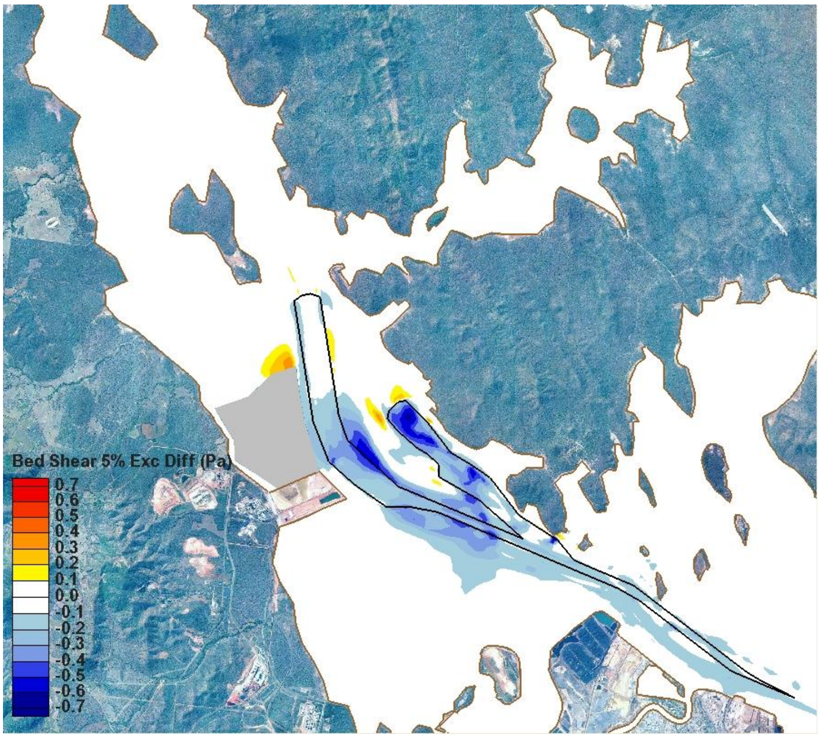
Figure 4-25 Bed Shear Stresses – Base Case (Existing Conditions)



Impact of Scenario 1



Impact of Scenario 2



Impact of Scenario 3

Figure 4-26 Impact on Bed Shear Stresses

The dredging in the three developed scenarios reduces the bed shear stresses in the dredged areas and laterally adjacent areas where current velocities are reduced due to the increased flow area provided by the dredging. For Scenario 1, increases in the bed shear stresses occur in the undredged channel areas where current velocities are higher upstream of the dredged areas, this being particularly noticeable east of the reclamation. This phenomenon persists in Scenarios 2 and 3 upstream of the eastern dredged channel adjacent to Curtis Island.

In all developed scenarios, there is a zone of increased bed shear stress in the shallow area adjacent to the north eastern edge of the reclamation. The increased bed shear stresses are well above the lower limit at which re-suspension of fine material occurs and hence, as the surface sediments in this area are expected to be fine cohesive material, scouring will occur in this area. This area is examined in further detail in Section 4.9. This phenomenon is also evident in the vicinity of the north-eastern corner of the existing Fisherman's Landing reclamation (Figure 4-25) where the bed shear stresses are around 0.3Pa compared with 0.4Pa at the north-eastern edge of the developed reclamation.

4.5.3 Silt Deposition

The Numerical Modelling Report (WBM 2009b) provides an assessment of potential silt deposition based on synthesised variations in turbidity derived from nephelometer measurements and modelled bed shear stresses to calculate the erosion / deposition potential at each point in the model. The report notes that there is a level of uncertainty surrounding the various assumptions made in the assessment, which, along with the absence of appropriate calibration / validation measurements, means that the assessment results should be treated as being qualitative / semi-quantitative.

The patterns of predicted net silt deposition potential for the Base Case is shown in Figure 4-27 and the three developed scenarios are presented in Figure 4-28.

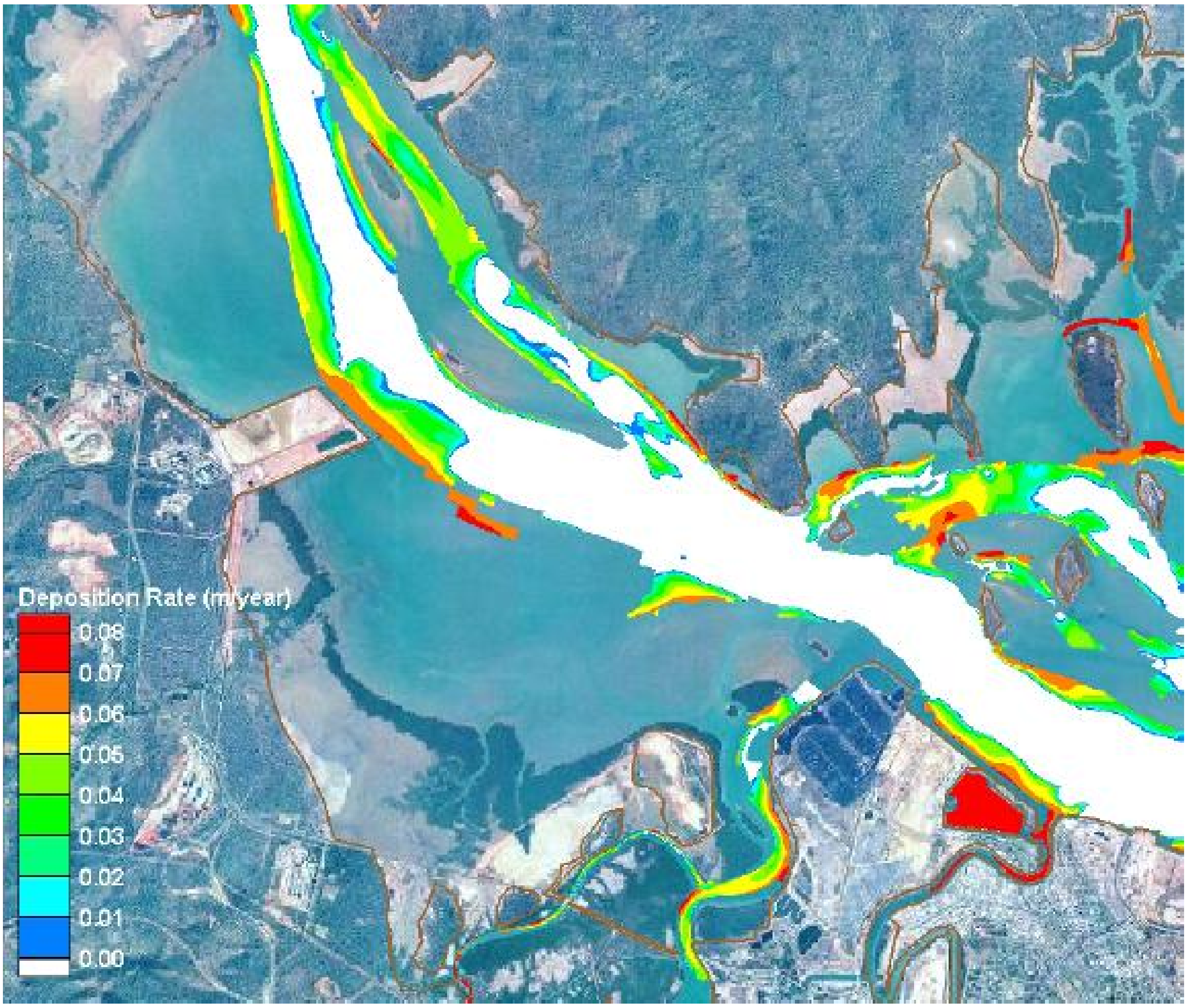
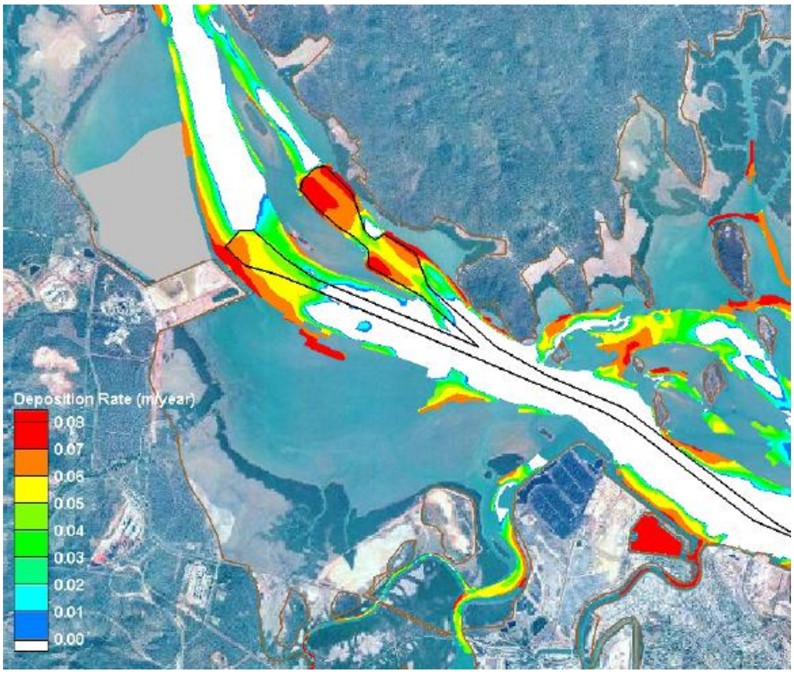
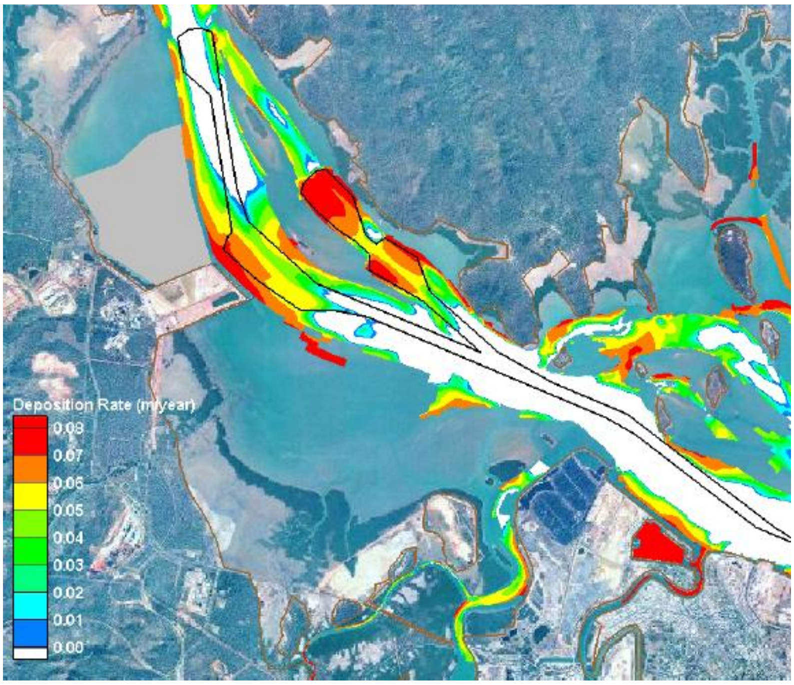


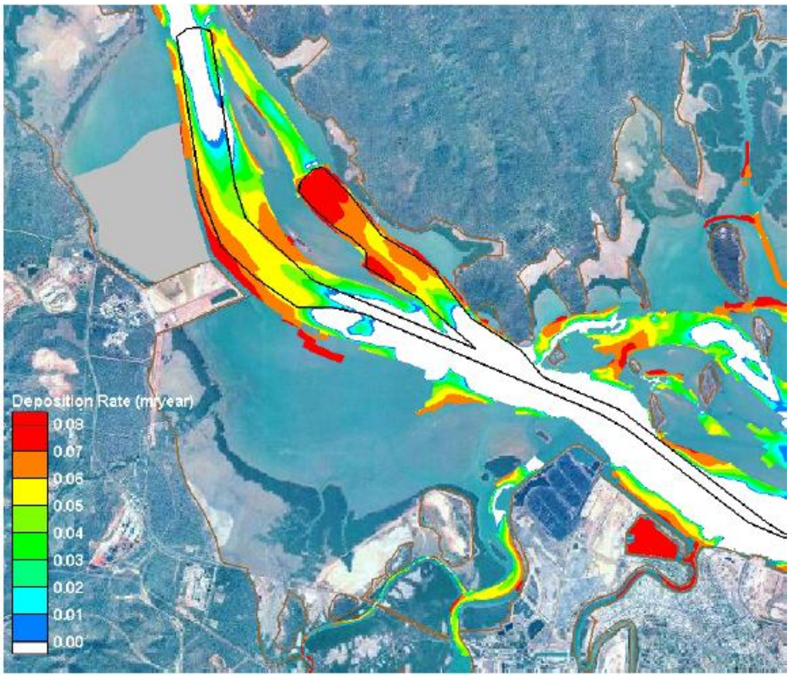
Figure 4-27 Silt deposition – Base Case (Existing Conditions)



Scenario 1



Scenario 2



Scenario 3

Figure 4-28 Silt deposition – Developed Scenarios

For the base case, there is little or no net deposition of fine silt predicted for:

» Channels downstream of the Western Basin

» Targinie Channel;

» Targinie Channel extension towards Laird Point; and

» The “Curtis” channel adjacent to China Bay.

Notable deposit areas are:

» Western side of Fisherman’s Landing swing basin; and

» “Curtis” Island channel upstream of South Passage Island and China Bay.

In Scenario 1 there is significant net silt deposition potential in both the new swing basins adjacent to Curtis Island, and in the Fisherman’s Landing swing basin. The total net silt deposition potential increases substantially from 15,000m^3/yr (base case) to 152,000m^3/yr for Scenario 1.

In Scenario 2, with additional dredging, there are further increases in net silt deposition potential in the same areas as Scenario 1. For this scenario the total net silt deposition potential increases by 28,000m^3/yr to 180,000m^3/yr.

In Scenario 3 the additional dredging along Curtis Island, and the widening of the Laird Point channel, are expected to further increase the net siltation by another 75,000m^3/yr to a total of 255,000m^3/yr.

The predicted volumetric rates of fine silt accumulation in the dredged channels in the Western Basin are summarised in Table 4-3.

Table 4-3 Modelled Net Silt Deposition Potential into Dredged Areas

Sedimentation m^3/year	Base Case	Scenario 1	Scenario 2	Scenario 3
Fisherman's Landing	15,000	52,000	66,000	69,000
BG/Santos Access Channel (Curtis Island)		3,000	4,000	12,000
Santos Swing Basin		41,000	43,000	50,000
BG Swing Basin		56,000	58,000	66,000
Laird Point Swing Basin and Approach			9,000	58,000
Total	**15,000**	**152,000**	**180,000**	**255,000**

Notes on table:
1. As reported in WBM 2009b.
2. Values are indicative only, due to calculation uncertainties

4.6 Impact of Reclamation

The reclamation affects the hydrodynamics of the harbour through a reduction in the tidal prism and obstructing flows that previously flowed across its footprint area. This leads to a reduction in flows downstream of the reclamation and an increase in flows adjacent to the reclamation from the reduction in the cross sectional area leading up to The Narrows. Most of the impacts of the reclamation are indicated in the results for the developed case Scenario 1 as this Scenario has the smallest amount of dredging associated with it. The reclamation also produces quite different flow conditions within its immediate vicinity, particularly in the shallow areas to the north and west, due to its physical presence in the tidal waterway.

4.7 Impact of Dredged Channels

The dredged channels reduce tidal flows within their footprint due to the increased cross sectional area available for the flow. However, the increased capacity of the dredged channel (albeit at a lower velocity) leads to increased flows in the undredged areas upstream increasing the sand transport potential into the newly dredged channels / swing basins. The quantity of sand sized material is relatively small and is likely to be concentrated at the northern end of the dredged areas at the toe of the dredged batter, but will nevertheless need to be removed when it becomes a problem.

The dredged channels will provide increased areas within the Western Basin that are in a relatively low energy hydrodynamic regime and hence are likely to experience significant silt deposition (255,000 m^3/yr) that will require regular maintenance dredging to maintain the design depth of the channel / swing basin / berth pocket. The expected level of maintenance dredging represents a significant increase compared to the current maintenance dredging commitment.

4.8 Impacts on Maintenance Dredging

The impacts of the reclamation and dredged channels on maintenance dredging are determined from the changes to the sedimentation patterns and quantities resulting from the development. The sediment considered includes sand sized sediment transported as bed load and fine silts transported as suspended load.

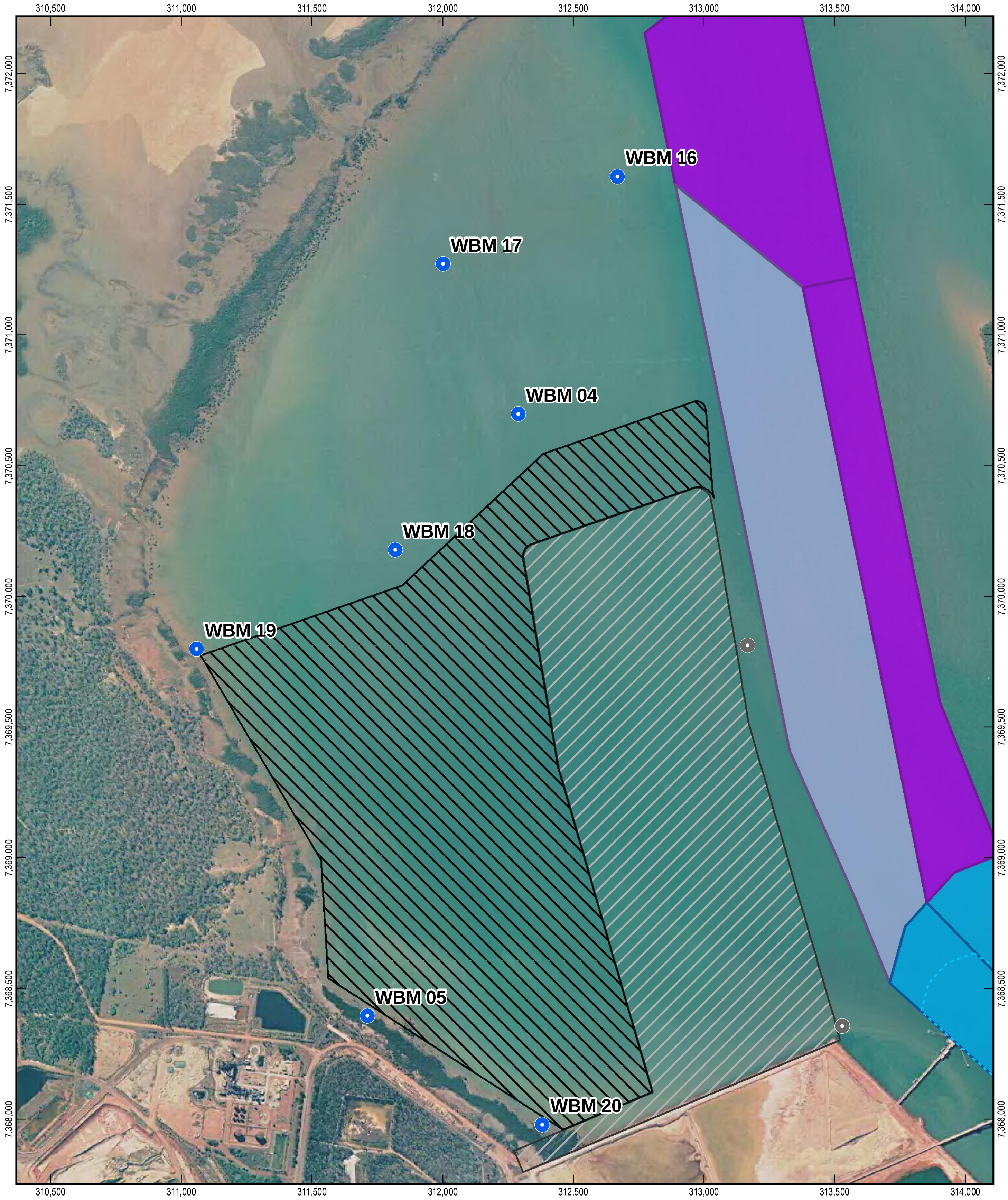
The highly variable nature of the sediments and the prevailing processes makes quantification of siltation rates and maintenance dredging requirements complex. While quantitative assessments of both sand and silt deposition have been made, the uncertainties associated with the assessments need to be taken into consideration.

Overall, additional sand-sized siltation is predicted to occur in the Western Basin for all developed scenarios because of the expanded dredge footprint. This additional siltation will cause an elevation of the bed but this likely to be localised to the edges of the swing basins and channels as the sand sized material falls into these deeper areas from upstream. Nevertheless, the material will need to be removed before it affects under keel clearances. However, the expected volume of siltation is relatively small and similar to existing maintenance dredging volumes, and could be removed during programmed maintenance dredging as the need arises.

In terms of fine silt, there will be a substantial increase in the silt deposition in the dredged channels and swing basins in the Western Basin due to the decrease in tidal current velocities (and hence bed shear stresses) caused by the reclamation footprint and the larger cross sections of the channels compared with the existing undredged waterways. The occurrence of silt deposition in the dredged channels in the western basin area up to a predicted 255,000m^3/yr represents a maximum of 0.08m/yr loss of depth. This rate of siltation could be accommodated by an over-dredging allowance to extend the time between maintenance dredging campaigns. For example, over-dredging by 0.3m would provide for 3 + years of sedimentation before the declared depth of the channel / swing basin was affected. Nevertheless, this material will eventually need to be removed so as not to interfere with ship navigation and under-keel clearances and could require a significant increase in the current maintenance dredging commitment should it reach its full potential.

4.9 Impacts in Northern Embayment

The embayment to the north of the proposed Western Basin reclamation will be impacted by the reclamation through changes to tidal water levels, tidal current velocities, bed shear stresses, and waves, and the impacts on each of these parameters in turn has been discussed in this report. However, because of the apparently conflicting impacts in this particular area, the impacts from each of the points located in the embayment will be examined in relation to each other in order to better understand the impacts of the development in this area. The extraction points in the immediate vicinity of the reclamation will used for this assessment and are shown in Figure 4-29.



LEGEND

- Results Extraction Points near Reclamation
- Western Basin Reclamation Area
- Fisherman's Landing Northern Expansion
- Stage 1A - North China Bay LNG
- Stage 1B - Fisherman's Landing LNG
- Stage 2 - Laird Point LNG
- Stage 3 - Fisherman's Landing
- Stage 4 - Hamilton Point
- Existing Channels, Swing Basins and Berths

1:20,000 (at A4)

0 100 200 300 400 500

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

N

GHD GPC

Port of Gladstone
Western Basin Dredging and Disposal Project

Results Extraction Points near
Western Basin Reclamation

Job Number	42-15386
Revision	A
Date	01 Sept 2009

Figure 4-29

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Level 4 201 Charlotte Street Brisbane QLD 4000 Australia T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

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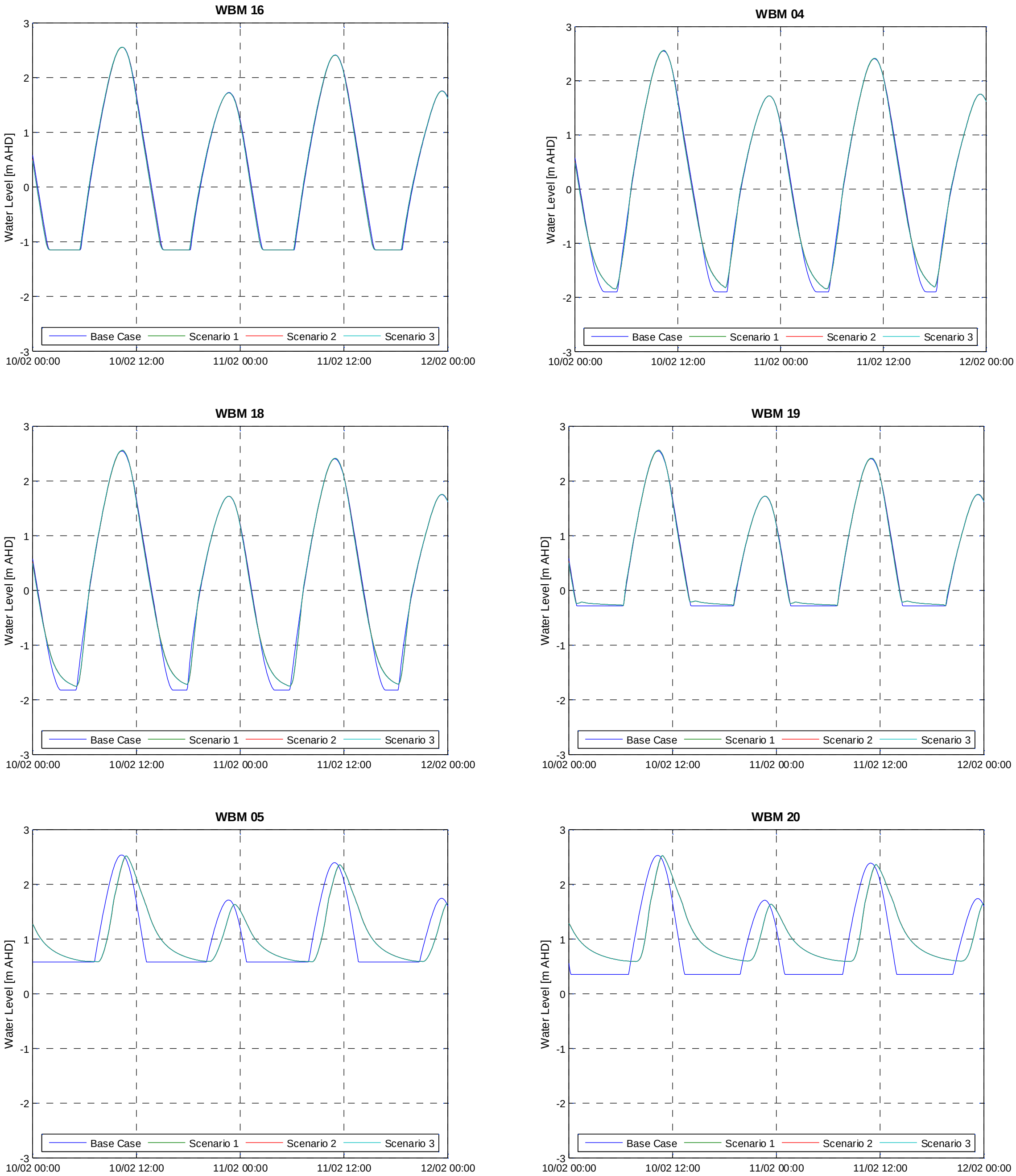


Figure 4-30 Water Level Plots

4.9.1 Water Level Plots

The following comments on water levels refer to Figure 4-30.

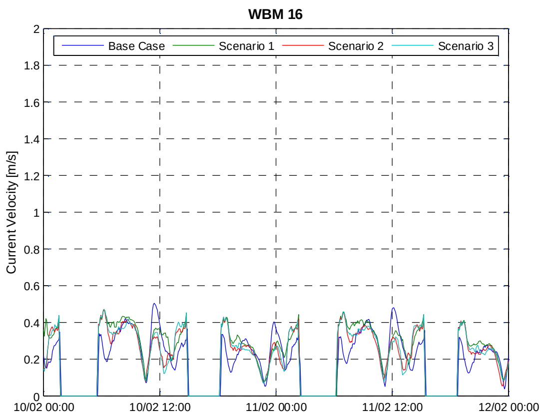
» The above plots show the progression of the impacts of the reclamation from the entrance to the embayment at 16, to the area immediately north of the reclamation at 04 and 18, to the entrance to the tidal channel along the western boundary at 19, and to the southern limit of that channel at 20.

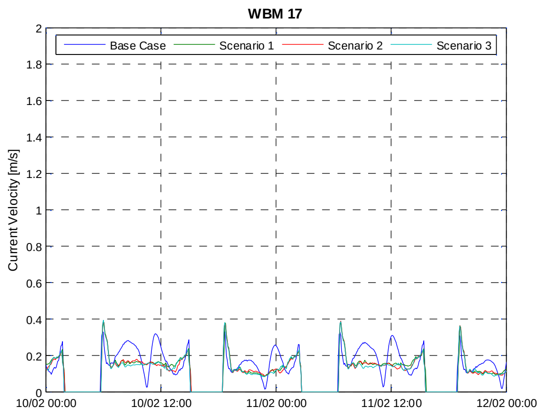
» The lag in the high tide part of the curve is mainly evident in the western tidal channel at 05 and 20. The flattening of the water level response for the ebb tide is also at its maximum at these locations such that the water will not drain completely compared to the existing situation where the bed is dry for substantial periods of time at low water.

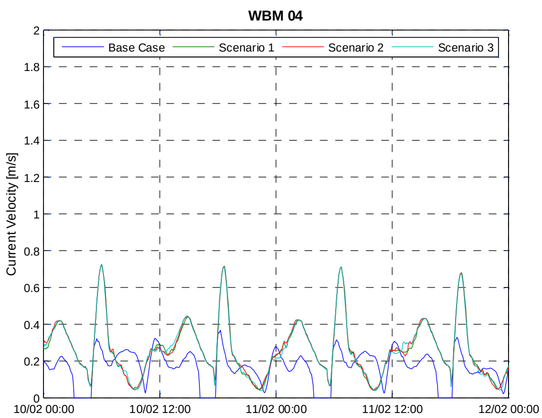
» The flattening of the water level response is also evident at 19, 18, and 04 but to a much lesser extent, only being evident near the bottom of the tide. Nevertheless, the small amount of dry time that is currently experienced at these locations will be impacted by the development.

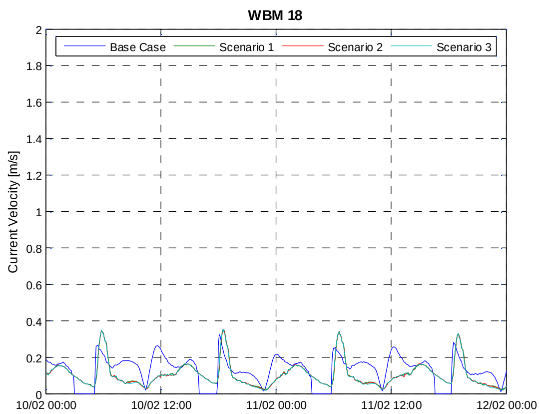
» Out near the entrance to the embayment at 17 and 16, there is no impact on the existing water levels. Note however, that the water level plots at these two locations indicate that there are periods up to 3 hours when the bed is dry.

» The caveat on the above comments is that the survey information of the 'remnant' Western Basin has some uncertainty. Hence draining of water from these tidal flats in the simulations needs to be interpreted with this uncertainty as a backdrop. However, this should not affect the trends indicated above i.e. a graded impact on water levels and time lag with distance from the embayment entrance.









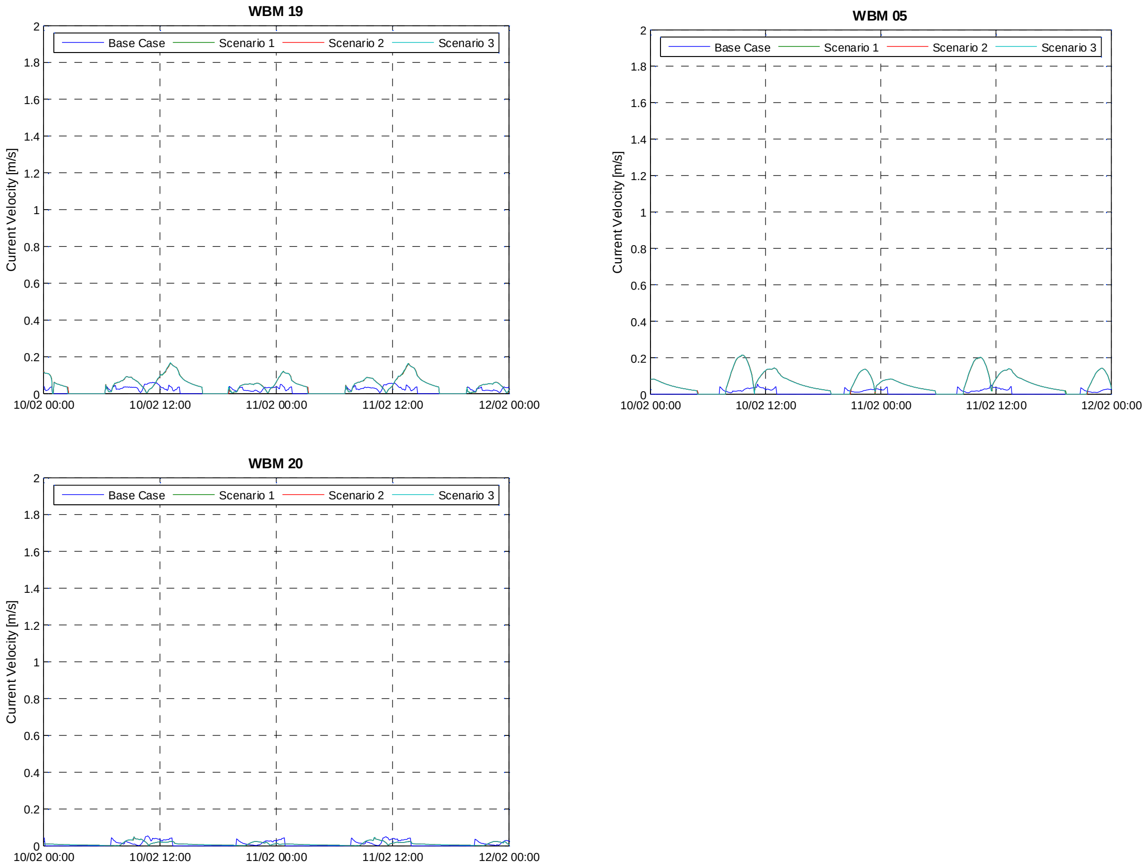
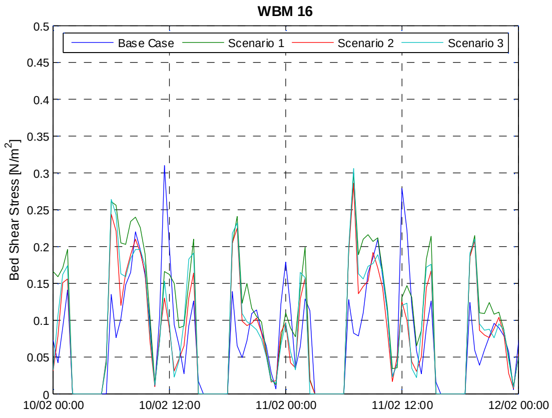


Figure 4-31 Tidal Current Velocities

4.9.2 Tidal Current Velocities

The following comments on tidal current velocities refer to Figure 4-31.

- At 16, 17, and 18 there are changes to the velocity profiles as a result of the reclamation. However, on average there are no increases in velocity at these locations. Velocities are a maximum of 0.45m/s at 16 decreasing to 0.35m/s at 18.
- There is a noticeable increase in the flood tidal velocities at 04 – double the velocities for the Base Case.
- Although there are increased velocities in the western tidal channel at 19, 05, and 20, the absolute velocities remain small being <0.2m/s.


WBM 16
Base Case
Scenario 1
Scenario 2
Scenario 3
Bed Shear Stress [N/m^2]
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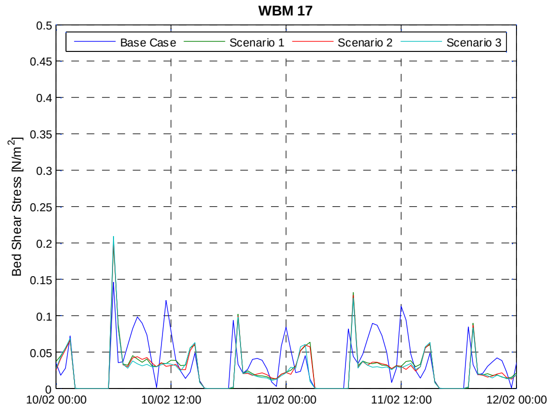
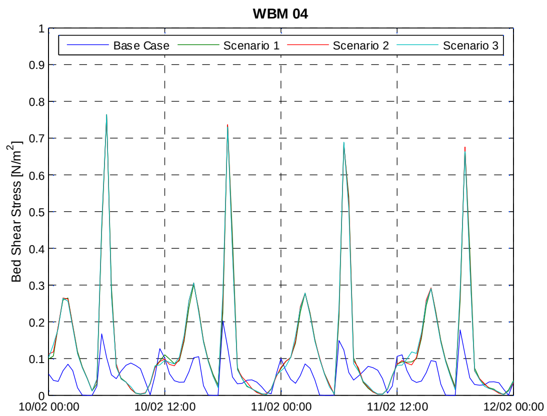
10/02 12:00
11/02 00:00
11/02 12:00
12/02 00:00


WBM 17
Base Case
Scenario 1
Scenario 2
Scenario 3
Bed Shear Stress [N/m^2]
10/02 00:00
10/02 12:00
11/02 00:00
11/02 12:00
12/02 00:00


WBM 04
Base Case
Scenario 1
Scenario 2
Scenario 3
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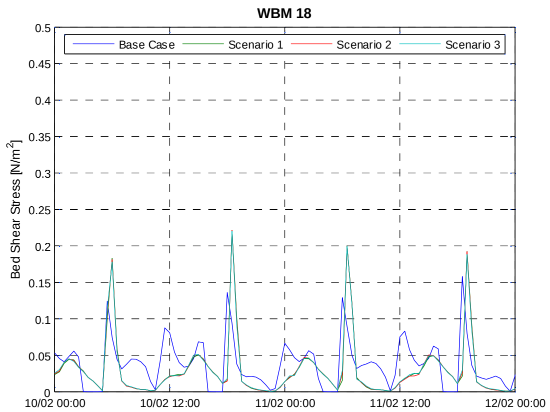
12/02 00:00


WBM 18
Base Case
Scenario 1
Scenario 2
Scenario 3
Bed Shear Stress [N/m^2]
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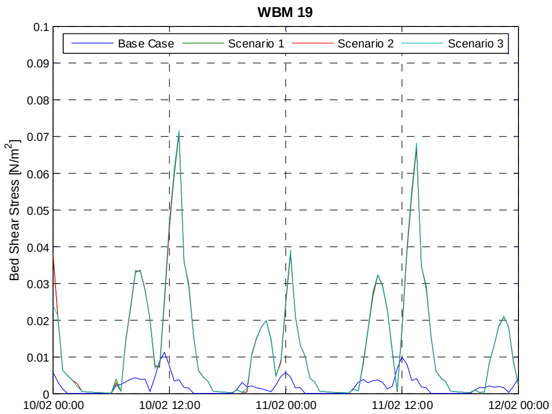
12/02 00:00


WBM 19
Base Case
Scenario 1
Scenario 2
Scenario 3
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10/02 12:00
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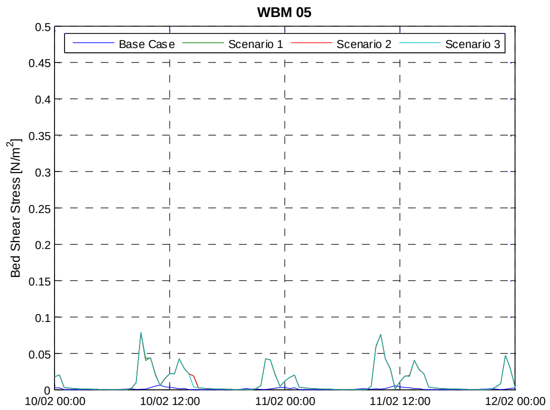
12/02 00:00


WBM 05
Base Case
Scenario 1
Scenario 2
Scenario 3
Bed Shear Stress [N/m^2]
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10/02 12:00
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11/02 12:00
12/02 00:00

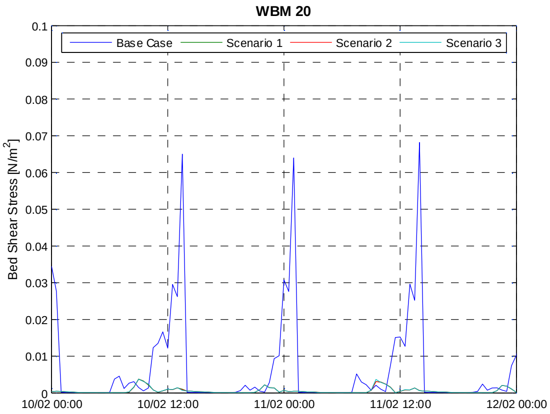

Figure 4-32 Bed Shear Stresses

4.9.3 Bed Shear Stresses

The following comments on bed shear stresses refer to Figure 4-32.

- Bed shear stresses are dependent on current velocities and water depth so variations in bed shear stress can be expected to be heavily influenced by the current velocity variations.
- Areas where the bed shear stress is < 0.2 N/m^2 will result in the deposition of fine silts (WBM 2009b). By inference these areas will not be subject to erosion and are likely to silt up over time.
- A bed shear stress of 0.5 to 1.0 N/m^2 is required for erosion of the bed to occur.
- The bed shear stresses at points 16, 17, and 18 do change for the developed case; however, there is no significant change to the average or the maximum shear stress at these points. In addition, stresses are < 0.3 N/m^2.
- There are significant changes to the bed shear stresses in the western tidal channel, however, the absolute values are all <0.07 N/m^2 so the changes are not relevant in terms of sediment movement.
- At point 04 there are significant increases in the bed shear stress from 0.2 to 0.75 N/m^2 and hence movement of fine silts is likely at this location.

The aerial extent of what is happening at point 04 is examined using the aerial plots of the bed shear stresses in Figure 4-33 to Figure 4-35.

Maximum

5% Exceedance

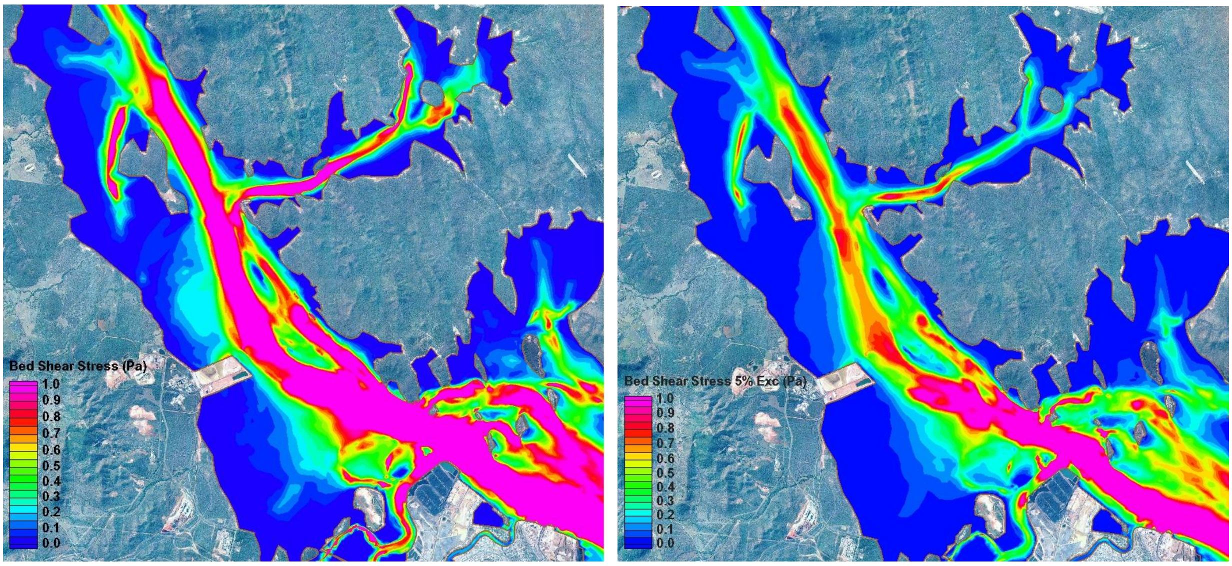

Figure 4-33 Bed Shear Plots – Base Case

Maximum

5% Exceedance

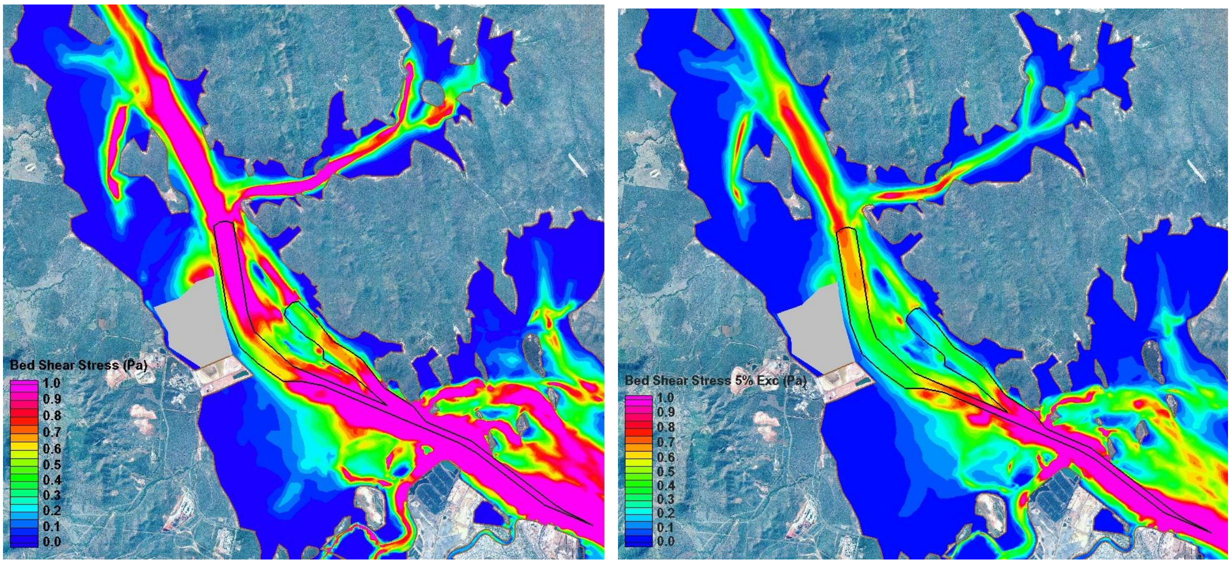

Figure 4-34 Bed Shear Plots – Developed Scenario 3

Maximum **5% Exceedance**

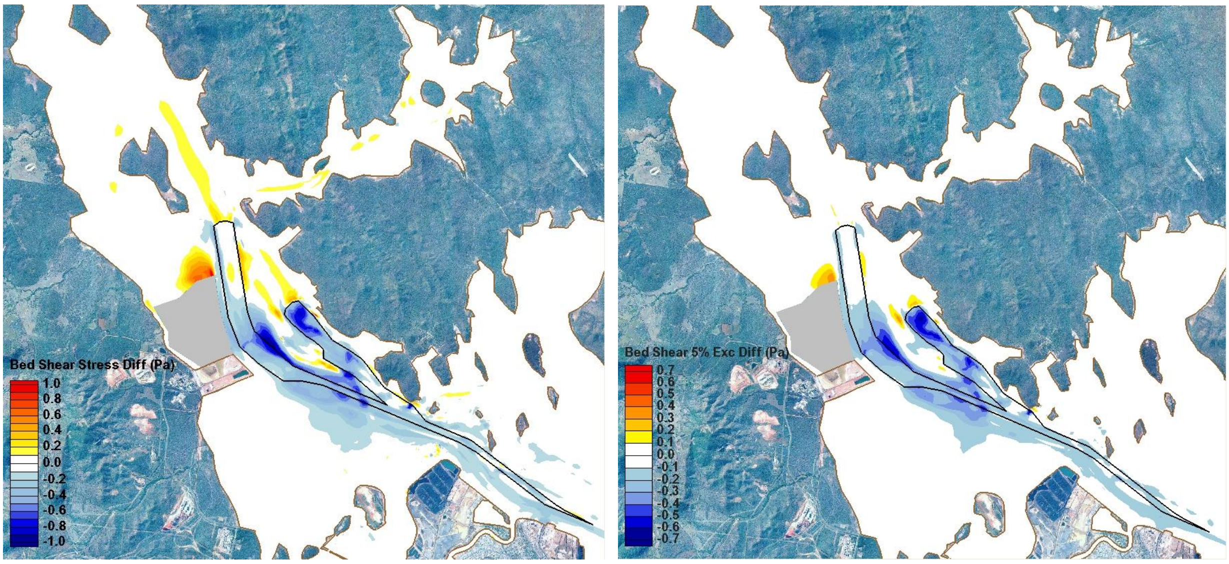

Figure 4-35 Bed Shear Plots – Difference: Existing / Developed

4.9.4 Bed Shear Stress Impacts

The following comments on bed shear stress impacts refer to Figure 4-35.

- The maximum and 5% exceedance results are provided for comparison. The 5% Exceedance plot will provide a more realistic assessment of the likely impacts over a tidal cycle. The maximum plots are useful in providing the link to the results at individual points.
- The difference plots show that there is a significant increase in the bed shear stress to a maximum of 0.9N/m^2 and an average of 0.5 N/m^2 adjacent to the northern extremity of the reclamation and extending west for about one third the length of the reclamation from the shoreline. Point 04 is on the edge of this area.
- In this area fine material will be mobilised and will move further into the embayment during the flood tide and out into the dredged channel during the ebb tide where it is likely to be deposited.

4.9.5 Waves

North of the reclamation footprint, wave heights will decrease and the predominant wave direction will move from south-east to east. This area will become more quiescent in terms of wave action and will be prone to increased siltation in all areas except where there are other impacts that indicate increased sediment movement e.g. adjacent to the northern extremity of the reclamation.

4.9.6 Northern Embayment Impacts Summary

Erosion of the bed through increased bed shear stresses is likely to occur in the embayment north of the proposed Western Basin reclamation but will be restricted to the area adjacent to the northern extremity of the reclamation.

All other areas within the embayment and in the western tidal channel are likely to silt up over time due to the effects of the reclamation on the tidal flows, the deepening of the channels, and the sheltering effects on the ambient wave climate. This tendency for siltation grades from minimal at the entrance to the embayment (WBM16) to significant at the western shoreline and along the western tidal channel.

4.10 Results Summary

From a physical coastal processes viewpoint, the potential impacts of the proposed development consisting of a large scale reclamation of part of the tidal waterway and extensive new dredged channels, swing basins, and berths are summarised as follows:

1. The physical presence of the reclamation within the footprint of the reclamation area;
2. The changes in flow and water level conditions adjacent to the reclamation to the north and west, particularly the changes to the rate at which the ebb tide level drops reducing the time that the tidal flats are dry during the lower parts of the tidal cycle;
3. The scour of fine silts from the north-eastern corner of the reclamation;
4. An increase in maintenance dredging of sand sized sediment in the new dredged channels and swing basins that is commensurate with the existing maintenance commitment; and
5. Potentially a large increase in maintenance dredging to remove fine silts from the new channels and swing basins adjacent to the Western Basin Reclamation and in the turning basins adjacent to Curtis Island.

5. Cumulative Impacts and Mitigation Strategies

The cumulative impacts of the proposed reclamation and associated channel dredging have been assessed through a consideration of the impact on a base case representing existing conditions compared to three development scenarios that progress the development from the reclamation and minimal dredging through to the final configuration with deep channels and swing basins to service the future berths in the Western Basin and along the western coastline of Curtis Island opposite Fisherman's Landing. As such, Scenario 3 represents all proposed future dredging in the Project Area.

The impacts of the development have been described in previous chapters. The majority of the impact on tidal flows and water levels can be attributed to the reclamation. The dredged channels contribute to the impact of the reclamation with further reductions in flows within their own footprints. This in turn leads to a lower energy hydrodynamic regime in a number of areas in the Western Basin that provides the conditions for potentially significant fine silt deposition.

It is not necessary to mitigate the changes to the tidal flows and water levels in themselves as the changes are within the normal bounds of the processes that occur in the natural system as a result of the inherent variability of coastal and estuarine environments in a macro tidal area. However, it may be necessary to mitigate against some of the effects that these changes bring about. The effects that appear to have the most impact are:

1. The reduction in the length of time that areas to the north and west of the reclamation are dry around the time of low water;
2. The increased potential for fine silt deposition in the newly dredged channels; and
3. The increased potential for sand sized deposition into the existing channels downstream of the Western Basin.

The need for mitigation of the reduced drying time in the areas near the reclamation will depend on considerations dealt elsewhere in the EIS such as Chapter 9 (Marine Ecology). If required, consideration could be given to dredging one or more shallow channels connecting the channel between the reclamation and the western foreshore through the northern embayment to the main eastern channel. This would allow the ebb tide to drain from this area more efficiently which should result in increased drying time in those areas that currently experience a substantial drying period around low water. Such a solution would need to be assessed using the hydrodynamic model to determine its effectiveness and it will have its own impacts that will need to be considered before it could be included as a confirmed mitigation measure.

The most practical mitigation measure for the increased potential for sedimentation in the dredged channels is to monitor the actual deposition rates and devise a maintenance dredging plan to arrange its removal so that there is no interruption to future ship movements. This rate of siltation of fine silts could be accommodated by an over-dredging allowance to extend the time between maintenance dredging campaigns. With an over-dredging allowance of 0.3m maintenance dredging of the fine silt material may only be required every 3 to 4 years should the rate of silt deposition reach its full potential.

6. Conclusion

The proposed reclamation and dredging of channels and swing basins will have an affect on the hydrodynamics of the Western Basin area, particularly in the immediate vicinity of the reclamation and within the footprint of the dredged channels. The proposed development also causes some changes in the tidal current velocities downstream as far as Auckland Point due to the reduction in the tidal prism taken up by the reclamation. Upstream of the Western Basin in The Narrows only minor changes in water levels and currents will occur.

In general terms, the changes to the hydrodynamics are within the normal bounds of the processes that occur in the natural system as a result of the inherent variability of coastal and estuarine environments in a macro tidal area and it can be expected that the bed and foreshores of the harbour will adapt to the new regime.

The most significant impact is the increase in the potential level of sand and fine silt deposition that will require a substantial increase in the maintenance dredging activity if the full potential of the predicted deposition is realised.

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