C3

DREDGING AND DREDGE MOVEMENTS

COASTAL PROCESSES AND WATER QUALITY

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3.1 INTRODUCTION

This chapter outlines the coastal processes and water quality baseline within the vicinity of the target sand extraction area in Moreton Bay associated with the Sunshine Coast Airport (SCA) Expansion Project (the Project).

The baseline component of the report defines the existing conditions at the target sand extraction area also referred to as the Spitfire Realignment Channel. Conditions at adjacent areas are also described to establish a baseline for which the potential impacts can be assessed.

The impact assessment provides a risk assessment of potential impacts on coastal processes and water quality from the proposed sand dredging using a suite of numerical modelling tools. Mitigation measures are identified for unavoidable impacts associated with the construction and operational stages of the Project including monitoring programmes and recommendations.

3.2 METHODOLOGY AND ASSUMPTIONS

3.2.1 Methodology

The objective of this study is to assess the risks associated with potential adverse impacts to Moreton Bay coastal processes and water quality from proposed sand dredging associated with the Project.

This includes detailed numerical modelling of those processes under both the existing and developed scenarios to identify any potential impacts that may occur to the shoreline areas adjacent to the target dredge area as well as quantifying potential temporary impacts to water quality during the dredging using validated numerical modelling tools.

The study draws on previous studies, observations (recorded data) and numerical modelling undertaken as part of previous assessments and previous monitoring at the sand extraction area (e.g. WBM 2005 and BMT WBM 2008), as well as broader scale information and reports associated with the Moreton Bay Sand Extraction Study (MBSES) (Queensland Government 2005).

3.2.2 Policy context and legislative framework

3.2.2.1 Coastal plans and policies

The Queensland Government addresses potential impacts to coastal processes and water quality through state planning policies, action plans and planning schemes. Those relevant to the Project include:

- The Queensland Coastal Plan (Department of Environment and Resource Management (DERM), 2012) was prepared under the *Coastal Protection and Management Act 1995* in February 2012.
  The Coastal Plan consists of the State Policy for Coastal Management (SPCM), containing policies and guidance for coastal land managers on managing and maintaining coastal land. This policy has recently been replaced by the draft Coastal Management Plan (2013) which carries forward the policy outcomes from the SPCM.
- The Coastal Protection State Planning Regulatory Provision (the Coastal SPRP) took effect on April 2013. Previously, the Draft Coastal SPRP had suspended the operation of the State Planning Policy 3/11: Coastal Protection. The Coastal SPRP provides outcomes for development assessment in the coastal management district.
- The single State Planning Policy (SPP) came into force December 2013, providing a single framework for considering a series of State Interests. The SPP is subordinate to the Coastal SPRP but must be considered in development assessment unless the provisions are adequately reflected in local planning schemes. Relevant state interests include the coastal environment, water quality and natural hazards (including storm tide inundation and coastal erosion).
- Sections and parts of the SPCM and Coastal SPRP that are relevant to the coastal processes and water quality include:
  - Coastal hazards
  - Nature conservation
  - Coastal dependent development
  - Dredging and disposal of dredged material.

The relevance and consistency of the Project with the SPCM and Coastal SPRP based on the key findings of this chapter are outlined in Chapter B2 – Land Use and Tenure.

3.2.3 Policies and guidelines – environmental values and water quality objectives

Environmental Values (EVs) and Water Quality Objectives (WQO) have been identified for those receiving waters above and immediately surrounding the Spitfire Realignment Channel. In documenting these, the process outlined within the Environmental Protection (Water) Policy 2009 (EPP Water) was followed, where a hierarchy of documents was used to derive which EVs and WQOs take precedence. The Policy states:

The following documents are used to decide the water quality guidelines or objectives for an environmental value for a waterway:

a. Site specific documents

b. Queensland Water Quality Guidelines

c. The Australian Water Quality Guidelines

d. Documents published by a recognised entity

e. The extent of any inconsistency between the documents for a particular water quality guideline, the documents are to be used in the order they are listed above.

In the case of the above, the scheduled EVs and WQOs from the EPP Water were considered to be site specific documents. It should be noted that the EVs and WQOs discussed above reflect several different legislative instruments and local policies including the South East Queensland Regional Water Quality Management Strategy.

Environmental Protection Act 1994, the Environmental Protection (Water) Policy 2009 and the Queensland Water Quality Guidelines

The Queensland *Environmental Protection Act 1994* is the principal legislative basis for environmental protection within the context of ecologically sustainable development in Queensland. To achieve this aim with regards to water quality, the Act provides for the EPP Water, which is the principal legislative basis for water quality management in Queensland. The EPP Water includes a process for:

- Identifying EVs of waterways, including both aquatic ecosystems values and human use values
- Establishing corresponding WQOs to protect identified EVs.

The EVs and WQOs for a number of regions are scheduled under the EPP Water (DERM 2010). The Moreton Bay region is part of Basin 144 and is set by Plan WQ1441. These regions are shown in **Figure 3.2a**.

The marine waters of central and eastern Moreton Bay within the region of the Spitfire Realignment Channel with the potential to be impacted by the dredge activities are classified as:

- High Ecological Value (HEV) marine environment, Area E1A to the east
- HEV marine environment, Area E1C to the north
- Slightly to moderately disturbed marine environment, Area E2A containing the Spitfire Realignment Channel and to the south
- Slightly to moderately disturbed marine environment, Area C2 to the west.

Furthermore, the Queensland Water Quality Guidelines 2009 (QWQG) set forth similar but more broadly focused environmental values and guidelines for waterways not covered by any specific EPP plan. The applicable waters with relevance to the Project would include waters affected by a dredge plume not included in the list above, which are:

- Slightly to moderately disturbed marine environment for South East Queensland (SEQ) (e.g. offshore Bribie Island).

ANZECC/ARMCANZ (2000) guidelines for fresh and marine water quality

The Australian and New Zealand Environment and Conservation Council (ANZECC)/ Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC Guidelines) (ANZECC/ARMCANZ 2000) guidelines can be used where regional guidelines (QWQG) are not adequate or available, for example when assessing toxicants such as metals and metalloids.

The main objective of the most recent ANZECC Guidelines (2000) (albeit more than 10 years old) is to provide an authoritative guide for setting water quality objectives required to sustain current, or likely future, environmental values for natural and semi-natural water resources in Australia and New Zealand. The guidelines are intended to provide government, industry, consultants and community groups with a sound set of tools for assessing and managing ambient water quality, according to designated environmental values. The guidelines, similar to the QWQG, were not intended to be applied as mandatory standards but do provide guidelines for recognising and protecting water quality.

With respect to toxicants (heavy metals and pesticides) in marine waters, the ANZECC Guidelines (2000) provide four levels of protection for different ecosystems (80th percentile, 90th percentile, 95th percentile and 99th percentile).

Description of environmental values and water quality objectives

Table 3.2a provides a summary of the relevant environmental values of the waterways within the study area as set forth by the EPP Water. There are several water types defined in the study area generally by tidal regime and hydrodynamic connection to the open ocean. These water types and their geographical division are presented in **Figure 3.2a**. The environmental values and water quality objectives presented are used to assist in the evaluation of existing (baseline) water quality conditions of the Moreton Bay study area and as a measure of the potential impacts from dredging.

With reference to the objectives and trigger values summarised in **Table 3.2b** and as noted herein, the EPP Water provides the quantitative measure of performance for the EVs where applicable, followed by the ANZECC Guidelines (2000) in order of precedence (**Table 3.2c**). Compliance with the most stringent aquatic ecosystem values will ensure achievement of all EV outcomes for the associated waterways.

Commensurate WQO's have been defined for the aforementioned EVs, and the application of these is defined as follows (DERM 2010):

- For slightly to moderately disturbed marine environments, water quality levels are assessed against annual median concentrations. Water quality from impacting activities in slightly to moderately disturbed areas are not to exceed the annual median concentrations
- For areas of HEV, water quality is assessed against changes to the 20th, 50th and 80th percentile values. Water quality parameter levels are to be maintained at levels equal to the percentile values set forth in the EPP Water.

Furthermore, the procedure of applying the WQOs for these water types is addressed in Section 5 of the QWQG. Compliance of a waterway against the WQOs is determined by comparing the appropriate statistical value (e.g. median concentration for slightly to moderately disturbed waters) of 'n' independent samples at a particular monitoring site against the water quality objective of the same indicator, water type and level of aquatic ecosystem protection.

Figure 3.2a: Moreton Bay water type and environmental values

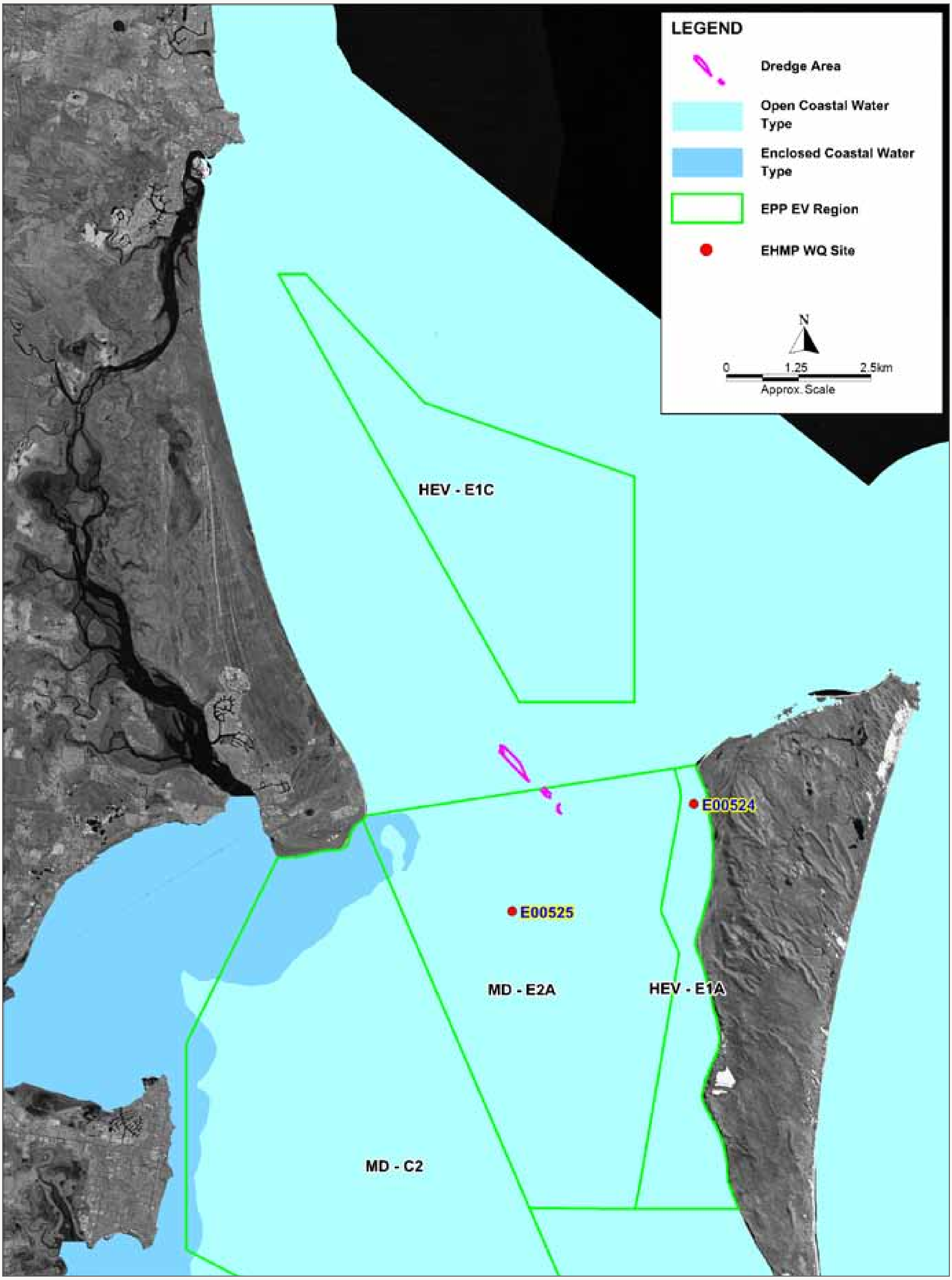


Table 3.2a: Study area and environmental values

Waterway Type	Eastern Moreton Bay	Central Moreton Bay	Open Coastal
Aquatic ecosystems	✓	✓	✓
Seagrass	✓	✓	✓
Irrigation			
Farm supply/use			
Stock water			
Aquaculture			
Human consumer	✓	✓	✓
Oystering		✓	
Primary recreation	✓	✓	✓
Secondary recreation	✓	✓	✓
Visual recreation	✓	✓	✓
Drinking water			
Industrial use			
Cultural and spiritual values	✓	✓	✓

3.2b: Water quality objectives

Region	Water Quality Objective
Eastern Moreton Bay, Area HEV E1A; Maintain existing water quality (20th, 50th and 80th percentiles)	• Turbidity: < 1 - < 1 - 1 NTU
	• Chlorophyll a: 0.5 - 0.6 - 1.0 µg/L
	• Total nitrogen: 100 - 120 - 160 µg/L
	• Total phosphorus: 9 - 12 - 16 µg/L
	• Dissolved oxygen: 95 - 100 - 105% saturation
	• pH: 8.2 - 8.3 - 8.4
Eastern Reef/headland waters, several, Area HEV E1C; Maintain existing water quality (20th, 50th and 80th percentiles)	• Turbidity: < 1 - < 1 - 1 NTU
	• Chlorophyll a: 0.5 - 0.6 - 1.0 µg/L
	• Total nitrogen: 100 - 120 - 150 µg/L
	• Total phosphorus: 9 - 12 - 16 µg/L
	• Dissolved oxygen: 95 - 100 - 105% saturation
	• pH: 8.2 - 8.3 - 8.4
	• Secchi depth: 6.0 - 8.5 - 11m
Eastern Moreton Bay, Area E2A (slightly to moderately disturbed); Annual median concentrations	• Turbidity: < 1 NTU
	• Chlorophyll a: < 1.0 µg/L
	• Total nitrogen: < 160 µg/L
	• Total phosphorus: < 16 µg/L
	• Dissolved oxygen: 95 - 105% saturation
	• pH: 8.2 - 8.4
	• Secchi depth: > 5.5m
Central Moreton Bay, Area C2 (slightly to moderately disturbed); Annual median concentrations	• Turbidity: < 5 NTU
	• Chlorophyll a: < 1.0 µg/L
	• Total nitrogen: < 160 µg/L
	• Total phosphorus: < 20 µg/L
	• Dissolved oxygen: 95 - 105% saturation
	• pH: 8.2 - 8.4
	• Secchi depth: > 2.7m
SEQ Open Coastal Area (slightly to moderately disturbed); Annual median concentrations	• Turbidity: < 1 NTU
	• Suspended solids: < 10 mg/L
	• Chlorophyll a: < 1 µg/L
	• Total nitrogen: < 140 µg/L
	• Total phosphorus: < 20 µg/L
	• Dissolved oxygen: 95 – 105% saturation
	• pH: 8.0 – 8.4
	• Secchi depth: > 5.0m

Table 3.2c: ANZECC/ARMCANZ (2000) toxicant trigger values for metals and inorganic nitrogen

Parameter	Unit	TTV
Arsenic	µg/L	5[b]
Antimony	µg/L	270[c]
Barium	µg/L	1000[b]
Cadmium	µg/L	0.7[d]
Chromium	µg/L	27.4
Cobalt	µg/L	1.0
Copper	µg/L	1.3
Lead	µg/L	4.4
Manganese	µg/L	70[c]
Mercury (inorganic)	µg/L	0.1[d]
Molybdenum	µg/L	23[c]
Nickel	µg/L	7[d]
Silver	µg/L	1.4
Vanadium	µg/L	100
Zinc	µg/L	15
Ammonia	µg/L	910[e]
NOx	mg/L	13[c]

a *TTVs assigned at the 95% protection level unless otherwise noted*

b *Based on more stringent recreational guideline value*

c *Trigger value of low reliability, used as an interim value*

d *Set at the 99% protection level due to potential for bioaccumulation or protection of key species*

e *Ammonia TTV is pH dependent - default ammonia TTV presented here is for pH of 8.*

3.2.2.2 Marine parks zoning plan

Moreton Bay is part of Queensland's coastal waters and generally all of the bay's tidal waters/areas are included within the Moreton Bay Marine Park declared under the *Marine Parks Act 2004*. Moreton Bay is managed under a statutory zoning plan that divides the bay into several categories of zones, which define particular use and conservation areas for regulation of activities. The proposed sand extraction area at the Spitfire Realignment Channel is in a General Use Zone which aims 'to provide for the general use and public enjoyment of the zone in ways that are consistent with the conservation of the marine park'. Sand extraction activities require permission under the zoning plan to occur in General Use Zones.

The closest zone of conservation significance to the proposed sand extraction area is Marine National Park Zone 03 'Northern Wedge' (a green zone) which is situated to the north of the proposed sand extraction area at Spitfire Banks. This zone was declared over the entire shallow sand bank system along the north-west channel in the bay as a representative habitat of that type and on the basis of its fishery values. The values of this area are further described in Chapter C4 – Marine Ecology. The waters within the Marine National Park Zone are also declared HEV waters under EPP Water as outlined above.

3.3 EXISTING CONDITIONS

3.3.1 Geological context

The nature and behaviour of the northern delta sand banks are determined by both their geological evolutionary development and the present day dominant forces of tidal currents and ocean waves. The sand banks there contain about 4,000 M m^3 of coastal sand and have been formed over the geological Holocene and Pleistocene timeframe, most particularly during the past 6,000 to 7,000 years of the Holocene period with the input of coastal system marine sands (Stephens 1992).

The vast scale of the delta system is now such that contemporary changes due to those natural processes are relatively slow and imperceptible. Even the proposed channel dredging by Port of Brisbane Pty Ltd is relatively small-scale in the context of the size of the overall delta system.

During the low sea-level phases of the Pleistocene ice ages, the present bay bed formed a terrestrial plain traversed by stream valleys of the ancestral Brisbane and Pine Rivers and their tributaries. At intermediate sea levels, the coastline location and zone of sand transport and dune formation were seaward of, and lower than, their present location. North Banks and Hamilton Patches between Cape Moreton and Caloundra were formed at such time. These old coastal deposits are now submerged forming large offshore shoals presently being remoulded by today's waves and currents.

Additionally, at the present sea level (over the past 6,000 to 7,000 years), sand is being deposited from the coastal longshore transport of sand along the and northern shoreline of Moreton Island at a rate estimated to be about 200,000 – 300,000 m^3/yr (Stephens 1992). It is subsequently redistributed southward into Moreton Bay to form the complex sand banks and channels now existing.

The sand banks of the northern delta are continuing to receive this ongoing supply of sand and are continuing to evolve their shape under the influences of waves and currents. There is no evidence of contemporary supply of sand from the North Banks directly to the shoreline of either Bribie Island or Caloundra (Jones 1992).

Moreton Island is experiencing slow but apparently persistent Holocene accretion along the northern shoreline to Comboyuro Point, from sand supplied with the longshore transport along the eastern coastline beaches. Its western shoreline has fluctuated substantially over the longer term. The recent geological record indicates a progressive erosion of former Holocene accretion deposits along the western shoreline of Comboyuro Point and south to at least Cowan Cowan. This pattern is likely to relate to the southward growth of the Yule Road shoals and its effects in directing strong tidal currents close to the shore.

3.3.2 Tides

The astronomical tides within Moreton Bay are predominantly semi-diurnal with two high tides and two low tides occurring daily. Observed water levels are also influenced by meteorological processes such as the wind and ambient pressure. These processes are particularly significant during extreme storm surge events which are described in **Section 3.3.5**.

The astronomical tide levels can be predicted based on tidal constituents derived from long term water level measurements. Maritime Safety Queensland (MSQ) publishes tidal planes for various sites within Moreton Bay relative to the predicted tide at the Brisbane Bar Standard Port. A summary of the predicted Mean High Water Spring (MHWS) and Mean Low Water Spring (MLWS) tidal planes for selected sites is provided in **Table 3.3a**.

Tidal flows enter and exit Moreton Bay through the main northern entrance and the significantly smaller passage between Moreton Island and North Stradbroke Island. As indicated in previous reports (e.g. Brisbane Airport Corporation, 2005; Queensland Government, 2005), there is significant amplification of the ocean tide in Moreton Bay. At the Brisbane Bar Standard Port, the average amplification compared to the open coast location at Caloundra is about 32 per cent. Further south at Redland Bay the average amplification increases to approximately 43 per cent. The southern section of Moreton Bay is dominated by islands and shoals. Throughout this area the tide interacts with flows entering at Jumpinpin (the passage between North and South Stradbroke Islands) causing an attenuation of the tidal amplitude.

A number of water level and current recording instruments were deployed throughout Moreton Bay as part of the SEQ Receiving Water Quality Model (RWQM) studies described in CSIRO (2012). The instrument located at the M3 Beacon provides information relevant to the sand extraction area. A sample of the recorded water level time series is provided in **Figure 3.3a** and is compared to the predicted tide at the Brisbane Bar. The comparison displays the following features:

- A small time difference between the sites with high and low water occurring at the M3 Beacon roughly 10 min before the Brisbane Bar
- The high water level at the two sites is relatively consistent, however low water is typically 0.2 – 0.3 m lower at the Brisbane Bar
- Tidal amplification occurs between the two sites. The tidal amplitude during spring tides at the M3 Beacon is approximately 2 m which is approximately 18 per cent smaller than the spring tide amplitude at the Brisbane Bar.

3.3.3 Currents

The majority of tidal flow into Moreton Bay occurs through the channels and across the sand shoals of the northern entrance (e.g. Dennison and Abal, 1999). These dynamic morphological features have a major influence of the tidal regime and flushing processes within the Moreton Bay.

Peak tidal current speeds at the entrance often exceed 1 m/s during spring tide periods. Stronger currents may be experienced during storm conditions when wind and wave forcing enhance the prevailing tidal currents. Current patterns in the shallow areas and across the shoals are more influenced by wind and wave activity in comparison the deeper channel regions.

In the western, central and southern parts of Moreton Bay the current magnitudes are generally lower, with the exception of some constricted areas nearshore and around some islands and shoals. Throughout these areas the wave energy is typically low however current patterns may still be influenced by winds.

Continuous current recordings have been obtained at a number of locations within Moreton Bay as part of previous studies (e.g. CSIRO, 2012; Brisbane Airport Corporation, 2005). As mentioned in **Section 3.3.2**, recoded data from the M3 Beacon instrument location is particularly relevant to the present study given its proximity to the sand extraction area. A sample of the recorded current speed and current direction time series at the M3 Beacon is provided in **Figure 3.3b** and **Figure 3.3c**.

Table 3.3a: Tidal planes for selected sites within Moreton Bay (MSQ, 2012)

Location	Water Level relative to mLAT		Mean Spring Range (m)	Time difference	
	MHWS	MLWS		High Water	Low Water
Brisbane Bar	2.17	0.37	1.80	Standard Port	
Dunwich	2.15	0.37	1.78	+0:11	+0:16
Amity Point	1.78	0.30	1.48	-0:40	-0:54
East Channel	2.06	0.35	1.71	-0:09	-0:13
Tangalooma	2.00	0.38	1.62	-0:23	-0:27
Beachmere	2.08	0.36	1.72	+0:06	+0:18

The sample presented covers a spring tide to neap tide period and indicates the following:

- A strong tidal component is apparent in the current speed data with highest currents typically recorded during the flooding tides and lowest current velocities measured during slack high and low water periods
- Currents were directed towards the south (between 140 – 180 degrees) during flooding tides and towards the north (between 340 – 360 degrees) during ebbing tides
- The data suggests a dominance of flooding over ebbing currents across the entrance as noted by Dennison and Abal (1999)
- During the spring tide period shown, the flood current magnitude is typically between 0.8 and 1.2 m/s. In contrast, the spring tide ebb current magnitude does not exceed 1 m/s. During neap tide periods the current magnitude remains below 0.6 m/s at all times.

Recorded current data for various other locations within Moreton Bay is presented in **Section 3.3.8** and used for hydrodynamic model validation. Currents similar in magnitude to the M3 Beacon location have been recorded at East Channel and Middle Banks. Relatively lower current velocities (typically less than 0.5 m/s) have been measured at South West Spit and Moreton Banks.

3.3.4 Waves

Moreton Bay is sheltered from the prevailing southerly 'swell' waves by North Stradbroke and Moreton Islands. The ocean swell energy that enters Moreton Bay and reaches the bay shorelines is substantially attenuated by the processes of refraction, diffraction, bed friction and breaking across the shallow shoals at the bay entrance. The shorelines within the bay are generally most affected by the locally generated 'sea' waves. In the vicinity of the Spitfire Realignment Channel both ocean swell and local sea waves have an influence on the sandy shoal morphology.

Figure 3.3a: Recorded water level at M3 Beacon (adjacent to sand extraction area) and Brisbane Bar

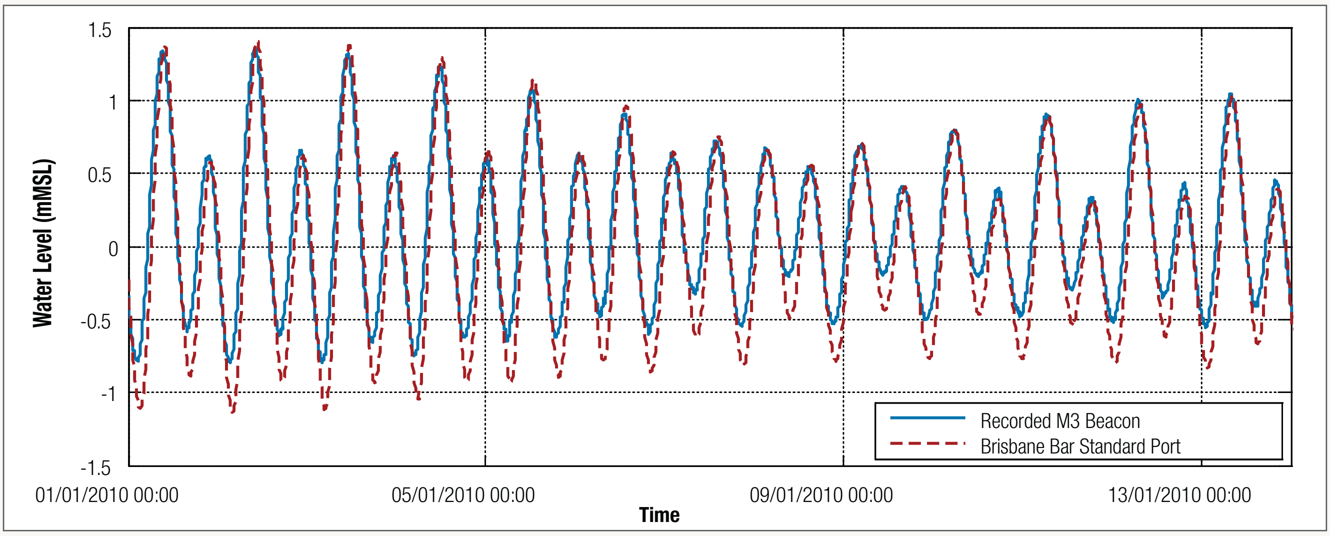


Figure 3.3b: Recorded current speed at M3 Beacon (adjacent to sand extraction area)

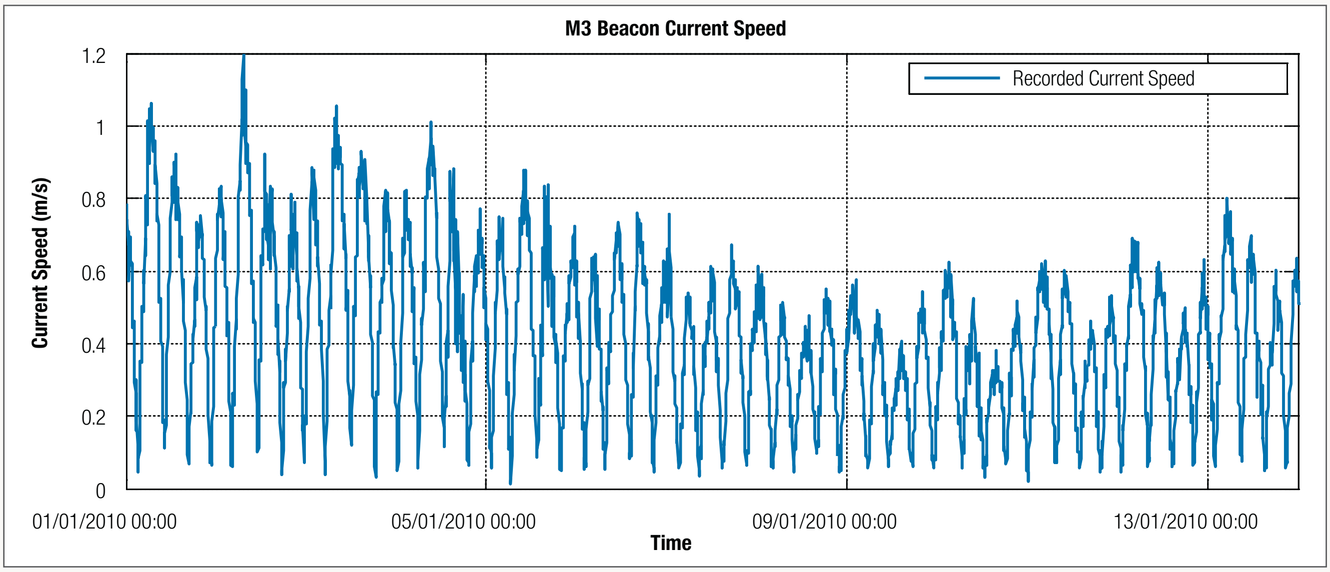
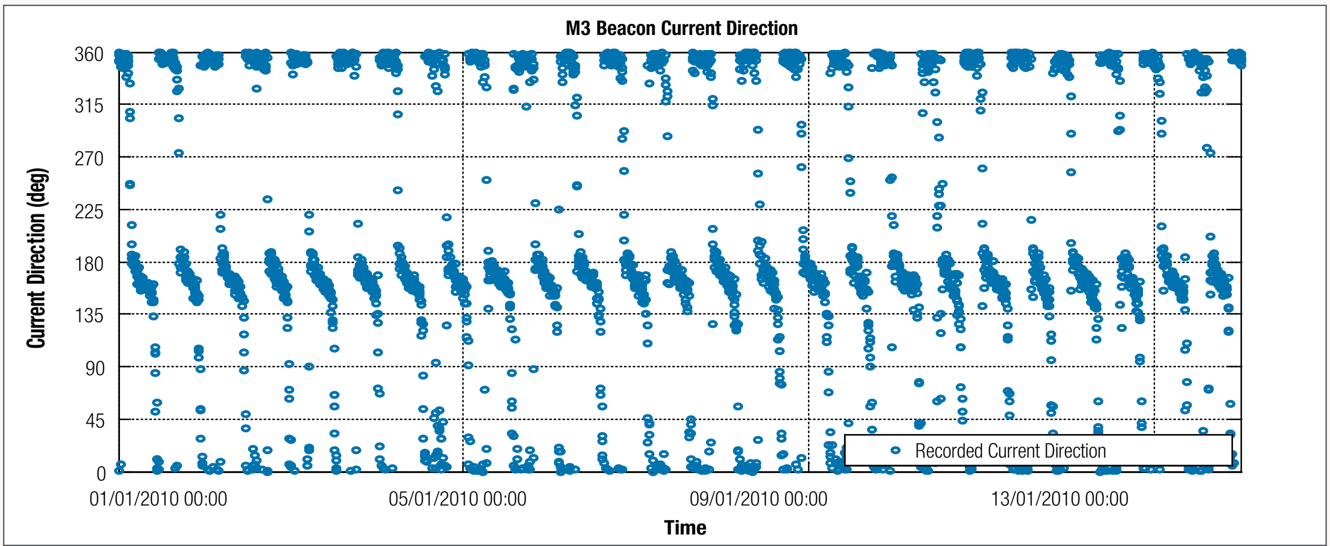


Figure 3.3c: Recorded current direction at M3 Beacon (adjacent to sand extraction area)



Knowledge of the wave climate along the SEQ open coast and within Moreton Bay is derived from observation and calculation of wave conditions by hindcasting techniques based on winds in the region. As described in BMT WBM (2005), previous studies have shown:

- The ocean wave climate (open coast) is of moderate to high energy, with median significant height about 1.3 m and extreme wave heights (typically generated by tropical cyclone conditions) up to 8 m
- Both longer period (8 to 15 seconds) swell and shorter period (5 to 7 seconds) sea waves are common along the open coast and at times may co-exist, sometimes with differing directions
- The open ocean swell waves are predominantly from the south-east directional sector
- North to north-east sector waves are seasonal, predominantly during spring through summer and are typically generated by local winds. These waves are typically of lower height and shorter period than the prevailing south-east sector swell waves
- Moreton Bay is dominated by waves generated by winds from within the bay itself. The available fetch lengths and depths are limited and restrict wave development substantially compared to the ocean. Significant wave heights rarely exceed 1.5 to 2 m
- The height and direction of Moreton Bay waves are determined directly by the prevailing winds and are highly seasonal in nature. These small sea waves can develop quickly with the onset of stronger local winds and at certain times of the year substantial daily variability may be observed.

The long-term average wave climate at Spitfire Channel Beacon (close to the sand extraction area) has been extracted from existing model results and is presented as a wave rose plot in **Figure 3.3d**. Wave height and direction frequency recurrence is also summarised in **Table 3.3b**.

Figure 3.3d: Spitfire Channel Beacon long-term average wave rose

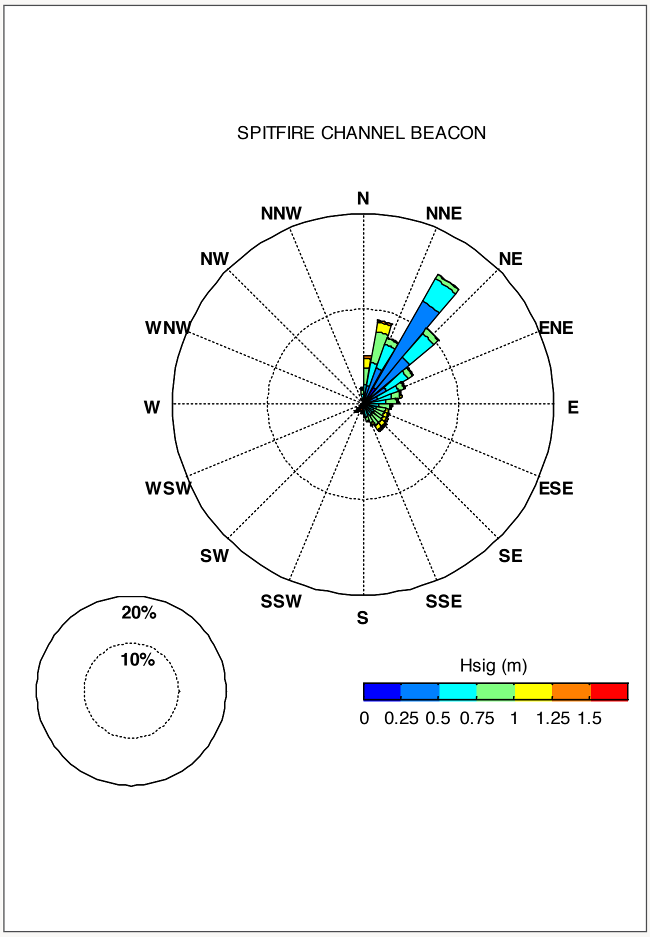


Table 3.3b: Wave frequency (per cent recurrence) table for Spitfire Channel Beacon

Hsig Bin (m)	Directional Bin (deg) 0	22.5	45	67.5	90	112.5	135	157.5	180	202.5	225	247.5	270	292.5	315	337.5	Total %
0.5	0.51	2.93	0.56	0.14	0.09	0.12	0.06	0.07	0.06	0.03	0.01	0.03	0.02	0.04	0.05	0.15	4.87
1.0	3.19	17.01	5.88	2.04	1.14	0.87	0.84	0.91	0.70	0.61	0.59	0.35	0.26	0.21	0.29	0.79	35.67
1.5	4.30	6.54	5.83	3.99	2.20	1.94	2.03	1.88	0.87	1.01	0.78	0.22	0.14	0.05	0.10	0.67	32.55
2.0	5.24	1.20	1.36	2.19	2.42	2.57	2.48	0.85	0.17	0.33	0.21	0.03		0.00	0.01	0.43	19.50
2.5	2.07	0.10	0.23	0.43	0.69	1.01	0.97	0.08	0.02	0.02	0.01					0.21	5.83
3.0	0.53		0.03	0.03	0.08	0.37	0.34	0.01								0.07	1.46
> 3.0	0.03			0.00		0.03	0.06										0.13
Total %	15.87	27.78	13.90	8.83	6.61	6.91	6.77	3.80	1.82	1.99	1.60	0.62	0.42	0.31	0.45	2.32	100.00

3.3.5 Storm surge

Moreton Bay is within a region where large-scale storm systems capable of generating a storm surge occur. The storm surge develops primarily due to low atmospheric pressure and wind stresses acting on the sea surface. The observed water level is a combination of the surge and tide and is referred to as the 'storm tide'. For exposed coastal locations, wave setup and wave run-up processes also contribute to the observed water levels.

Significant historical storm surge events that have affected SEQ and Moreton Bay have been associated with tropical cyclone activity and have typically occurred between December and March, including:

- Unnamed tropical cyclone event (1953/54 season)
- Tropical Cyclone Dinah (1966/67 season)
- Tropical Cyclone Daisy (1971/72 season).

For these events, surges within Moreton Bay and at the Brisbane Bar of up to 0.7 m were recorded, however, anecdotal evidence suggests more extreme water levels occurred at some locations, with boats being retrieved from tree tops at Beachmere (western Moreton Bay) following the 1953/54 event.

A comprehensive storm tide hazard study was completed in 2009 for the Moreton Bay Regional Council (Cardno, 2009). Storm tide levels associated with both cyclonic and non-cyclonic conditions were considered, with cyclonic conditions typically generating higher water levels for a given average recurrence interval (ARI). The exception was for open coast locations at Bribie Island where the non-cyclonic events produced slightly higher water levels up to the 100-year ARI. The results for the 100-year ARI level are shown in **Figure 3.3e**.

3.3.6 Sedimentation and morphological processes

The sand extraction area is centrally located within the entrance to Moreton Bay.

The closest shorelines to the proposed sand extraction area are Woorim at Bribie Island, approximately 7.5 km to the west-south-west and Comboyuro Point at Moreton Island, approximately 9 km to the east-south-east.

A comprehensive review of the sedimentation and morphological processes of northern Moreton Bay was previously developed for the Spitfire Sand Extraction Project Hydraulic Impact Assessment (WBM 2005) and is provided below.

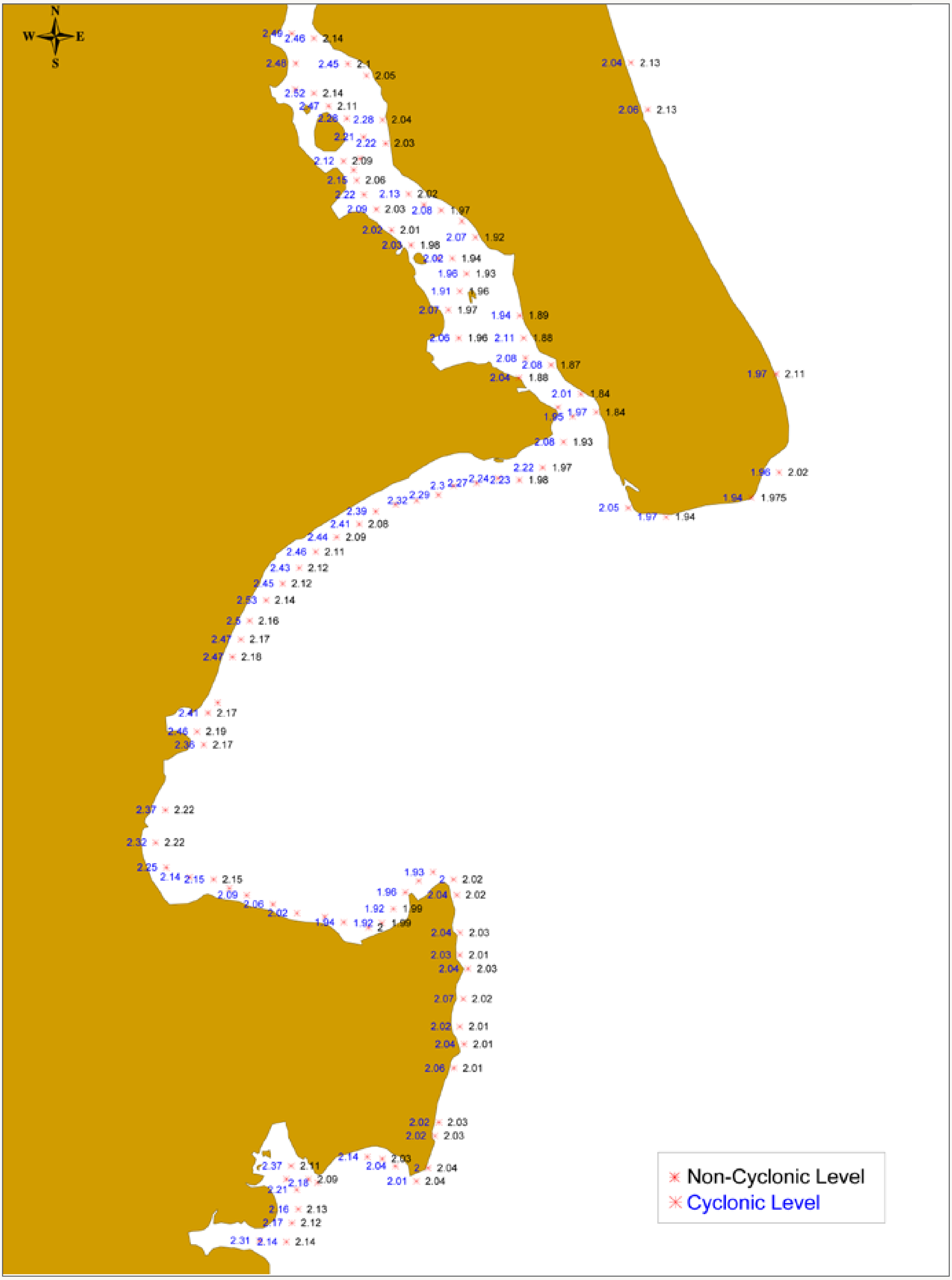
3.3.6.1 Northern delta sand shoals

The northern entrance to Moreton Bay contains massive sand shoals that have a substantial influence on the tidal flow of waters to and from Moreton Bay. These shoals have formed as the result of persistent inflow of coastal sand as part of the longshore transport regime of the regional beach system, a process that is continuing (Stephens 1992).

The tidal regime of the bay is determined largely by the bathymetry of the northern delta sand shoals and channels, as well as the size and shape of the bay itself. However, the vast size of the delta is such that there has been no discernible change in the tidal regime of the bay over the past century or more, due to the ongoing natural supply of sands, any changes in bathymetry by natural means or sand extraction to date, which are negligible in context of the scale of the delta.

The northern delta comprises two parts: a seaward ebb-delta and a landward flood-delta. The dominant hydrodynamic controls are waves and tides, but their relative importance varies with location. The landward flood-delta is protected from ocean swell and is therefore tide dominated. The northern delta shoals are highly mobile under the action of the tidal currents and associated waves and have been fashioned into a system of mutually evasive ebb and flood-dominated channels separated by linear sand ridges (Stephens 1978; Harris and Jones 1988).

Figure 3.3e: 100-year ARI storm tide levels for Western Moreton Bay (Cardno, 2009)



The ebb-delta has two sectors. The north-western sector is of simple morphology and comprises a large submarine spit (North Banks) on which ocean swell breaks, giving some protection to the tidally-dominated North West Channel and Bribie Island. The north-eastern sector has complex ebb and flood channel/delta formations and consists of several channels separated by shallow arcuate sand banks and linear sand ridges. The morphology here suggests that both waves and tides have a strong influence.

Modelling undertaken for previous studies show that most of the shallower parts of the entire northern delta are active under tidal currents. Wave action from ocean swell and local sea increases sand mobility further, particularly in the outer areas more exposed to the ocean waves. Most parts of the northern delta sand banks experience relatively high bed shear stresses from the combined action of waves and currents and exhibit a highly mobile surface layer, which may be centimetres to metres thick. Where there are actively moving bed forms such as ripples and dunes, the active layer may (over time) involve thicknesses of up to 5 m or more.

The broad spatial extent of the highly active areas has been assessed previously by modelling of the natural peak tidal currents, recognising that wave action would contribute further to the sand mobility. The modelling was based on a mean spring tide range, which is exceeded typically 25 – 30 per cent of the time. Areas of active sand correspond to areas experiencing current speeds in excess of about 0.4 m/s, with a high degree of mobility where currents exceed about 0.6 m/s. The peak flood and ebb tide currents are shown in **Figure 3.3f**.

This indicates that the tidal flow is not specifically confined to the deeper channels and the flow patterns are not strongly controlled by the bathymetric shape of the shoals and channels in the region. Essentially all areas across the delta experience currents over 0.4 m/s, with widespread areas exceeding 0.5 – 0.6 m/s. Thus, with the entire northern part of the delta exposed also to ocean swell, reducing in the southerly direction, and the southern parts exposed to waves generated within the bay itself, it is clear that the delta sands are highly mobile.

3.3.6.2 Sand bank evolution patterns

Sand supplied to the northern delta from the longshore drift along the northern shoreline of Moreton Island is dispersed throughout the sandbank fields in the North East Channel area. Beyond that region, sand movement and long term evolution of the delta shoals are determined by the tidal flow in combination with wave action in some areas.

The patterns of sand transport are indicated by the location and distribution of large-scale bedforms. The bedforms are indicators of the net transport direction and interdigitation of sand streams and of the relative supply of sand to an area. The sand banks are not “closed circulation cells” since they have been shown to migrate, grow and decay over 1 – 10 year intervals.

The tidal delta is formed as a complex series of sand banks, which range in height from 7 to 20 m and have crestlines from 3 to 9 km in length (Stephens 1978). The crestlines of the sand banks are represented by the bathymetric contours, illustrating their sinuous and three-dimensional nature. The parabolic crest of Yule Bank is estimated to have migrated southwards at an average rate of from 7 to 8 m/year (Stephens 1978), demonstrating the mobile nature of the sand banks composing the tidal deltas.

Sandwaves found in association with the sand banks are up to 5 m in height and often have their flatter updrift faces covered by smaller sandwaves of the order 0.6 to 1.5 m high (Stephens 1978). Crestlines of linear sand banks separate zones of ebb and flood-dominated sand transport. Reflecting this pattern, sandwaves on opposite sides of a given linear sand bank have opposite cross-sectional asymmetries.

Linear sand bank crestlines are oriented between about 7 and 15 degrees to the direction of regional peak tidal current flow. Thus, one side of the bank is exposed to a greater amount of tide induced bottom friction whilst the other side is protected. Inequalities, which may exist between ebb and flood tidal currents, result in the net migration of a sand bank in the direction of dominant tidal flow. In cross-section, the sand bank will be asymmetrical, the steeper (lee) slope facing in the approximate direction of net movement.

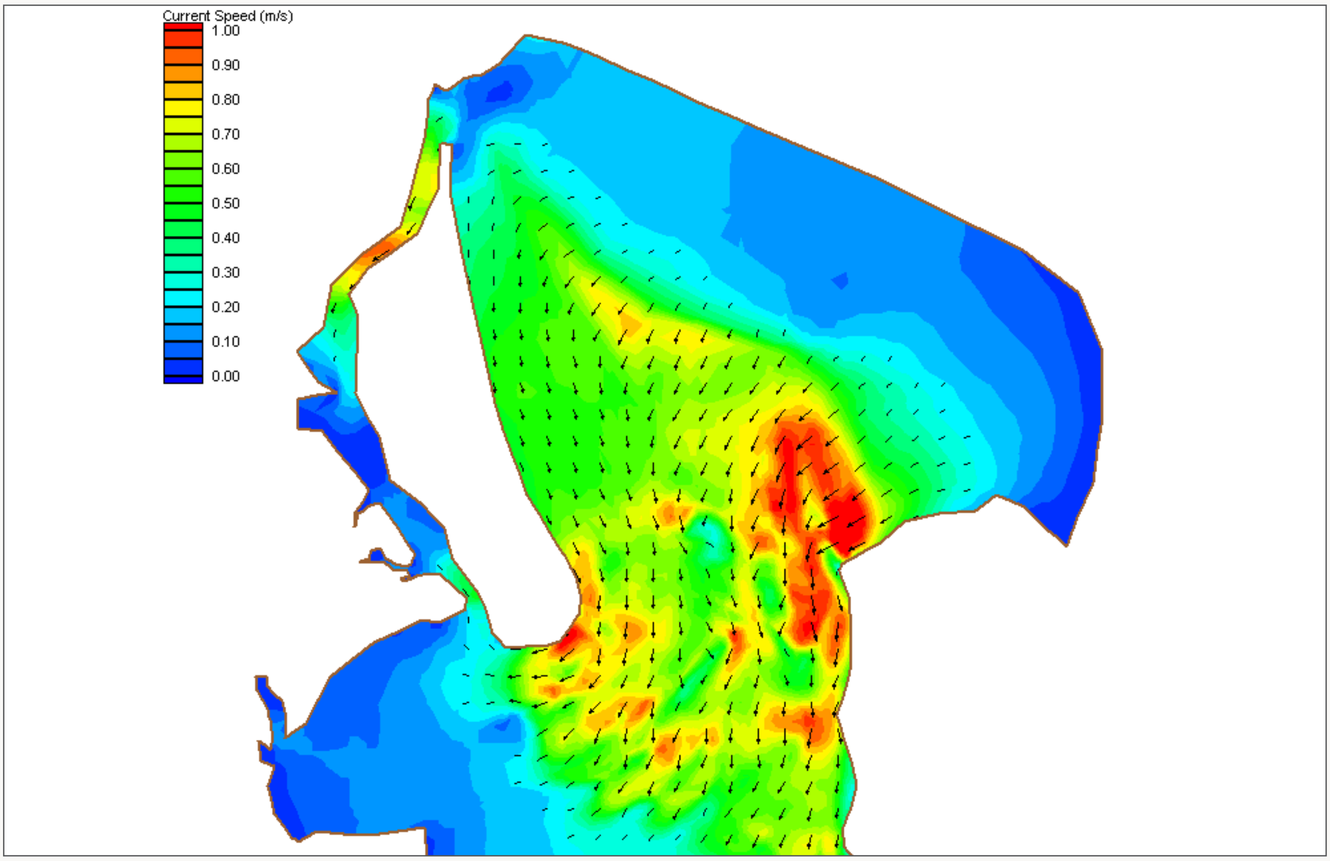
The curvilinear crestline is thought to be the product of sand bank “sequential development” and appears as two basic shapes: “V”-shaped (parabolic) and “S”-shaped. The underwater parabolic dune shape has been produced by horizontal flow separations, resulting in “mutually evasive ebb and flood channels” alternating across the tidal delta area. The closed, crescentic ends of these channels have been produced by deposition of traction load sand, during flow expansion and resultant velocity decrease, as the currents fan out over the crests of the ridges. The ridges are composed entirely of oceanic quartzose sand, with some shelly sand lag accumulations in the deepest channels.

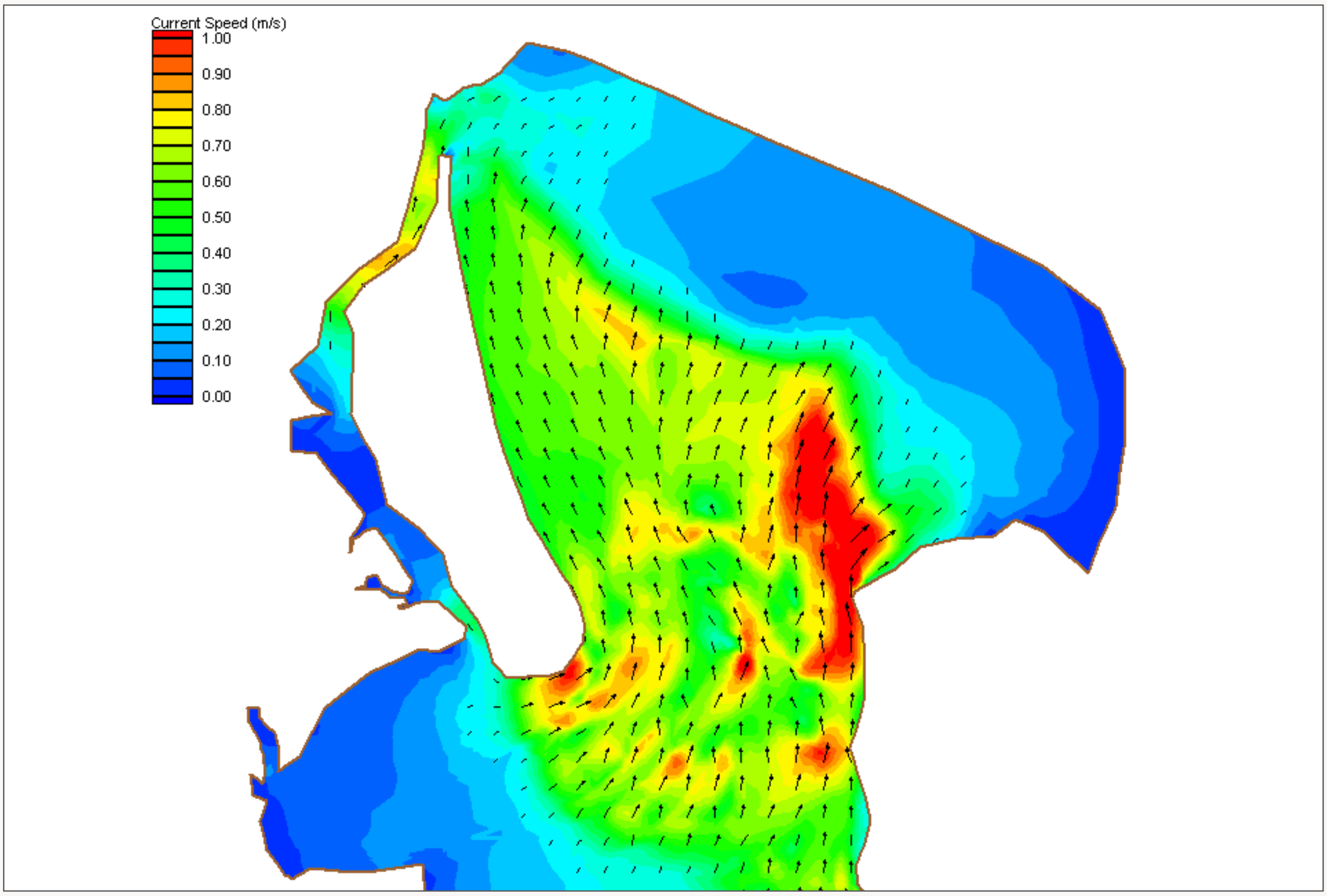
The deeper channels to the west or south (downdrift) of the active sand shoals, either natural or dredged for the shipping channels, are subject to some deposition of sand that falls from the shallower surface of the shoals as ‘dropovers’. Currents in those channels may be sufficient to further redistribute that sand along and/or across the channel. The currents may create large dunal bedforms under certain circumstances, potentially affecting navigational depths.

3.3.6.3 Shoreline processes

The shorelines of northern Moreton Bay are predominantly sandy beaches with only few bedrock control points. As such, they have formed over geological time due to an excess of sand supply over the capacity for wave/current action to transport the sand away to other areas, without dependence on ‘headland’ controls. They comprise:

Figure 3.3f: Peak mean spring tide current speeds at the northern delta (WBM 2005)





- Bribie Island beaches, exposed to ocean swell towards the northern part of the island but quite sheltered from the predominant south-east sector swell in the southern parts
- The western shoreline beaches of Moreton Island, subject to only minor refracted ocean swell that is progressively less significant with distance south from Comboyuro Point, together with the combined action of locally generated 'sea' waves from within the bay itself and predominantly longshore directed tidal currents
- Deception Bay beaches, sheltered almost completely from the ocean swell by both the blocking effect of Moreton Island and the southern tip of Bribie Island and the considerable attenuation of wave energy by breaking and bed friction across the northern delta shoals. Thus, this shoreline is subjected predominantly to locally generated east to south-east 'sea' waves from within the bay itself.

Sand on the shoreline beaches and in the nearshore zone is subject to continual movement under the complex influences of the prevailing waves and currents. Such movement can be in an offshore/onshore direction and/or in an alongshore direction. Changes in the foreshore alignment and profile can occur in response to this movement of sand.

Beach erosion is typically characterised in two main categories:

- Short-term erosion where high waves and elevated water levels induce cross-shore transport resulting in sand being eroded from the upper beach and deposited in the nearshore zone. This sand typically moves back onshore gradually under the influences of smaller waves following the storm.
- Long-term shoreline movement where imbalances in the overall sediment budget can lead to gradual erosion or accretion of the foreshore and changes in the coastal alignment. Such shoreline movement typically occurs as a result of variations in the rate of sand transport along the shoreline and/or changes in the supply of sand. Erosion in one area is typically accompanied by accretion in another.

These processes are naturally occurring and many shorelines are still gradually adjusting in a geological time frame and context to a substantial post-glacial sea level rise that ended over 6,000 years ago. Thus, the shorelines of Moreton Bay are subject to short term changes, in response to weather and associated wave/current events, and long term progressive changes within the geological timeframe. Nevertheless, while shoreline fluctuations are a part of naturally occurring processes, human activities and interference can have an influence in certain situations.

With respect to northern Moreton Bay and the adjacent shorelines of Bribie and Moreton Islands, there is evidence of substantial natural sediment movement under the influences of the complex interaction of waves and currents in the region. Naturally occurring beach erosion and accretion can be expected in some areas as part of those processes.

Shoreline processes are controlled predominantly by one or all of the following, depending on location:

- Wave induced longshore transport of the foreshore sand, being the dominant sand supply to some areas. Any differentials in the longshore transport rates may result in erosion in some areas and accretion in others. This process may occur over short or quite long timeframes.
- Direct storm wave attack causing short term beach erosion with sand being moved directly offshore to the immediate nearshore zone, either to be returned to the beach where significant swell exists (e.g. Bribie Island) or lost to the shoreline where the normal waves do not have the capacity to force it back onshore.
- Effects of strong shore-parallel tidal currents that, either through tidal channel meandering or in-channel sand transport, may supply sand or remove sand in certain areas and/or undercut the stable nearshore profile slope, causing accretion or erosion of the adjacent foreshore.

The northern end of Moreton Bay has continually changed through time (Neil 1998). It is reported from the 19th century (Harbours and Marine 1986) that "banks grew out and closed channels, while other channels opened and deepened. In 1882 the growth of Venus Banks to the northward necessitated the shifting of the Yellow Patch Lighthouse 300 ft to the north-east and by 1891 this light was being moved for the fourth time". While no comprehensive studies of shoreline evolution of the bay as a whole have been undertaken, of particular note with regard to these processes for Moreton Bay are the following specific examples:

- *Cowan Cowan Erosion:* This area on the western side of Moreton Island comprises Holocene sand deposited during the past 6,500 years from the supply entering at Comboyuro Point and being transported southward along the island shoreline predominantly by waves and currents. This is a dynamic process, with different parts of this shoreline at times eroding and at other times accreting, with overall net accretion. The erosion at Cowan Cowan was reported as early as 1898 when the lighthouse there was endangered by encroachment of the sea washing away the foreshores at the point (Harbours and Marine 1986). The lighthouse was moved in 1901 due to erosion.
- *Comboyuro Point Erosion:* The early erosion history of Comboyuro Point is recorded also because of its impacts on navigational lights at the site. It is reported (Harbours and Marine 1986) that *"Comboyuro Point light and the keeper's cottage were moved some 200 ft further inland in 1890, a move necessitated not by the movement of the channels but by the encroachment of the sea. …Owing to the erosion of the sea the lighthouse at Comboyuro Point also had to be moved back 366 ft in 1905… The lighthouse was discontinued in 1960 when considerable erosion of the foreshore had occurred".*

- *Bribie Island Shoreline Changes:* The shoreline of Bribie Island has evolved over the long-term geological timeframe of the Pleistocene (prior to 100,000 years BP) and Holocene (past 6,500 years). Long term accretion has resulted from supply of sand during Pleistocene times. The Holocene and contemporary natural pattern of ocean shoreline change appears to be one of slight erosion due to sand transport southwards to Skirmish Point not matched by onshore supply at present sea level. This has resulted in net accumulation of the southern end of the island, although the shoreline there fluctuates considerably depending on short-term sand supply patterns and wave climate. It is also feasible that natural changes in the bathymetry of the North Bank area affects ocean swell wave propagation to the island such that local shoreline changes are caused from time to time.

These are natural processes that, in a dynamic system such as Moreton Bay, lead to continual changes in the shape of the shoreline. Any significant changes in the strength of tidal currents immediately adjacent to the foreshores and/or the height or direction of waves impinging on the shoreline may potentially change the natural pattern of erosion/accretion.

Stability of the eastern beach/dune foreshore of Bribie Island is determined predominantly by the prevailing waves, particularly the ocean swell reaching the island, and the associated longshore transport of sand. Further south along the island towards Skirmish Point, the stability becomes increasingly dependent also on the tidal currents that flow past the southern tip of the island.

In particular, the shoreline of Bribie Island experiences a slight southward net sand transport and an associated progressive erosion, particularly towards the northern end, as evidenced by wartime gun emplacements now exposed on the beach. This southward sand transport has led to substantial accumulation of sand around Skirmish Point to South Point over the longer term. The southward net transport may be supplied, at least in part, over the long term by an onshore movement of sand at the northern end of the island, although this has not been established.

However, any such onshore movement of sand to the Bribie Island beach system would be predominantly a swell wave related process, with most onshore transport in deeper water occurring only during higher wave events. Because of the substantial attenuation of the ocean swell due to breaking and bed friction over the North Banks, onshore movement of sand to the beach from nearshore would be limited to depths of less than about 10 m.

However, it is considered that there is little or no modern day sediment transport to the shoreline from the shallower North Banks, as these are separated from the shore by the naturally deep North West Channel (14 – 16 m deep in most places), across which sand transport is anticipated to be negligible.

It is understood that there has been ongoing erosion at the township of Woorim (e.g. BMT WBM 2007), along the south-eastern shoreline of Bribie Island, over many years and various remedial works have been undertaken, including beach nourishment. It is also evident from aerial photography that there has been substantial accretion further to the south of Skirmish Point. This, together with consideration of the wave exposure indicates that the erosion is associated with the southward net transport of sand along the beach. The observed erosion and accretion patterns are consistent with the long-term natural evolution of the shoreline in this area.

The western shoreline of Moreton Island is somewhat more complex, with:

- A slight southward net sand transport by the very small refracted ocean waves, most particularly along the northern part of the island shoreline
- Sand movements along the shoreline in both directions by the local 'sea' waves from north-west to south-west directions
- Northward and southward movements of sand further offshore from the immediate shoreline due to the tidal currents flowing adjacent to the shore in somewhat deeper water.

At this stage there is no information available to suggest whether the shoreline along Moreton Island is controlled by wave induced sand transport or tidally induced sand transport. The location of spits to the south of the prominent points indicates net transport to the south but this could be due to either waves, tides or a combination of both. The geological record indicates relatively recent (decades to centuries) progressive erosion of the Holocene accretion deposits along the shoreline south from Comboyuro Point to at least Cowan Cowan. This indicates that, while there has been a surplus of sand supply to that shoreline over the longer term, combined with local processes including a southward net longshore transport of sand by swell action, local shorter term processes of shoreline change, possibly affected by the effects of the growth of the Yule Road shoals in directing strong tidal currents close to the shore, have led to shoreline fluctuations involving erosion and accretion from time to time.

3.3.7 Water quality

The receiving waters of eastern Moreton Bay are where potential impacts from the construction phase of the Project will need to be managed. Specifically, dredging of sands in the Spitfire Channel area will be required as part of the surcharge and filling of the runway area to promote consolidation of soils at the airport site. The proposed dredging has the potential to liberate fine sediment (on both the surface of the banks and in porewaters extracted) and other contaminants which may be associated with the dredging operation.

The management of the water quality surrounding Spitfire Realignment Channel is under the jurisdiction of the Department of Environment and Heritage Protection (DEHP) and the Department of National Parks Recreation, Sport and Racing in terms of the Moreton Bay Marine Park. In managing these waters DEHP has specified water quality objectives that if achieved will protect the environmental values of the receiving waters including marine park values.

Water quality close to Spitfire Realignment Channel in Moreton Bay has been monitored as part of the Healthy Waterways Ecosystem Health Monitoring Program (EHMP) for more than 10 years. Monitoring results of two locations within the general vicinity of the Spitfire Realignment Channel were examined to determine ambient water quality in that region. EHMP Site E00525 is likely to be the best surrogate of water quality information, as both the Spitfire Realignment Channel and the EHMP site reside, at least partially, within the E2A water area/type (refer to **Figure 3.2a** in **Section 3.2.3**). While EHMP Site E00524 is the next closest site to the sand extraction area, it is located near shore to Moreton Island and within a different water area/ type (refer to **Figure 3.2a**).

Discussion of existing water quality will largely focus on EHMP Site E00525. Analysis of the water quality of these two locations is presented in the following manner:

- Box and whisker plots for the two sites are displayed in **Figure 3.3g** to show the distribution of values for selected water quality parameters. These data represent the entire period of record for the two EHMP sites.
- Time series of the two EHMP sites for the entire period of record are presented in **Figure 3.3h**. These figures show how each parameter changes with season and from year to year.
- **Table 3.3c** presents the 20th, 50th and 80th percentile values for the two EHMP locations for the selected parameters. Also included in **Table 3.3c** are the relevant water quality objectives for two of the water area/types as it is assumed, these two location would experience the greatest potential impacts:
  - HEV marine environment, Area E1C to the north
  - Slightly to moderately disturbed marine environment, Area E2A containing the SCR.
- A brief discussion of salient observations relating to the presented data:
  - Salinity is typically consistent at the mouth of Moreton Bay with a median value typical of enclosed coastal environments with a good hydraulic connection to open coast waters. As an enclosed coastal environment, salinity is also affected by large catchment inflow events, demonstrating drops in salinity to below 30 ppt. There are no specific salinity WQOs within the EPP Water.
  - Typical seasonal water temperatures range from 15 – 16 °C in the winter months to 25 – 26 °C in the summer. There are no specific temperature WQOs within the EPP Water.
  - Dissolved Oxygen concentrations in eastern Moreton Bay are generally good, generally complying with both the E2A and E1C HEV water type WQOs with median concentrations at approximately 100 per cent saturation.
  - Overall, pH values are slightly lower than the WQOs for the E1C HEV area; however, by no more than 1 per cent at the most for the 20th, 50th and 80th percentile values. The pH values are within the water quality range for the E2A area.
  - Total nitrogen and phosphorus values are lower than the E1C HEV 20th, 50th, and 80th percentile values by as much as 10 per cent, however, this difference decreases with increasing percentile. These water quality values generally comply with the WQOs of the E1C HEV. Similarly, nutrient concentrations are in compliance with the E2A water quality objective. Like salinity, nutrient concentrations in Moreton Bay appear to be influenced only by significant rainfall events.
  - Both the 20th and 50th percentile turbidity values of E00525 are less than 1.0 NTU, however, the 80th percentile value is slightly elevated above the WQO of the E1C HEV area. Generally turbidity appears to comply with the WQOs with detected natural exceedences of turbidity occurring when medium to large rainfall events result in catchment inflows to Moreton Bay.
  - Chlorophyll *a* concentrations in Moreton Bay are elevated above the E1C WQOs and do not comply with the 50th and 80th percentile WQOs. The median concentration complies with the E2A area WQO.

Figure 3.3g: Moreton Bay EHMP water quality data

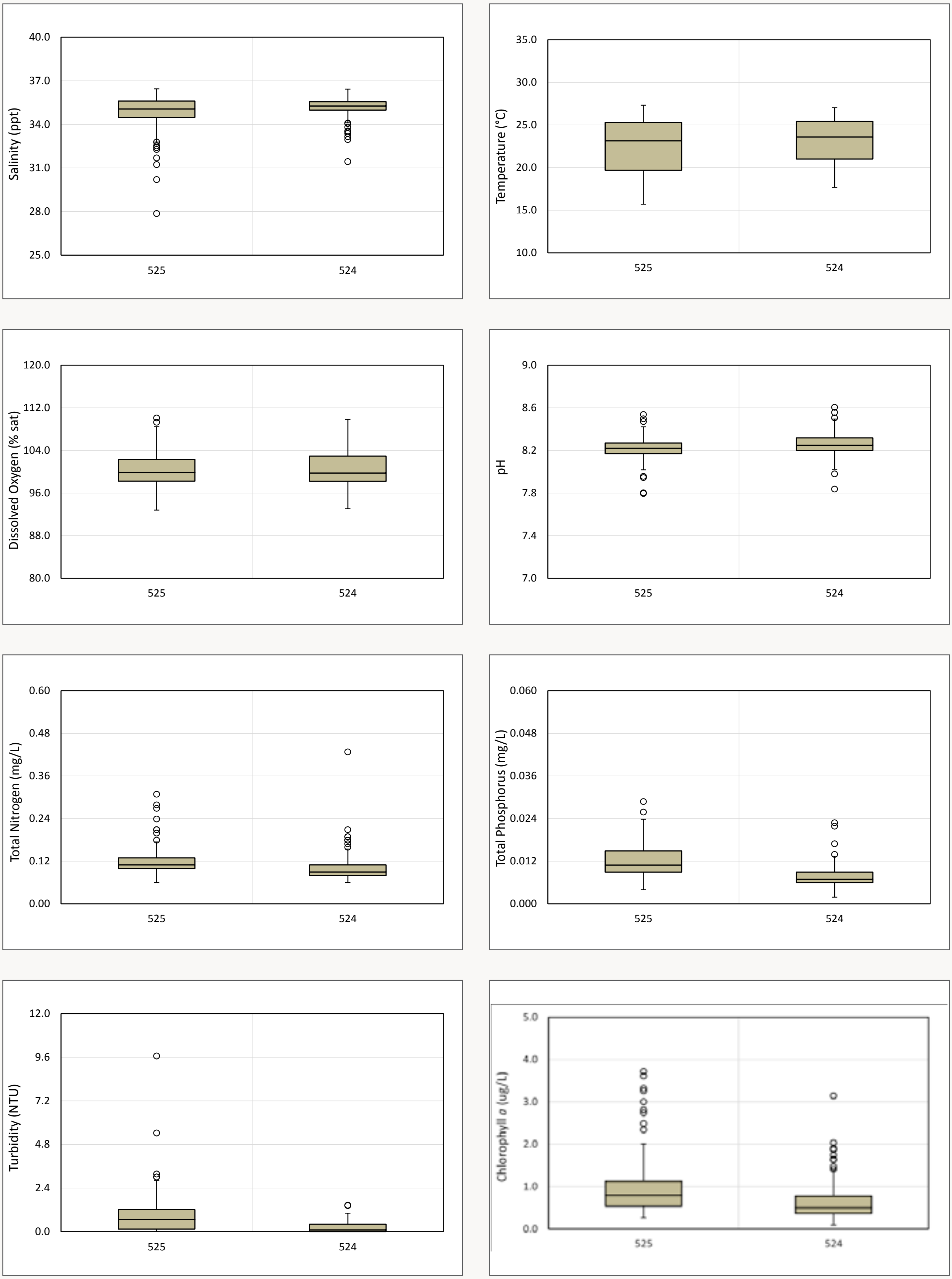


Figure 3.3h: Moreton Bay EHMP water quality data as time series

Table 3.3c: Existing Moreton Bay water quality and water quality objectives

Water Quality Percentile	EHMP Site 525	WQO		EHMP Site 524	WQO E1A
		E2A	**E1C**		
Salinity (ppt)					
20	34.2	-	-	34.7	-
50	35.1	-	-	35.3	-
80	35.7	-	-	35.6	-
Temperature (°C)					
20	19.1	-	-	20.3	-
50	23.1	-	-	23.6	-
80	25.6	-	-	25.9	-
Dissolved Oxygen (% Sat)					
20	97.8	-	95.0	97.7	95.0
50	99.9	95 - 105%	100.0	99.8	100.0
80	102.7	-	105.0	103.7	105.0
pH					
20	8.16	-	8.20	8.18	8.20
50	8.22	8.2 - 8.4	8.30	8.25	8.30
80	8.29	-	8.40	8.34	8.40
Total Nitrogen (mg/L)					
20	0.089	-	0.100	0.080	0.100
50	0.109	0.16	0.120	0.089	0.120
80	0.139	-	0.150	0.119	0.160
Total Phosphorus (mg/L)					
20	0.008	-	0.009	0.006	0.009
50	0.011	0.016	0.012	0.007	0.012
80	0.016	-	0.016	0.010	0.016
Turbidity (NTU)					
20	0.10	-	< 1.0	0.00	< 1.0
50	0.67	1.0	< 1.0	0.09	< 1.0
80	1.38	-	1.0	0.63	1.0
Chlorophyll a (µg/L)					
20	0.50	-	0.50	0.33	0.50
50	**0.79**	1.0	0.60	0.50	0.60
80	**1.20**	-	1.00	0.92	1.00

Entries highlighted in bold represent exceedences of the water quality objectives

3.3.8 Baseline modelling

The measured data describing the hydrodynamics of the marine environment within Moreton Bay have been supported and enhanced using validated numerical models. These models facilitate description of complex interactions of processes, including those not able to be measured directly for practical and logistical reasons, and were used as the key method of assessing impacts of the Project. They have been shown in many previous studies to simulate the hydrodynamic processes reliably and in a manner suitable for impact assessment purposes.

The methodology for evaluation of hydrodynamic (HD) and dredge plume advection-dispersion (AD) processes associated with the proposed dredging was based on coupled two-dimensional modelling. The modelling system TUFLOW FV was used. This is a finite volume model that handles both HD and AD components within a flexible mesh computational grid format.

Spectral wave modelling based on the SWAN software system was used to describe the wave climate and wave propagation. SWAN is an industry standard modelling system and is linked to TUFLOW FV to cater for interaction of wave, water level and current processes and their effects on sediment re-suspension, transport and deposition. These models have been applied and verified as reliable for the purpose of impact assessment by BMT WBM on several other major studies involving wave/current driven sedimentation processes.

A key advantage of employing the flexible mesh model framework was its ability to adjust the spatial resolution of the computational network and, in particular, to increase resolution in areas of specific interest to the study. In the current study, the proposed sand extraction area and estuary resolution has been increased to allow representation of dredging operations and the associated plume (note that three-dimensional Maroochy River estuary assessments are reported separately in Chapter B6 – Surface Water and Hydrology). The hydrodynamic model mesh resolution has been reduced in areas away from the sand extraction area and estuaries. As such, simulation times and efficiencies were not constrained by the highest resolution required.

Previous hydrodynamic modelling studies conducted for Spitfire Realignment Channel dredging by Port of Brisbane Pty Ltd include BMT WBM (2005), which focussed on the hydraulic and shoreline impacts associated with the proposed sand extraction. This study also provided an overview and summary of historical data and investigations of hydrodynamic behaviour in Moreton Bay with a focus on the northern delta area, providing a basis for assumptions about sediment transport patterns and their relationship to wind and wave processes. Additional information was also obtained from BMT WBM (2008), which reports the results of a dredge plume monitoring campaign within the sand extraction area. This was used to inform the modelling undertaken for the present EIS.

Formal calibration of the numerical modelling system was undertaken as part of the EIS and is described below. Data used for calibration included MSQ tidal predictions, Acoustic Doppler Current Profiler (ADCP) velocity and water level measurements from previous studies (Brisbane Airport Corporation 2005 and CSIRO 2012) and targeted ADCP flow measurement and tide recording in the Maroochy River estuary undertaken as part of the current EIS. The locations for the various data sources are indicated in **Figure 3.3i**.

To assess beach system impacts along northern Moreton Bay shorelines, the SWAN wave modelling provided the basis of determination of effects of the developed Spitfire Realignment Channel on the prevailing waves that cause both alongshore transport of sand and cross-shore transfer of sand during storm events.

3.3.8.1 Modelling system development and validation

<u>Hydrodynamic model</u>

The hydrodynamic model TUFLOW FV has been used to simulate HD and AD in two-dimensional mode for the present EIS. An existing regional scale model of the Coral Sea has been used to provide boundary conditions to the model developed specifically for the EIS. The Coral Sea model has a main open boundary approximately 900 km offshore of the Queensland coastline. The model requires prescribed tidal water levels along this boundary and the relatively smaller boundaries to the north and south (Torres Strait and extending seaward from northern NSW). Harmonic tidal constituents at 29 locations along the open boundaries were obtained from the National Tide Centre (NTC). Water level variation output from the Coral Sea model provides the open boundary conditions to the Moreton Bay model. Detail of the high resolution Moreton Bay model mesh is shown in **Figure 3.3j**.

A critical component of any hydrodynamic model development and calibration is the construction of a sufficiently accurate digital elevation model of the study area. In the case of the Moreton Bay model the following bathymetric data sources have been used:

- Sunshine Coast Bathymetric LiDAR, Queensland Government (2011)
- Project 3DGBR bathymetry model for the Great Barrier Reef 100m grid (approx.), James Cook University (2010)
- Australian Bathymetry and Topography 250m Grid, Geoscience Australia (2009)
- Hydrographic chart derived bathymetry (various AUS chart sources).

Figure 3.3i: Hydrodynamic and wave model validation locations

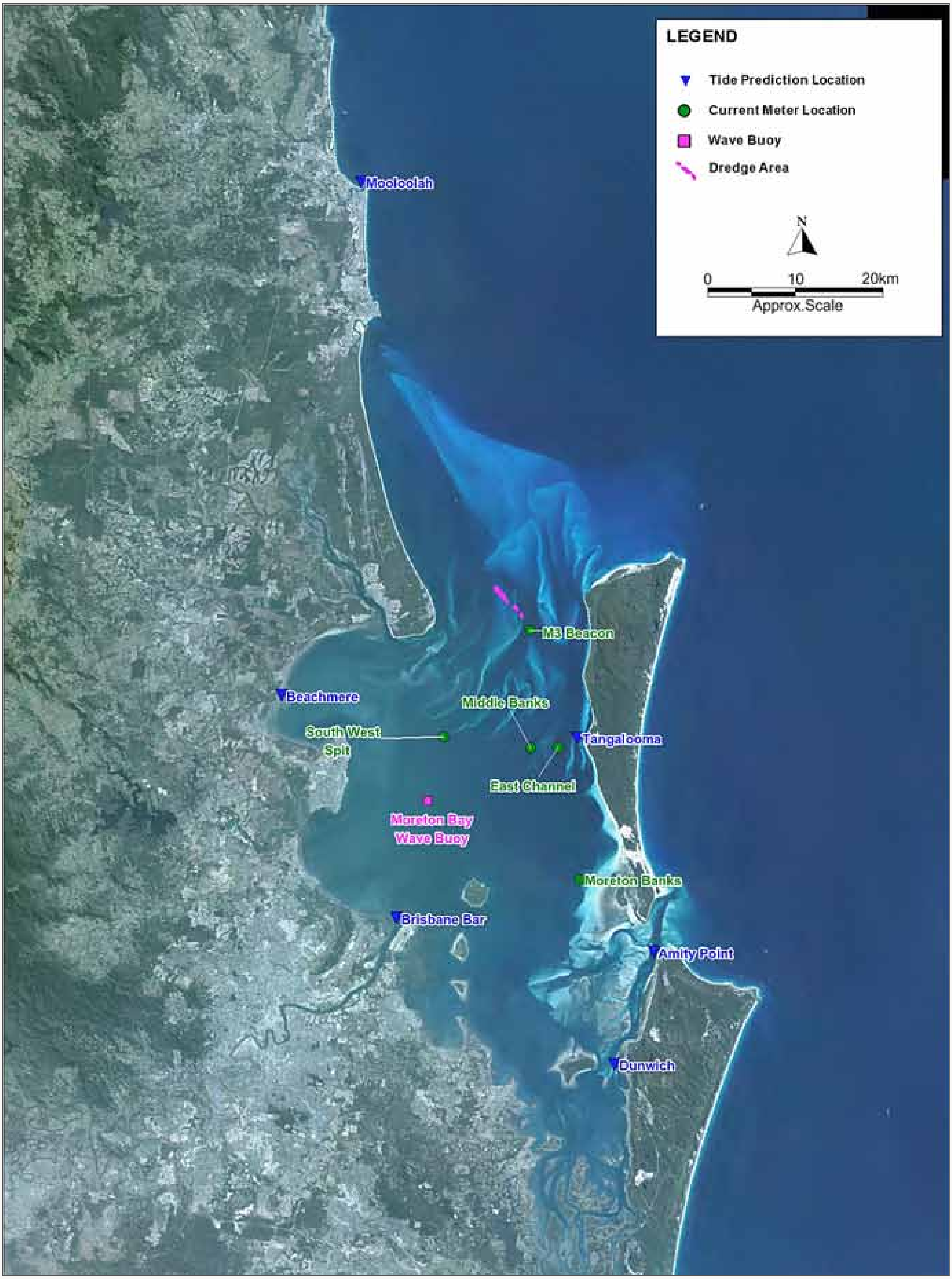
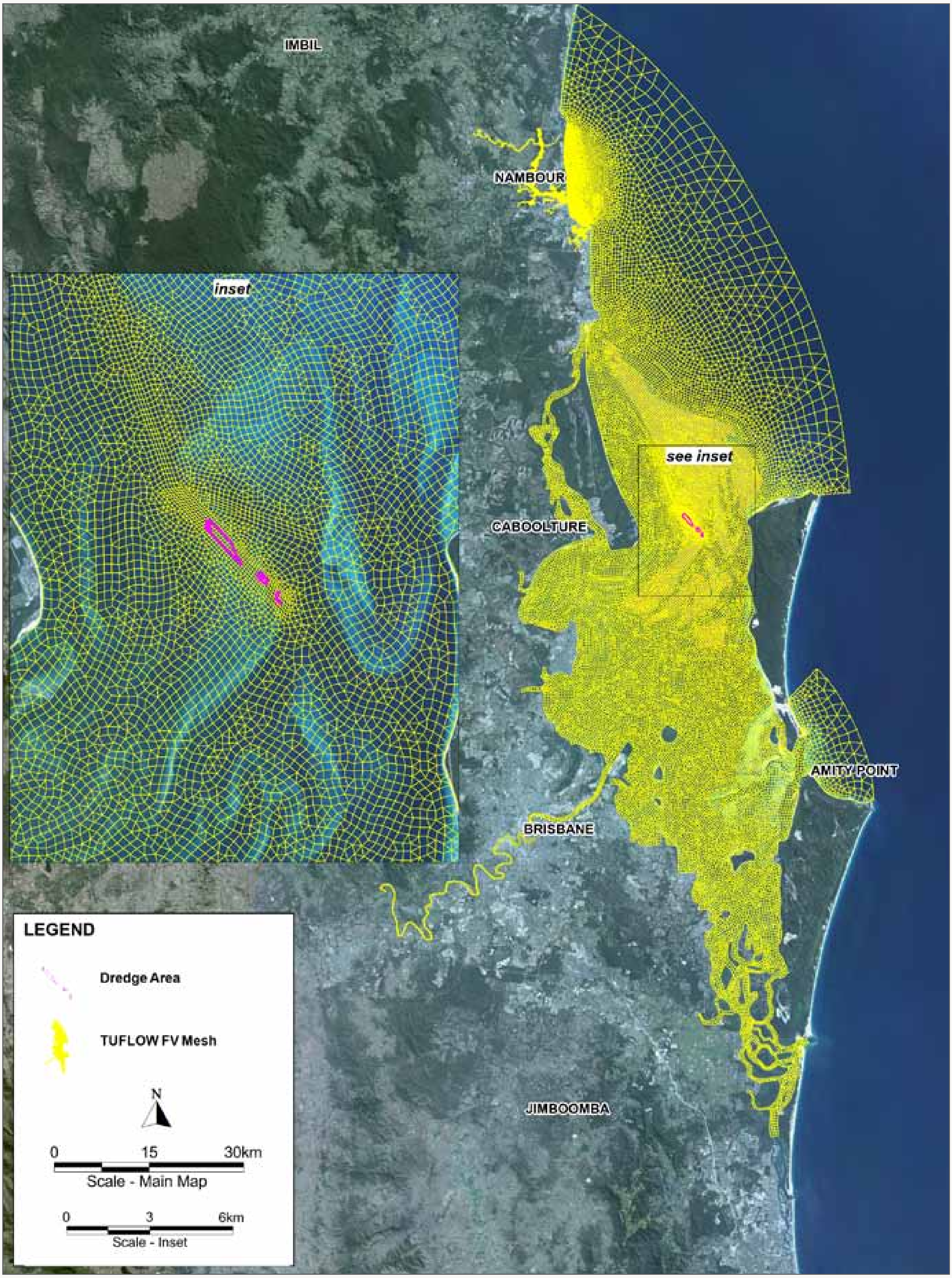


Figure 3.3j: TUFLOW FV model extent



Wave model

Comprehensive spectral wave models covering the broader region surrounding and within Moreton Bay were established to assess the wave climate and wave propagation in the context of the Project. The detailed wave modelling results were used to guide the assessment of shoreline processes and for coupling with the hydrodynamic model.

Wave conditions were simulated using SWAN models of the study area. SWAN is a third generation spectral wave model that estimates wave parameters in coastal regions from given wind, wave and current conditions. SWAN is developed by Delft University of Technology and is widely used by the coastal engineering community.

The SWAN input parameters employed in this study are considered to be realistic and are based upon previous experience with similar models. Default values for the whitecapping dissipation coefficient and wave steepness parameter were used for the Komen et al (1984) calculations. The bottom friction formulation of Collins (1972) was implemented with a coefficient of 0.025. The first order Backward Space Backward Time scheme was used for the numerical propagation scheme. A mid-range refraction coefficient was chosen to achieve an accurate result without spurious oscillations.

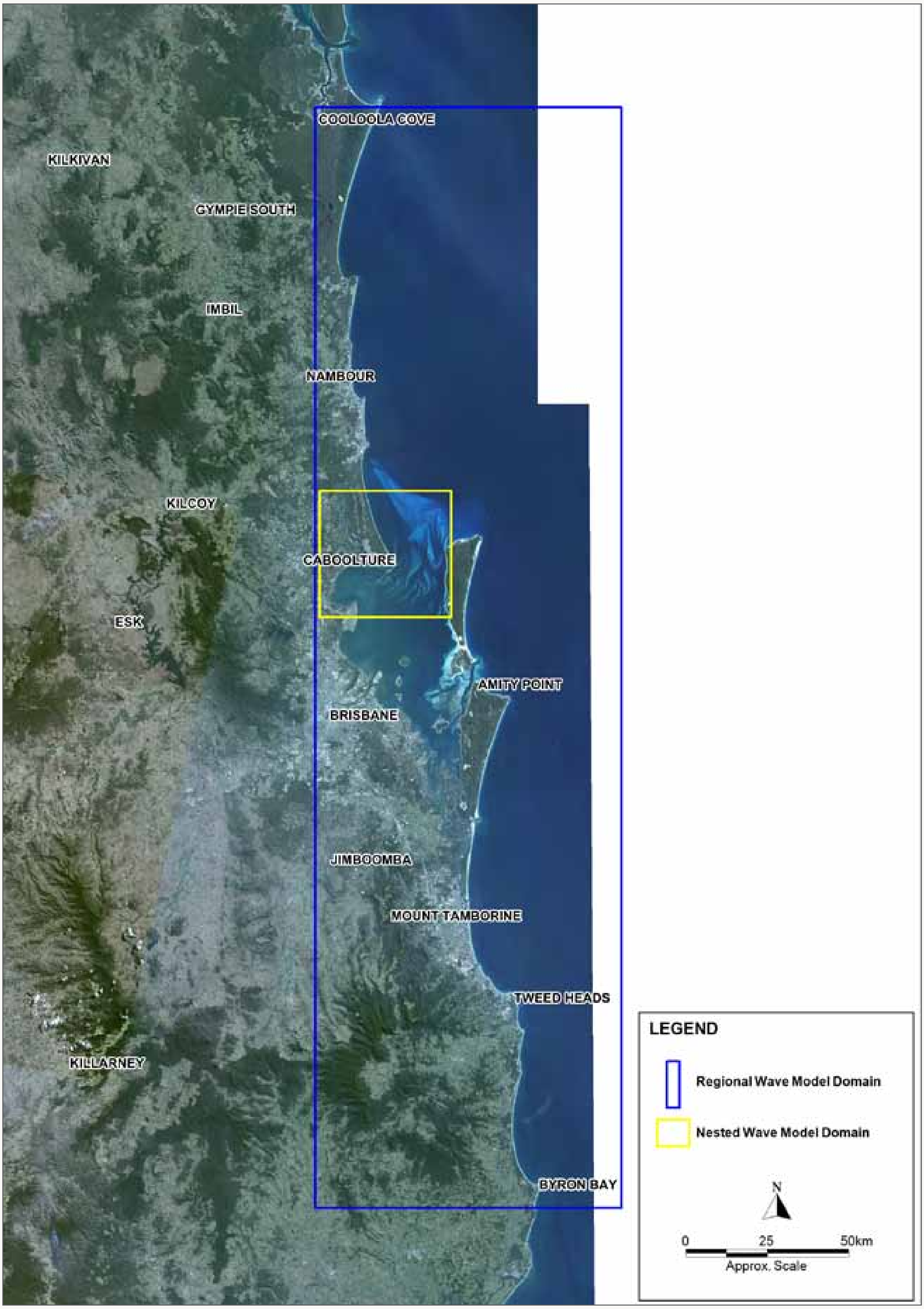
A nested grid system was used to maximise wave model efficiency while minimising inaccuracies associated with the model boundary definitions. Following this approach, the finest-scale grid surrounds the study area and its boundary conditions are obtained from the encompassing coarser grid. The nested wave model extents are shown in **Figure 3.3k** and described as:

- Regional scale (400 m grid resolution) model extending from Cape Byron to Double Island Point and offshore to the continental shelf
- Local scale (100 m grid resolution) model representing Northern Moreton Bay and including the sand extraction area.

Wave conditions at the offshore boundary of the regional domain were derived by transforming measured bulk wave parameters from the Stradbroke Island wave rider buoy (operated by DEHP) to deep water offshore values (see **Figure 3.3i** for the buoy location). This procedure used an existing BMT WBM SWAN model to construct transformation tables for representative swell conditions as a function of significant wave height (Hsig) and the spectral peak wave direction. Recorded wave data for the four years from June 2006 to April 2010 were then converted to the corresponding deep water wave conditions using these transformation tables. The spectral peak period (Tp) and spectral peak wave direction in conjunction with the significant wave height were used as the best estimate bulk wave parameters describing the dominant sea state.

A spatially interpolated wind field was also applied to the model based on recorded wind data from the Bureau of Meteorology (BOM).

Figure 3.3k: Wave model extents



Water level validation

The Moreton Bay model has been calibrated to ensure that it reproduces tidally varying water levels with sufficient accuracy throughout the study area. This exercise included optimisation of model resolution across the sand shoals at the Moreton Bay entrance. The tidal calibration results for Standard Port and selected Secondary Port locations within the Moreton Bay model domain are presented in **Figure 3.3l** to **Figure 3.3q**. In these figures the tidal variation calculated by the TUFLOW FV model is compared to MSQ tidal predictions.

Generally the phase and amplitude of the tide is well predicted by the modelling system at all locations. The sum of the root mean square error of the instantaneous tidal predictions for the locations throughout Moreton Bay is typically within ±0.1 m. These results suggest that the TUFLOW FV model can predict the instantaneous tidal water levels with an accuracy of ±0.1 m for these locations. This is a satisfactory result with some of the error attributed to the input boundary conditions to the Coral Sea model, which come from a reduced set of harmonic constituents supplied by the NTC, and potential bathymetric inaccuracies.

Figure 3.3l: Water level validation – Mooloolaba Standard Port

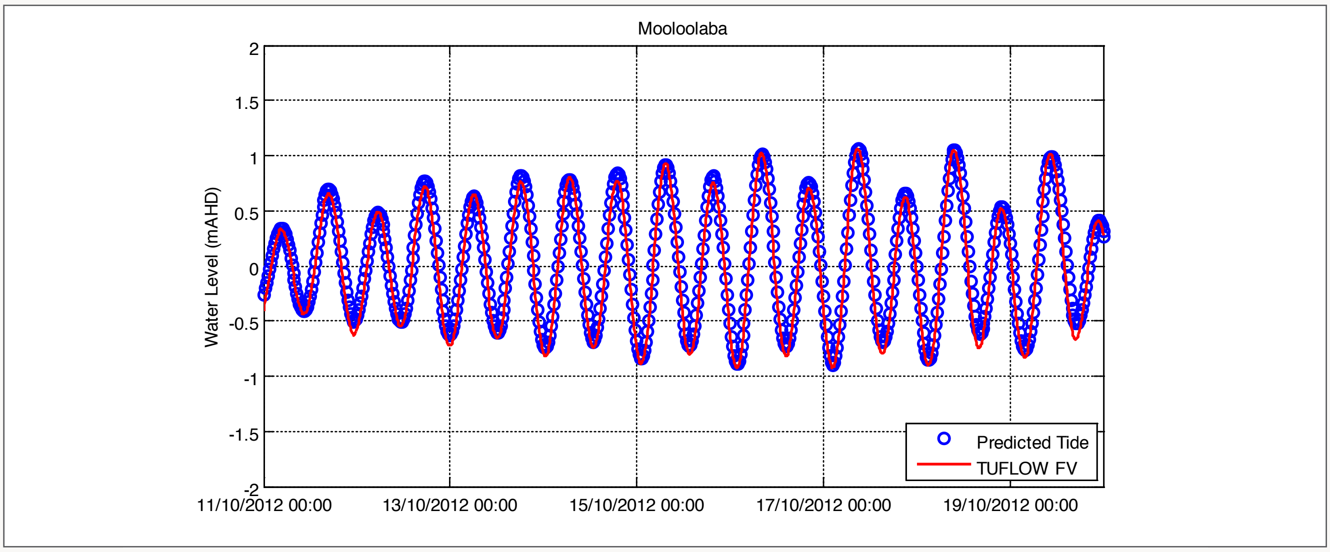


Figure 3.3m: Water level validation – Brisbane Bar Standard Port

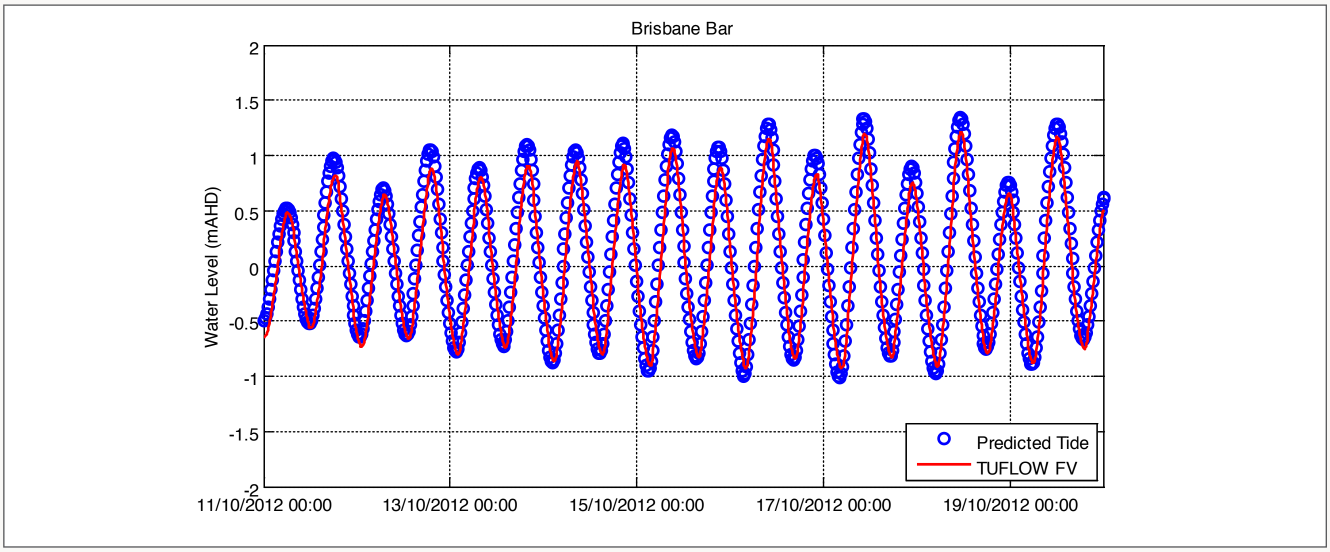


Figure 3.3n: Water level validation – Beachmere (Caboolture River) secondary place

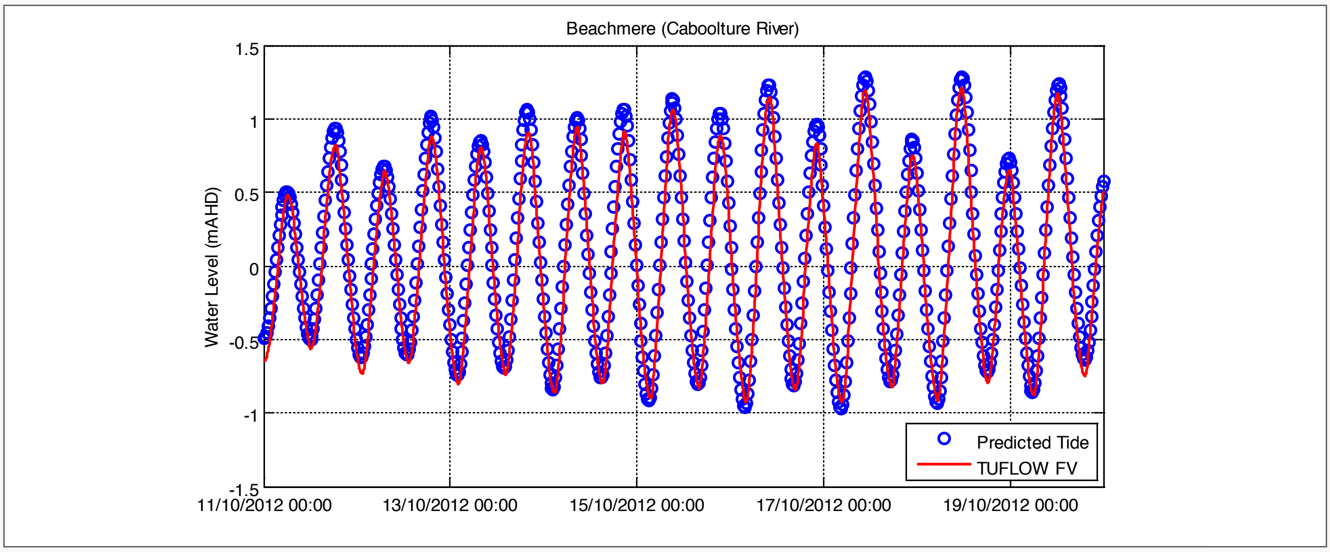


Figure 3.3o: Water level validation – Dunwich (North Stradbroke Island) secondary place

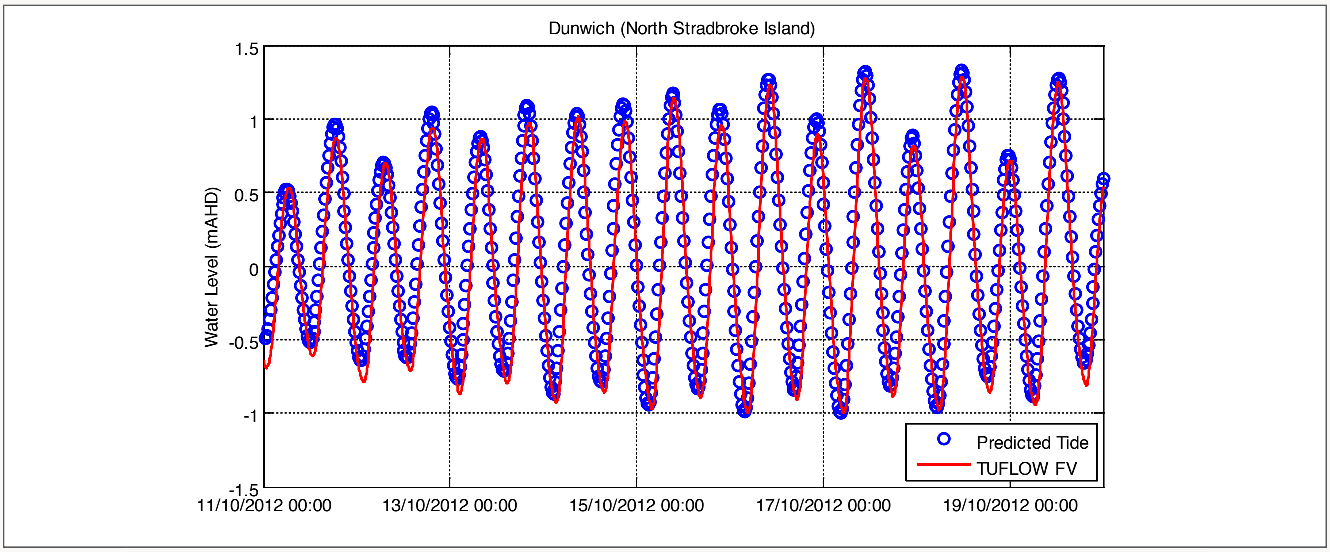


Figure 3.3p: Water level validation – Amity Point (North Stradbroke Island) secondary place

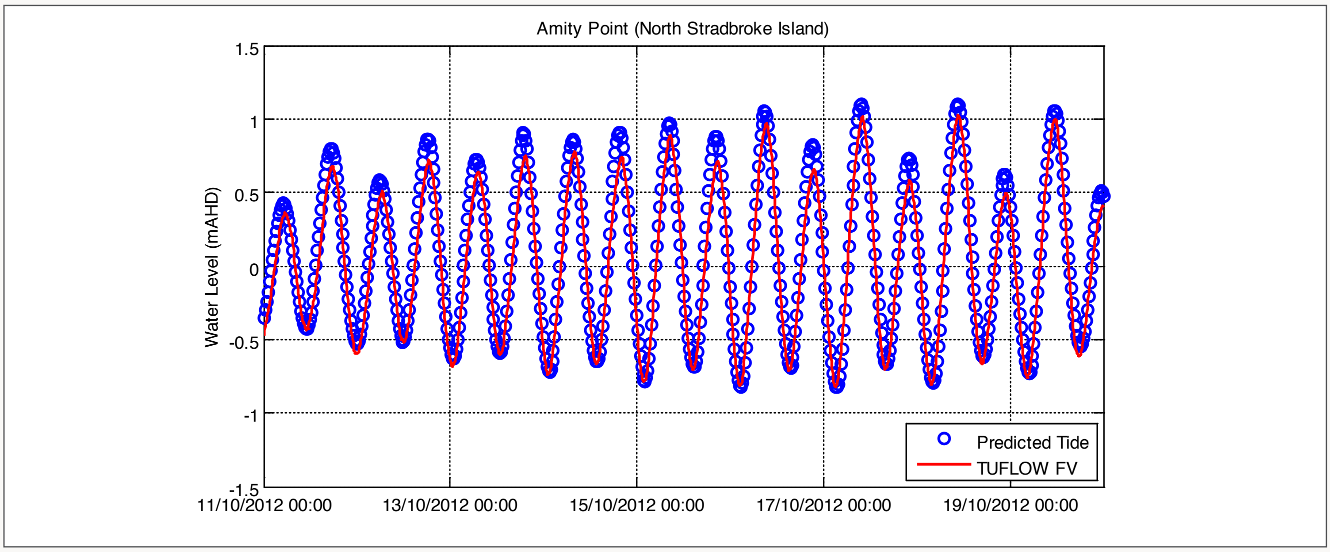
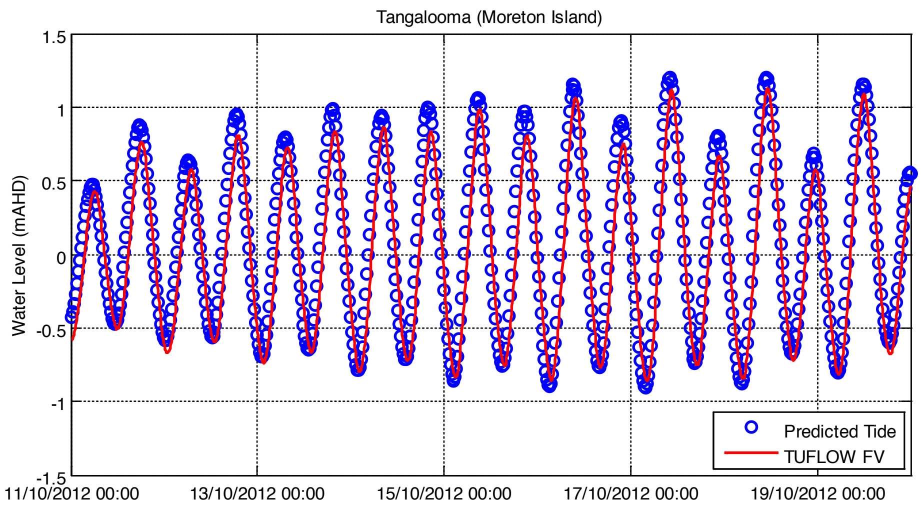


Figure 3.3q: Water level validation – Tangalooma (Moreton Island) secondary place



<u>Current speed and direction validation</u>

Model outputs were compared to currents recorded at various locations throughout Moreton Bay as part of previous studies (Brisbane Airport Corporation, 2005 and CSIRO 2012). The locations are indicated in **Figure 3.3i** and referred to as:

- East Channel
- Middle Banks
- M3 Beacon
- South West Spit
- Moreton Banks.

Time series comparisons of the measured and predicted depth-averaged current speed and direction are presented in **Figure 3.3r** to **Figure 3.3aa**. Note that the direction convention is Cartesian and corresponds to the direction the current is going (measured counter-clockwise from the positive x-axis). Model performance at the locations where validation data was available is generally acceptable and within the bounds of the accuracy of the recording instruments. Specifically, the model data comparisons display the following features:

The recorded current speed and direction is generally well predicted at East Channel (**Figure 3.3r** and **Figure 3.3s**) and Middle Banks (**Figure 3.3t** and **Figure 3.3u**) during both the ebb (aligned approximately 90 degrees) and flood (aligned approximately 260 degrees) phases of the tide. The data and model show a clear tidal component with higher peak velocities associated with the flooding tide. Occasionally the peak current speeds are slightly under/over predicted by up to ±0.2 m/s.

Model performance at the M3 Beacon (**Figure 3.3v** and **Figure 3.3w**) adjacent to the sand extraction area is considered satisfactory with occasional under/over prediction of the peak current speed by up to ±0.2 m/s. At this location the ebb and flood current align close to 360 degrees (or 0 degrees) and 170 degrees respectively which is well predicted.

Model performance is relatively poor at South West Spit (**Figure 3.3x** and **Figure 3.3y**) with the peak flood conditions consistently under predicted. The current recording instrument was located at the end of a linear sand bank (refer **Figure 3.3i**) and it appears this location was exposed to the flood current and relatively sheltered from the ebb current. It is assumed the poor model performance is due to misrepresentation of the model bathymetry at this location. It is noted that hydrodynamic simulations in three-dimensional mode did not improve the comparison. Model inaccuracy at this location is not expected to bias impact assessment outcomes.

- The flood and ebb currents at Moreton Banks are relatively consistent with no obvious tidal component. This behaviour is generally well predicted by the model with occasional over prediction of the peak flood current speed. The model slightly over predicts the current direction alignment by approximately 10 degrees during both phases of the tide. The most likely cause for this is poor representation of the sand bank morphology in the model bathymetry at this location.

Figure 3.3r: Current speed validation – East Channel

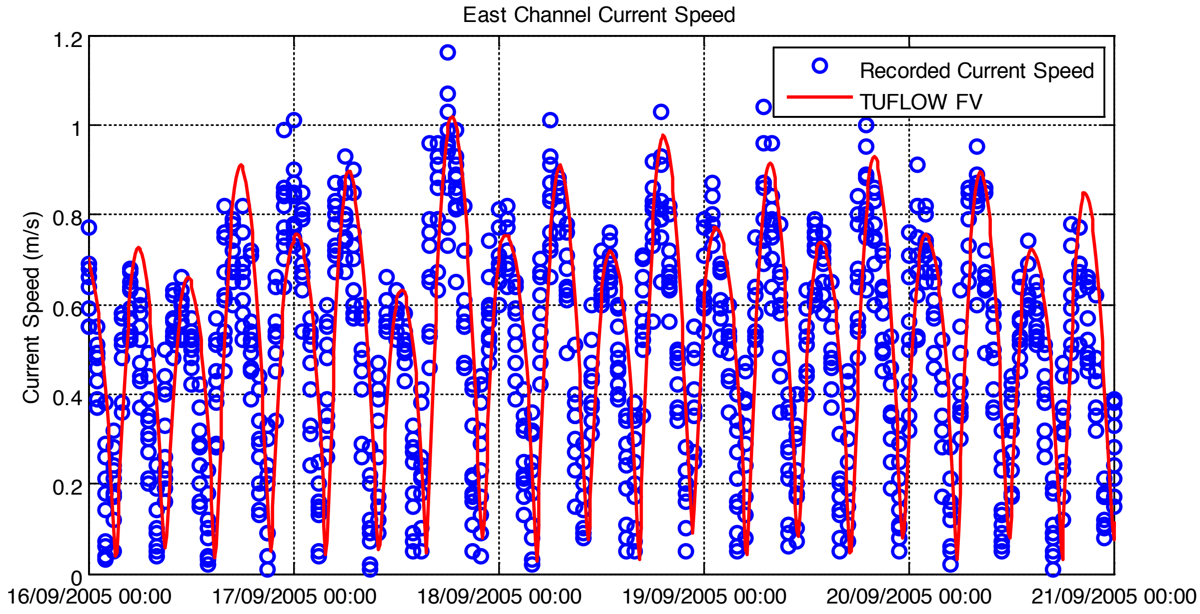


Figure 3.3s: Current direction validation – East Channel

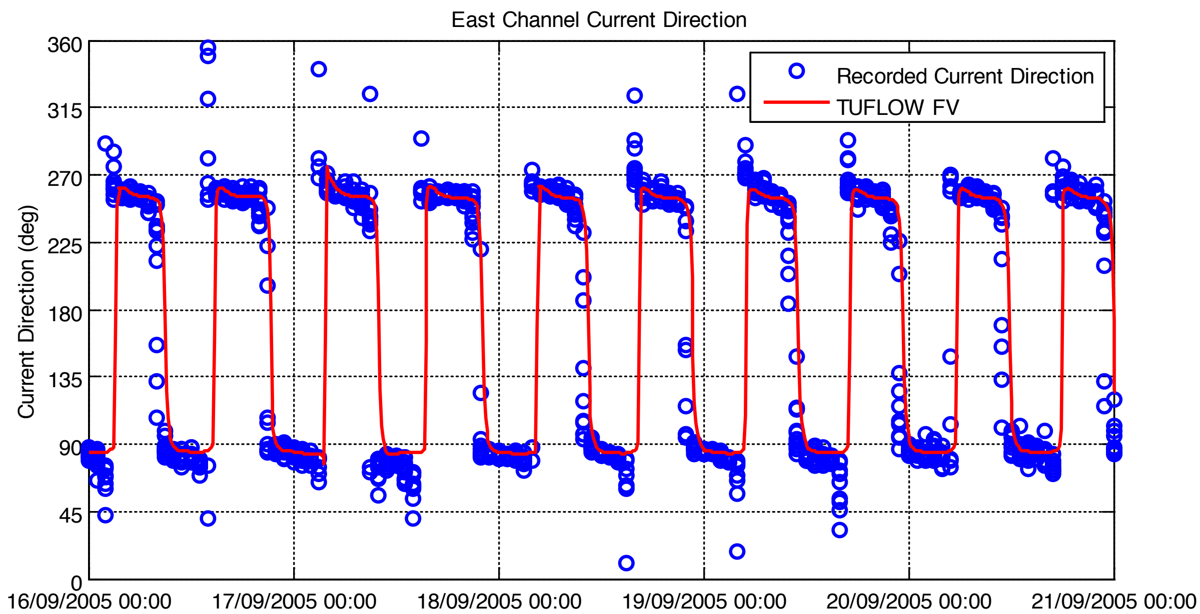


Figure 3.3t: Current speed validation – Middle Banks

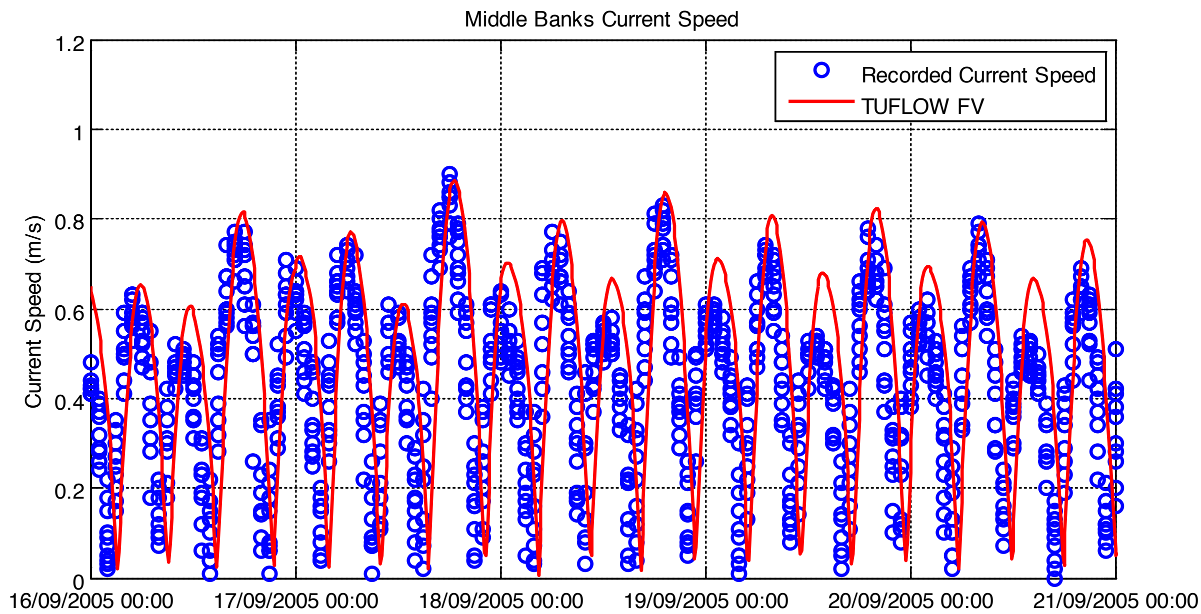


Figure 3.3u: Current direction validation – Middle Banks

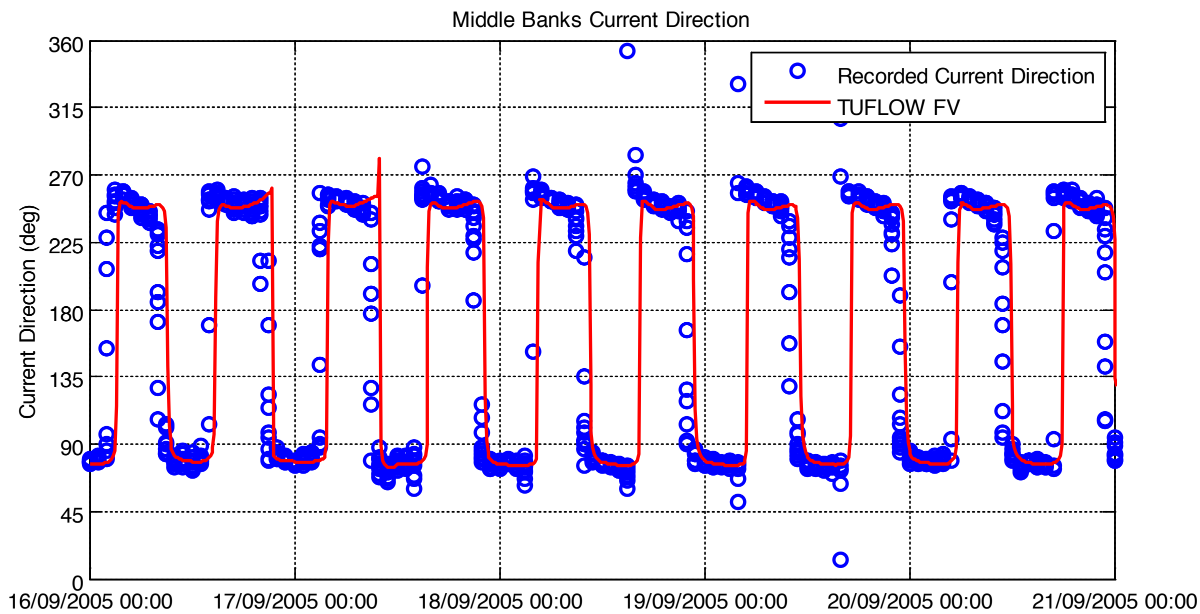


Figure 3.3v: Current speed validation – M3 Beacon

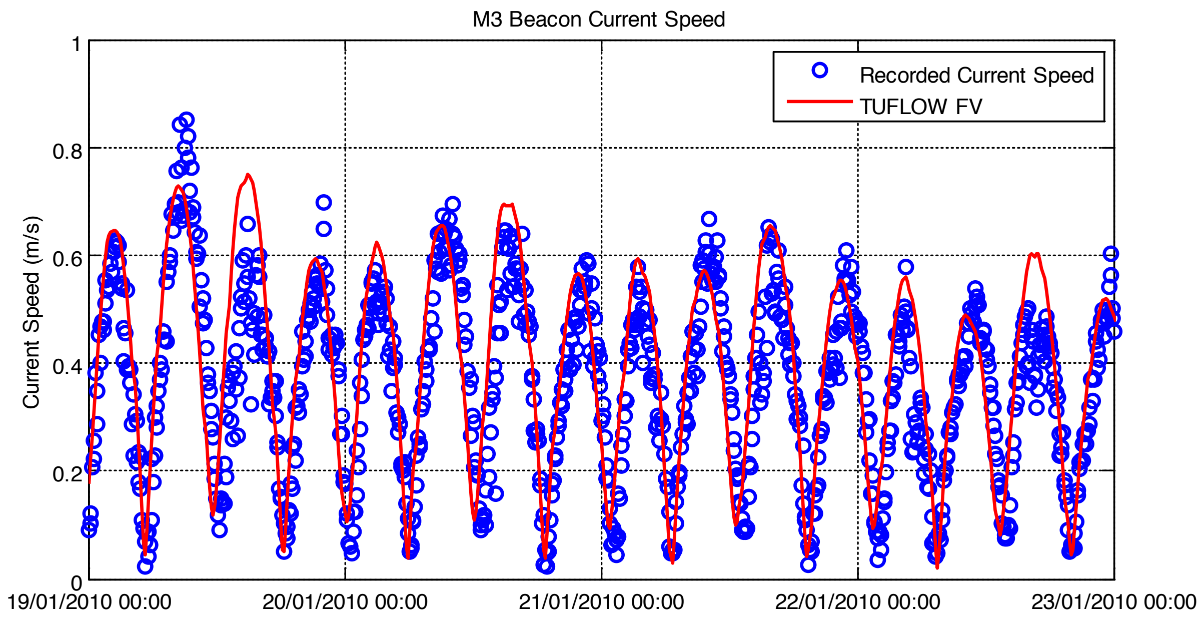


Figure 3.3w: Current direction validation – M3 Beacon

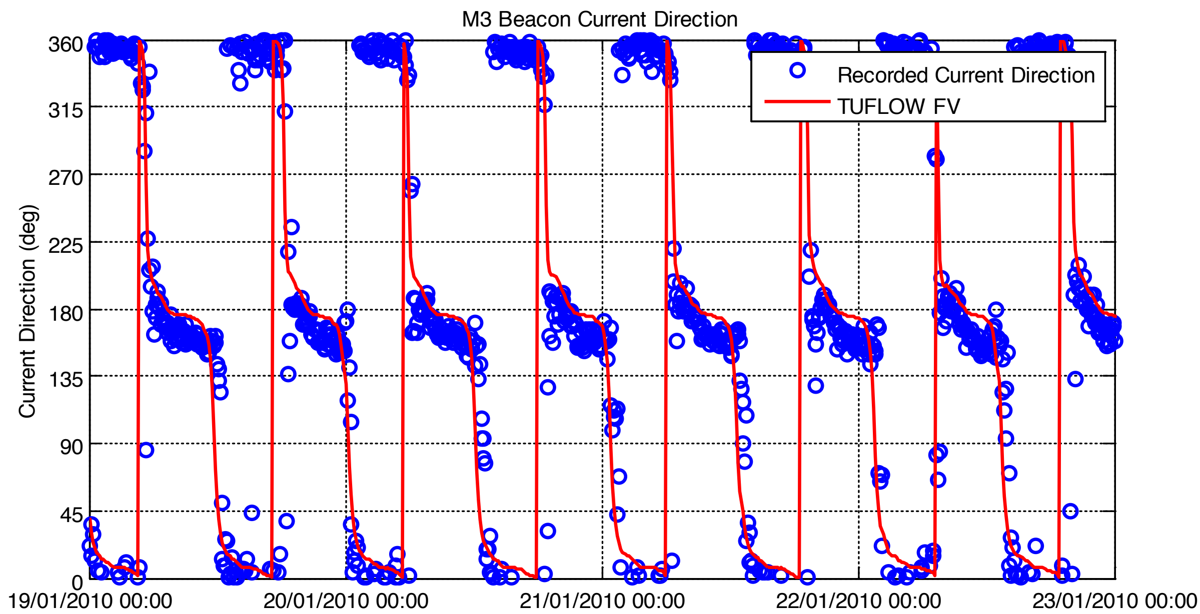


Figure 3.3x: Current speed validation – South West Spit

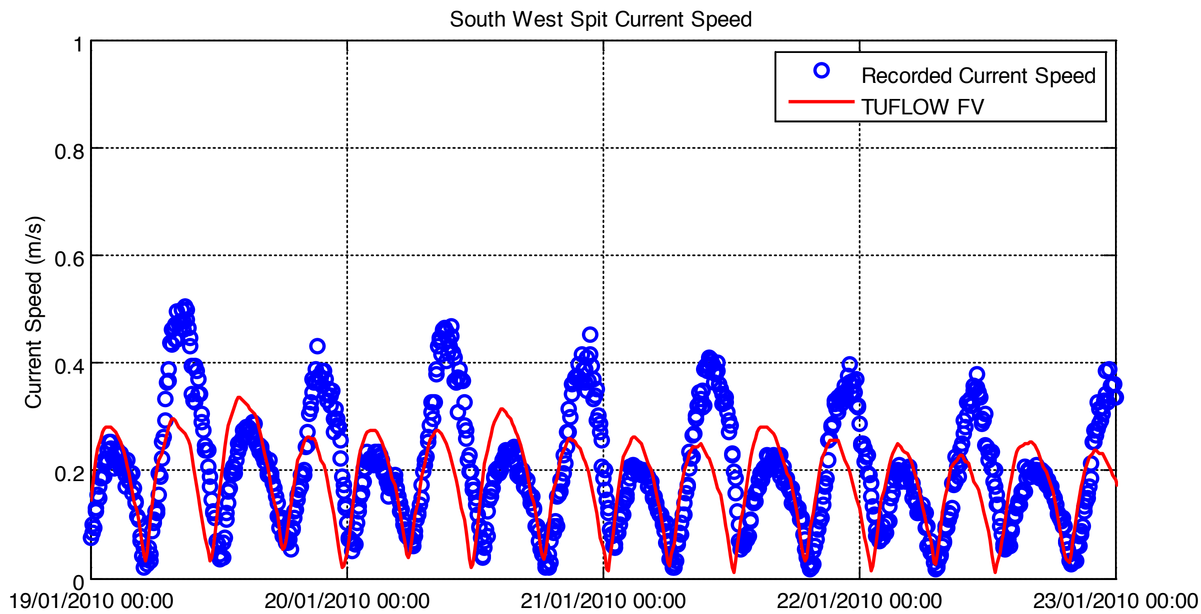


Figure 3.3y: Current direction validation – South West Spit

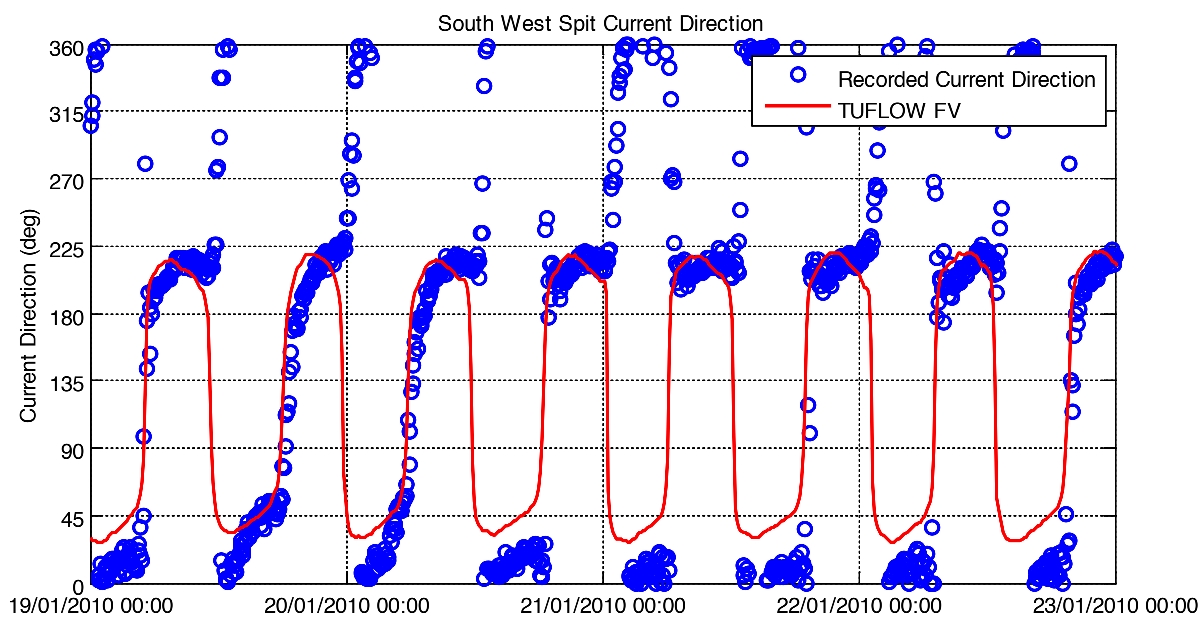


Figure 3.3z: Current speed validation – Moreton Banks

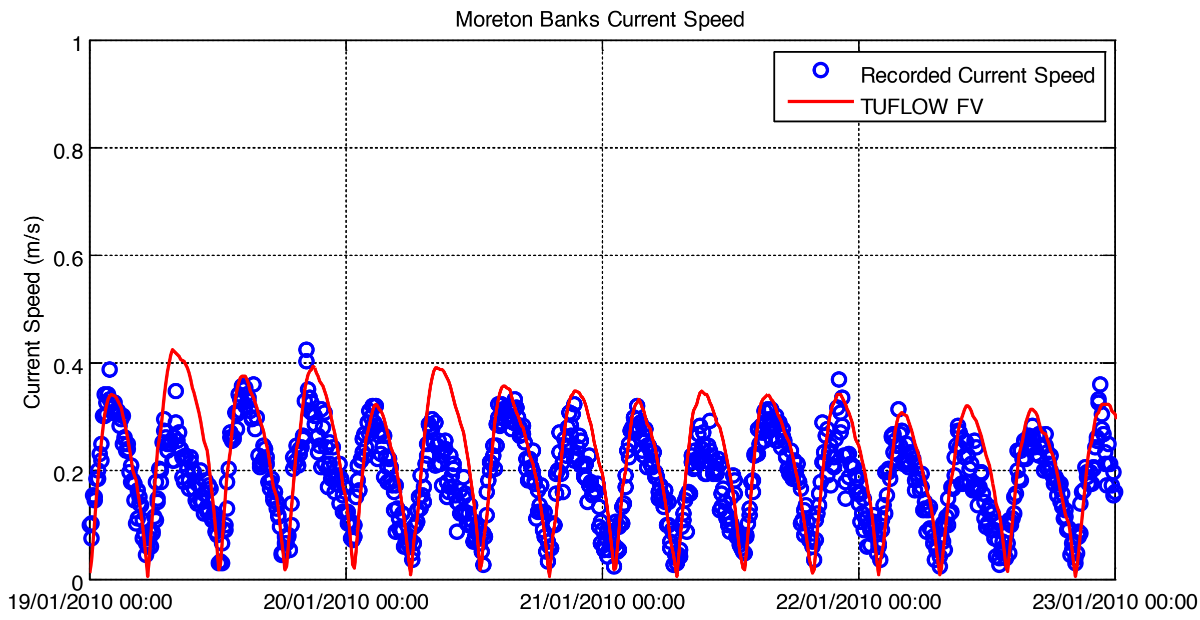
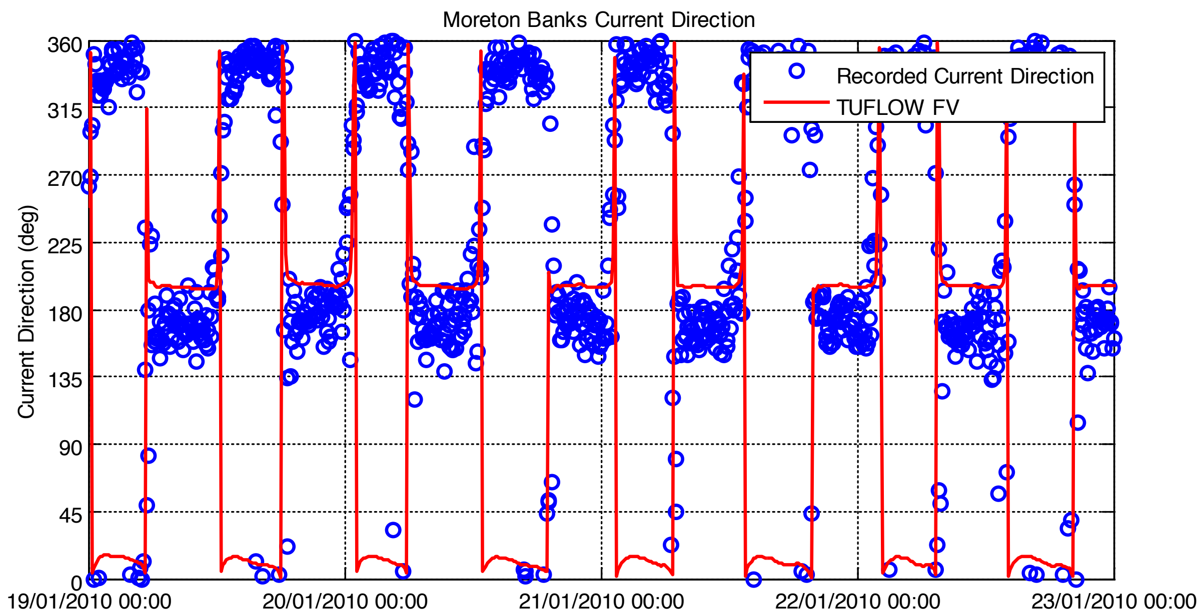


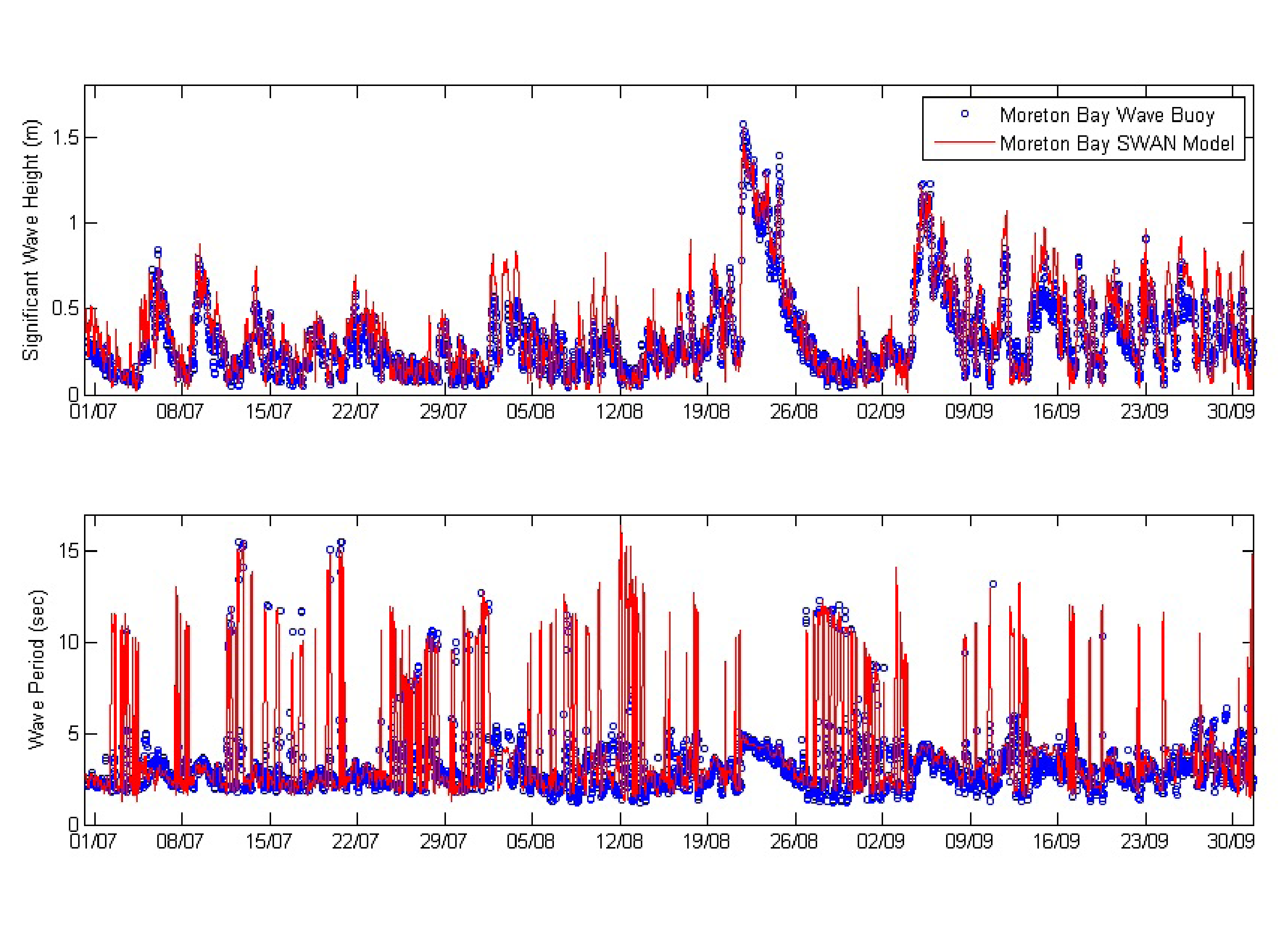
Figure 3.3aa: Current direction validation – Moreton Banks



Waves

Wave model output was compared to measurements from the Moreton Bay non-directional Waverider buoy (location indicated in **Figure 3.3i**) operated by DEHP. A comparison of the model results with the measured bulk wave parameters for August to September 2009 are shown in **Figure 3.3ab**. The model reproduces the temporal variation and magnitude of the significant wave height and peak period recorded at the Moreton Bay buoy very accurately.

Figure 3.3ab: Wave height and wave period validation – Moreton Bay wave buoy



3.4 DESCRIPTION OF SIGNIFICANCE CRITERIA

A risk-based approach has been adopted in this environmental impact assessment. This is based on the identification of potential impacting processes and characterisation of the likely level of impact to the existing environment. The risk assessment process is described generally in Part A of this EIS.

For the purposes of this coastal processes and water quality chapter, impact levels and risks were defined on the basis of the following:

- Significance of Impact – made up of assessment of the intensity, scale (geographic extent), duration of impacts and sensitivity of environmental receptors to the impact. **Table 3.4a** is a summary of the categories used to define impact significance.
- Likelihood of Impact – which assesses the probability of the impact occurring. **Table 3.4b** is a summary of the categories used to define impact likelihood.
- Risk rating – which assesses the level of risk for key impacting processes. The risk rating was generated from the significance and likelihood scores, based on the matrix shown in **Table 3.4c**.

Table 3.4a: Categories used to define significance of impact

Significance	Description
Very High	The impact is considered critical to the decision-making process as it would represent a major change to the physical processes within Moreton Bay. This level of impact would be indicated by: • Very large changes to the natural physical processes within Moreton Bay, such as major shoreline realignment or major changes to hydrodynamics, sediment transport patterns • A permanent change in the ecosystem of Moreton Bay and surrounds resulting from changes in water quality as a direct result of impacts from dredging of the Spitfire Realignment Channel and associated activities.
High	The impact is considered important to the decision-making process as it would represent a detectable change to the physical processes within Moreton Bay. This level of impact would be indicated by: • Large changes to the natural physical processes within Moreton Bay, such as shoreline realignment or major changes to hydrodynamics, sediment transport patterns • Water quality within Moreton Bay and surrounds is permanently altered by direct impacts of the dredging such that the scheduled EVs and WQOs are no longer achievable if currently being achieved, or are prevented from being achieved in the future if currently not being achieved.
Moderate	While important at a state or regional or local scale, these impacts are not likely to be critical decision making issues. This would be indicated by: • Moderate changes to the natural physical processes within Moreton Bay, such as shoreline realignment or moderate changes to hydrodynamics and/or sediment transport patterns • Water quality within Moreton Bay and surrounds is altered in the medium-term by direct impacts of the dredging such that the scheduled EVs and WQOs are no longer achievable if currently being achieved, or are prevented from being achieved in the future if currently not being achieved.
Minor	Impacts are recognisable/detectable but acceptable. These impacts are unlikely to be of importance in the decision making process. Nevertheless, they are relevant in the consideration of standard mitigation measures. This would be indicated by: • Minor changes to the natural physical processes within Moreton Bay, such as subtle shoreline realignment or minor changes to hydrodynamics and/or sediment transport patterns • Water quality within Moreton Bay and surrounds is impacted in the short-term and mitigation measures may need to be considered to further minimise impacts to water quality, although short-term exceedences may still occur during construction activities.
Negligible	Minimal change to the existing situation. This could include, for example, impacts that are below levels of detection, impacts that are well within the normal bounds of variation or impacts that are within the margin of forecasting error. No perceptible changes to water quality occur.

Table 3.4b: Categories used to define likelihood of impact

Likelihood Categories	
Highly Unlikely/ Rare	Highly unlikely to occur but theoretically possible
Unlikely	May occur during construction/life of the Project but probability well <50 per cent.. Unlikely but not negligible
Possible	Less likely than not but still appreciable. Probability of about 50 per cent
Likely	Likely to occur during construction or during a 12 month timeframe. Probability >50 per cent
Almost Certain	Very likely to occur as a result of the proposed Project construction and/or operations. Could occur multiple times during relevant impacting period

Table 3.4c: Risk ratings

		Significance Rating				
		Negligible	Minor	Moderate	High	Very High
Likelihood	Highly unlikely	Negligible	Negligible	Low	Medium	High
	Unlikely	Negligible	Low	Low	Medium	High
	Possible	Negligible	Low	Medium	Medium	High
	Likely	Negligible	Medium	Medium	High	Extreme
	Almost certain	Low	Medium	High	Extreme	Extreme

The subsequent report sections present the impact assessment of the Project for the key coastal processes and water quality issues identified in the baseline section which are:

- Hydrodynamics and waves
- Shoreline and beach system
- Water quality.

Key assumptions and limitations of the impact assessment are outlined and discussed where relevant.

3.5 ASSESSMENT OF POTENTIAL IMPACTS AND MITIGATION MEASURES

The proposed extraction of up to 1.1 M m^3 of sand for construction of the Project will induce changes to current magnitudes and directions in the immediate vicinity of the sand extraction area. The numerical modelling system described in **Section 3.3.8** was used to assess the significance and likelihood of the impact.

Following development and validation of the modelling system, two hydrodynamic scenarios were simulated and analysed:

- Base Case. This represented existing conditions (existing bathymetry of the Spitfire Realignment Channel)
- Developed Case. This considered an ultimate Spitfire Realignment Channel scenario with a 500 m wide channel and dredge depth to approximately −17.05 m LAT (equivalent to −18.225 m AHD).

As outlined in Volume A of the EIS, the Spitfire Realignment Channel was selected as the preferred sand extraction area for the Project on the basis that it is already subject to approved sand extraction by Port of Brisbane Pty Ltd (PBPL). The proposed works represent a deepening of the existing approved dredge footprint. As such, the current assessment builds on previous assessments and studies undertaken for the area including the MBSES and subsequent assessments and field monitoring studies undertaken by PBPL associated with recent dredging campaigns at the Spitfire Realignment Channel location.

In this context, it is noted that the developed case scenario is conservative and assumes that the dredge depth is below PBPL's existing allocation of 15 M m^3 to dredge the Spitfire Realignment Channel (as previously discussed in Chapter A3 and A5).

This is also below the dredge cut depth previously considered and assessed by BMT WBM (2005). The model geometry for the base case and developed case is shown in **Figure 3.5a** and **Figure 3.5b**.

For hydrodynamic impact assessment purposes, the model was run for a period including both spring and neap tides.

Figure 3.5a: Hydrodynamic model bathymetry – base case

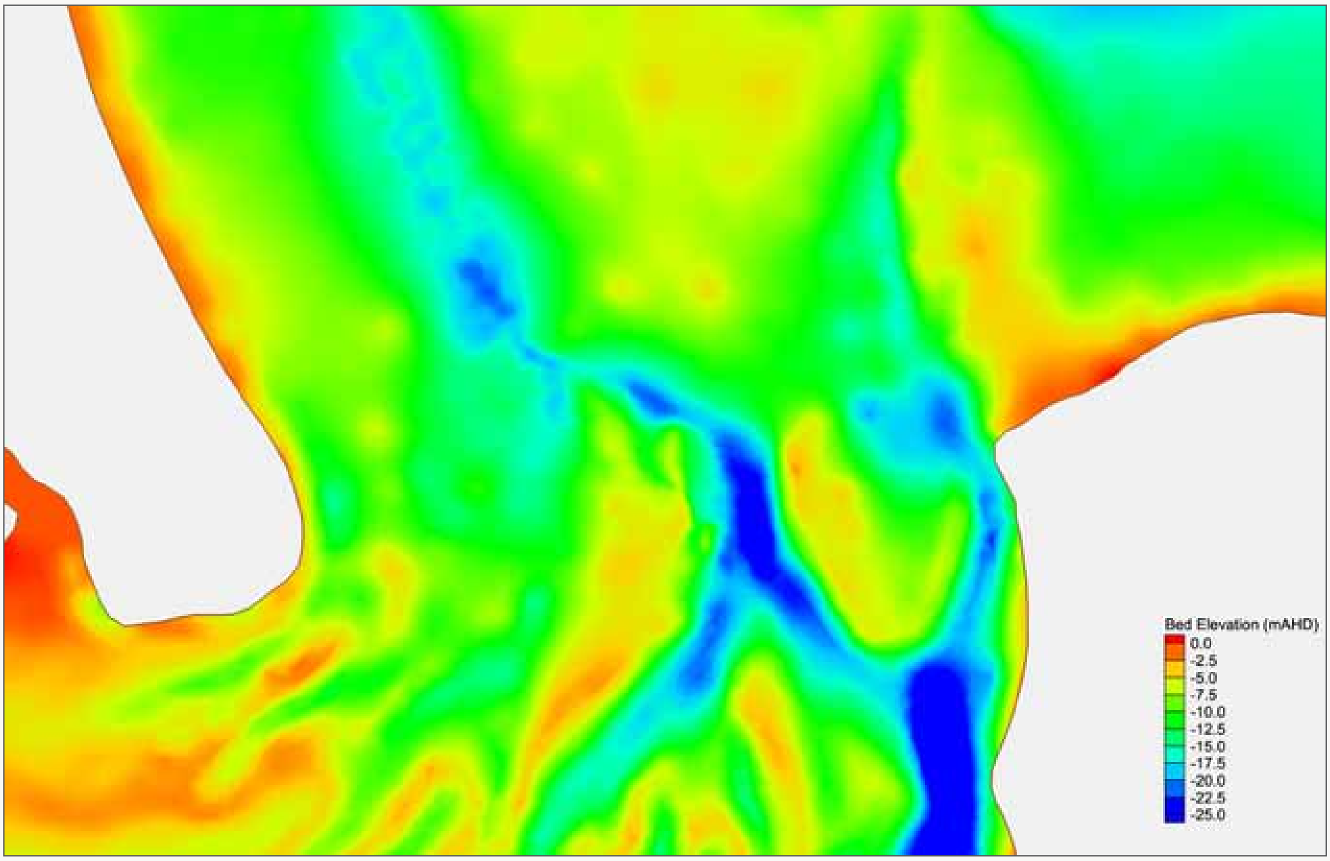
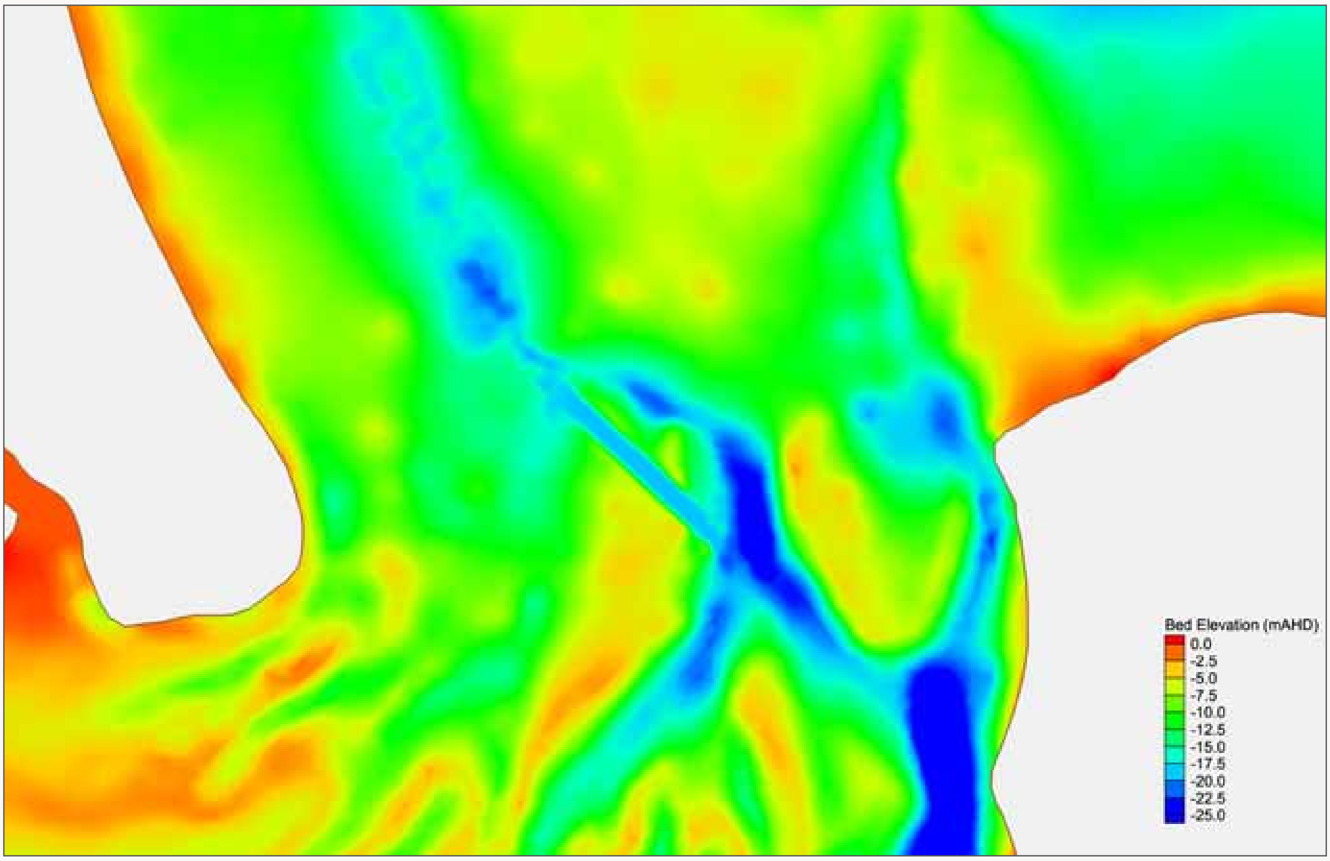


Figure 3.5b: Hydrodynamic model bathymetry – developed case



For dredge plume (water quality) impact assessments, both summer and winter periods were simulated to ensure the typical range of wind and wave conditions were considered. This is described further in **Section 3.5.3.4**.

In the following sections impact assessment results are presented both in terms of:

- Spatial impacts at specific times between the base case and developed case
- Spatial time-exceedance (or percentile) impacts
- Time series comparisons at specific locations between the base case and developed case.

The locations for time series comparisons are presented in **Figure 3.5c**.

3.5.1 Hydrodynamic impact modelling results and discussion

The northern delta shoal and channel bathymetry play a major role in determining the flow and tidal level regime in Moreton Bay. Some parts of the delta dominate over other areas, with conveyance through the North East Channel likely to be the most significant. Previous studies (e.g. WBM 2002 and WBM 2005) have shown that the vast size of the delta is such that relatively small scale sand extraction activities has a negligible effect in modifying the bathymetric and frictional controls on flow to and from Moreton Bay.

The spatial distribution of the changes to the peak ebb and flood tide current speed associated with the proposed dredging is presented **Figure 3.5d** and **Figure 3.5e** and show that minor impacts to current speed are restricted to the vicinity of the sand extraction area. Spatial plots of water level impact are not shown due to the negligible magnitude of the changes.

Time series comparisons between the base case and developed case of water level, current speed and current direction for each location are presented for a neap tide and spring tide period in **Appendix C3:A**. The spatial impact and time series plots have been interpreted and considered in determining the potential impact of the proposed works and suggest the following:

- There are no discernible impacts to water level at any of the locations considered and it is therefore assumed that the proposed dredging would have a negligible impact on the tidal regime of Moreton Bay
- There are no cases where current speed or direction has been significantly altered along shoreline locations at Bribie Island (locations BI1 and BI2) or Moreton Island (locations MI1, MI2, MI3 and MI4)
- There are no cases where current speed or direction has been significantly altered within designated Marine National Park Zone 03 areas (GZ1, GZ2 and GZ3)
- Generally, impacts to current speed and direction are restricted to the vicinity of the Spitfire Realignment Channel (M3B, SF1, SF2 and SF3) where some local realignment and magnitude changes are predicted to occur. Modification to the current speed is typically within about 0.1 m/s in areas where the existing current speeds are typically between 0.6 – 1.0 m/s.

Considering the above, the proposed dredging is not expected to change the overall flushing and circulation patterns within Moreton Bay and any local impacts are not likely to be of significance. Despite the natural mobility and continual evolution of the northern delta, including the ongoing deposition of sand from the coastal system, there is no evidence of change in the tidal regime of Moreton Bay as a whole due to the natural morphological changes or historical sand extraction activities (e.g. WBM 2002, WBM 2005). Similarly, modelling indicates the dredging for the Project is not likely to alter hydrodynamics within Moreton Bay.

3.5.2 Shoreline processes

Three principal processes may adversely affect shoreline stability along the coastlines of Moreton Bay, particularly the western shore of northern Moreton Island and southern Bribie Island. These are:

- Effects of strong shore-parallel tidal currents that, either through meandering or channel bed erosion, may undercut the stable nearshore profile slope, causing foreshore erosion through slumping of sand into the channel
- Wave induced longshore transport of the foreshore sand, causing differentials in the transport rates that result in erosion in some areas and accretion in others
- Direct storm wave attack causing beach erosion with sand being moved offshore from the foreshore, either to be returned to the beach where significant swell exists (e.g. Bribie Island) or lost to the shoreline where the normal waves do not have the capacity to force it back onshore.

These are natural processes that, in a dynamic system such as Moreton Bay, lead to continual changes in the shape of the shoreline. However, any permanent significant changes in the strength of tidal currents immediately adjacent to the foreshores and/or the height or direction of waves impinging on the shoreline may potentially change the existing natural dynamic pattern of erosion/accretion.

For dredging at the sand extraction area, to influence the sediment transport regime and stability of the adjacent foreshores of Bribie and Moreton Islands, it would have to:

- Alter the prevailing wave and/or current conditions near the foreshores, and/or
- Alter the supply of sand, if any, to the foreshore.

Figure 3.5c: Hydrodynamic and wave impact assessment point locations

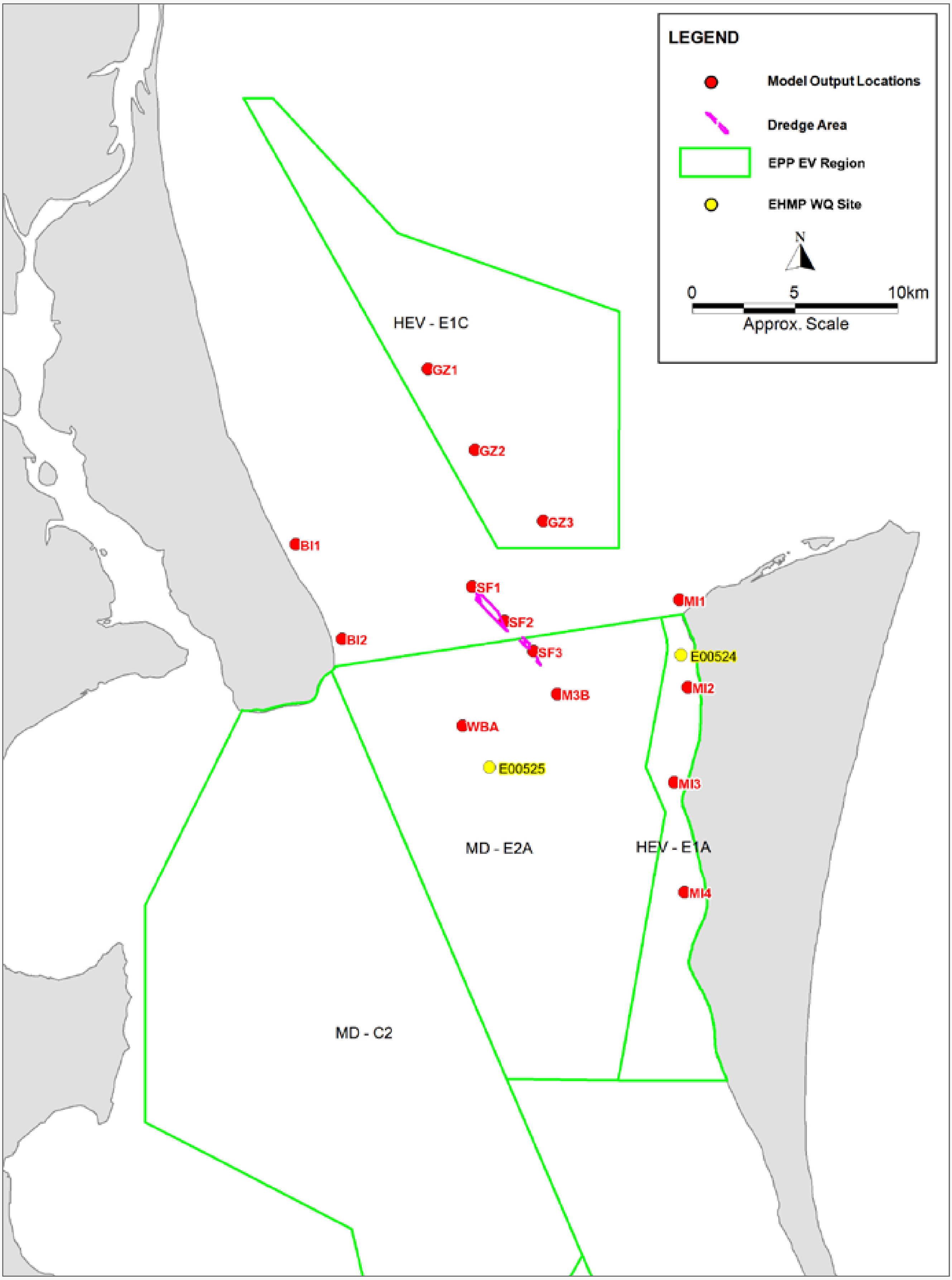


Figure 3.5d: Change in peak current speed for Spring ebbing tide

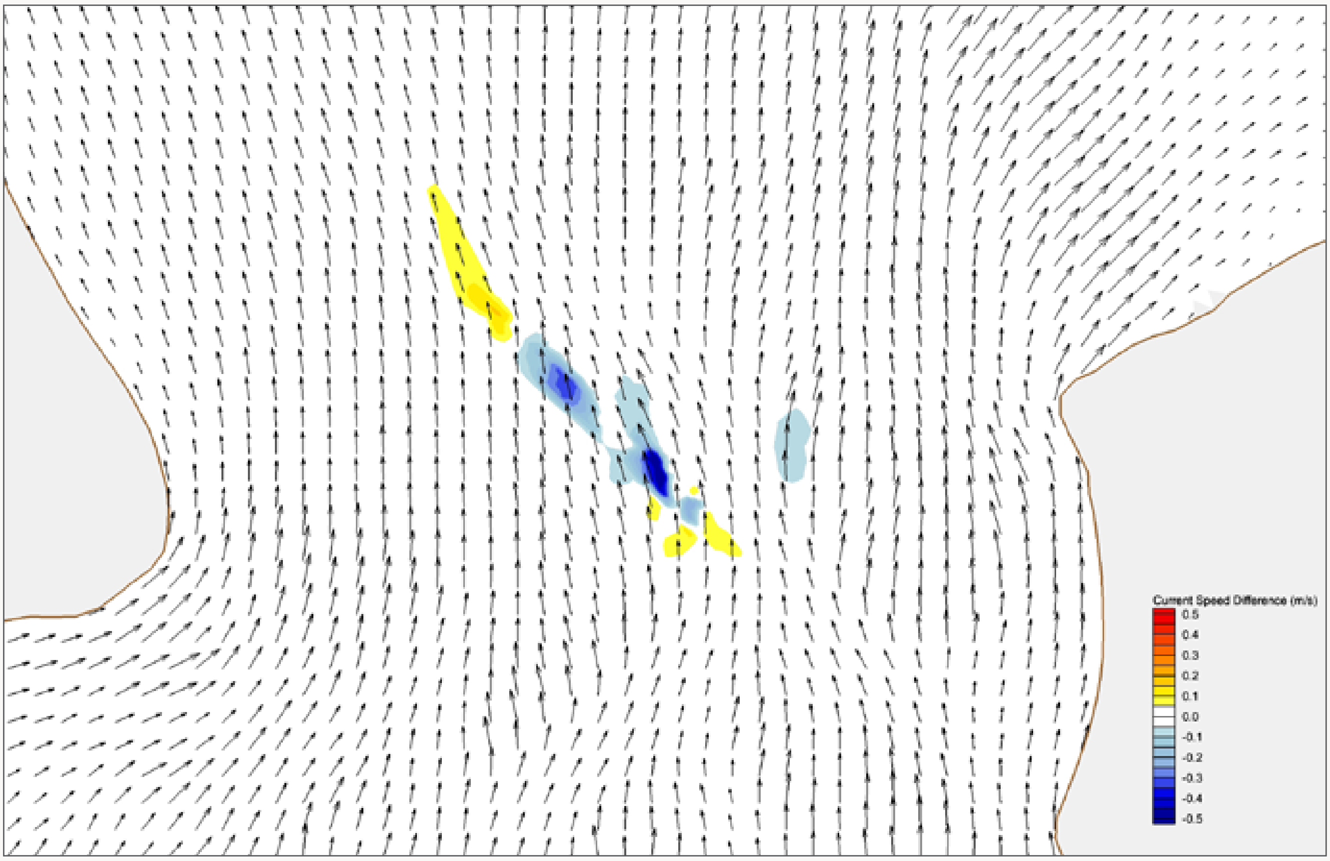
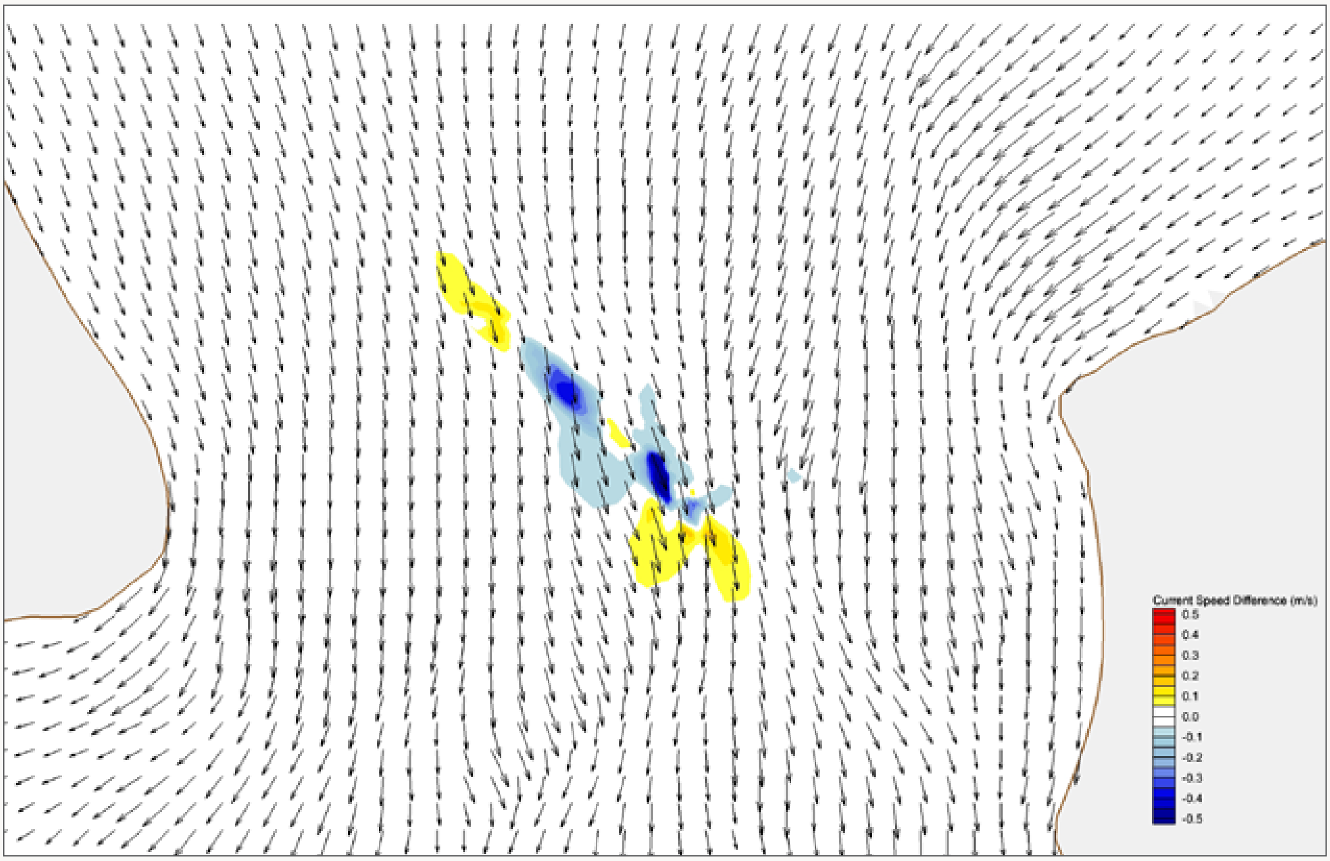


Figure 3.5e: Change in peak current speed for Spring flood tide



Both the present and all previous investigations (e.g. WBM 2001, WBM 2003, WBM 2005) have indicated that there is no regional impact to tidal currents or waves from large-scale sand extraction from the northern delta region generally, and the Spitfire Realignment Channel area in particular.

Time series comparisons at Bribie Island (BI1 and BI2) and Moreton Island (MI1, MI2, MI3 and MI4) shoreline locations of base case and developed case wave model results are shown in **Appendix C3:B**. The selected simulation period is representative of real conditions and follows the modelling methodology described in **Section 3.3.8**. The simulation period includes times when local seas and/or swell conditions are prevalent.

The wave modelling for this investigation indicates that there would be no changes in wave height, period or direction of any significance at any shoreline location as a result of the Project. Also, there are no significant changes in the local sea conditions as the proposed sand extraction area forms only a minor component of the fetch for wave growth and the shorter period waves have less potential to refract and shoal as they pass over the dredged area.

Under ocean swell conditions, the absolute wave height levels along the western shoreline of Moreton Island are of little or no significance being typically less than 0.3 m (WBM 2005).

It has previously been estimated (WBM 2005) that the low absolute wave heights along Moreton Island under swell conditions would produce less than one cubic metre of sand transport per day per metre of active zone width. Therefore, it is more likely that sand transport there is dominated by the tidal currents, with only some minor contribution from wave induced re-suspension. Any minor changes in wave heights due to the dredging would have no discernible impact on sand transport under these conditions.

It should be noted that the existing navigation channel generally follows the naturally occurring deep channels through this area. Many reaches require little or no dredging for navigation. The proposed dredging involves incremental deepening of a relatively naturally deep area, with excavation of only those areas shallower than 18 m below LAT. Accordingly, the deepening involved in the proposed works would be expected to have only minimal local impacts, as confirmed by the modelling.

With respect specifically to the observed existing erosion along the eastern Bribie Island shoreline (e.g. BMT WBM 2007), this is part of the natural shoreline evolution and there is no indication of any potential impact that would alter the sediment supply or stability of the shoreline. This position is consistent with that previously indicated by State regulators (e.g. Queensland Government 2008). The natural seabed between the North West Channel and the shoreline remains unaltered by any works or dredging and any naturally occurring onshore sand transport from this area would be continuing unimpeded.

Further, while the dredging would remove sand from the system, there is also an ongoing commensurate supply to the overall northern delta region from the ocean beach longshore transport. The vast size, natural mobility and changing nature of the northern delta dominate the overall processes.

Based on this analysis, it is concluded that there is no risk that the proposed sand extraction would affect nearby shoreline areas and there would be no adverse impact on the regional morphological process of Moreton Bay.

3.5.2.1 Vessel wash impacts

Were dredging operations to be undertaken close to shore, the dredger movements may cause shoreline erosion from the generation of boat wash waves and/or propeller-induced sediment transport. However, given the large distance from the target dredge area to the nearest shoreline (approximately 7.5 km), and the significant number of ship movements that occur at the entrance to Moreton Bay, dredge movements associated with the Project are expected to have a negligible (unmeasurable) impact on shoreline processes.

3.5.3 Dredge plume dispersion and water quality impacts

The proposed dredging will cause the suspension of seabed material, in addition to that naturally suspended by wave and current action, and the generation of plumes of suspended sediment through a number of potential sources/ mechanisms. The nature and extent of these plume sources will be dependent on the characteristics of the sediment as well as the type and operational characteristics of the dredging operations. The dredge plume impact assessment methodology and assumptions are described in the following sections.

3.5.3.1 Bed sediment characteristics

The bed sediments in the sand extraction area have been previously assessed and described as clean, fine to medium silica sands, very well sorted and containing very low (less than 3 per cent) silt fraction and negligible levels of nutrients and/or toxicants (e.g. Coffey Geosciences 2004; WBM 2004; BMT WBM 2011). This is consistent with the bed material sampled to a depth below the dredge cut proposed for the Project. Bed sediment characteristics are further discussed in Chapter C2 – Marine Geology.

3.5.3.2 Suspended sediment characteristics

A number of different sources of field measurements have been compiled to characterise the levels and composition of naturally suspended material, as well as the likely characteristics of dredge plumes at the sand extraction area.

Background turbidity

Measurements of naturally suspended material, referred to as the "background turbidity", were previously undertaken by BMT WBM (2008) prior to the commencement of dredging operations by PBPL at the Spitfire Realignment Channel. The measured background turbidity was low during both ebb and flood tide monitoring events, typically ranging between 1 and 3 Nephelometric Turbidity Units (NTU). The corresponding background surface water clarities measured by Secchi disc were approximately 3.0 – 3.5 m during the flood tide monitoring event. The Total Suspended Solids (TSS) concentrations for all background water samples determined by Queensland Health Forensic and Scientific Services Laboratory were approximately 1 mg/L.

During subsequent monitoring at the Spitfire Realignment Channel during a flood tide event (BMT WBM 2011) particularly low background turbidity levels of 0.2 NTU and surface water clarity to 7 m was measured.

Dredge plumes

Concurrent sampling of turbidity and TSS within dredge plumes at the Spitfire Realignment Channel has also been undertaken recently and is described in BMT WBM (2008) and BMT WBM (2011).

Monitoring of capital dredging at the Spitfire Realignment Channel by the Van Oord dredger Volvox Asia was completed during April 2008 for both ebb and flood tides. The aim of the monitoring was to determine compliance of dredging works with criteria outlined in the dredging environmental management plan.

The Volvox Asia is a trailing suction hopper dredger (TSHD) with a hopper capacity of approximately 10,800 m^3. The Volvox Asia discharges hopper overflow water containing fine sediments (typically the primary source of turbidity plumes during TSHD operation) at a depth approximately 5 m below the water surface in an effort to decrease sediment suspension times and consequently reduce the duration of a visible turbidity plume.

Volvox Asia dredge plume turbidity measurements were at depths of 2 m below the water surface. Drogues were used to track the direction of plume movement (via GPS) and concurrent turbidity measurements and water samples were obtained prior to and during the drogue deployment. Drogues were initially released a short distance from the dredger and **Figure 3.5f** presents an example of the measured turbidity with distance for two drogue releases (red and yellow) during Volvox Asia operation. At the 2 m depth sample location the measured turbidity remained below 6.5 NTU at all distances and in the case of the yellow drogue tracking event reduced to background levels (i.e. between 1 and 3 NTU) within a distance of 1 km from the dredger. It is noted that the turbidity compliance criteria for the Volvox Asia at the Spitfire Realignment Channel was "background + 10 NTU" and that the dredging operation was compliant during all monitoring events. The derived relationship between the measured turbidity (NTU) and the TSS (mg/L) concentration from the collected water samples yielded:

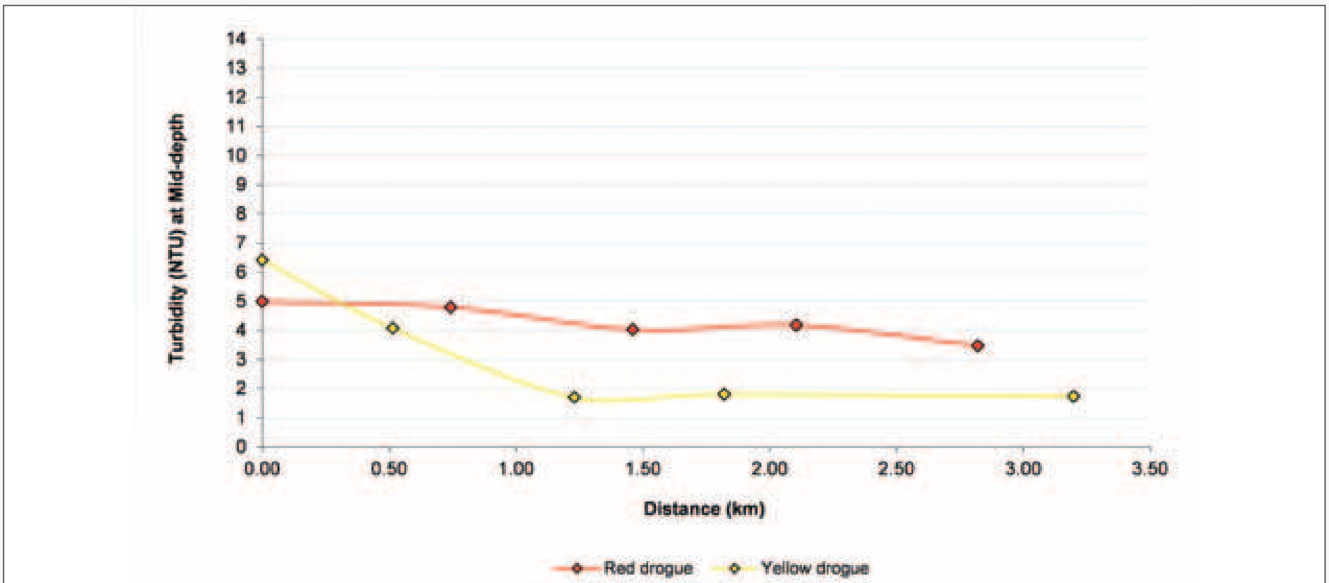
Equation 3.5a

$$TSS \approx 1.4NTU$$

As part of an extensive monitoring study of various dredgers for PBPL, BMT WBM (2011) reported monitoring results for maintenance dredging at Spitfire Channel by The Brisbane, a small TSHD with a hopper capacity of approximately 2,900 m^3. The Brisbane discharges excess water and fine sediments from the hopper via a weir to the underside of the keel approximately 5 m below the water surface.

Monitoring of The Brisbane's Spitfire Channel maintenance dredging using ADCP backscatter techniques provided more information about the extent of the subsurface plume. The measured dredge plume turbidity was generally low with the highest concentrations, approximately 10 NTU, found at depths close to 10 m and below. Generally, the plumes were not visible after approximately 25 minutes and the measured turbidity had returned to background levels after about 50 minutes and within 800 m of the dredger.

Figure 3.5f: Dredge plume turbidity (NTU) at a depth of 2m with distance from the drogue release point (BMT WBM 2008)



Analysis of the suspended sediment contained within a dredge plume water sample showed that approximately 55 per cent of the plume consisted of silt particles and 28 per cent of the plume consisted of medium sized sand. The material type fractions in the suspended plume are shown in **Figure 3.5g**. It is noted that material from maintenance dredging typically consists of relatively freshly deposited fine material and that the suspended plume particle size distribution shown in **Figure 3.5g** may not be representative of capital dredging from Spitfire Realignment Channel.

A relationship between the measured turbidity (NTU) and TSS (mg/L) for all the monitoring undertaken for PBPL and described in BMT WBM (2011) was developed for turbidity measurements below 100 NTU and is shown in **Figure 3.5h**. This relationship considers dredging and monitoring at various locations with different bed sediment characteristics within Moreton Bay (including Spitfire Channel) and the lower Brisbane River. Despite the variability between sites the following statistically significant relationship was obtained:

Equation 3.5b

$$TSS \approx 1.5NTU$$

The consistency between the TSS-NTU relationships derived for capital dredging at the Spitfire Realignment Channel (**Equation 3.5a**) and for various dredging campaigns within Moreton Bay and the lower Brisbane River (**Equation 3.5b**) provides confidence in the monitoring methodologies. The previous monitoring campaigns also provide valuable information for the dredge plume modelling impact assessments described herein.

Figure 3.5g: Particle size distribution for the 'Brisbane' maintenance dredging at Spitfire Channel (BMT WBM 2011)

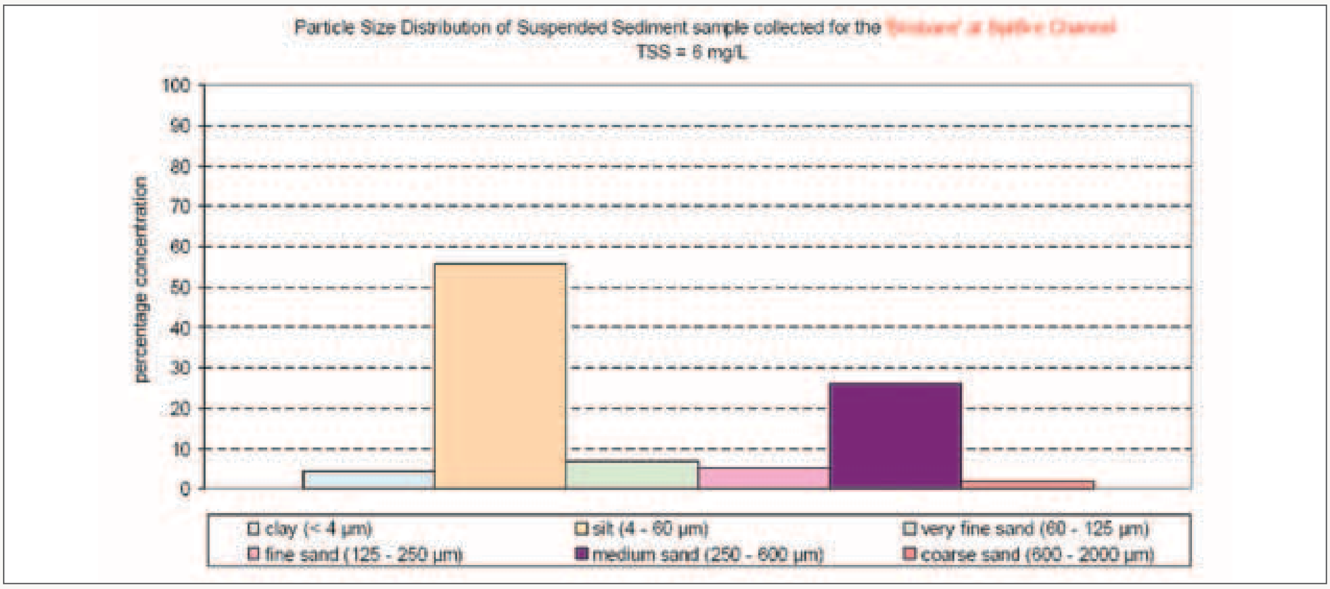
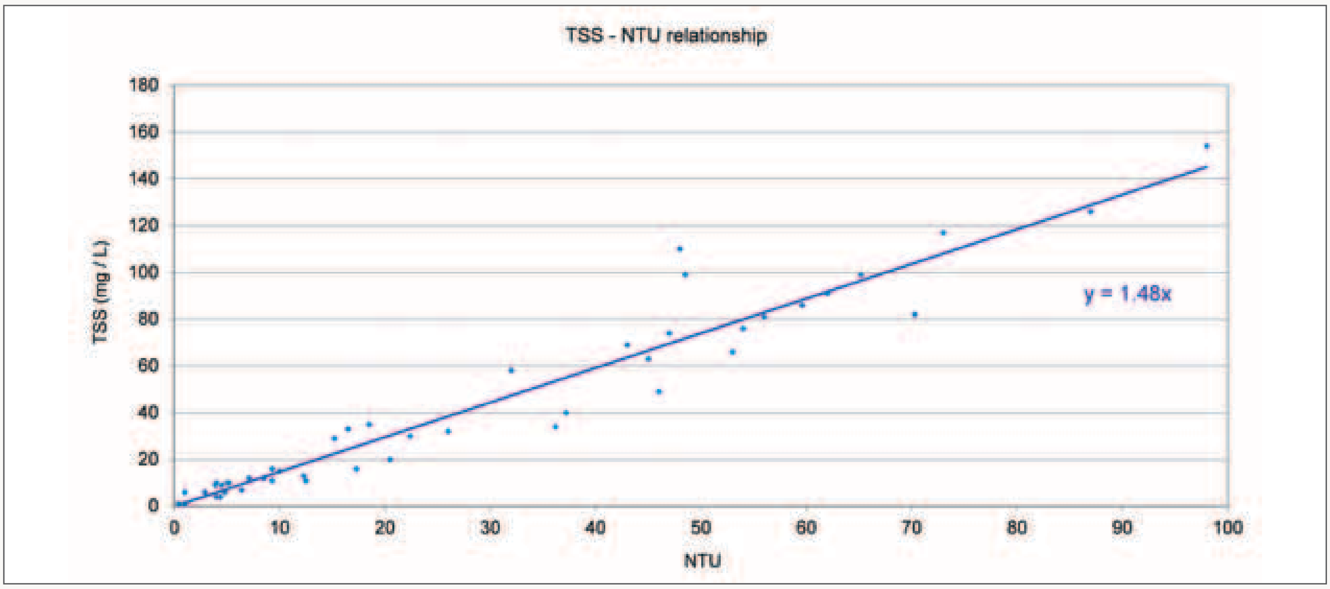


Figure 3.5h: Relationship between turbidity (NTU) and TSS (mg/L) for PBPL monitoring where turbidity is less than 100NTU



3.5.3.3 Dredge plume impact assessment key assumptions

The dredging of material for the Project is anticipated to take up to 32.5 weeks depending on the dredger. Through consultation with the Project marine engineers and dredge experts and consideration of previous dredge plume monitoring campaigns near the sand extraction area, parameters for dredge plume water quality impact modelling have been developed. For impact assessment modelling purposes the following has been assumed:

- Dredging will be undertaken by a medium-large sized TSHD operating for a six (6) week period. Of the dredge vessel types considered for the Project, the medium-large sized TSHD is likely to generate the highest concentration plumes at the sand extraction area. A smaller dredge vessel would be expected to generate lower concentration plumes, albeit over an extended operational period (up to 32.5 weeks). The ecological consequences of exposure to lower concentration plumes over an extended period are considered in Chapter C4 – Marine Ecology
- The TSHD average hopper load is 12,000 m^3 and the dredger would work on an 8.7 hr cycle time (i.e. the time taken to fill the hopper, steam to the pump-out site and steam back to the sand extraction area)
- Dredging duration (i.e. time to fill the hopper) is 85 min with an overflow discharge for 78 min
- The turbidity discharge at the TSHD draghead is 40 kg/sec and at the overflow is 93 kg/sec
- Plume loading can occur at any model cell within the proposed sand extraction area (it is resolved by 232 model cells) and it is assumed the dredger makes linear passes during each 85 min dredging duration.

Information on the composition of substrate material to be dredged along with information on the suspended sediment characteristics of the Volvox Asia and Brisbane plumes while working the Spitfire Realignment Channel area have been used to derive the "expected case" long term plume fractions. The composition of turbidly plumes generated at the TSHD draghead is assumed to be consistent with the in-situ sediment composition. For the TSHD overflow turbidity plume, it has been assumed that approximately 20 per cent of the total silt material dredged is lost to the overflow and contributes to the long term plume. The remaining sediment in the overflow consists of fine and medium sands. As an "extreme case" modelling scenario, the entire sediment load lost to the overflow is assumed to be silt material which corresponds to approximately 50 per cent of the total fines dredged. The relative fractions of both the in-situ sediment and long-term plume source material and key plume loading assumptions are summarised in **Table 3.5a**.

In this impact assessment dredge plumes have been modelled using three suspended sediment classes (silt, fine sand and coarse sand) each with an assumed still water sediment settling velocity based on the equivalent Stokes grain size diameter, which is also summarised in **Table 3.5a**.

The modelled rate of sediment settling is a function of the depth-averaged sediment concentration, the still water sediment settling velocity (w_{50}) and the bed shear stress (T_b), according to the relationship:

Equation 3.5c

$$Q_{sd} = w_{50} max(0,(1- \tau_b/\tau_{cd}))$$

where τ_{cd} is a model parameter defining the critical shear stress for sediment deposition. As such, sediment settling is reduced below its still water value by the action of bed shear stress and associated vertical mixing in the water column. A critical shear stress for deposition of 0.5 N/m^2 was adopted for the simulations and settling will occur in areas of reduced current and wave action where bed shear stresses are typically below the threshold value. Deposited plume material is available for re-suspension, however re-suspension of other bed material is not considered.

Table 3.5a: In-situ sediment and long term plume suspended sediment composition and key plume loading assumptions

	Coarse Sand	Fine Sand	Silt
Nominal grain diameter (µm)	300 - 475	150 - 300	<4
Settling velocity (m/s)	0.1	0.01	0.0001
In-situ sediment composition (%)	16	82	2
TSHD draghead plume source (kg/s)	5.8	29.9	0.7
Long-term plume composition, expected case (%)	-	85 (3% of total sand dredged)	15 (23% of total silt dredged)
TSHD overflow plume source, expected case (kg/s)	-	73.0	12.9
Long-term plume composition, extreme case (%)	-	65 (2% of total sand dredged)	35 (53% of total silt dredged)
TSHD overflow plume source, extreme case (kg/s)	-	55.8	30.1

The turbidity plumes being considered are therefore above background levels and directly related to the Project.

3.5.3.4 Dredge plume modelling scenarios

Given the potential for the dredge campaign to take up to a 32.5 week period, and the seasonal differences in wind and wave action experienced at the study location that will influence the advection-dispersion of the dredge plume, two separate dredge plume simulation periods were considered to assess seasonal variation:

- Summer period simulation from 01/01/2010 to 01/03/2010
- Winter period simulation from 01/07/2009 to 01/09/2009.

Wind and wave roses for the summer and winter periods are provided in **Figure 3.5i** through **Figure 3.5l**. The significant wave height time series for the summer and winter simulation periods are shown in a **Figure 3.5m** and **Figure 3.5n**.

The mean significant wave height for the summer period is 0.7 m and maximum significant wave height close to 1.5 m. The mean and maximum wave heights during the winter period, 0.5 m and 1.2 m respectively, are comparatively smaller, indicating that the winter period is less energetic than the summer period.

Figure 3.5i: Summer period simulation wind climate

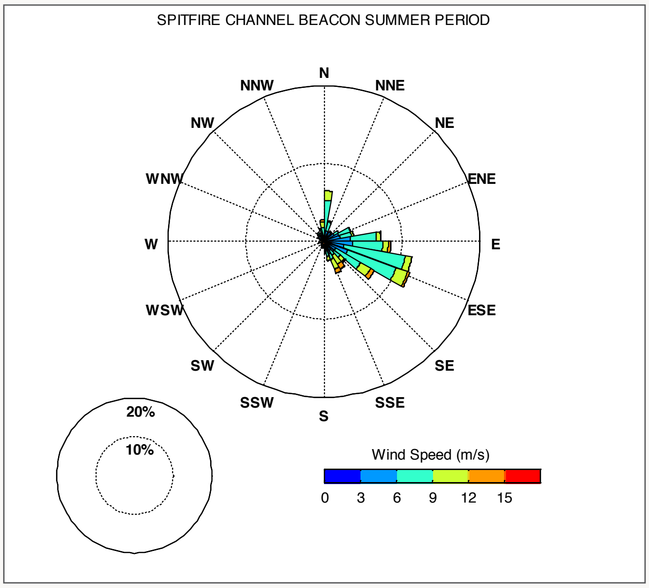


Figure 3.5j: Summer period simulation wave climate

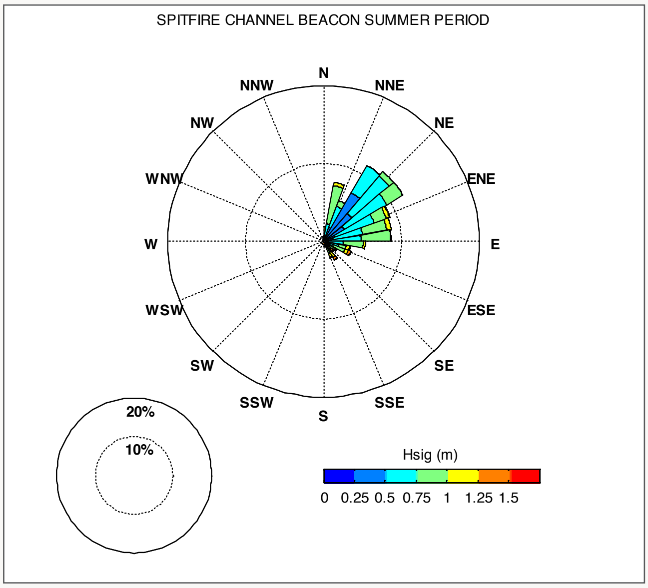


Figure 3.5k: Winter period simulation wind climate

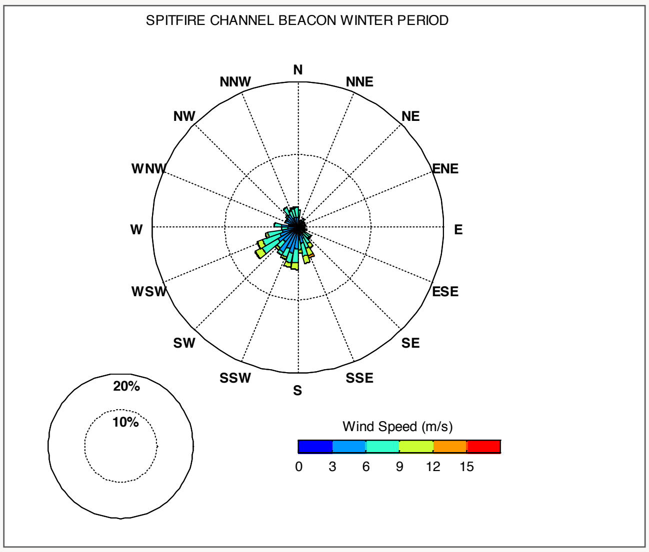
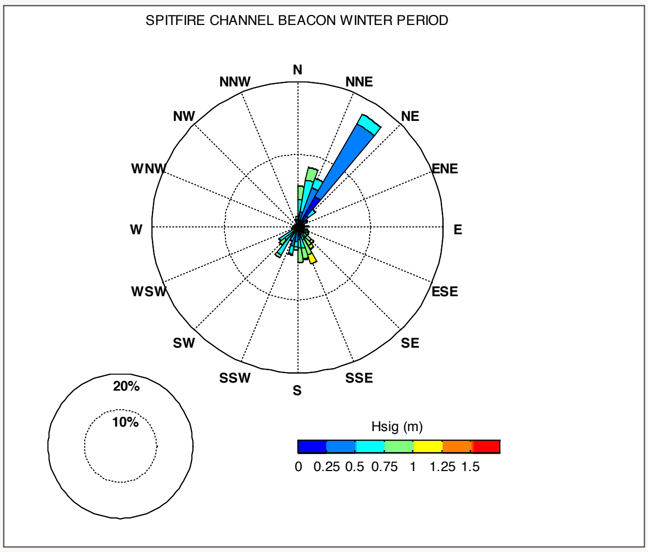


Figure 3.5l: Winter period simulation wave climate



During the simulations the plume advection-dispersion is primarily influenced by tidal currents and therefore the direction of plume sediment transport for a given instant in time is strongly related to the phase of the tide. This is illustrated in **Figure 3.5o** and **Figure 3.5p** that show examples of instantaneous plumes for both ebbing and flooding tide conditions. Operations undertaken during an ebbing tide will typically lead to dredge plume advection-dispersion in a north-westerly direction. Conversely, during the flooding tide the plume will be typically transported to the south of the sand extraction area.

The model mesh cells where plume loadings are applied are approximately 100 m^2 in size, which will introduce some artificial dilution in the near field since the model represents the plume concentration averaged over the extent of the cell. In reality, the plume near its source will not necessarily be uniformly mixed over the entire area represented by the model cell and this means higher than predicted near field concentrations may occur. Away from the plume source, the model inaccuracies in the near field due to the initial dilution effect are negligible since natural flow dispersion and turbulent diffusion processes result in horizontal mixing of the plume.

Figure 3.5m: Summer period simulation significant wave height time series at Spitfire Channel beacon

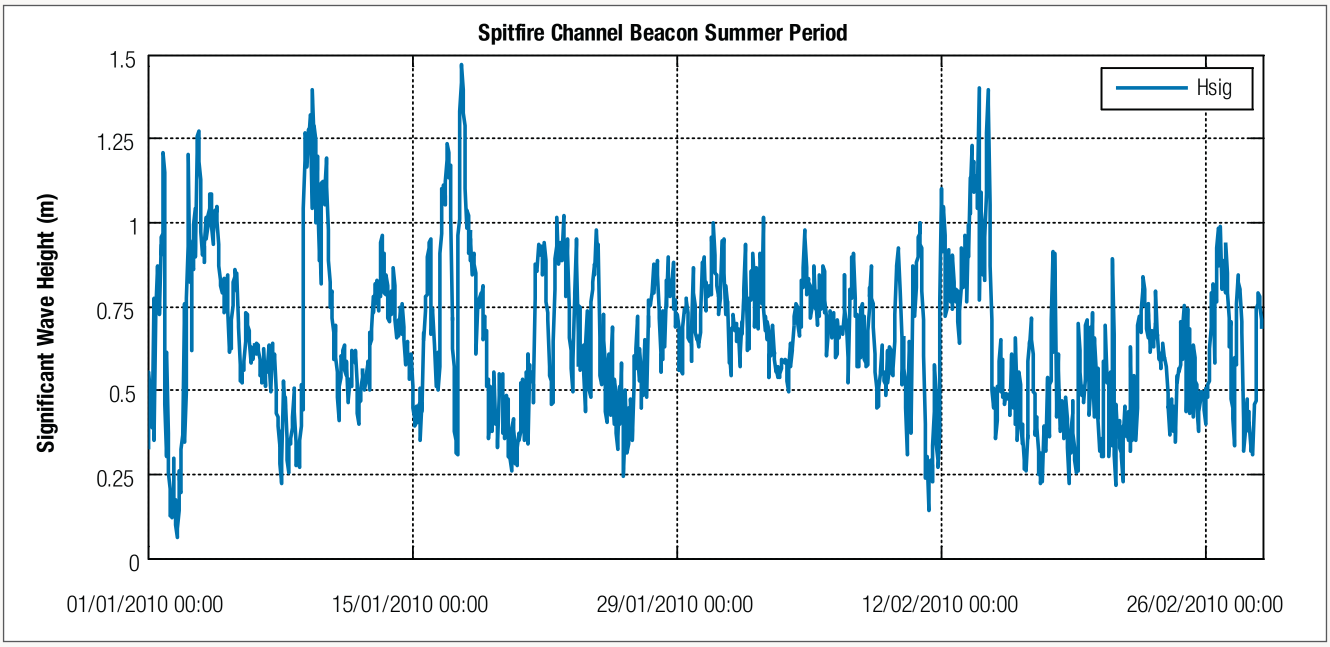


Figure 3.5n: Winter period simulation significant wave height time series at Spitfire Channel beacon

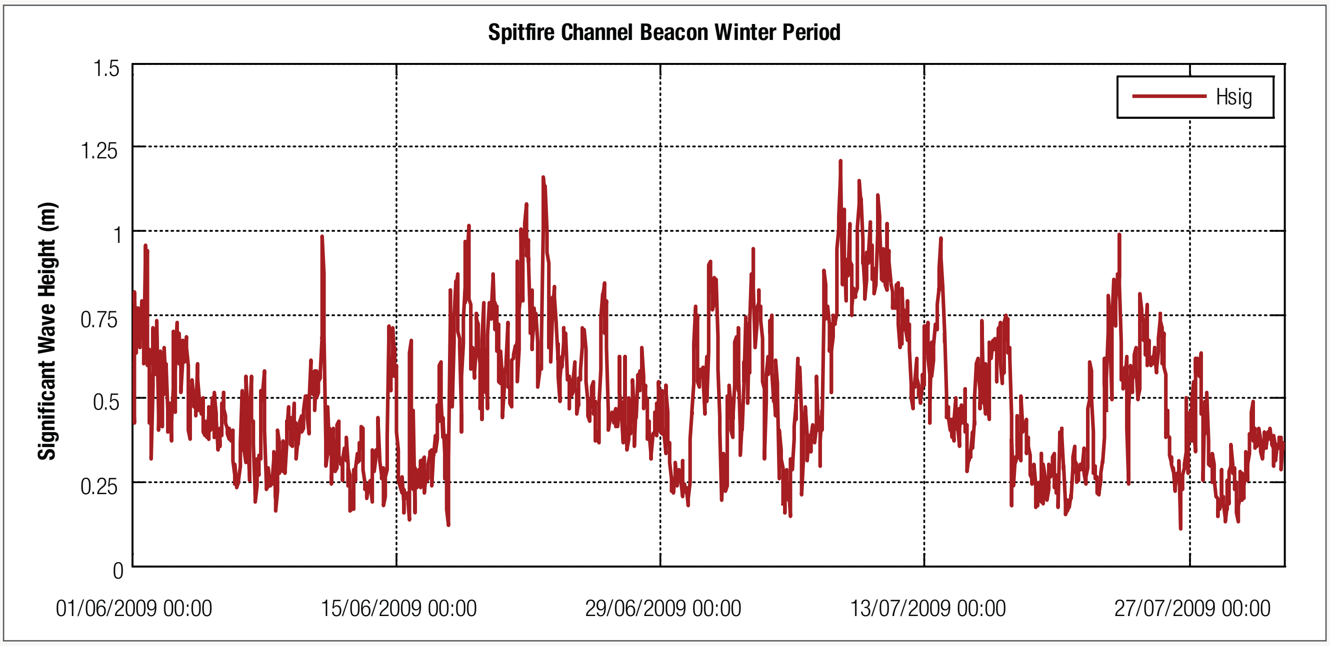


Figure 3.5o: Example plume advection-dispersion during ebb tide conditions

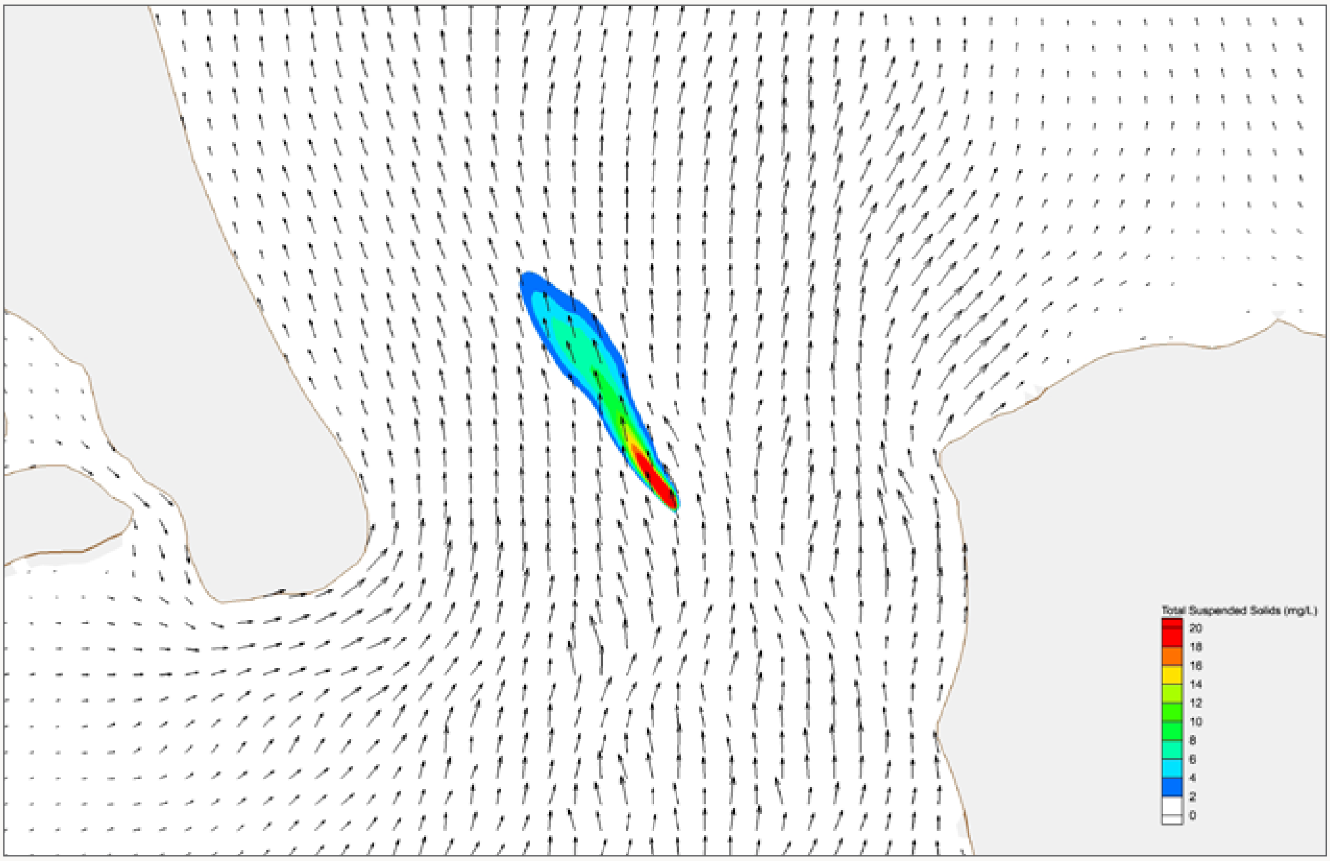
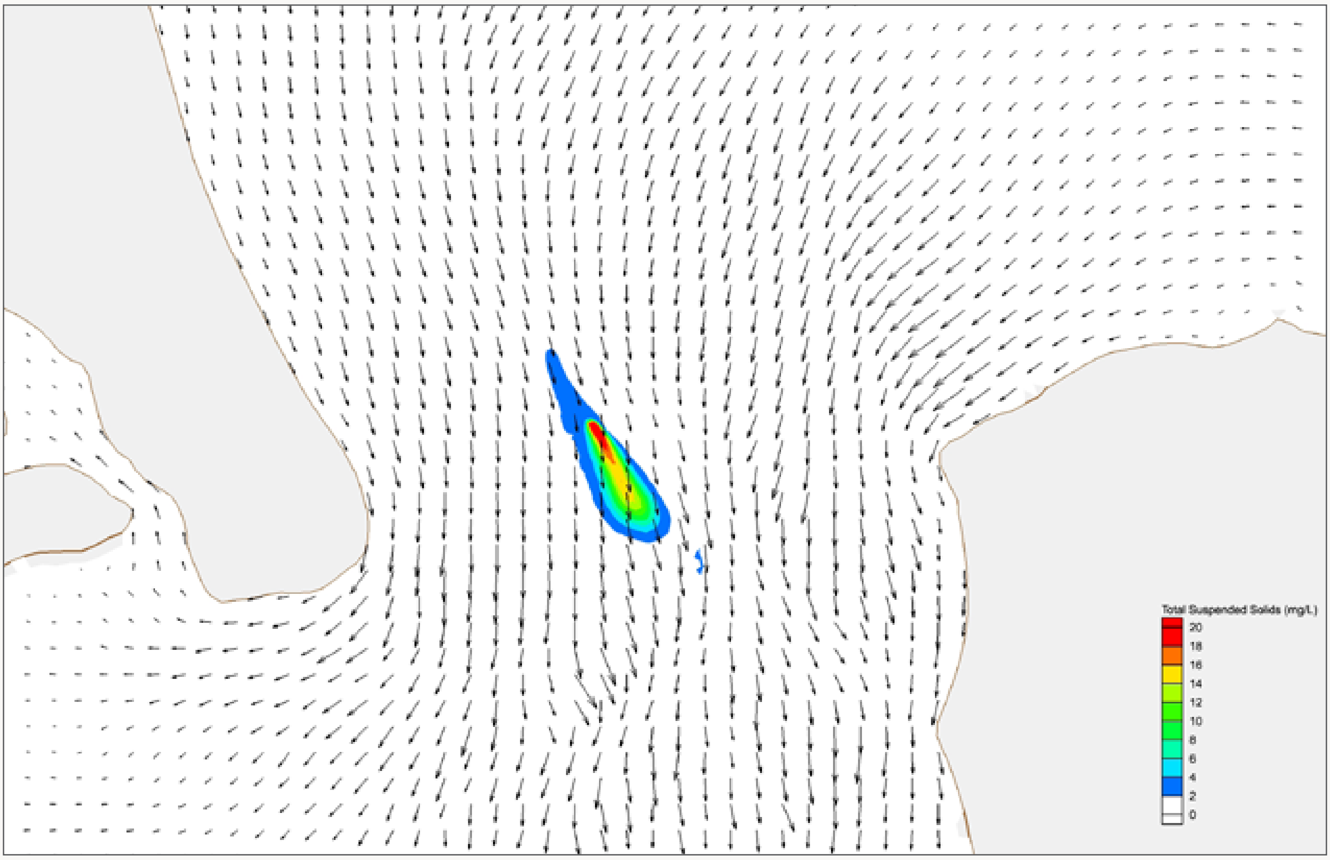


Figure 3.5p: Example plume advection-dispersion during flood tide conditions



3.5.3.5 Expected case dredge plume water quality impact assessment results

The “expected case” dredge plume impacts for summer and winter scenarios have been presented as:

- Tables showing the predicted depth-averaged TSS concentration at the 95th percentile, 80th percentile, median, and 20th percentile (or 5 per cent, 20 per cent, 50 per cent, 80 per cent time exceedance) for the model output locations indicated in **Figure 3.5c**
- Spatial plots of the 80th percentile (20 per cent time exceedance) depth-averaged TSS concentration
- Time series of the plume depth-averaged TSS concentration at the model output locations indicated in **Figure 3.5c**.

All dredge plume TSS concentration results are presented for above background conditions. A threshold plume TSS concentration of 2 mg/L has been adopted for illustration of the time exceedance (or percentile) spatial extent. Plume concentrations in excess of 20 mg/L near the plume source have been simulated but are not plotted. It is reiterated that deposited plume sediments are available for re-suspension by wave and current forces and therefore the spatial extent of the plume impact is greater than the extent of the visible dredge plume. The dredge plume impact assessment results are summarised below.

- **Table 3.5b** and **Table 3.5c** summarise the predicted increase to TSS concentration for the summer and winter simulation periods for the model output locations indicated in **Figure 3.5c**. Outside of the sand extraction area, the increase to TSS is generally less than 3 mg/L for 95 per cent of the time. For locations within the sand extraction area (SF1, SF2 and SF3), the 95th percentile increase to TSS concentration is between 4 – 8 mg/L. This suggests that the above background TSS concentration within the Spitfire Realignment Channel may reach approximately 8 mg/L for 5 per cent of the time during dredging operations
- Small increases to TSS concentrations are predicted within the Marine National Park Zone 03 Area to the north of the sand extraction area (GZ1, GZ2 and GZ3) during dredging operations. These increases are less than 4 mg/L for 95 per cent of the time. The peaks in TSS concentration within the Marine National Park Zone 03 are episodic in nature and between relatively longer periods with little or no increase to the background TSS concentration (refer to time series plots in **Appendix C3:C**)
- During both the summer and winter periods the 80th percentile increase to TSS concentration is typically less than 3 mg/L. TSS concentration increases of this magnitude or less are within the range natural variability and are unlikely to be visible as plumes
- Minor to no TSS concentration increases are predicted at the shoreline locations (BI1, BI2, MI1, MI2, MI3 and MI4)
- Comparison of the 20 per cent time exceedance (80th percentile) spatial plots suggests dredge plume material is transported slightly further to the north during the summer period. This is due to greater wave energy and winds predominantly from the south-easterly sector during the summer months that promotes the re-suspension and transport of the plume material.

Table 3.5b: Expected case predicted TSS impacts associated with proposed Project dredging – summer months

Model Output Location	Above Background Depth-Average TSS (mg/L)			
	95th Percentile	**80th Percentile**	**Median**	**20th Percentile**
BI1	0.85	0.45	0.31	0.18
BI2	0.50	0.33	0.20	0.09
MI1	0.04	0.02	0.00	0.00
MI2	0.06	0.04	0.02	0.00
MI3	0.06	0.05	0.04	0.01
MI4	0.05	0.04	0.03	0.02
M3B	1.34	0.64	0.32	0.20
WBA	2.88	1.54	0.78	0.36
GZ1	1.52	0.57	0.10	0.02
GZ2	2.41	1.06	0.26	0.04
GZ3	1.02	0.43	0.14	0.03
SF1	4.16	2.19	1.18	0.63
SF2	7.43	2.11	1.02	0.53
SF3	3.36	1.35	0.66	0.40

Table 3.5c: Expected case predicted TSS impacts associated with proposed Project dredging – winter months

Model Output Location	Above Background Depth-Average TSS (mg/L)			
	95th Percentile	**80th Percentile**	**Median**	**20th Percentile**
BI1	0.78	0.34	0.22	0.12
BI2	0.47	0.22	0.11	0.04
MI1	0.05	0.03	0.00	0.00
MI2	0.09	0.07	0.03	0.01
MI3	0.10	0.08	0.06	0.02
MI4	0.10	0.08	0.05	0.03
M3B	1.42	0.72	0.39	0.25
WBA	3.10	1.50	0.69	0.29
GZ1	2.14	0.72	0.16	0.03
GZ2	3.41	1.20	0.38	0.08
GZ3	1.24	0.56	0.21	0.06
SF1	5.14	2.30	1.21	0.63
SF2	5.89	2.13	1.09	0.56
SF3	3.67	1.42	0.75	0.44

3.5.3.6 Impacts to Moreton Bay water quality objectives for the expected case

Compliance with WQOs (EPP Water 2009) is determined by comparing annual statistical measures (20th, 50th and 80th percentile or annual median) of observation (i.e. EHMP) water quality data to the commensurate WQOs set forth for the environmental values of the waterway. These are referred to subsequently as medium- to long-term impacts. While this addresses the water quality impacts in terms of the WQOs, consideration has also been given to impacts in the short term, as the dredge period modelled was 6 weeks.

1. Medium- to long-term impacts (impacts to WQOs) – The modelling predicted turbidity levels as a result of the dredging alone. To determine overall turbidity levels (including background) during the dredge operation the observed background (EHMP) data (see **Section 3.3.7**) were added to model time series results for the expected case were. For the two different water way types, this involved:
    a. <u>For HEV areas (National Marine Park Zone 03 and Moreton Island HEV E1A)</u>, combining 20th, 50th and 80th percentile background with corresponding 20th, 50th, and 80th percentile turbidity values for the dredge operation
    b. For slightly to moderately disturbed areas adding the annual median turbidity value in the background to the annual median value for the dredge operation.

The combination of these factors (i.e. output location, water area/level of protection, background water quality site, and assessment method) are summarised in **Table 3.5d**. These analyses were done for both summer and winter periods, however both periods demonstrated identical results in terms of the WQOs. The results of this assessment and impacts on the water quality in Moreton Bay are presented in **Table 3.5e**. **Figure 3.5q** presents a time series of increases of a summer dredge campaign above background turbidity levels at Site GZ2 relative to the WQO for a short period within the dredge operation (top) and for the entire year (bottom).

Model outputs in TSS were converted to turbidity based on the conversion factor discussed previously, (i.e. TSS ≈ 1.5*NTU).

2. Short-term impacts – The analysis of the previous item demonstrates there are no impacts to the WQOs when assessed on an annual basis. However, short-term increases in turbidity levels are predicted to occur during dredging operations. These increases are brief (typically 90 minutes) and episodic (periods of 7 or more hours between dredge runs at the Spitfire Realignment Channel). The 95th percentile increase in turbidity (**Table 3.5f** and **Table 3.5g**) is less than 7.5 mg/L TSS (corresponding to less than 5 NTU) for all assessed sites.

    <u>To address these impacts, turbidity trigger values will be set which will act as limits corresponding to corrective action in the event that monitoring detects exceedences of the criteria (see **Section 3.5.3.8**)</u>.

There are also potential impacts from the release of nutrients (nitrogen and phosphorus) or toxicants (e.g. metals) within porewater from dredged material. In the Summary of Findings of the MBSES (NIWA 2004), monitoring of dredge plumes at Middle Banks yielded undetectable changes to nutrients compared to background. Additionally, it was determined in the Brisbane Airport Parallel Runway EIS that porewater is significantly diluted within the hopper prior to discharge, and resulted in no impacts on background water quality, and hence no impacts on WQOs (Brisbane Airport Corporation 2005).

Impacts to water quality objectives observed as a result of the dredge plumes are summarised as follows:

- The top graph in **Figure 3.5q** demonstrates that there are brief and periodic increases at Site GZ2 as a result of the dredging. These impacts occur only during the dredging campaign. Mitigation of these impacts are discussed in **Section 3.5.3.8**
- The bottom graph in **Figure 3.5q** and the results in **Table 3.5f** shows that the annual turbidity levels at each site and for each statistical value are not impacted because of the short duration of the dredging campaign. While the figure and the table show summer results, potential impacts to water quality from the winter dredging campaign were identical
- Impacts to water quality at all sites are likely to be minor and result in no long-term adverse changes in water quality or ability to comply with the WQOs
- Impacts for porewater constituents are likely to be negligible.

3.5.3.7 Impact significance

The impact significance for water quality are as follows:

- Exceedances in the HEV were shown to be temporary in nature (a few hours per dredge cycle) and are not expected to result in long-term change to water quality. This has been observed in two previous dredge operations by PBPL without any measureable changes to water quality in the eastern bay
- The temporary water quality impacts have been assessed in Chapter C4 – Marine Ecology to be of low significance to ecological values and uses of the HEV area with mitigation
- The impacts to water quality due to release of porewater nutrients or toxicants are likely to be negligible

- The modelling performed for these assessments is by its nature conservative using best practice numbers supplied by the marine engineer and observations by BMT WBM in the field. While some impact may be unavoidable under certain tidal/weather conditions, the Project will monitor the plumes to validate modelling and use a reactive monitoring program to ensure the dredge program is adaptive and that impacts are either avoided or minimised.

3.5.3.8 Mitigation measures

Turbid plumes generated during the dredging operations of the Project will result in some minor but unavoidable impacts to water quality. Based on the modelling, these exceedences will be short-term and episodic corresponding to the dredge scheduling.

Measures that can be implemented to mitigate these temporary impacts include:

- At the outset of dredging, implementing a short-term model validation water quality monitoring program similar to *Volvox Asia* (BMT WBM 2008) to validate the model findings
- Setting out a range of proposed trigger values at sensitive receptors during dredging to guide proposed monitoring and mitigation activities (see below)
- Implementing a reactive monitoring program to ensure compliance with proposed trigger values and WQOs during dredging. Monitoring data would be downloaded remotely and assessed against threshold trigger values, with appropriate corrective actions implemented if those trigger values are exceeded
- Corrective action could include:
  - Dredging, where practical, during flood tides when migration of the plume would likely be to the south over the area defined by M3B and WBA location (i.e. slightly to moderately disturbed area E2A and away from the HEV area)
- Dredger to be fitted with an 'environmental' or 'green' valve that reduces overflow turbulence and thereby further reduces surface water turbidity impacts.

These measures are outlined further in the relevant section of the Dredge Management Plan outlined in Chapter E4.

Performance criteria during dredging will be established to describe the tolerance limits for turbidity concentrations and to be enforced through continuous and reactive monitoring described above. The performance criteria for the Project is as follows:

- Turbidity shall not continuously exceed 6 NTU within 150 m immediately downstream of the origin of the dredge plume for more than 1 hour during any dredge cycle (assumed to be ~8 hours).

The primary justification for the adoption of this limit is based on:

- Monitoring of the *Volvox Asia* dredger at the Spitfire Realignment Channel in 2008 observed maximum turbidity of approximately 6 NTU directly within the plume, with turbidity returning to within background conditions (1.2 – 2.5 NTU) no more than 1 km from the dredger
- Monitoring of dredge plume of the '*Pearl River*' (POBC 2005) indicated peak turbidity of 9 – 18 NTU near the dredge vessel, and a peak 3.6 NTU approximately 150 m downstream
- In both the *Volvox Asia* and *Pearl River* dredging, the turbid plumes were transient and of short duration. In both instances, there were no long-term or permanent impacts to water quality
- The TSS modelling indicates that increases in turbidity are likely to be less than 6 NTU (including background) at receptor sites and of short duration (approximately 1 – 2 hours). This is corroborated by turbidity monitoring of Spitfire Realignment Channel dredging described above
- The maximum EHMP background turbidity level is 9.7 NTU, which did not occur during a large storm event. The next highest turbidity concentration was 5.4 NTU measured after the January 2011 floods. The EHMP data are based on single monthly grab samples which don't allow for the capture of short-term variations of turbidity, especially during high wind and wave conditions, which would likely result in higher turbidity.

Table 3.5d: Summary of water quality objective assessment factors

Model Output Location	Water Area	Level of Protection	Background EHMP	Assessment Statistic
GZ1	E1C	HEV (Green Zone)	E00525	Maintain 20th-, 50th-, and 80th-percentile values
GZ2				
GZ3				
MI1	E1A	HEV	E00524	Maintain 20th-, 50th-, and 80th-percentile values
MI2				
MI3				
MI4				
SF1	E2A	Slightly to Moderately Disturbed	E00525	Annual Medians
SF2				
SF3				
M3B				
WBA				
BI1	Open Coastal -SEQ	Slightly to Moderately Disturbed		
BI2				

Table 3.5e: Summary of impacts to Moreton Bay water quality and compliance with water quality objectives for the expected case, summer months

	Annual Turbidity Increase from Dredging (NTU) (Percentile)			Background Turbidity (EHMP; NTU) (Percentile)			Combined Turbidity (NTU) (Percentile)			WQO Turb (NTU) (Percentile)		
Location	20th	50th	80th	20th	50th	80th	20th	50th	80th	20th	50th	80th
GZ1	0	0	0	0.1	0.67	1.38	0.1	0.67	1.38	< 1	< 1	1
GZ2	0	0	0	0.1	0.67	1.38	0.1	0.67	1.38	< 1	< 1	1
GZ3	0	0	0	0.1	0.67	1.38	0.1	0.67	1.38	< 1	< 1	1
MI1	0	0	0	0	0.09	0.63	0	0.09	0.63	< 1	< 1	1
MI2	0	0	0	0	0.09	0.63	0	0.09	0.63	< 1	< 1	1
MI3	0	0	0	0	0.09	0.63	0	0.09	0.63	< 1	< 1	1
MI4	0	0	0	0	0.09	0.63	0	0.09	0.63	< 1	< 1	1
SF1	-	0	-	-	0.67	-	-	0.67	-	-	< 1	-
SF2	-	0	-	-	0.67	-	-	0.67	-	-	< 1	-
SF3	-	0	-	-	0.67	-	-	0.67	-	-	< 1	-
M3B	-	0	-	-	0.67	-	-	0.67	-	-	< 1	-
WBA	-	0	-	-	0.67	-	-	0.67	-	-	< 1	-
BI1	-	0	-	-	0.67	-	-	0.67	-	-	< 1	-
BI2	-	0	-	-	0.67	-	-	0.67	-	-	< 1	-

Entries highlighted in red represent exceedences of the WQO criteria

Figure 3.5q: Time series of turbidity including nominal median background of 0.67NTU at site GZ2 (top graph – over six weeks; bottom graph – over 1 year)

Figure 3.5r: 20 per cent time exceedance (80th percentile) TSS concentration summer period

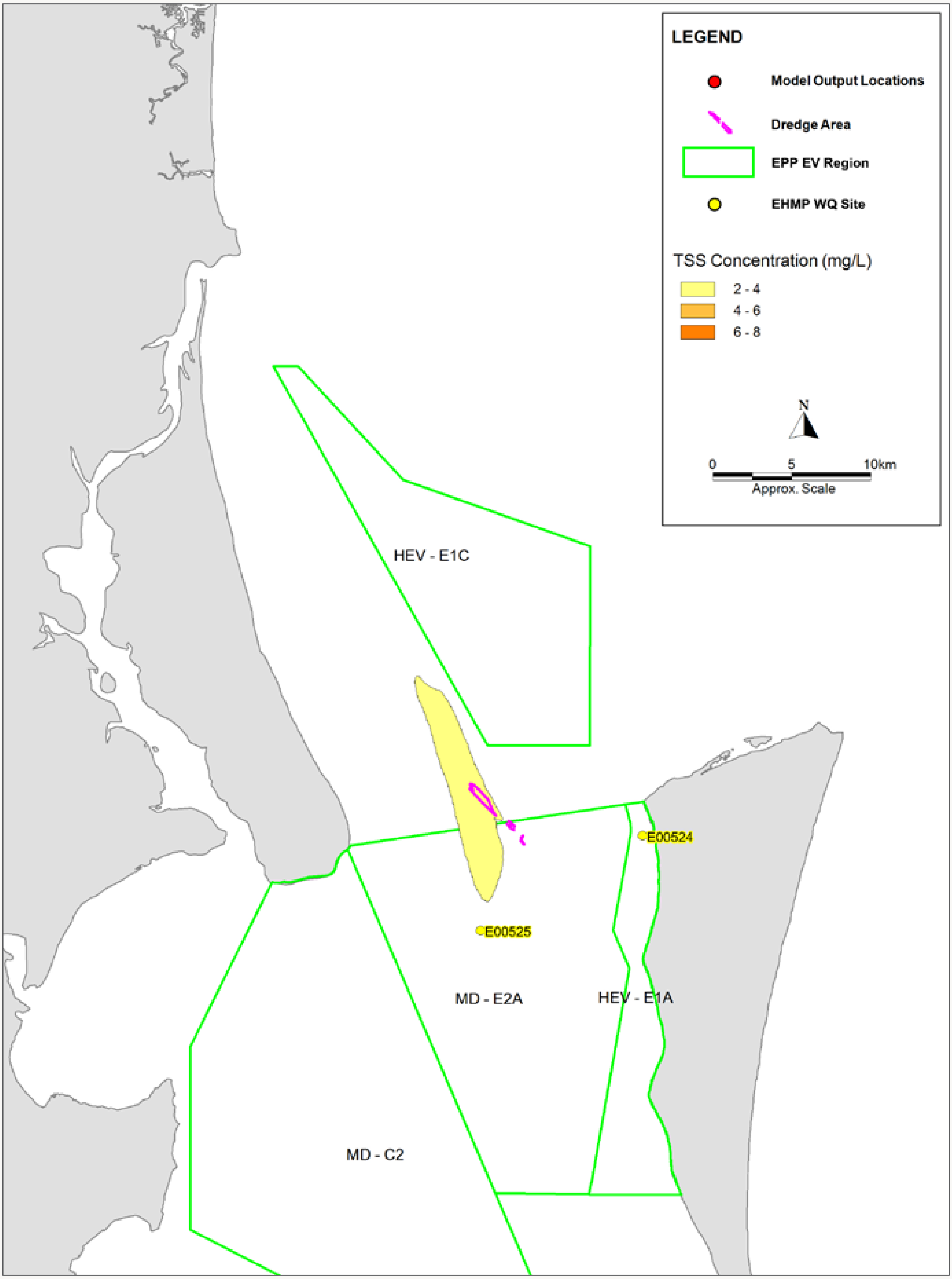
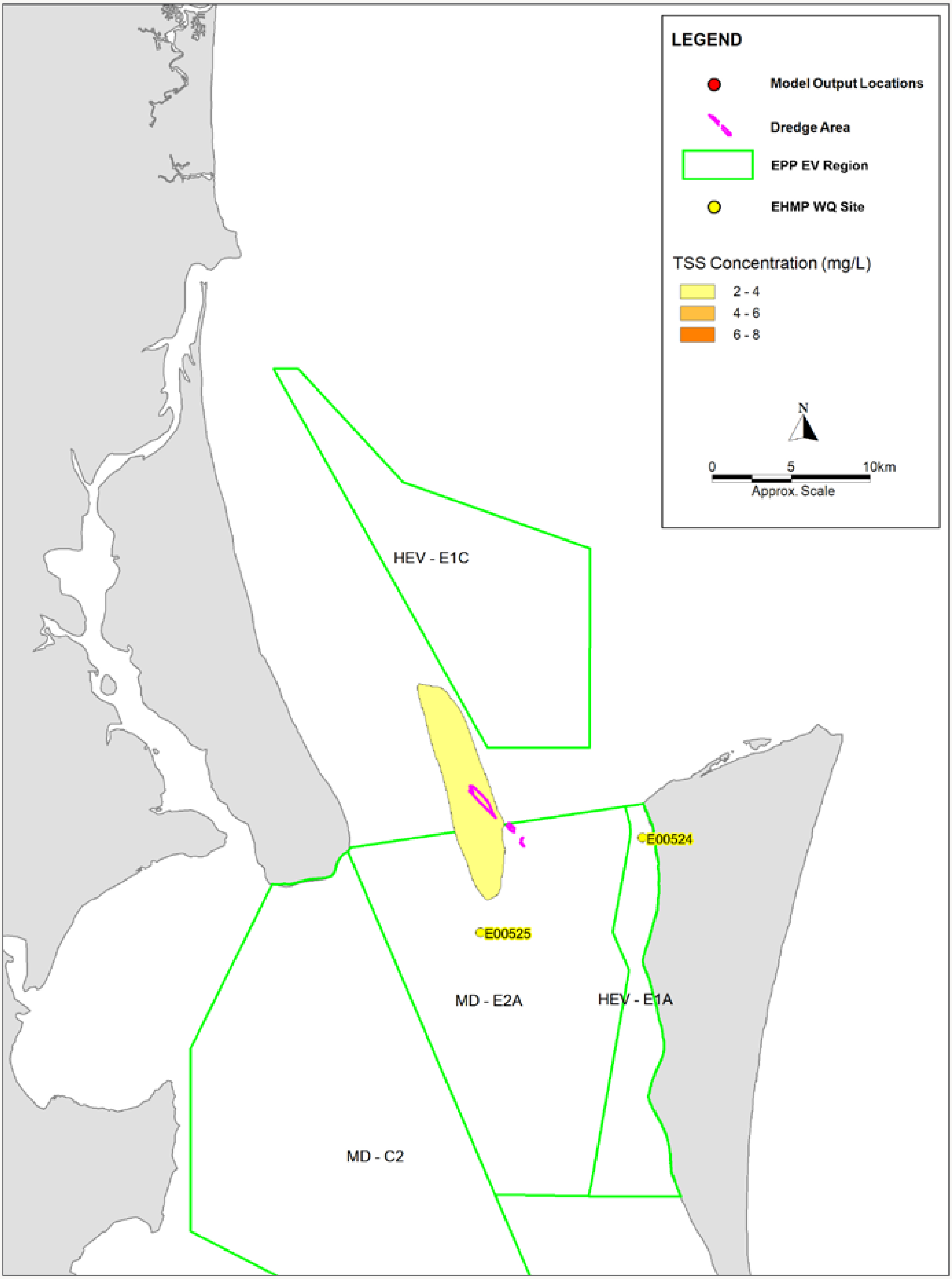


Figure 3.5s: 20 per cent time exceedance (80th Percentile) TSS concentration winter period



3.5.4 Extreme case dredge plume water quality impact assessment results

An "extreme case" dredge plume assessment has been developed as a sensitivity analysis to capture uncertainties regarding the dredging program, including the type of dredger, conditions at the time of operation and in particular, the potential for the dredger to encounter finer sediment material in the dredge footprint than indicated by previous investigations of the sand extraction area (e.g. Coffey Geosciences 2004; WBM 2004; BMT WBM 2011; refer also Chapter C2 – Marine Geology).

The extreme case dredge plume impacts for summer and winter scenarios are presented in **Table 3.5f** and **Table 3.5g** and are considered to represent the upper-bound depth-averaged TSS concentration at the 95th percentile, 80th and 20th percentile and median (or 5 per cent, 20 per cent, 50 per cent and 80 per cent time exceedance) for the model output locations indicated in **Figure 3.5c**.

Time series output for the locations within the Marine National Park Zone 03 are also presented in **Figure 3.5t** to **Figure 3.5y**. The results for the extreme case TSS impacts are summarised here:

- **Table 3.5f** and **Table 3.5g** summarise the predicted increase to TSS concentration for the extreme case summer and winter simulation periods. Generally the extreme case percentile (or time exceedance) TSS impacts are only slightly greater than the expected case results presented in **Section 3.5.3.5**. Despite the increased silt content in the dredge overflow adopted for the extreme case, the relatively long dredge cycle times (i.e. plume generation only occurs for approximately 78 minutes every 8.7 hours) lead to only minor additional TSS time exceedance impacts
- Compared to the expected case, only small increases to TSS concentrations are predicted within the Marine National Park Zone 03 to the north of the sand extraction area (GZ1, GZ2 and GZ3) for the extreme case. The increase to TSS concentration is up to 4 mg/L for 95 per cent of the time. The peaks in TSS concentration within the Marine National Park Zone 03 are predicted to occasionally reach 8 mg/L.

Table 3.5f: Extreme case predicted TSS impacts associated with proposed Project dredging – summer months

Model Output Location	Above Background Depth-Average TSS (mg/L)			
	95th Percentile	**80th Percentile**	**Median**	**20th Percentile**
BI1	1.16	0.85	0.69	0.41
BI2	0.86	0.69	0.44	0.20
MI1	0.08	0.04	0.00	0.00
MI2	0.13	0.10	0.05	0.01
MI3	0.13	0.11	0.08	0.03
MI4	0.12	0.09	0.07	0.04
M3B	1.67	0.94	0.57	0.36
WBA	3.34	2.03	1.28	0.65
GZ1	1.91	0.89	0.17	0.03
GZ2	2.91	1.44	0.42	0.08
GZ3	1.33	0.66	0.25	0.06
SF1	4.67	2.61	1.68	1.04
SF2	8.06	2.44	1.42	0.84
SF3	3.73	1.75	0.99	0.64

Table 3.5g: Extreme case predicted TSS impacts associated with proposed Project dredging – winter months

Model Output Location	Above Background Depth-Average TSS (mg/L)			
	95th Percentile	80th Percentile	Median	20th Percentile
BI1	1.04	0.59	0.47	0.26
BI2	0.70	0.47	0.24	0.09
MI1	0.12	0.06	0.01	0.00
MI2	0.21	0.16	0.07	0.02
MI3	0.23	0.19	0.13	0.05
MI4	0.21	0.17	0.12	0.08
M3B	1.82	1.11	0.71	0.46
WBA	3.45	1.97	1.12	0.53
GZ1	2.37	1.04	0.28	0.06
GZ2	3.80	1.67	0.64	0.14
GZ3	1.66	0.89	0.38	0.10
SF1	5.73	2.72	1.77	1.16
SF2	6.47	2.55	1.56	1.00
SF3	4.17	1.91	1.15	0.78

In terms of compliance with WQOs, the method of assessment of impacts for the extreme case was the same as that utilised in the expected case. The results of this assessment and impacts to the water quality in Moreton Bay are presented in **Table 3.5h**.

The increases in turbidity levels presented in **Table 3.5f** and **Table 3.5g** are increases for the dredging period only (6 weeks), not for a year-long period for which potential impacts to water quality have been assessed.

Impacts to water quality objectives from the extreme case as a result of the dredge plumes are summarised as follows:

- Impacts to water quality at all sites are likely to be minor and result in no adverse impacts to water quality or compliance with the WQOs
- The modelling showed no exceedances of the HEV criteria within the Marine National Park Zone 03. Exceedances in the HEV were shown to be temporary in nature (a few hours per dredge cycle) and are not expected to result in long-term change to water quality. This has been observed in two previous dredge operations by the PBPL without any measureable changes to water quality in the eastern bay.

These findings reinforce the view that sand dredging is only predicted to have temporary impacts on marine water quality, and that mitigation and monitoring measures outlined in the previous section are sufficient to further reduce the risk of impact.

Table 3.5h: Summary of impacts to Moreton Bay water quality and compliance with water quality objectives for the extreme case, summer months

	Annual Turbidity Increase from Dredging (NTU) (Percentile)			Background Turbidity (EHMP; NTU) (Percentile)			Combined Turbidity (NTU) (Percentile)			WQO Turb (NTU) (Percentile)		
Location	20th	50th	80th	20th	50th	80th	20th	50th	80th	20th	50th	80th
GZ1	0	0	0	0.1	0.67	1.38	0.1	0.67	1.38	< 1	< 1	1
GZ2	0	0	0	0.1	0.67	1.38	0.1	0.67	1.38	< 1	< 1	1
GZ3	0	0	0	0.1	0.67	1.38	0.1	0.67	1.38	< 1	< 1	1
MI1	0	0	0	0	0.09	0.63	0	0.09	0.63	< 1	< 1	1
MI2	0	0	0	0	0.09	0.63	0	0.09	0.63	< 1	< 1	1
MI3	0	0	0	0	0.09	0.63	0	0.09	0.63	< 1	< 1	1
MI4	0	0	0	0	0.09	0.63	0	0.09	0.63	< 1	< 1	1
SF1	-	0	-	-	0.67	-	-	0.67	-	-	< 1	-
SF2	-	0	-	-	0.67	-	-	0.67	-	-	< 1	-
SF3	-	0	-	-	0.67	-	-	0.67	-	-	< 1	-
M3B	-	0	-	-	0.67	-	-	0.67	-	-	< 1	-
WBA	-	0	-	-	0.67	-	-	0.67	-	-	< 1	-
BI1	-	0	-	-	0.67	-	-	0.67	-	-	< 1	-
BI2	-	0	-	-	0.67	-	-	0.67	-	-	< 1	-

Entries highlighted in red represent exceedences of the WQO criteria

Figure 3.5t: Extreme case summer period increase to total suspended solids – location GZ1

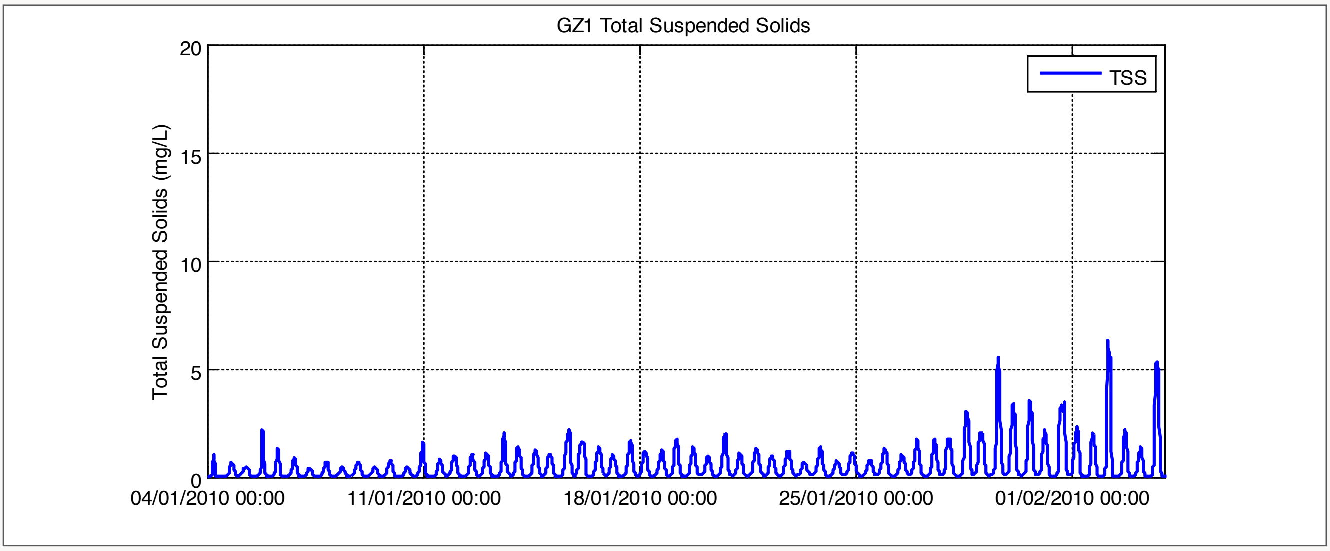


Figure 3.5u: Extreme case winter period increase to total suspended solids – location GZ1

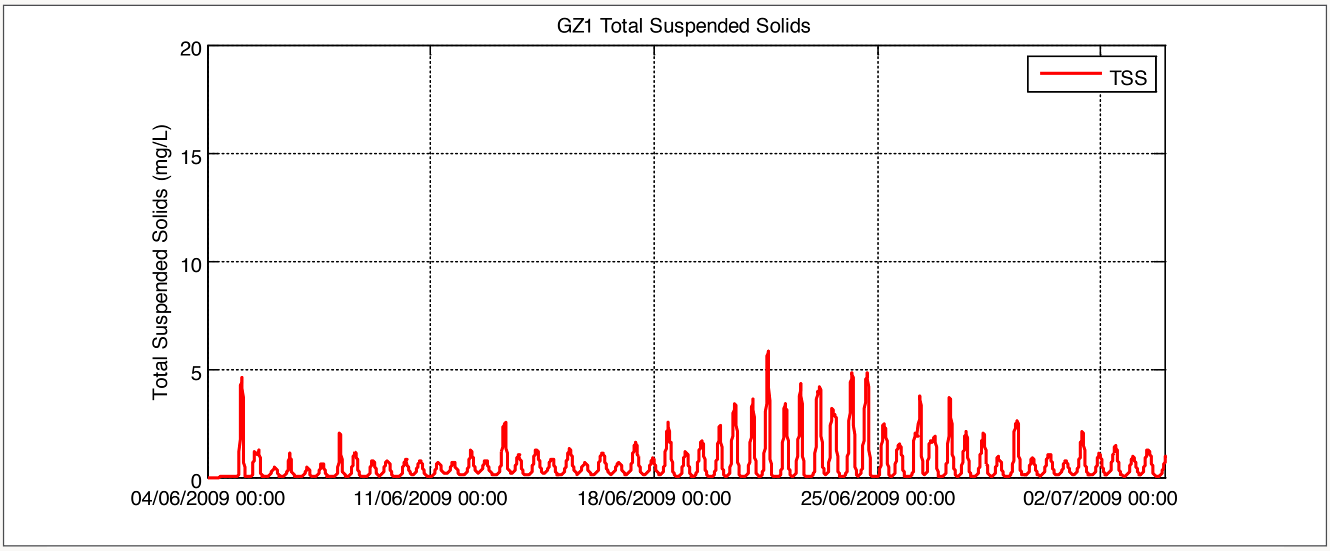


Figure 3.5v: Extreme case summer period increase to total suspended solids – location GZ2

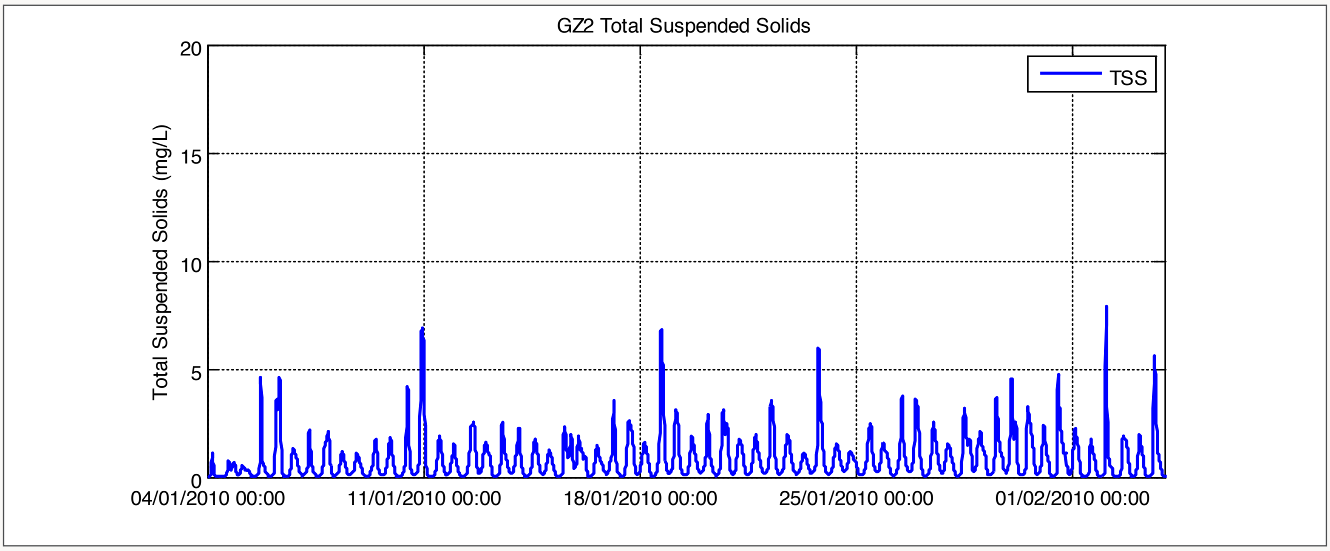


Figure 3.5w: Extreme case winter period increase to total suspended solids – location GZ2

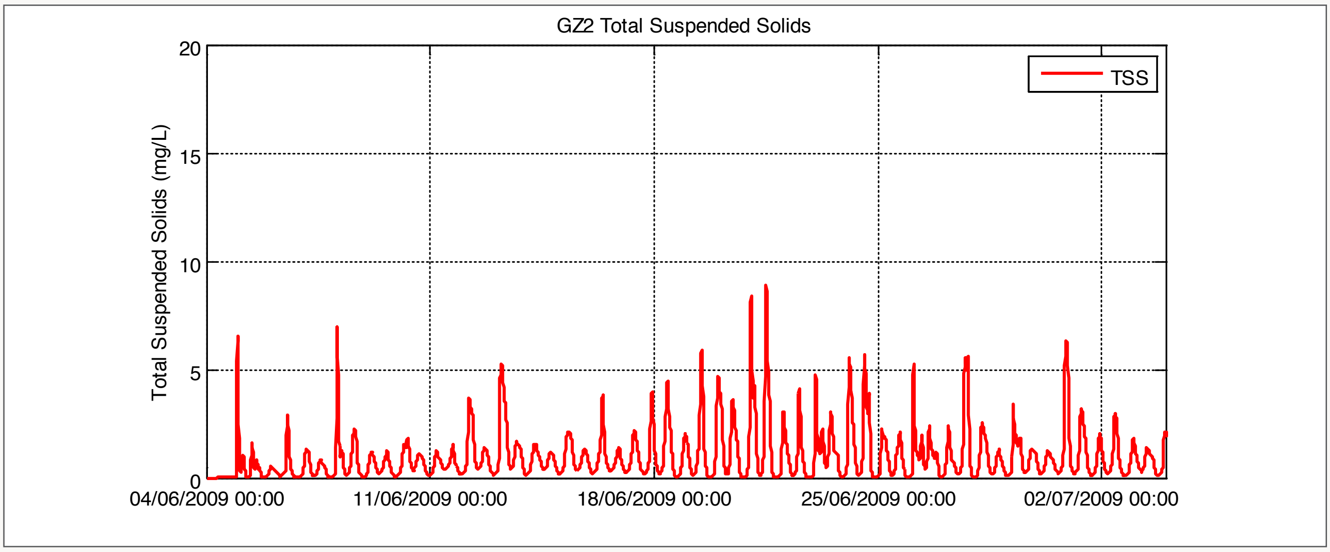


Figure 3.5x: Extreme case summer period increase to total suspended solids – location GZ3

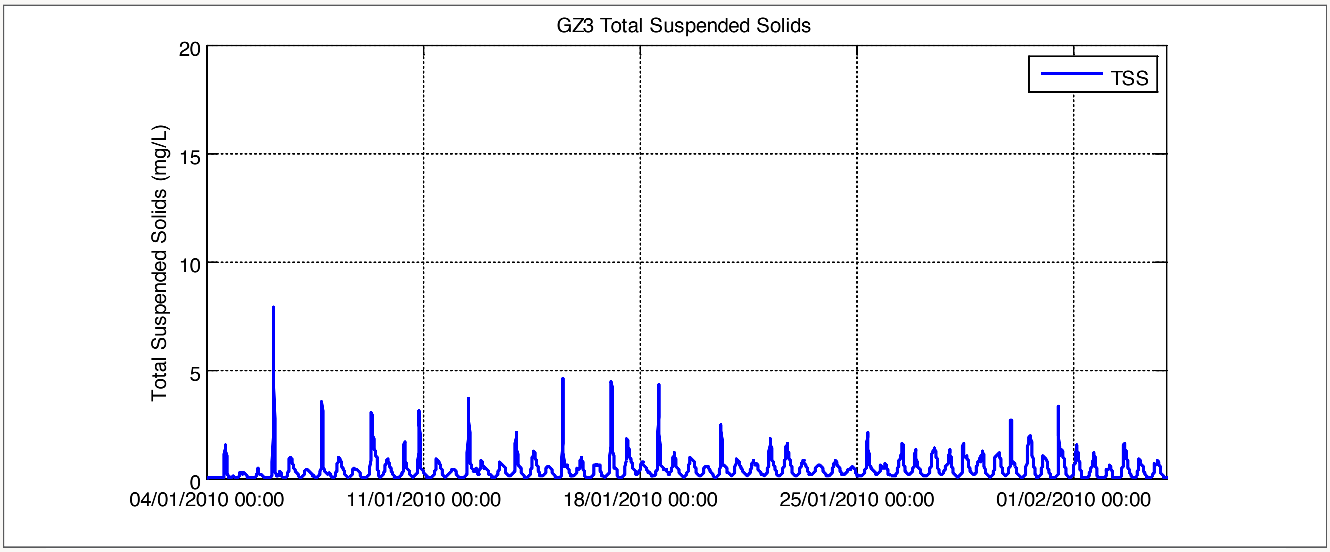
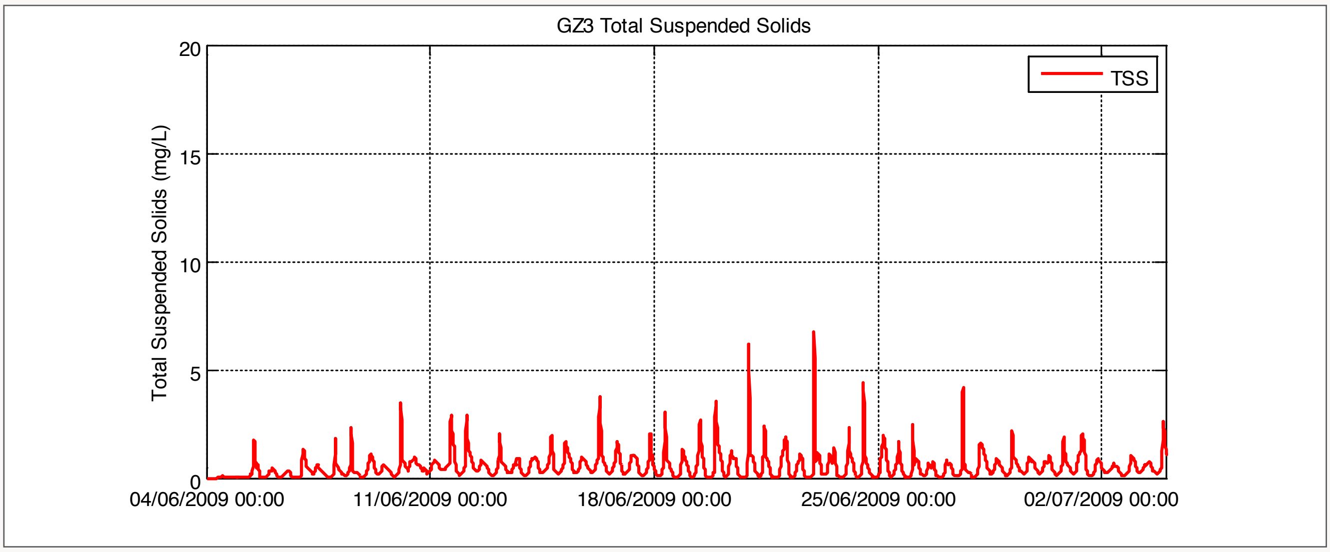


Figure 3.5y: Extreme case winter period increase to total suspended solids – location GZ3



3.5.5 Dredge plume deposition assessment results

The areas of predicted dredge plume sediment deposition in terms of bed level change (in mm per month) are indicated in **Figure 3.5z**. Deposition generally occurs in areas where naturally deep channels exist. Within these areas the threshold bed shear stress for sediment re-suspension is not typically exceeded and therefore deposition is predicted. The deposition results indicate the following:

During dredging operations deposition up to approximately 2 mm/month is predicted in naturally deep areas adjacent to the Spitfire Realignment Channel

No deposition is predicted within the Moreton Bay Marine National Park Zone 03 located to the north of the sand extraction area. Although the dredge plume is predicted to occasionally enter the Marine National Park Zone 03, deposition is not predicted to occur. The bed shear stress (due to combined tidal current and wave forces) is sufficient to keep the fine plume material in suspension across the shallow Marine National Park Zone 03 area

Predicted deposition within the sand extraction area is an artefact of the modelling approach and is considered negligible since the area has been approved for long term sand extraction and future dredge operations will continually remove material settling in this area.

Noting that the sedimentation has the potential to impact benthic habitat quality, the ecological implications of the patterns and extent of sedimentation are discussed further in Chapter C4 – Marine Ecology.

3.6
Impact assessment summary

The various coastal processes and dredging-related water quality assessments have shown that impacts of the proposed sand dredging as part of the Project will not be of significance with respect to shoreline areas in northern Moreton Bay and designated Marine National Park Zone 03. This finding is consistent with previous assessment studies relating to Moreton Bay sand extraction works (e.g. WBM 2005). As such, long term adverse impacts to coastal processes and/or water quality are highly unlikely.

Specifically, the modelling results show that:

There will be negligible impacts (unmeasurable) on the tidal regime within Moreton Bay

There will be negligible impacts on tides, currents and waves at adjacent shorelines (Bribie Island and Moreton Island)

Generally, impacts on tidal currents are highly localised and in the immediate vicinity of the sand extraction area where some local realignment and modification of current speeds will occur

Impact to water quality and environmental values within Moreton Bay and the Marine National Park Zone 03 immediately to the north associated with dredging is likely, with minor adverse significance due to the temporary non-compliance with water quality objectives. The proposed monitoring and reactive mitigation measures will likely reduce the risk of the impact to acceptable levels.

The wave propagation modelling for both this investigation and previous studies indicates that there would be no changes in wave heights of any significance at adjacent shoreline areas associated with the proposed sand extraction. Under typical swell and sea state conditions, the absolute wave height levels along the western shoreline of Moreton Island and eastern shoreline of Bribie Island are not affected.

It is more likely that the existing sand transport along the Moreton Island shoreline is dominated by the tidal currents in conjunction with local sea waves generated within Moreton Bay. The proposed works will have no adverse impacts on those processes.

The coastal processes and Moreton Bay water quality impact assessments are summarised in **Table 3.6a** together with the anticipated risk and potential mitigation measures (where relevant). Based on the assessments, all risks to coastal processes and dredging related water quality that have been identified can be reduced to a low or medium residual risk through the application of existing controls (associated with the design of key infrastructure elements of the Project) and through the proposed implementation of risk mitigation measures.

Figure 3.5z: Monthly dredge plume sediment deposition

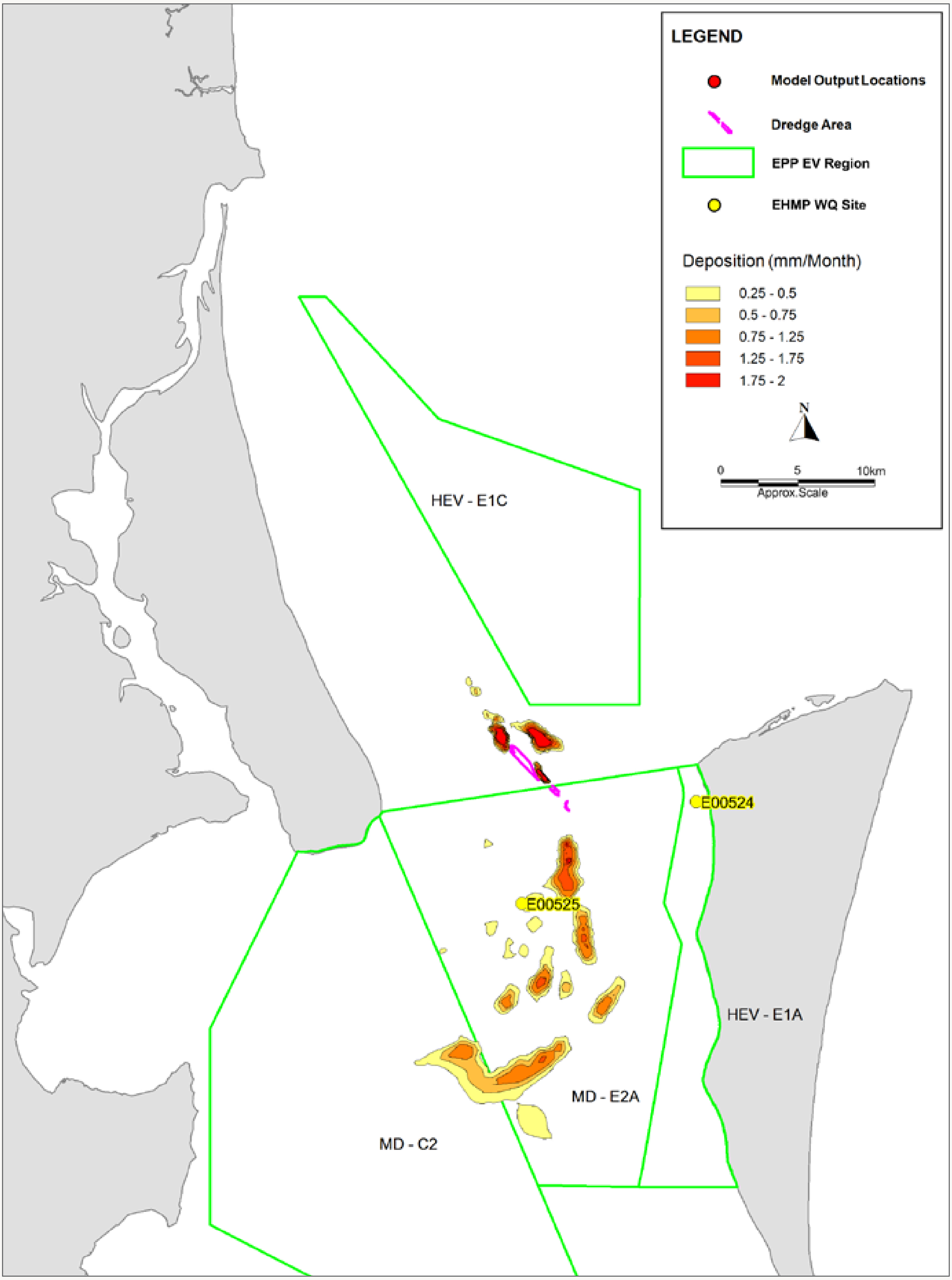


Table 3.6a: Impact assessment summary table

Coastal Processes	Initial assessment with mitigation inherent in the Preliminary design in place				Residual Assessment with additional mitigation in place (i.e. those actions recommended as part of the impact assessment phase)			
Primary impacting process	**Mitigation inherent in the design**	**Significance of impact**	**Likelihood of impact**	**Risk rating**	**Additional mitigation measures proposed**	**Significance of impact**	**Likelihood of impact**	**Residual risk rating**
Changes to water levels and the tidal regime within Moreton Bay	NA	Moderate	Highly Unlikely	Low	NA	Moderate	Highly Unlikely	Low
Modification to tidal currents at Bribie Island and Moreton Island shoreline locations	NA	Moderate	Highly Unlikely	Low	NA	Moderate	Highly Unlikely	Low
Modification to tidal currents within designated Marine National Park Zone 03	NA	Moderate	Highly Unlikely	Low	NA	Moderate	Highly Unlikely	Low
Localised modification to tidal currents in the vicinity of target sand extraction area	Sand extraction restricted to designated Spitfire Realignment Channel	Negligible	Almost Certain	Low	NA	Negligible	Almost Certain	Low
Modification to the prevailing wave climate at Bribie Island and Moreton Island	NA	Moderate	Highly Unlikely	Low	NA	Moderate	Highly Unlikely	Low
Changes in sand supply to Bribie Island foreshores	NA	Moderate	Highly Unlikely	Low	NA	Moderate	Highly Unlikely	Low
Local changes to northern Moreton Bay shoal morphology	NA	Negligible	Almost Certain	Low	NA	Negligible	Almost Certain	Low
Regional changes to northern delta shoal morphology	NA	Moderate	Highly Unlikely	Low	NA	Moderate	Highly Unlikely	Low
Elevated turbidity levels associated with short-term sand extraction activities	Sand extraction restricted to designated Spitfire Realignment Channel with low fine sediment fraction	Minor	Likely	Medium	See **Section 3.5.3.8**	Minor	Unlikely	Low
Increased nutrient or toxicant concentrations associated with porewater release during sand extraction activities.	Sand extraction restricted to designated Spitfire Realignment Channel with low fine sediment fraction	Negligible	Highly Unlikely	Negligible	NA	Negligible	Highly Unlikely	Negligible

Coastal Processes	Initial assessment with mitigation inherent in the Preliminary design in place				Residual Assessment with additional mitigation in place (i.e. those actions recommended as part of the impact assessment phase)			
Primary impacting process	**Mitigation inherent in the design**	**Significance of impact**	**Likelihood of impact**	**Risk rating**	**Additional mitigation measures proposed**	**Significance of impact**	**Likelihood of impact**	**Residual risk rating**
Deposition of suspended sediment in designated marine park Marine National Park Zone 03	NA	Moderate	Highly Unlikely	Low	NA	Moderate	Highly Unlikely	Low

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