C3

VOLUME C: MIDDLE BANKS, MORETON BAY

Coastal Processes and Natural Features

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KEY FINDINGS

Baseline Conditions

- Middle Banks form part of the Northern Entrance Tidal Delta that contains approximately 4,000 Mm^3 of sand.
- The Northern Entrance Tidal Delta has accumulated substantially over the last 6,000 years since the sea rose to its present level following the last glacial period.
- There is a continuing inflow of marine sand into Moreton Bay from the longshore transport of sand along the ocean beach system and past Comboyuro Point via the North East Channel area.
- Middle Banks have formed as a result of natural processes related to southward transport of sand along the East Channel by tidal currents.
- The southward migration of sand along the East Channel is relatively strong and persistent, due to tidal currents that peak up to about 1 m/s.
- Wave action at Middle Banks and along the adjacent shoreline of Moreton Island is predominantly locally generated 'sea' waves of relatively short period (less than 5-6 seconds) and height generally less than 0.8 - 1 m and rarely greater than 1.1 - 1.2 m. Ocean swell reaching the site is highly attenuated by refraction and bed friction, with heights generally less than 0.1 - 0.2 m, and is thus essentially of no discernible significance with respect to the transport of sand either at Middle Banks or at the shoreline.
- The adjacent shoreline of Moreton Island is subject to northward movement of sand along the shoreline predominantly due to locally generated 'sea' waves.
- There is a long term natural trend of erosion at about 0.6 m/yr at and north from Cowan Cowan Point, as derived both in previous studies based on comparison of old charts and aerial photographs and in the present study based on analysis of aerial photographs. This erosion is predominantly wave induced due to a negative differential in longshore sand transport north from Cowan Cowan Point.
- The shoreline in the vicinity of Tangalooma Resort has been relatively stable over at least the past 50 or more years, except for some local changes due to impacts on wave propagation processes associated with placement of The Wrecks.
- Previous dredging at Middle Banks in the 1980s involved excavation of about 16 Mm^3 of sand from an area west of the East Channel, followed later by removal of about 2 Mm^3 from the southern end of East Channel[1].
- Surveys shows that the dredged bathymetry remains essentially unchanged in 2005 except for some inflow of sand at the northern end of the East Channel, smoothing of the dredged profile and ongoing migration of the margins of the southern Middle Banks lobe and the southern part of Ridge Shoal.

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[1] *Part of 4 Mm^3 estimated to be removed for the International Terminal development at Brisbane Airport in the early 1990s*

Impacts

- The impact assess modelling shows impacts consistent with the findings of the Moreton Bay Sand Extraction Study as follows:
    - No regional impacts on the hydrodynamics (water levels, currents, circulations) of Moreton Bay.
    - Only minor and local impacts on wave propagation, with essentially no impacts at the adjacent Moreton Island shoreline.
    - Local impacts on currents, with increases to the immediate north and south of the dredged footprint and decreases in adjacent areas to the east and west.
    - A substantial increase in the net sand transport southwards along the un-dredged part of the East Channel immediately south of the dredging footprint, with a commensurate increase in the flow of sand to the southern drop-over margin of the Middle Banks shoal along the alignment of the dredged footprint.
    - An increase of up to 10 - 12 percent in the southward net sand transport in the area north from the dredged area towards Cowan Cowan Point, reducing to about 5 - 6 percent in the vicinity of Cowan Cowan Point.
    - A decrease in sand transport in the dredged part of the East Channel and in the areas to the immediate east and west of the dredged area.
- No impacts on the processes or stability of the Moreton Island shoreline. The present wave dominated erosion trend at Cowan Cowan will continue in the future.
- The dredged footprint will most probably remain in its dredged configuration with only minor changes over the future longer term (decades).

3.1 Introduction

The existing environment of the Middle Banks region as it relates to the hydrodynamics and coastal processes of Moreton Bay are described in this Chapter. This outlines the morphological processes of the Bay bed, including Middle Banks, and the behaviour of the adjacent western shoreline of Moreton Island, together with their dependence on the fundamental hydrodynamic and wave processes within the Bay.

3.2 Proposed Development

The proposed development involves dredging of 15 Mm^3 of sand from Middle Banks for use in the NPR reclamation. Such removal will alter the bathymetry of the Middle Banks area by deepening some areas from existing depths at or below about -10 m down to depths of about -21 m LAT. This is similar to the exercise undertaken for the previous airport redevelopment in the early 1980s, for which comprehensive investigations of processes, potential effects and subsequent monitoring were carried out.

The effects of the proposed dredging in changing the bathymetry of the area will include some changes in the local hydrodynamics and morphological processes, particularly tidal currents, wave propagation and sand transport. The Moreton Bay Sand Extraction Study (WBM Oceanics Australia 2002, 2003, 2004) showed that these changes would be confined to the local Middle Banks area and have no impacts either regionally in Moreton Bay or on the shoreline of Moreton Island. Nevertheless, these potential impacts are again assessed in greater detail in this EIS/MDP, utilising more refined locally site-specific project design details and analysis procedures.

3.3 Methodology

Investigation of these processes has involved both research of existing information and further investigations including:

- Additional data collection and comprehensive modelling of wave, hydrodynamic and morphological processes to determine the nature and behaviour of currents and seabed sand transport at and near Middle Banks. The models used have been validated locally to data recorded in the immediate region as part of the present study.
- Assessment of the adjacent Moreton Island shoreline processes using analysis of aerial photography and beach profile surveys to identify historical and contemporary trends of shoreline change and dominant factors affecting shoreline stability.

The WBM hydrodynamic models used in previous investigations, including the Moreton Bay Sand Extraction Study (MBSES) (WBM Oceanics Australia 2003, 2004), have been substantially refined in local detail around Middle Banks for the present study, to incorporate a greater level of detail and computational refinement in the analyses undertaken. Extensive additional hydrographic survey and sub-bottom coring has been undertaken to ensure comprehensive definition of the existing conditions.

Investigations of significance relating to the previous sand extraction project in the 1980s associated with redevelopment of Brisbane Airport, in which some 16 Mm^3 of sand were dredged from Middle Banks, have been reviewed and include:

- Detailed hydrographic surveys of Middle Banks and adjacent Moreton Island shoreline.
- Investigations undertaken for impact assessment prior to the works, including investigation of Moreton Island shoreline processes and assessment of likely impacts of Middle Banks dredging.
- Monitoring during and after implementation of the works of the Moreton Island shoreline, sediment plumes, and waves near the site.

3.4 Limitations and Assumptions

The hydrodynamic and morphological processes of such a large tidal embayment system as Moreton Bay involve extremely complex interactions of ocean tidal forcing at a number of entrances to the Bay, gravity controlled tidal wave propagation, wind-induced current forcing and bed friction resistance to flows. These co-existing interactions can only be simulated dynamically through the application of modelling techniques that represent the physics involved.

Because of its large size, Moreton Bay cannot be modelled accurately in a physical model basin, due to the considerable scale effects involved. As well, the time and cost of such a model would be preclusive.

The numerical modelling approach offers considerable advantages over any other, in that:

- The essential physics defining the hydrodynamic characteristics involved can be represented mathematically through the well-known and proven equations of momentum (acceleration) and continuity to include all of the dominant factors such as:
    - Gravity driven water surface gradient forcing.
    - Momentum and inertia.
    - Bed friction.
    - Wind stresses on the water surface.
    - Coriolis force.
    - Where appropriate, incorporation of wave forces arising in the breaker zone creating currents and affecting sediment transport.
- The numerical model methodology facilitates interactive simulation of all of those factors in a dynamically coincident manner.
- Scale effects are avoided.
- Calibration and validation of the model against recorded data (water levels and flows) is undertaken to confirm that it is representing the hydrodynamics of the Bay accurately at the key locations of interest.

Nevertheless, such modelling has some limitations relating to the spatial size of the Bay and the refinement of the model mesh that can be used to represent it, as restricted by practical constraints of computer storage and computational speed. For the present project, the Bay is represented in two-dimensional (in plan) form such that the processes of current speed and boundary forcing are simulated as depth-averaged values rather than in vertically layered (three-dimensional) form. As such, to simulate bed friction and shear stress forces at the bed, the depth varying current characteristics are represented in terms of established relationships between the depth-averaged values and those immediately near the bed.

The numerical modelling applied to this project involves established conventional software and procedures that have been proven as accurate and reliable over many years. This has become increasingly so as computer power has increased, facilitating greater refinement of the models. As well, the use of the WBM finite element (RMA) modelling software provides a high degree of flexibility in the design of the model mesh to ensure good definition in those specific areas of particular interest or significance.

3.5 Baseline - Locality and Previous Dredging

3.5.1 Location of Middle Banks

The location and general morphological features of Middle Banks are shown in the context of the adjacent shoreline of Moreton Island in the satellite image **Photo 3.5a**. It can be seen that Middle Banks are separated from Moreton Island and the shallow nearshore banks and shoals (Ridge Shoal and Dring Bank) by the relatively deep East Channel. As such, there is no direct connection between Middle Banks and the adjacent shoreline of Moreton Island. The shallowest parts of Middle Banks are at approximately 4 m depth below the Lowest Astronomical Tide (LAT) in the area. East Channel is typically at about 20 m depth.

Photo 3.5a: Location of Middle Banks and Moreton Island.

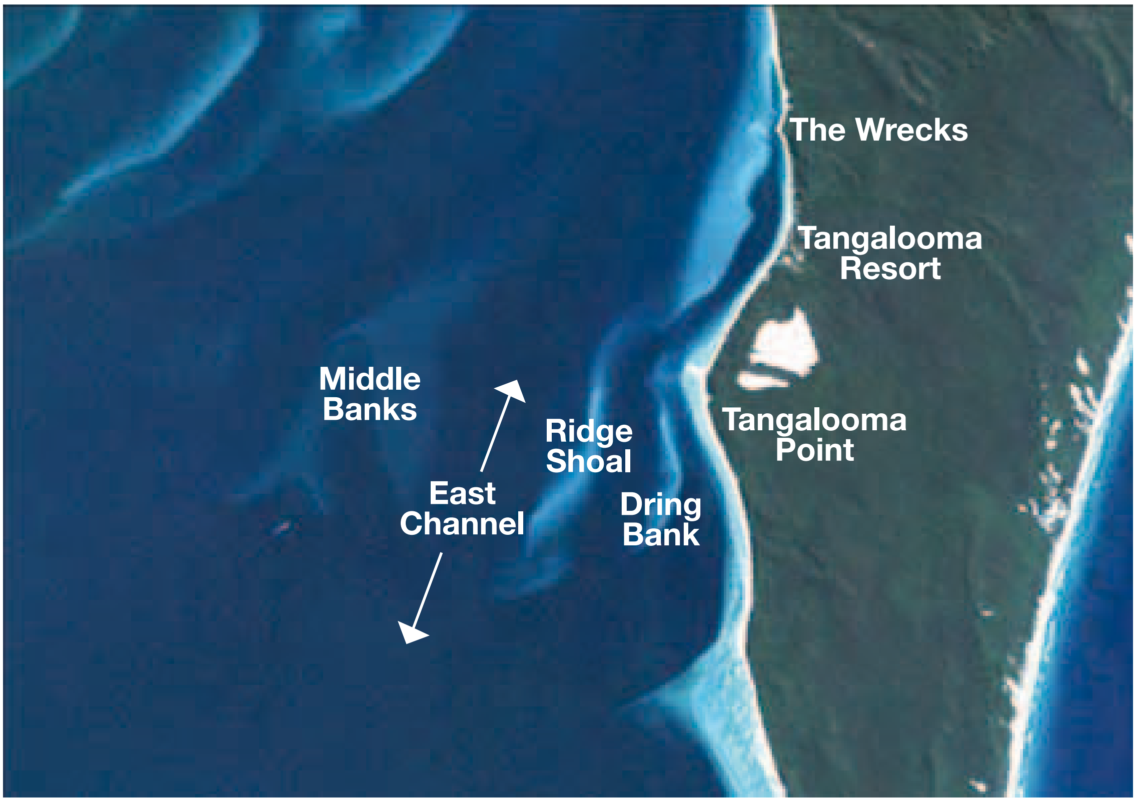
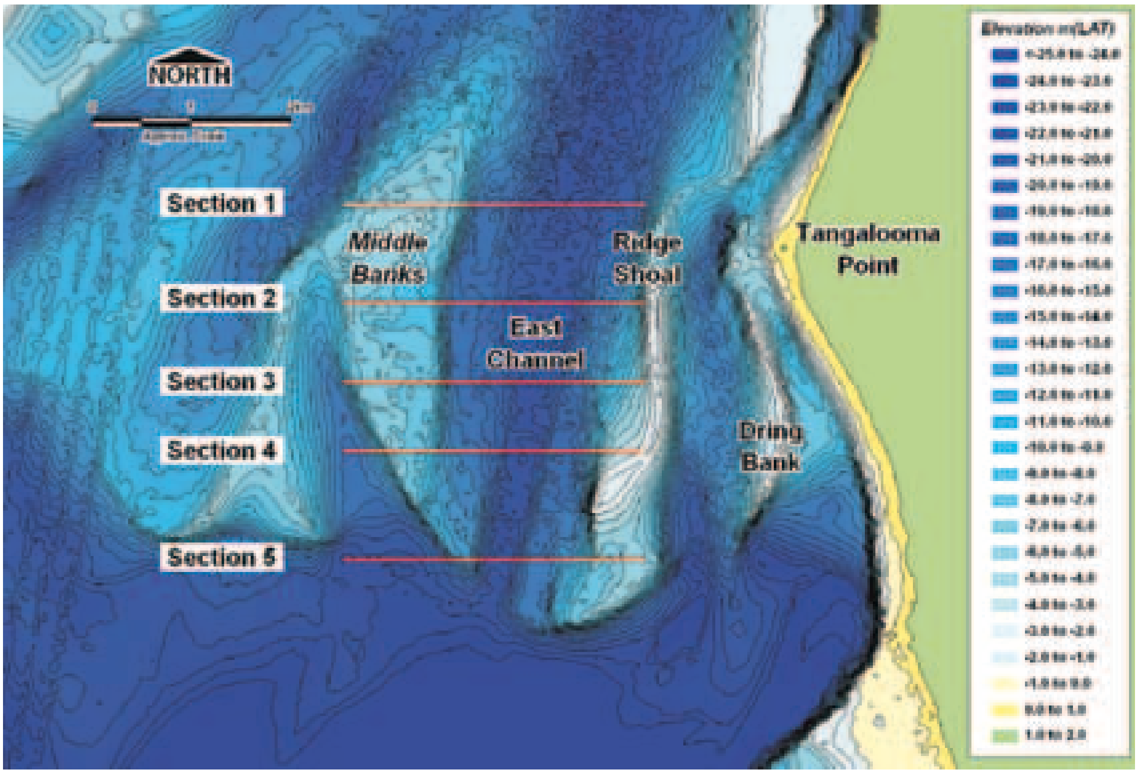


Figure 3.5a: *Middle Banks Bathymetry and Location of Survey Cross-Sections.*



3.5.2 Previous Dredging

Some uncertainty exists about details of the previous dredging of sand from Middle Banks and the response of the morphological processes following the works. Available documentation indicates that 14 Mm^3 were proposed to be dredged (Willoughby and Crabb 1983). Some limited survey data is available showing the pre-dredging and post dredging depths at July 1983, in the form of cross-section profiles. The cross-section locations are shown in **Figure 3.5a.** These have been analysed and are reproduced in re-plotted cross-section format in **Figure 3.5b** (dated December 1979 and July 1983). Indicative analysis of these surveys suggests removal of about 16 Mm^3 of sand to 1983. Additionally, there appears to have been subsequent removal of up to about 2 Mm^3 from the southern end of the East Channel (**Figure 3.5a,** Section 5).[2]

Also shown in **Figure 3.5b** are cross-sections derived from the recent 2005 survey, providing an indication of changes that may have occurred following the previous dredging. Of particular note in **Figure 3.5b** is that the 1983 dredged profile remains essentially intact today, although there has been some general smoothing out of irregularities and some minor infilling at the northern end of the East Channel and at the southern extremity of the main lobe of Middle Banks. There is evidence of some growth of the western slope of Ridge Shoal at its southern end, east of the limit of the dredging (**Figure 3.5a,** Sections 4 and 5). This is likely to be the continuation of the natural trend of long term development of the shoal by southward transport of sand in that area, not significantly influenced by the dredging.

The lack of infilling of the dredged area is not consistent with the finding of Harris et al (1992) based on their 1989 survey (not located in this study), as also reported in the MBSES, that suggests that the eastern fringe of Middle Banks (referred to as East Bank) at the western edge of the dredge footprint had infilled again rapidly over just six years following its dredging to depths up to 17 m. Nevertheless, the available survey data clearly shows that not to be the case, East Bank having been left largely un-dredged initially. The reason for this discrepancy is unclear, but may have resulted from comparison by Harris et al of the 1989 survey with the originally proposed dredging extent at the time, including batter slopes across the East Bank part of Middle Banks that were neither actually dredged nor slumped to the batter slope indicated in the original dredge footprint design.

Additionally, there are three currently licensed sand extraction operations over Middle Banks. These are located on the shallower parts of the sand shoals as shown in **Figure 3.5c** and extraction typically takes place in water depths of approximately 5 m. Licence details are:

LOCATION	LICENSEE	QUANTITY
Area F: SW Region	Marine Contracting Pty Ltd	20,000 m^3/yr
Area J: Central Region	Boral	40,000 m^3/yr
Area K: Northern Region	Boral	75,000 m^3/yr

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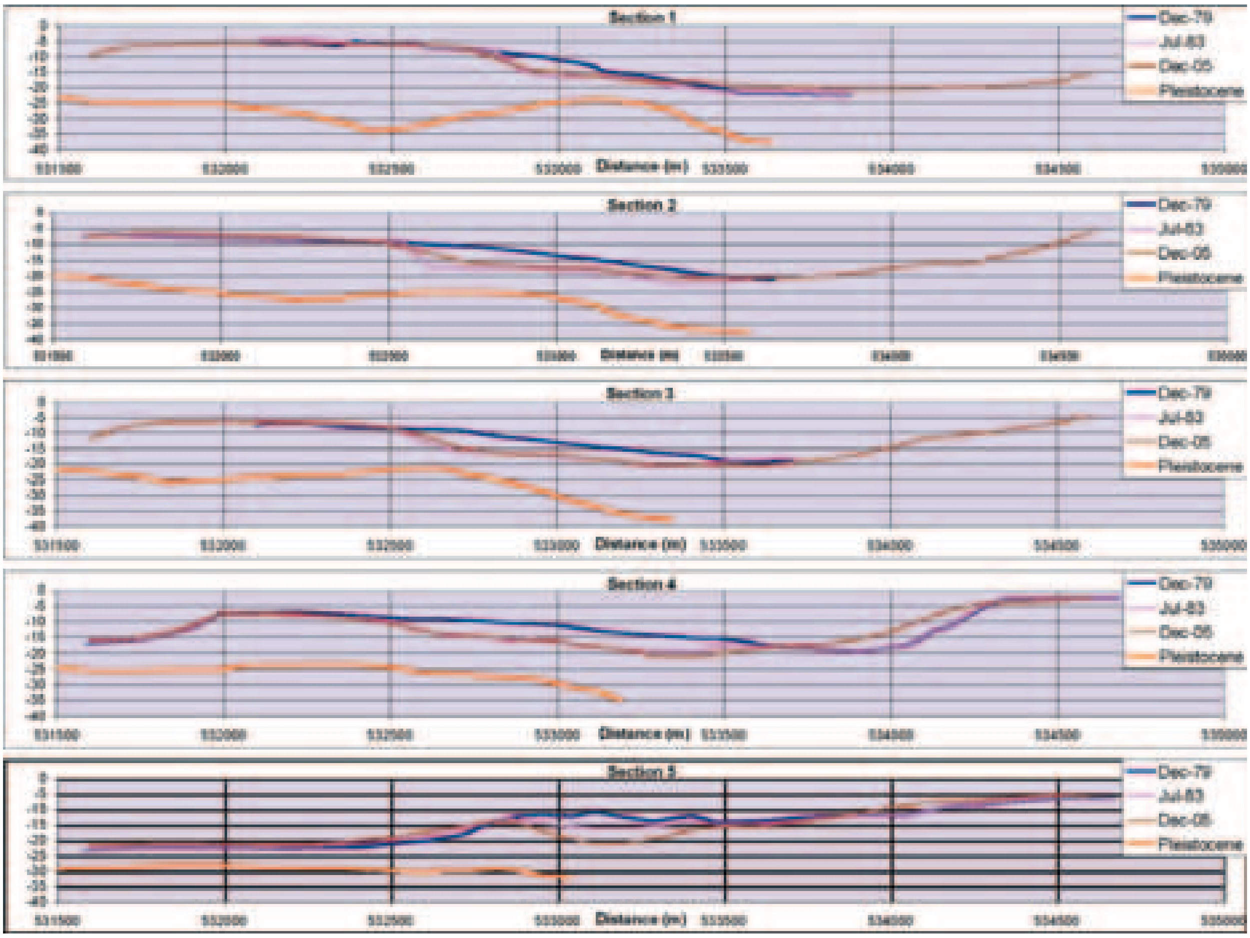
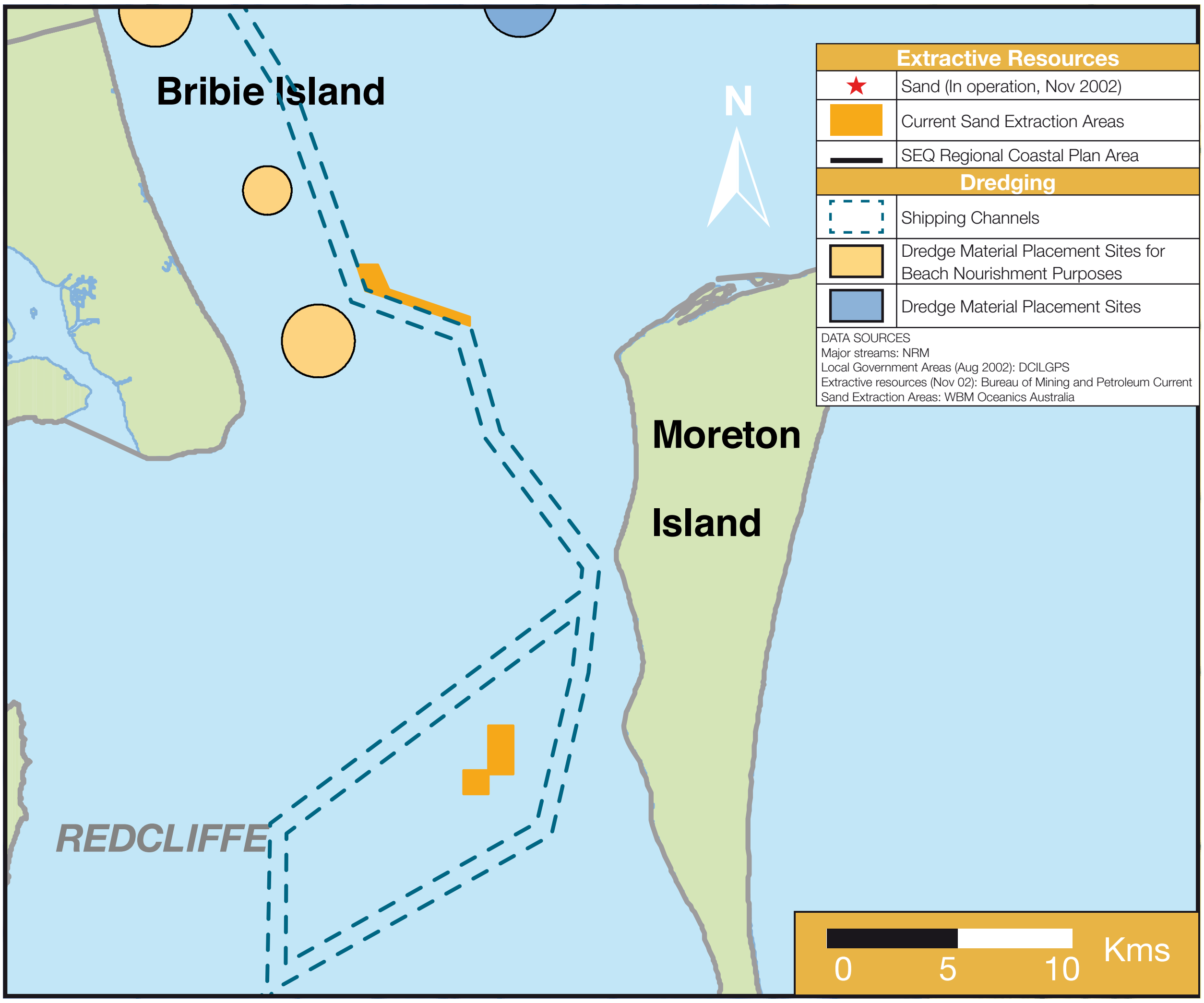
[2] *Part of 4 Mm^3 estimated to be removed for the International Terminal development at Brisbane Airport in the early 1990s.*

Figure 3.5b: *Cross-section Surveys of Previous Dredging and Present Bathymetry.*



Note: The scale in these plots is distorted to exaggerate the vertical dimension. The actual bed slopes are less than those as they appear in these plots.

Figure 3.5c: *Location of Middle Banks Sand Extraction Licenses.*



DATA SOURCES
Major streams: NRM
Local Government Areas (Aug 2002): DCILGPS
Extractive resources (Nov 02): Bureau of Mining and Petroleum Current
Sand Extraction Areas: WBM Oceanics Australia

3.5.3 Geological Context

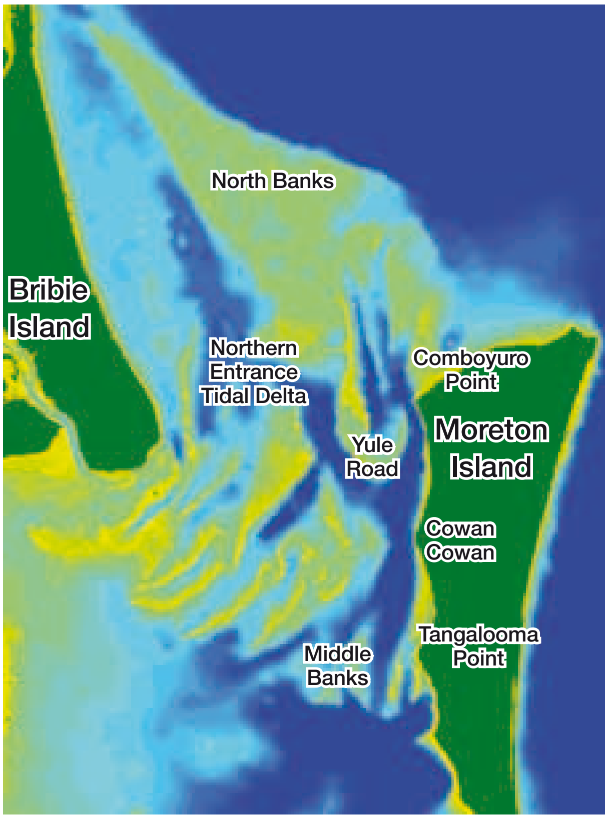
The nature and behaviour of the morphological processes of Moreton Bay are determined by both their geological evolutionary development and the present day dominant forces of tidal currents and ocean waves. The sand banks of the entire Northern Entrance Tidal Delta (**Figure 3.5d**) area contain about 4,000 Mm^3 of marine sand (Stephens 1992). They have been formed over the longer geological Holocene and Pleistocene timeframe, most particularly during the past 6,000 to 7,000 years of the Holocene period with the input of open ocean beach 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 dredging of 15 Mm^3 from Middle Banks 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 there from the coastal longshore transport of sand

Figure 3.5d: *Northern Entrance Tidal Delta Sand Shoals.*



along the eastern 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 Moreton Bay 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 natural erosion of former Holocene accretion deposits along the western shoreline from Comboyuro Point south to at least Cowan Cowan. This pattern is likely to relate, at least in part, to the southward growth of the Yule Road shoals and its effects in directing strong tidal currents close to the shore, in conjunction with wave effects in moving sand along the shoreline.

3.6 Basline - Tidal Hydraulics

There is presently an extensive body of knowledge of the tidal processes occurring within Moreton Bay. Considerable previous research and investigation work involving field measurements and numerical (computer) modelling of the tidal hydrodynamics (water levels and currents) have been undertaken (for example Queensland Transport 2004, Church 1979, Milford and Church 1976, Newell 1971, Patterson and Witt 1993, WBM Oceanics Australia 2002, WBM Oceanics Australia 2003). The key findings of these investigations can be summarised as set out below.

3.6.1 Tidal Propagation

The ocean tide penetrates into the Moreton Bay-Broadwater system through the four separate entrances of the Northern Entrance Tidal Delta, South Passage, Jumpinpin and the Gold Coast Seaway. Whereas the tidal processes in the southern Bay and northern Broadwater areas are complex due to the interaction of these entrances, tidal propagation and the associated tidal currents in northern Moreton Bay and at Middle Banks are aligned predominantly north-south and dominated by flow through the Northern Entrance Tidal Delta. This dominant north-south Moreton Bay tidal incursion extends southwards to beyond the southern end of Russell Island. Some additional flow occurs through South Passage.

Thus, the Northern Entrance Tidal Delta sand shoals are subject to strong north-south oriented tidal currents together with a combination of ocean swell waves, more so in the northern areas, and locally generated sea waves. The wave and current forces are sufficient to cause significant transport of the surface layer of the sand shoals of the Northern Entrance Tidal Delta, which is constantly changing in response to the hydrodynamic processes, with mobile bed forms (dunes and major ebb/flood delta formations at local and sub-regional scales).

3.6.2 Tide Levels

The dominant processes affecting water levels in the Bay region relate to:

- Astronomical tides.
- Storm surges associated with cyclones and low pressure systems.
- Wind stresses.
- Sea level rise associated with climate change.

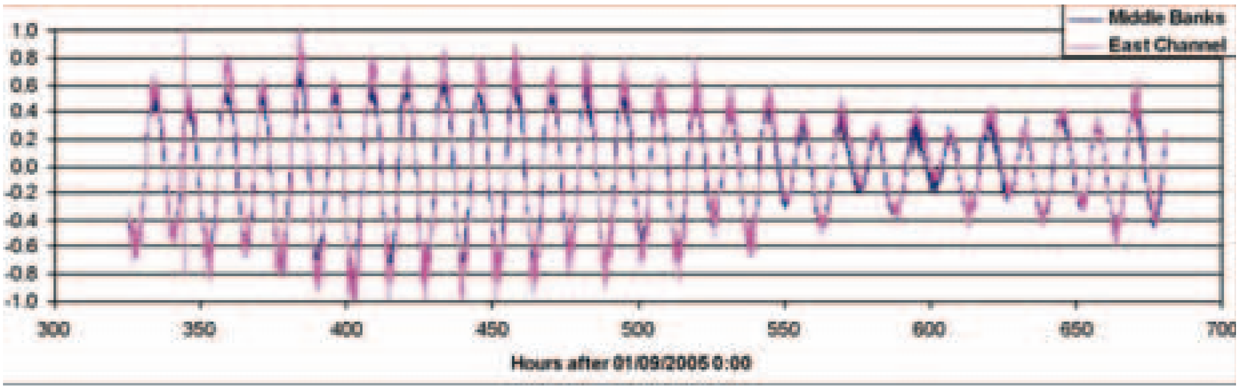
Astronomical tide levels for various sites in the Moreton Bay region are typically as shown in **Table 3.6a** (Queensland Transport 2004).

There is an amplification of the ocean tide in Moreton Bay. At the West Inner Bar tide recording site, the average amplification compared to Caloundra is about 30 percent, while at Redland Bay it is greater, at about 40 percent. South from Russell Island, the Bay tides interact with the inflow from Jumpinpin and the Broadwater in a complex way. Tidal amplitudes inside the Jumpinpin entrance are attenuated compared with those in the ocean, particularly the low tides, with a range there of about 85 percent of that in the ocean and only 60 percent of that at Redland Bay.

Table 3.6a: Moreton Bay Tides – Level Above LAT Datum.

Location	MHWS	MLWS	Mean Spring Range (M)	Time Difference relative to Brisbane Bar	
				High	Low
Caloundra	1.62	0.26	1.36	-1:30	-1:40
NW Channel	1.62	0.26	1.36	-1:30	-1:40
Tangalooma	1.99	0.32	1.67	-0:30	-0:40
Woorim	1.71	0.28	1.43	-0:22	-0:34
Bongaree	1.86	0.30	1.56	0:00	-0:15
East Channel	2.05	0.33	1.72	-0:09	-0:13
Redcliffe	2.07	0.34	1.73	0:00	0:00
West Inner Bar	2.16	0.35	1.81	0:00	0:00
Dunwich	2.20	0.36	1.84	+0:10	+0:17
Redland Bay	2.35	0.38	1.97	+0:30	+0:45
Russell Island	2.29	0.37	1.92	+0.31	+0:42

Figure 3.6a: *Recorded Current Speeds at Middle Banks (flood tide +ve).*



3.6.3 Tidal Currents

Consistent with the pattern of tidal propagation into Moreton Bay, the dominant tidal currents flow in the north-south direction across the Northern Entrance Tidal Delta shoals and extend southward through the Bay to beyond Russell Island. There is also tidal exchange through South Passage via Rainbow and Rous Channels.

Thus, the majority of the tidal flow into the Bay occurs through the channels and across the sand shoals of the Northern Entrance Tidal Delta. Peak tidal current speeds in that area are noted to be commonly in the range 0.5-1.0 m/s. Such currents are sufficient to cause extensive mobility of the shoal sands, particularly in conjunction with wave action in that area, resulting in significant frictional resistance to tidal flow. In that regard, the Northern Entrance Tidal Delta shoals have a major controlling influence on the tidal regime and flushing/exchange processes within the Bay.

In the central and southern parts of the Bay, current speeds are generally lower in the deeper areas but greater in shallower and/or more constricted areas nearshore and around islands and shoals. The tidal current patterns may be altered by winds over the Bay, particularly in shallower regions of the western embayments.

Tidal currents have been recorded at Middle Banks as part of the present investigations. Recorders were installed during September 2005 at three sites: Middle Banks, East Channel and between Ridge Shoal and Dring Bank **(Photo 3.5a)**. Unfortunately, the recorder at Ridge Shoal was interfered with such that the mooring system became entangled and the recorder was shifted at least 600 m out of position. The data from that recorder has not been used. In addition, high current speeds encountered during the recording period resulted in a minor correction being applied to the recorded values based on the slight shift in relative depth in the water column associated with tilting of the mooring.

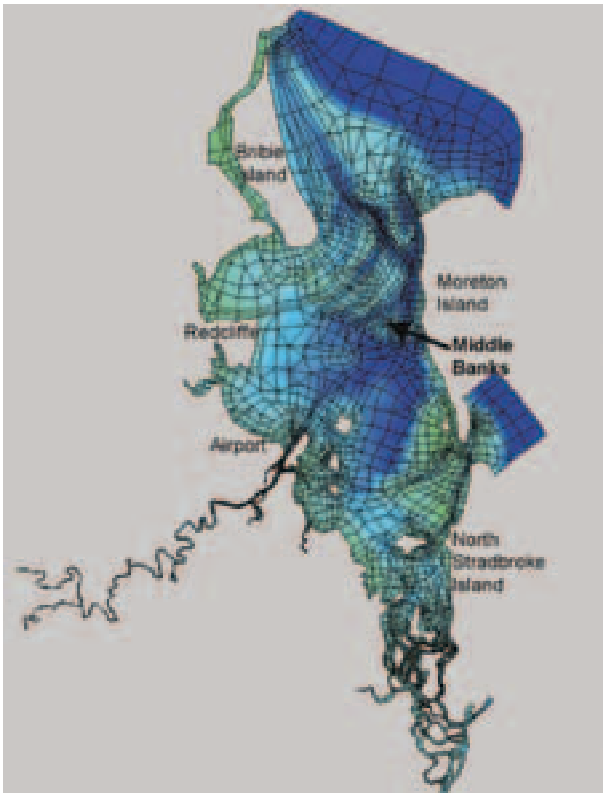
The recorded current speeds at Middle Banks and East Channel are shown in **Figure 3.6a** and indicate peak spring tide current speeds of 0.8 - 1.0 m^3/s, with some asymmetry such that the flood tide currents (-ve) are somewhat stronger than those for the ebb tide (+ve). This results in the net southward movement of sand in this region.

3.7 Baseline - Storm Surges and Storm Tides

Abnormally high water levels associated with storm surges together with the astronomical tide (storm tides) affect the eastern side of Moreton Bay in the Middle Banks area primarily through propagation of the ocean storm tide into the Bay through the northern entrance, much as the normal tide does. As such, it will amplify and reach higher levels than those in the ocean. However, the waters of the eastern Bay will not experience local wind setup at the peak of the storm surge, as the wind direction will be predominantly from the east to southeast sector, causing water level setup along the western shore and a possible set-down at the eastern side.

Apart from possible increases in currents and increased water level impacts at the Moreton Island shoreline during such event, storm tides are of little significance at Middle Banks. Further discussion

Figure 3.7a: *RMA Moreton Bay Model Mesh Detail.*



of storm surges and storm tides in the Bay is presented in relation to the Airport and Surrounds section of this report.

3.8 Baseline - Modelling of Existing Hydrodynamic and Morphological Processes

3.8.1 RMA Hydrodynamic and Morphological Model Framework

The existing models of Moreton Bay, used for previous studies, include the RMA finite element hydrodynamic model and the SWAN wave propagation model. The RMA model had been upgraded to incorporate the most up-to-date bathymetry data for the Sand Extraction Study (WBM Oceanics Australia 2004).

For this study, the model grid mesh has been refined to best suit the bathymetric detail at Middle Banks and adjacent areas. This has facilitated more refined representation of the bathymetry in a number of key areas and incorporated updated survey from BAC of the Middle Banks, the East Channel, Ridge Shoal, Dring Bank and the shoals and channels adjacent to Moreton Island. The revised mesh, as shown in **Figure 3.8a**, has been used in conjunction with the RMA10S hydrodynamic and morphological modeling module, providing for the dynamically combined effects of.

- Water levels.
- Tide and wind driven currents.
- Wave influences as imported from the SWAN wave modelling module.
- Sediment transport due to combined effects of waves and currents.
- Morphological seabed evolution.

Modelling of tidal propagation into the Bay over the neap/spring tide range was used to simulate the hydrodynamics of the whole Bay, extending from the Northern Entrance Tidal Delta south through the southern Bay region to the Gold Coast Broadwater, incorporating the ocean connections at South Passage and Jumpinpin. The variable resolution facilitated via the finite element modelling framework provided for representation of the hydrodynamic behaviour at Middle Banks in very high model mesh resolution and relatively less in other areas.

3.8.2 Hydrodynamic Model Verification

The model used in the present investigation has been established and progressively refined and upgraded over several years. It has been calibrated and verified previously against a range of measured data to confirm its suitability as an assessment tool for various previous investigations (eg WBM 2001).

For the present application, representation of the characteristics of the Middle Banks region is of particular relevance. As such, the bathymetry and model grid mesh resolution there have been reviewed and refined on the basis of very detailed new survey of the area undertaken as part of the present studies (MHS 2006). Further validation of the model's capability to simulate the hydrodynamic processes of the Bay generally and in the Middle Banks area specifically has been undertaken.

In principle, given that the bathymetry of the Bay is accurately represented in the model, based on all available detailed charts of each section of the Bay, the flow into the Bay through the entrance(s) will be correctly modeled if the water levels within the bay are accurately reproduced. Further, correct simulation of the recorded currents in the Middle Banks area will confirm that the distribution of the flow is appropriate.

Accurate simulation of water levels is particularly relevant for Moreton Bay in view of the amplification of the tide from north to south. Bed friction is the dominant factor controlling the flow into the Bay, particularly in the Northern Entrance Tidal Delta region where the current speeds are relatively high. Thus, if the bed friction settings there are correct, the amount of water flowing into the Bay, as reflected in the variation in water levels from low to high tide (the tidal range) will be correct.
If the friction is too high or too low, the tide ranges within the Bay will be too low or too high respectively.

It has been found that some spatial variation of bed friction in different parts of the Northern Entrance is necessary to achieve model validation to both water levels and currents. This most probably relates to

Figure 3.8b: *Modelled and Recorded Tide Levels at Brisbane Bar.*

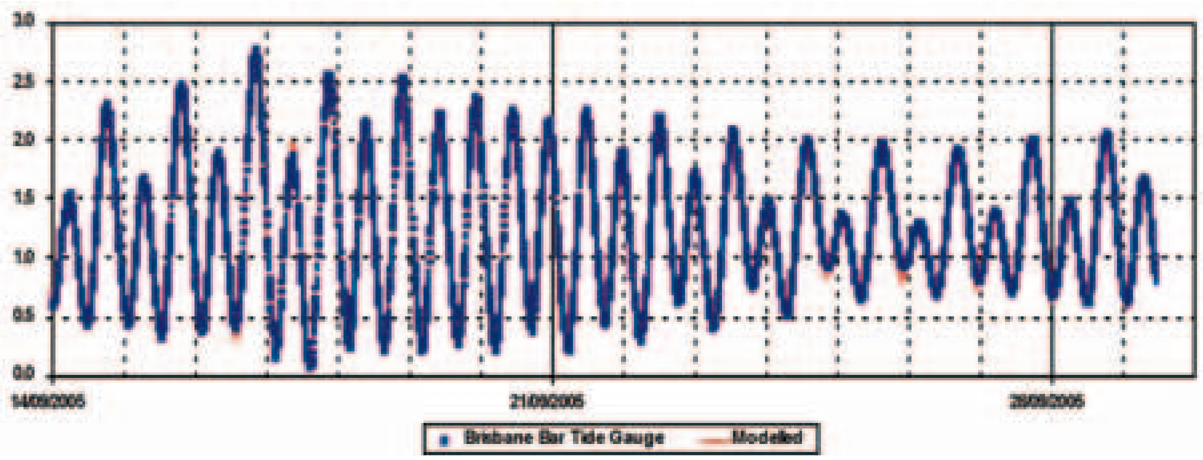
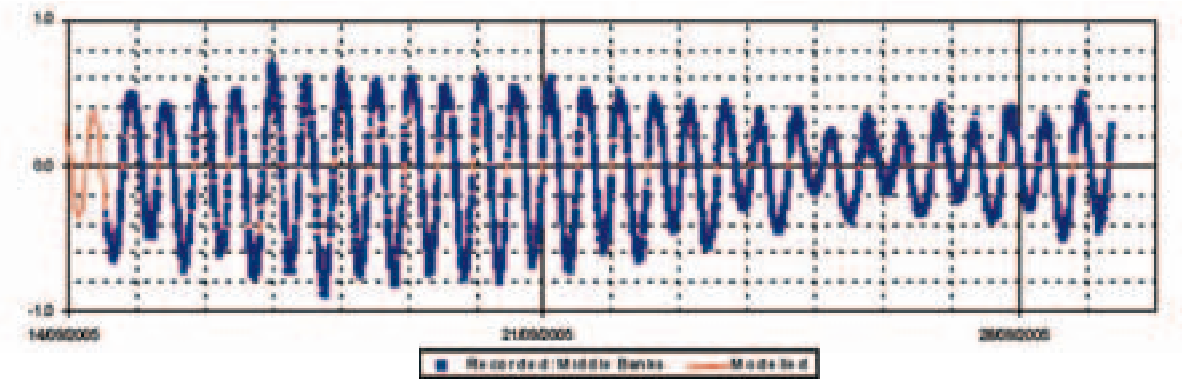


Figure 3.8c: *Modelled and Recorded Currents at Site 1 - Middle Banks.*



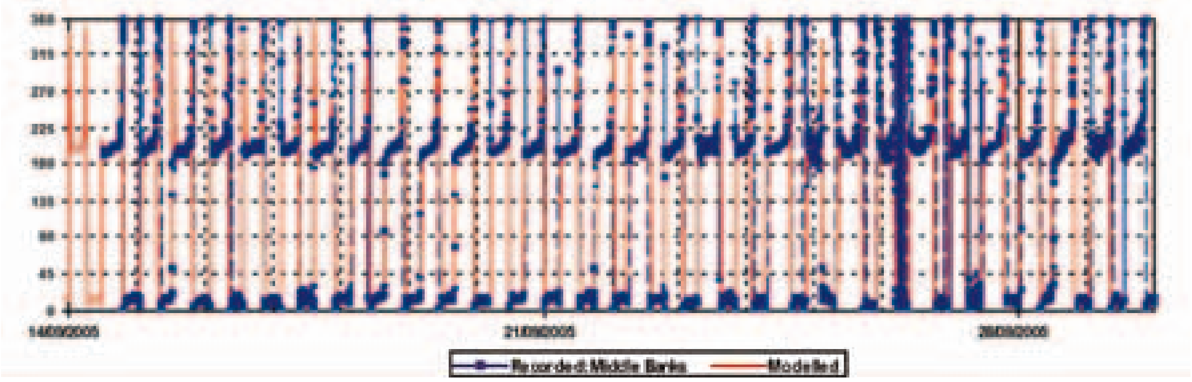
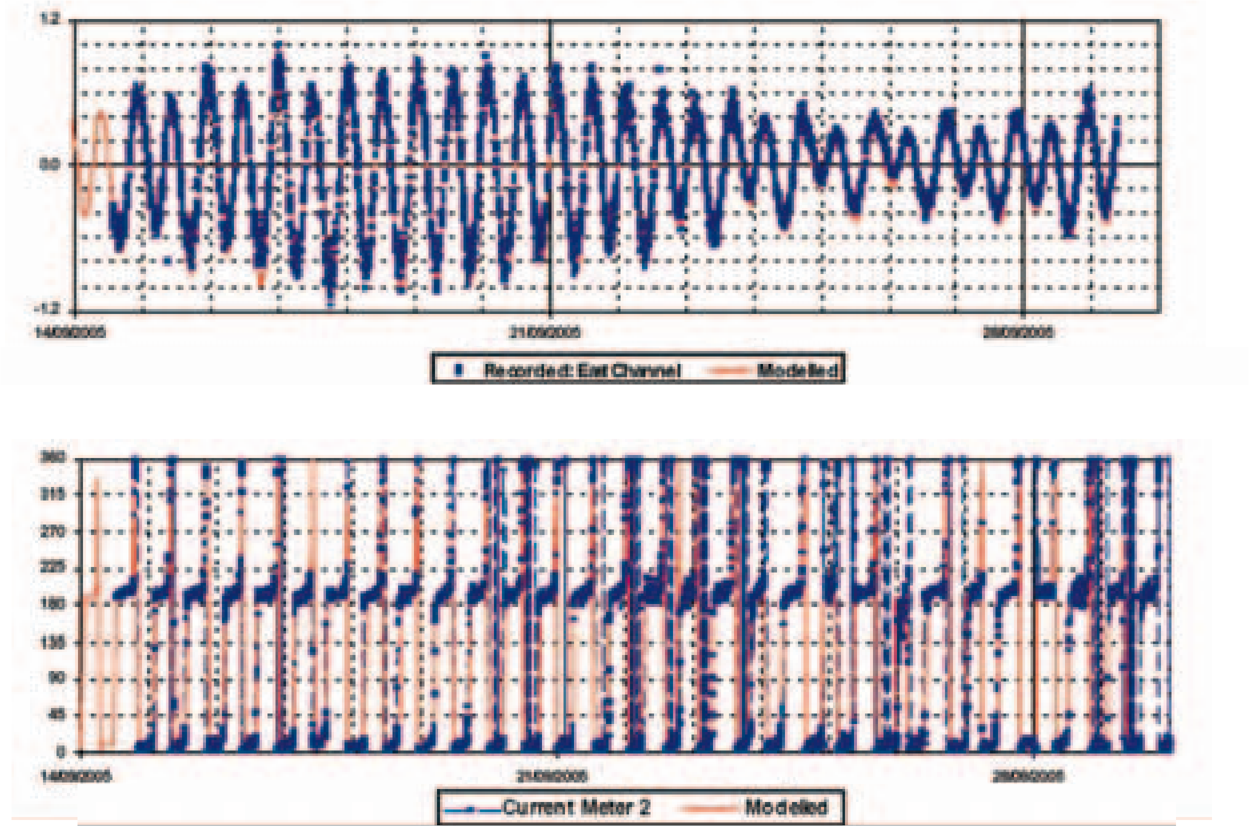


__Figure 3.5d:__ Modelled and Recorded Currents at Site 2 – East Channel.



the spatial differences in bed form, in which relatively large asymmetric dunes exist in some parts of the deep East and North West Channels whereas vast expanses of the shallower sand banks have smaller bed forms, as evidenced in the video surveys undertaken for this project.

Sensitivity testing of the bed friction calibration has been undertaken in the context of matching the model and measured values of:

- Mean spring tide range values at various locations around the Bay.
- Time series over a neap/spring cycle of the tide at the Brisbane Bar (standard port location) as measured during September 2005, giving the correct amplification of the ocean tide and phasing of the tidal wave propagation into the Bay.
- Currents at Middle Banks over a neap/spring tide cycle as measured in September 2005.

A range of Mannings 'n' bed friction values within the expansive sand banks and deeper channels were assessed, noting that an average value of 0.022 had been derived previously (WBM Oceanics Australia 2003). This analysis shows that, following all refinements of bathymetry and model grid mesh detail, the appropriate Manning values are 0.020 over the shallower sand shoals and 0.027 along the East Channel and other channels where large dune bed forms are present.

The water levels through the Bay are accurately reproduced, as shown for the Brisbane Bar in **Figure 3.8b**, indicating that the flow through the entrances, particularly the Northern Entrance Tidal Delta, is reliably simulated. As well, validation of the modelled currents against those measured at Middle Banks and East Channel in September 2005 is good, as shown in **Figure 3.8c** and **Figure 3.8d**.

Figure 3.8e: *Flood Tide Current Pattern.*

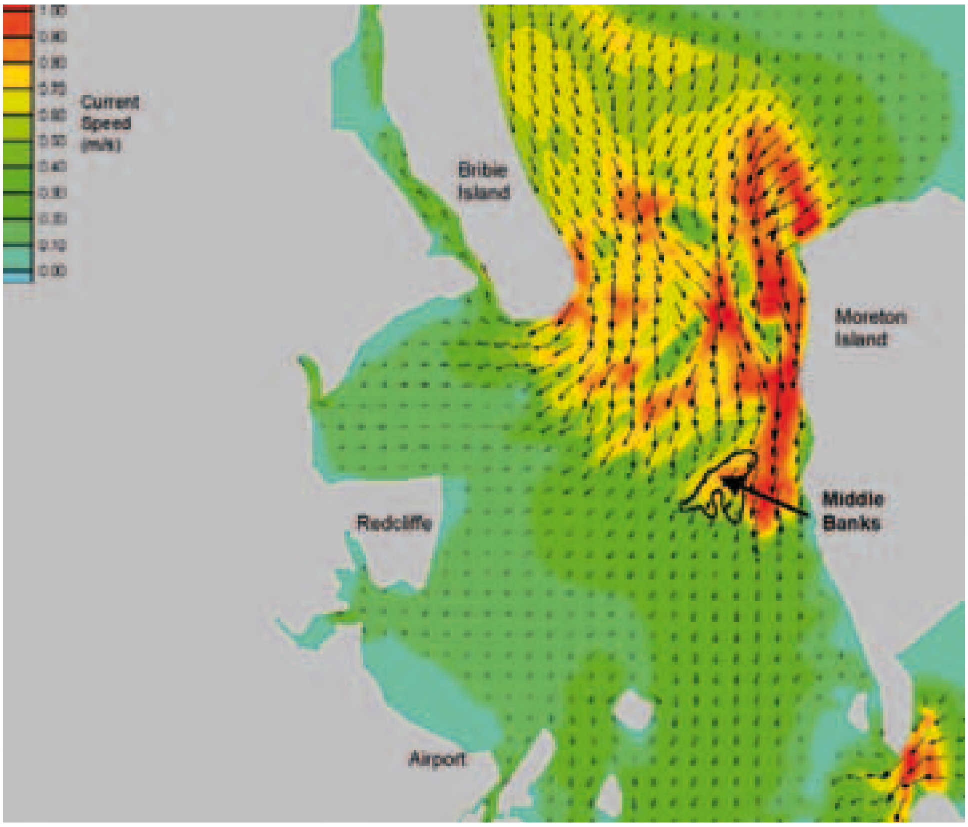
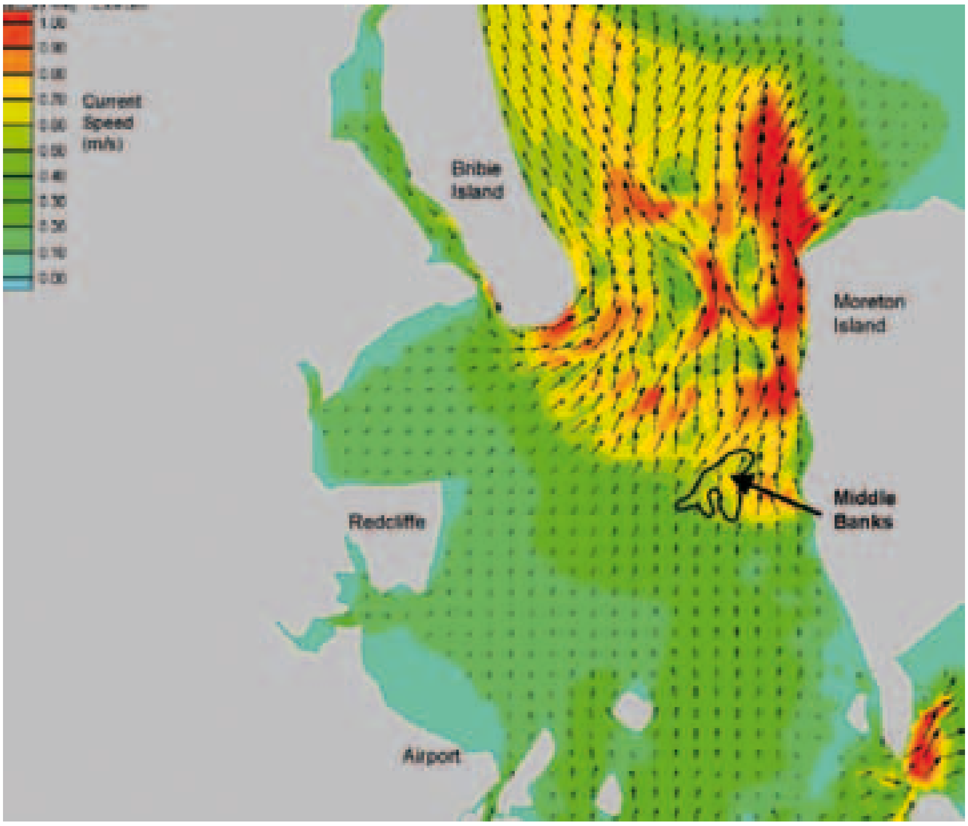


Figure 3.8f: *Ebb Tide Current Pattern.*



3.8.3 Modelled Current Patterns

The model has been used to identify the regional and local patterns of currents in the Bay as a whole and at Middle Banks. Typical flood tide and ebb tide currents for a spring tide are shown in **Figure 3.8e** and **Figure 3.8f** respectively. Typically, the peak flood tide current speed at the Middle Banks area is greater than that for the ebb tide, reaching up to about 1 m/s in some parts of the channel. The current is focussed predominantly within the East Channel and impinges close to the shoreline at and north from Cowan Cowan Point. It remains some distance offshore at Tangalooma.

3.9. Baseline - Wave Climate

3.9.1 General Considerations

Moreton Bay is largely sheltered from the southern ocean 'swell' waves by North Stradbroke and Moreton Islands. Only the more northerly parts of the Northern Entrance Tidal Delta are exposed to substantial ocean wave energy. The ocean waves penetrating to Moreton Bay and its adjacent shorelines are substantially attenuated by the processes of refraction, diffraction, bed friction and breaking across the Northern Entrance Tidal Delta shoals at the Bay entrance.

Wave action in the Bay thus includes the influences of both attenuated ocean swell and local wind-generated sea waves. The nature of these influences depends uniquely on location in the Bay and prevailing wind and weather conditions. Ocean swell waves have greater effect towards the northern areas, most particularly across the Northern Entrance Tidal Delta shoals. The shorelines of the Bay are generally most affected by the locally generated 'sea' waves. Accordingly, within the Bay itself, the dominant wave is relatively low, short period 'sea' generated by local winds.

In the Northern Entrance Tidal Delta area, where the proposed dredging is to occur, both ocean swell and local sea waves have an influence on the mobility and transport of sand shoals and the behaviour of sandy shoreline beaches. Thus, ocean swell may dominate in coastal areas of Bribie Island and adjacent to Comboyuro Point, as well as over the expansive outer banks of the Northern Entrance Tidal Delta.

Most knowledge of the wave climate within Moreton Bay has been derived from observation and calculations of wave conditions by hindcasting techniques based on winds in the region. However, wave recording was undertaken to the north of Comboyuro Point during 1980-84 (Lawson and Treloar 1985) and there is some systematically recorded wave data within the Bay (refer WBM Oceanics, 2002). Two wave recording stations, operated by EPA, have been located adjacent to the area of this study. These are:

- Woorim – 200 m offshore from Woorim Beach – 24-09-1988 to 15-8-2003.
- Moreton Bay – 8.7 km NE of Redcliffe – 19-10-2000 to date.

3.9.2 Regional Ocean Waves

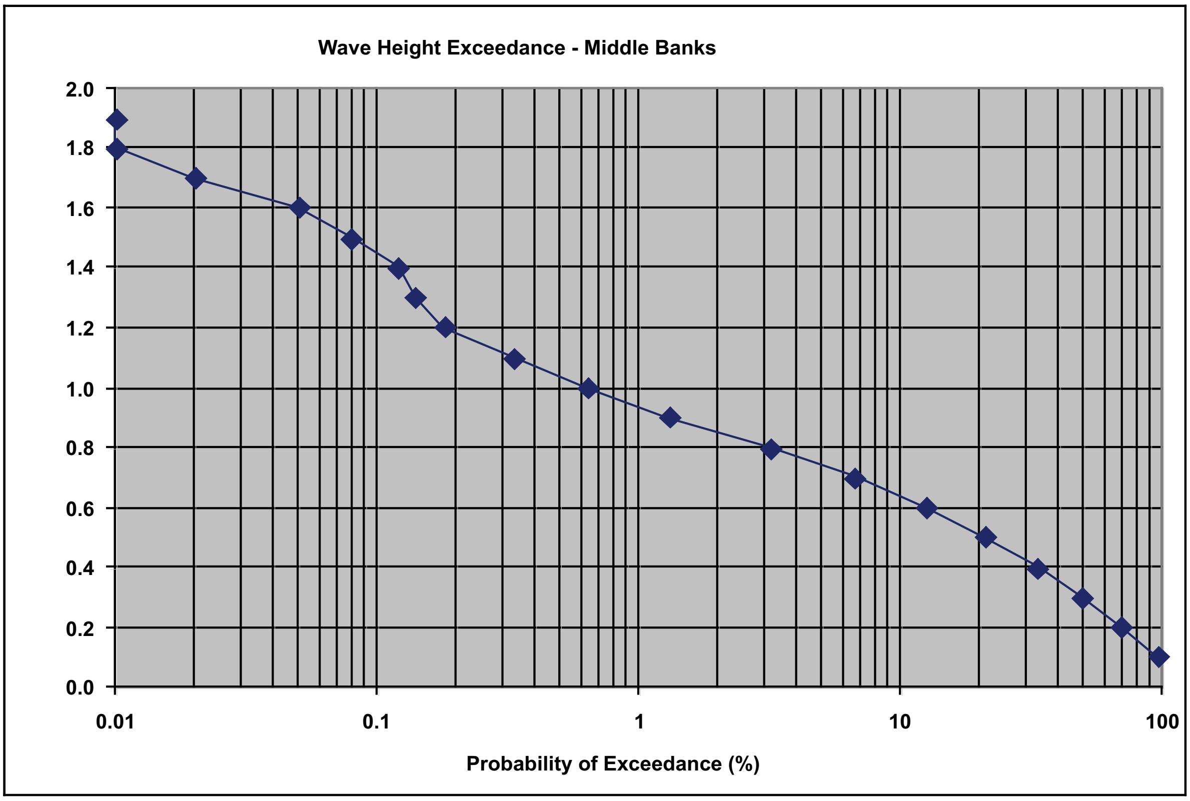
The South East Queensland open ocean coastal region is subject to persistent and sometimes high energy prevailing wave climate. Previous studies have shown that:

- The ocean wave climate in the region to the east of Moreton Island is of moderate to high energy, with median significant height about 1.3 m and higher cyclone-related heights ranging up to 6 - 8 m.
- Both longer period (8 to 15 seconds) swell and shorter period (5 to 7 seconds) sea are common and, at times, may co-exist, sometimes with quite different directions.
- The ocean waves are predominantly from the south-east direction sector, with essentially all longer period swell from directions in the range east-north-east to south-south-east.
- Higher cyclone waves occur from a relatively narrow directional range, predominantly around east-north-east to east-south-east.
- North to north-east sector waves are seasonal, predominantly during spring through summer, and are generated by winds in the immediate region. They are typically of lower height and shorter period than the general south-east sector ocean waves.

Table 3.9a: Wave Height versus Wave Period for Middle Banks.

Wave Ht (Hs m)	Percentage Occurrence for Height-Period Combinations Shown														
	Spectral Peak Period (sec)														
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15
0.0-0.1		0.97	0.77	0.54	1.12	0.45	0.13	0.10	0.06	0.11	0.11	0.13	0.19	0.03	0.04
0.1-0.2		4.78	9.09	5.45	4.33	0.77	0.35	0.12	0.12	0.19	0.09	0.14	0.01	0.01	
0.2-0.3		1.44	13.04	4.34	2.01	0.26	0.02	0.01							
0.3-0.4		0.19	8.39	5.96	0.65	0.07	0.02			0.01					
0.4-0.5			3.22	8.48	0.60	0.02									
0.5-0.6			0.32	7.37	0.76	0.01									
0.6-0.7				4.52	1.35										
0.7-0.8				2.19	1.33	0.01									
0.8-0.9				0.61	1.27										
0.9-1.0				0.02	0.62	0.01									
1.0-1.1					0.30	0.01									
1.1-1.2					0.15										
1.2-1.3					0.03	0.02									
1.3-1.4						0.02									
1.4-1.5					0.02	0.02									
1.5-1.6						0.02									
1.6-1.7					0.01	0.02									
1.7-1.8						0.01									
1.8-1.9															
1.9-2.0						0.01									

__Figure 3.9a:__ Significant Wave Height Exceedance Probabilities for Middle Banks.



Thus, the majority of swell waves must propagate around the prominent headlands of Point Lookout and Cape Moreton in order to approach the Moreton Bay entrances at South Passage and the Northern Entrance Tidal Delta. They are reduced substantially in height in the process. They are attenuated further in entering the Bay across the relatively shallow and complex delta sand shoals and are typically of low height within the Bay itself. However, the north to northeast sector ocean waves have direct access to the Northern Entrance Tidal Delta and may propagate directly into the Bay, particularly at higher tide levels. Thus, the influence of ocean waves on the Bay, its shoreline and delta shoals depends intimately on the prevailing seasonal wind and weather conditions.

The EPA has operated a wave recording station near Point Lookout (named the Brisbane station - about 10 km ENE of Point Lookout) from 1976 to date and has reported on extreme wave conditions in South East Queensland (Allen and Callaghan, 2000).

3.9.3 Waves at Middle Banks

Most of Moreton Bay and the inner shoals of the Northern Entrance Tidal Delta are dominated by waves generated within the Bay itself by local winds. The available fetch lengths and depths are limited and restrict the wave heights and periods substantially compared with those in the ocean.

Comprehensive wave recording was undertaken at Middle Banks during the period October 1980 to October 1984 as part of monitoring of the previous dredging of Middle Banks (Lawson and Treloar 1985). Significant wave height (Hs) versus the spectral peak wave period (Tp) data are shown **Table 3.9a**. Significant wave height exceedance probabilities are shown in **Figure 3.9a**.

These data show that the waves are dominated by locally generated ‘sea’, with significant wave heights and spectral peak periods rarely exceeding 1.1-1.2 m and 5-6 seconds respectively. The height and direction of these locally generated sea waves are determined directly by the prevailing winds and are highly seasonal in nature. There is often also a substantial diurnal variability associated with the land/sea breeze effect that extends some distance across the Bay. Because of the relatively restricted fetch lengths, these sea waves develop quickly with the onset of stronger local winds, but also diminish rapidly as the winds ease. Thus, different parts of the Bay are subjected to higher or lower wave energy at different times of the year, with substantial daily variability.

The waves of longer period greater than 7 seconds evident in **Table 3.9a** are residual ocean swell and are almost exclusively less than 0.2 m in height at Middle Banks. The propagation direction of such swell would be uniformly from the north towards the south. The energy in the swell relative to that of the sea waves and the currents in the area is negligible in terms of affecting sand transport and shoreline processes. Further reduction in the swell wave heights occurs due to refraction towards the Moreton Island shoreline. As such, the swell can essentially be disregarded with respect to the present assessments of morphological and shoreline processes.

3.9.4 Wave Propagation Modelling

A wave generation and propagation model of the study area has been developed using the SWAN model. SWAN is a phase-averaged, spectral wave model developed at Delft University of Technology (Booij et al., 1999). Its modelling capabilities include;

- Wave shoaling and refraction.
- Wave/current interaction.
- Wave generation by wind.
- Wave energy dissipation by whitecapping, depth-induced wave breaking and bottom friction.
- Non-linear wave-wave interactions (quadruplets and triads) which cause an internal re-distribution of wave energy between different frequencies.

The model can be run in first, second or third-generation mode. These modes refer to the level of physics incorporated into the model capabilities.

The model bathymetry has been developed from a WBM Digital Elevation Model of Moreton Bay that is largely based on navigation chart data.

The numerical wave model incorporates swell wave propagation, generation and growth of sea waves due to local winds, dissipation processes of bottom friction and breaking and shoaling and refraction as affected by the shallower areas. The wave model software used is the SWAN package from Delft Hydraulics. In this model the waves are described with a two-dimensional energy density spectrum which gives reliable results in non-linear situations such as wave breaking. Thus, SWAN can reliably represent the physical wave transformation processes occurring within the study area and has been successfully used for many previous wave generation and propagation studies worldwide as well as in Moreton Bay.

The SWAN model allows for the selection of several parameters that can influence the processes of wave growth and decay. Conventionally used calibration parameter values have been adopted. Most of these parameters have default settings, based on experience in similar situations, and these have been used unless otherwise noted.

3.9.5 Model Parameters

For this study, the water levels, shape of the wave spectra and the representation of bottom friction effects are the most important considerations and these are described below.

3.9.5.1 Tidal Variation

Sensitivity runs carried out over the full range of water levels for the Sand Extraction Study (WBM Oceanics Australia 2002) indicated that the tidal influence did not significantly affect the relative wave impact assessment outcomes for sand removal of the scale proposed. As such, for the assessment of wave conditions and impacts at the shoreline areas, a water level of RL+1 m LAT (approximately mean sea level) was adopted. However, since the tide is generally dominant in driving the currents in the area, the water level was varied appropriately through mean spring tide cycles for each of the wave cases assessed during the sand transport simulations. In that way, the full interaction of tidal and wave-induced currents have been simulated dynamically.

3.9.5.2 Spectral Shape

The two primary spectral shapes commonly considered are JONSWAP and Pierson-Moskowitz (PM). JONSWAP was developed for the North Sea and has an enhanced peak typical of strongly developing 'sea' conditions prevailing at the time of the measurement exercise from which it was devised. PM has no enhancement of the spectral peak and is more suited to 'swell' conditions. The Pierson-Moskowitz spectral shape is considered representative of the south east Queensland waves because of the continual presence of low to moderate swell waves and has been used in this study.

3.9.5.3 Bed Friction

SWAN offers the choice of JONSWAP, Collins or Madsen for bottom friction. Although there are no studies indicating relative suitability for each of theses formulations, our experience in other studies has indicated that the method of Collins (Collins 1972) gives consistent and reliable wave attenuation results which appear reasonable for the prevailing wave conditions on sandy bottoms and is used in this study.

Because of the short wave period of the locally generated sea waves and relatively deep water across much of Moreton Bay, the bed will not have significant effect on the waves other than in the shallow banks and shoals. Further, it is predominantly the larger waves that are affected most by bed friction attenuation. Thus, a bed friction coefficient value is most appropriately chosen for this study in the context of its effects at Middle Banks on the larger waves, that is waves of around 1 m height and 5 - 6 second period.

A default value of the friction coefficient (fw) of 0.015 is recommended in the SWAN user manual. The methodology of Nielsen (1992) for estimating wave induced ripple heights and related bed friction coefficient values indicates fw values in the range 0.011 to 0.034 for wave heights in the range 0.6-1 m in 4 m depth over Middle Banks. The value of 0.025 has been adopted.

It should be noted that there is no site specific information to help choose an alternative value and, because of the comparative nature of this study (e.g. assessing differences), selection of a different bed friction coefficient value is unlikely to have any significant effect on the relative impact outcomes of this study.

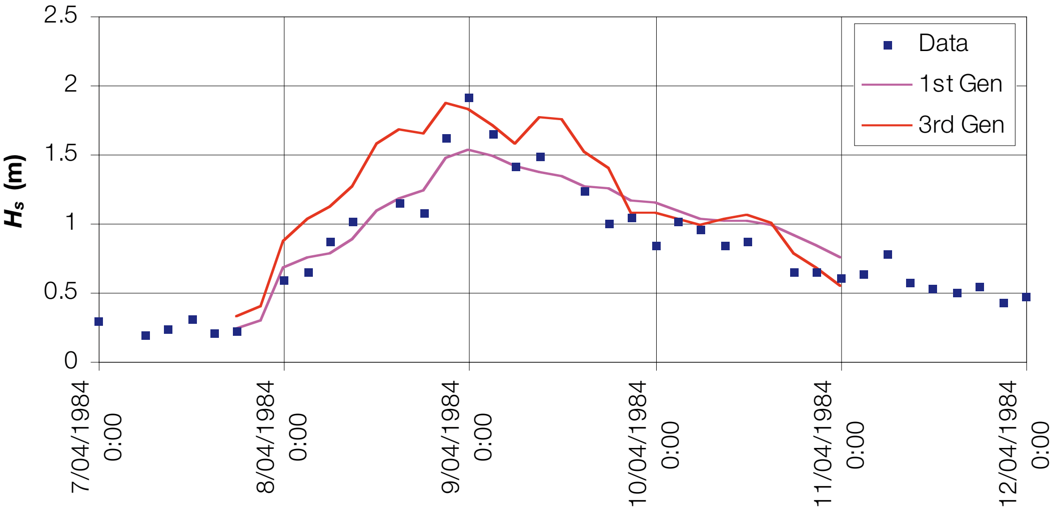
3.9.6 Wave Model Validation

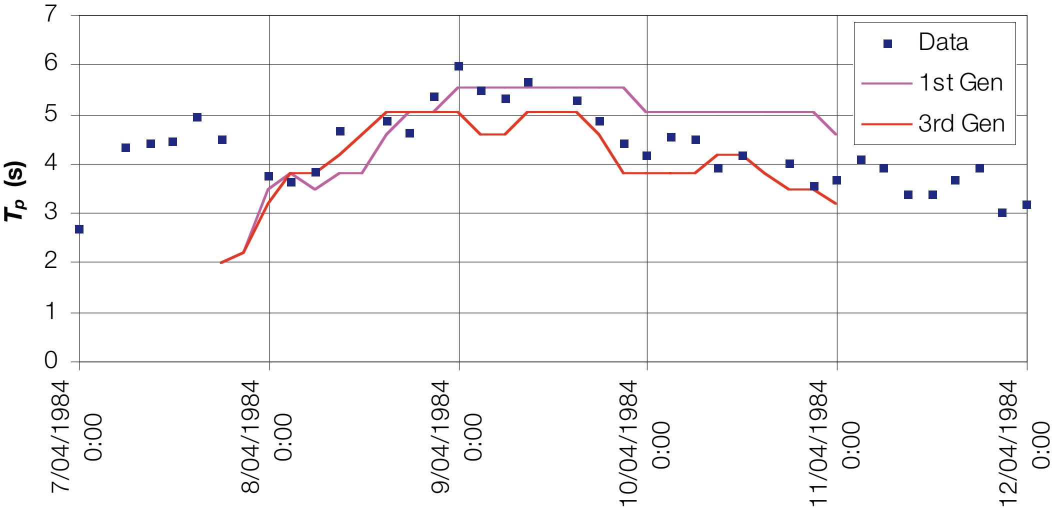
Measured wind and wave data from a Water Research Laboratory (WRL) report entitled *"Redevelopment of Brisbane International Airport, Moreton Island Beach Monitoring, Storms in Moreton Bay, April 1984"* has been utilised for the purpose of model calibration. This dataset includes a storm event with prolonged south-westerly winds with an average speed of 40 knots (21 m/s). Waves were measured by a waverider buoy located on the western side of Ridge Shoal (27°12'34.62"S, 153°20'45.42"E).

The SWAN wave model is comprised of many sub-models for the various processes that it resolves (e.g. wind generation, whitecapping etc.). Many of these sub-models have tuneable input parameters, but unless very extensive calibration data exists it is recommended that the default parameters be adhered to. One of the choices to be made when performing a SWAN model is whether the first-, second- or third-generation mode is utilised. As part of the model calibration exercise a comparison of the first- and third-generation modes has been performed and is shown along with the measured data in **Figure 3.9b**. The third-generation mode predicts larger significant wave heights than the first-generation mode. The over-prediction during the rising limb of the wave-event is likely due to the assumption of a fully-developed wave field at each instant in time.

A sensitivity analysis was undertaken on the bottom friction coefficient used and confirmed that the SWAN model results at the Middle Banks area are relatively insensitive to the adopted bottom friction formulation and coefficient value within the reasonable limits discussed above.

Figure 3.9b: Validation of the Wind Wave Model.





3.9.7 Wave Model Output

Figure 3.9c to Figure 3.9g illustrate typical existing SE, E and NE ocean swell and local sea conditions. These show that swell heights along the western shore of Moreton Island are quite low (generally less than 0.2 m) for the predominant southeast ocean swell. However, wind waves generated locally within the Bay by south-west to north-west winds, or immediately outside the northern entrance to the Bay by north to northeast winds may be of significance at Middle Banks.

3.10 Baseline - Sedimentation and Morphological Processes

3.10.1 Northern Entrance Tidal 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 delta comprises two parts; a seaward ebb-delta and a landward flood-delta. The dominant hydrodynamic controls are waves and tides, but

Figure C.3.9c: *SE Ocean Swell Propagation. (Hs=3m; Tp=10s)*

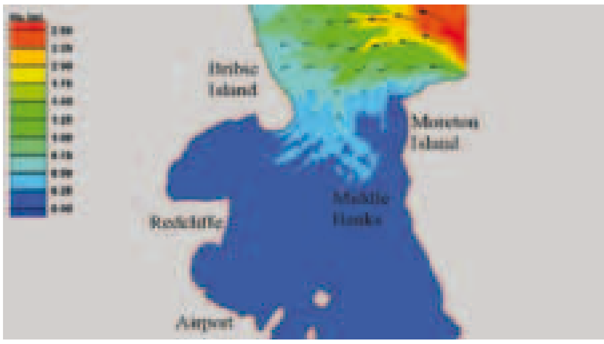


Figure 3.9d: *E Ocean Swell Propagation. (Hs=3m; Tp=10s)*

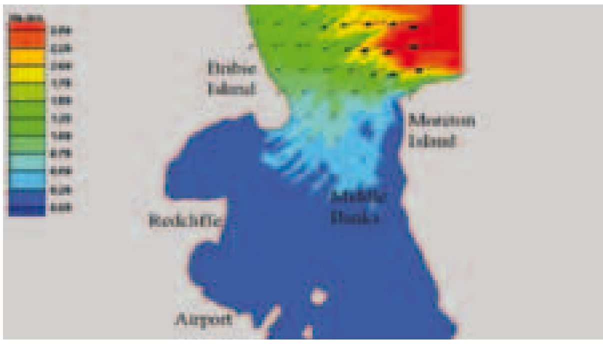


Figure 3.9e: *NE Ocean Swell Propagation. (Hs=2m; Tp=7s)*

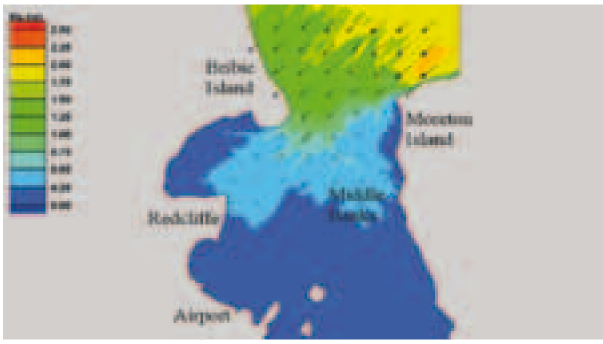


Figure 3.9f: *Locally Generated SW Sea Waves in Moreton Bay – 25 Knot Wind.*

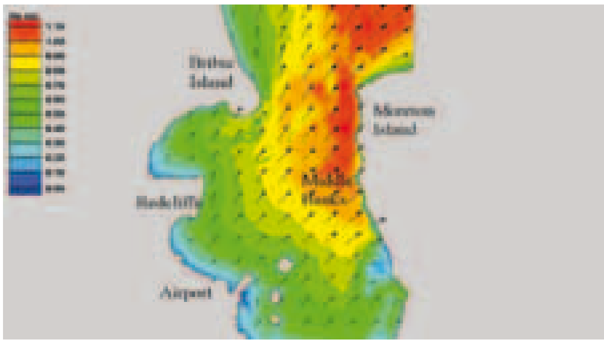
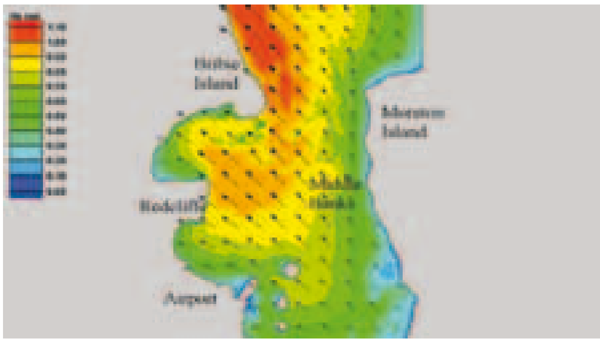


Figure 3.9g: *Locally Generated SE Sea Waves in Moreton Bay – 25 Knot Wind.*



their relative importance varies with location. The landward flood-delta is protected from ocean swell and is therefore tide dominated. The Northern Entrance Tidal Delta shoals are highly mobile under the action of the tidal currents and associated waves and has been fashioned into a system of mutually evasive ebb and flood-dominated channels separated by linear sand ridges (Stephens 1978; Harris and Jones 1988).

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.

The tidal regime of the Bay is determined largely by the bathymetry of the Northern Entrance Tidal 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 (for example) the ongoing natural supply of sands, any changes in bathymetry by natural means or sand extraction to date, which are relatively insignificant in context of the scale of the Delta.

Modelling undertaken for previous studies shows that most of the shallower parts of the entire Northern Entrance Tidal 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 Entrance sand banks experience relatively high bed shear stresses due to 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.

3.10.2 Sand Bank Evolution Patterns

Sand supplied to the 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 channel, are subject to some deposition of sand that falls from the shallower surface of the shoals as ‘drop-overs’. 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.

The Middle Banks area forms the southward extension of the Northern Entrance Tidal Delta shoals at the eastern side of Moreton Bay. They are thus composed of marine sand with its origin the ocean coastline of northern NSW and South East Queensland. A conceptual model explaining the evolution of the Middle Banks and adjacent shoals has been proposed by Castons (1972), as illustrated in **Figure 3.10a**.

The processes shown in **Figure 3.10a** are consistent with the interpreted broader geological evolution and imply a strong ongoing southward transport of sand from the area of the Northern Entrance Tidal Delta adjacent to Moreton Island. This suggests that the zone of southward sand transport into the Bay is predominantly past

Comboyuro Point and along the eastern side of the Bay. Constriction of the flow by the southward extension of Yule Road and the proximity of the shallow banks immediately west of the deep shipping channel to the western shoreline of Moreton Island near Cowan Cowan has scoured East Channel extensively (to depths up to 38 m), with the sand moved southward to Middle Banks and the adjacent Ridge Shoal and Dring Bank.

Modelling by Pattiaratchi and Harris (2002) confirms this process. They conclude that Middle Banks are relatively immature in their evolution and are at the end of the sand transport pathway in this region.

South of Middle Banks, the Bay bed is the former Pleistocene land surface submerged by the sea level transgression, with deposited fine muddy sediment derived from the Brisbane River catchment during flood events. The water depth there exceeds 20 m and currents and wave action is not sufficient to resuspend these fine sediments, allowing ongoing accumulation.

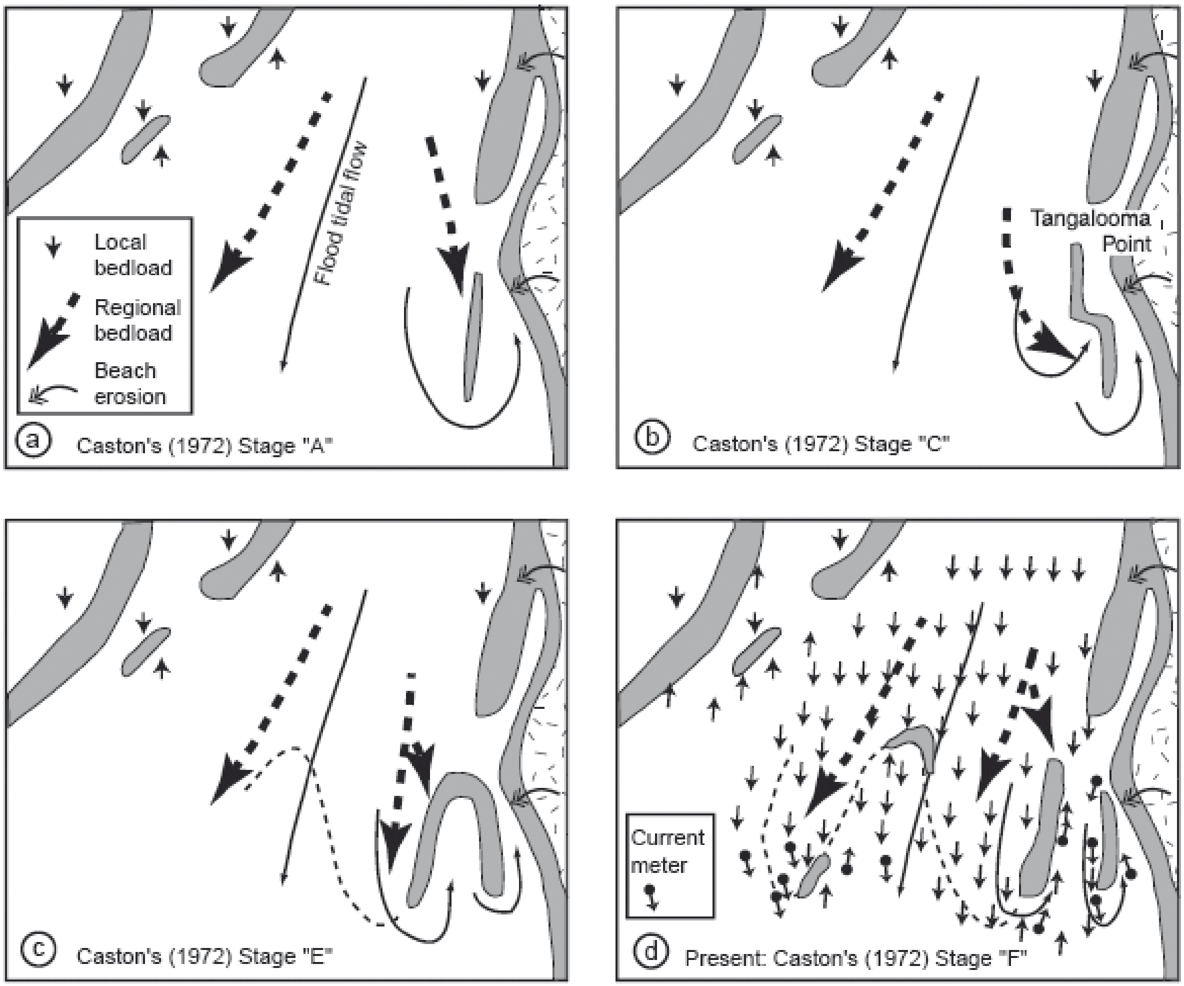
3.10.3 Modelling of Middle Banks Region Bed Morphology

Modelling of the morphology of the Bay bed at the Middle Banks region has been undertaken as part of the present investigations in order to:

- Gain better detailed understanding of the processes taking place.
- Establish a baseline model against which impacts of the proposed dredging may be assessed.

Validation of the model is only at a level that shows correlation with the known behaviour, as described above and as interpreted from bed forms evident in

Figure 3.10a: *Conceptual Model of Middle Banks Evolution (from Castons 1972).*



aerial photos, showing dominant directions of sand movement.

Results of that modelling are presented in the form of plan views of:

- Directions and rates of net sand transport.
- Rates of sand transport across several key control lines.

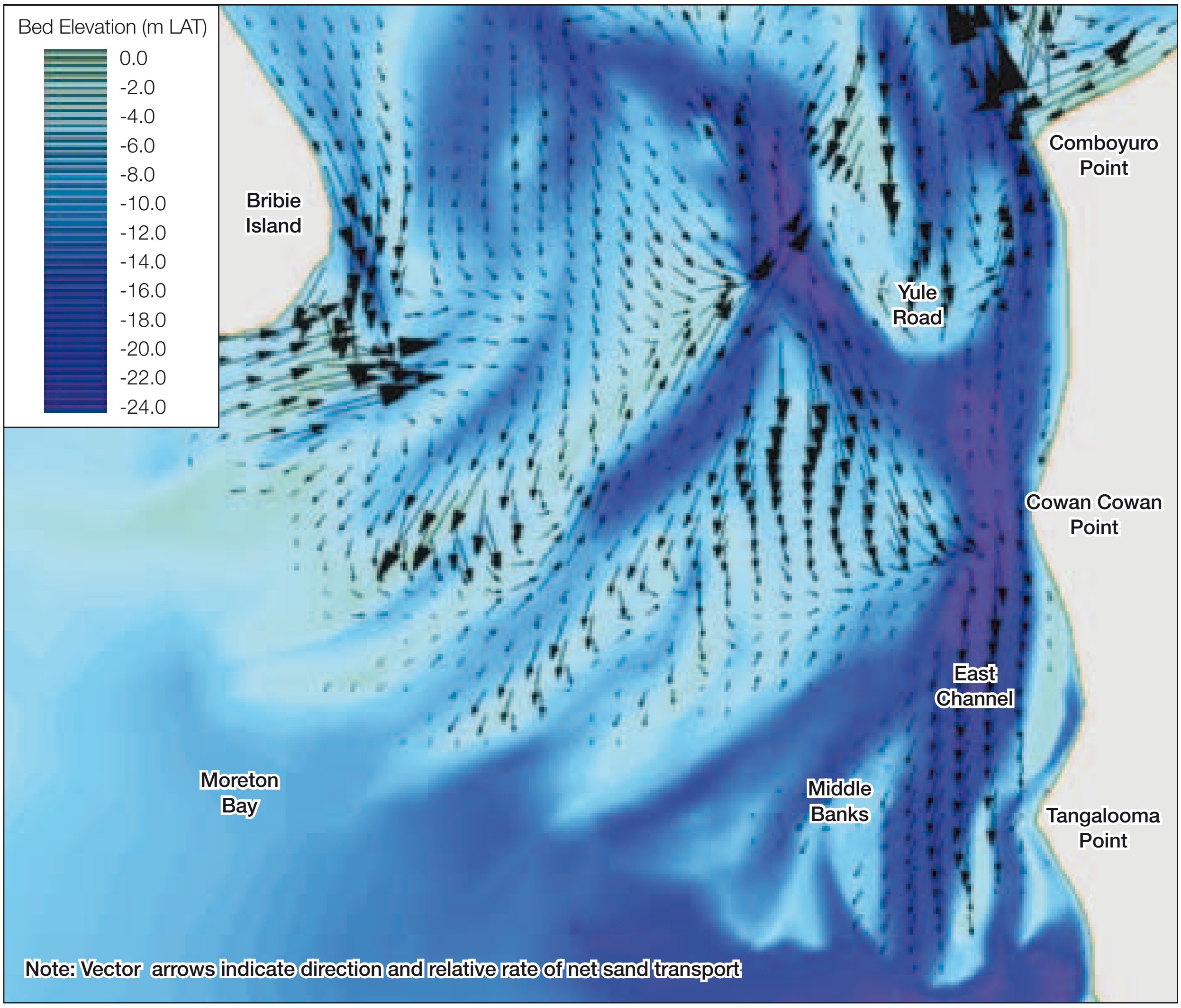
Modelling of the bed morphology has been based on a mean spring tide range, which is exceeded typically 25-30 percent of the time, found in previous studies to be a reasonable representation of the hydrodynamics for the highly non-linear sediment transport processes. Areas of active sand correspond to 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 net sand transport rates and directions derived from the modelling as the net residual transport over a cycle of neap and spring tides is shown in **Figure 3.10b.**

These results indicate that:

- Much of the Northern Entrance Tidal Delta shoals is highly mobile, including the Middle Banks area.
- The dominant flood tide transport along the East Channel is reproduced in the model.
- Directions and rates of net sand transport across the Northern Entrance Tidal Delta derived from the model are consistent with the shape and nature of the sand shoals and channels.
- There is a clear capacity for Middle Banks to have formed from sand transported southward along the East Channel.

Figure 3.10b: *Modelled Net Sand Transport in Northern Tidal Delta.*



- Further north along the East Channel, there is a complex interaction of southward net transport at Yule Road, northward net transport along the deep constricted channel between Yule Road and Comboyuro Point north from Cowan Cowan Point and a nearshore zone of southward net transport immediately adjacent to Cowan Cowan.

These results conform to the observed and/or interpreted behaviour and confirm that the model is reproducing both the hydrodynamics and the morphological processes of the bed of the Bay. In that regard, it is of note that the model reproduces features even at quite fine scale, such as the mechanism for the contemporary accretion of Tangalooma Point. There, the model shows a zone of converging net sand transport in the location of accretionary development of the Point (**Figure 3.10c** and **Photo 3.10a** and **Photo 3.10b**).

This accretion shows also in the beach surveys undertaken as part of the monitoring of the previous dredging in the 1980s and 1990s when compared with the most recent survey in February 2006 **Figure 3.10d**.

The model is considered sufficiently reliable and accurate for use as a basis for assessment of the impacts of the proposed dredging.

3.11 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:

- 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.

Figure 3.10c: *Modelled Zone of Convergent Net Sand Transport at Tangalooma Point.*

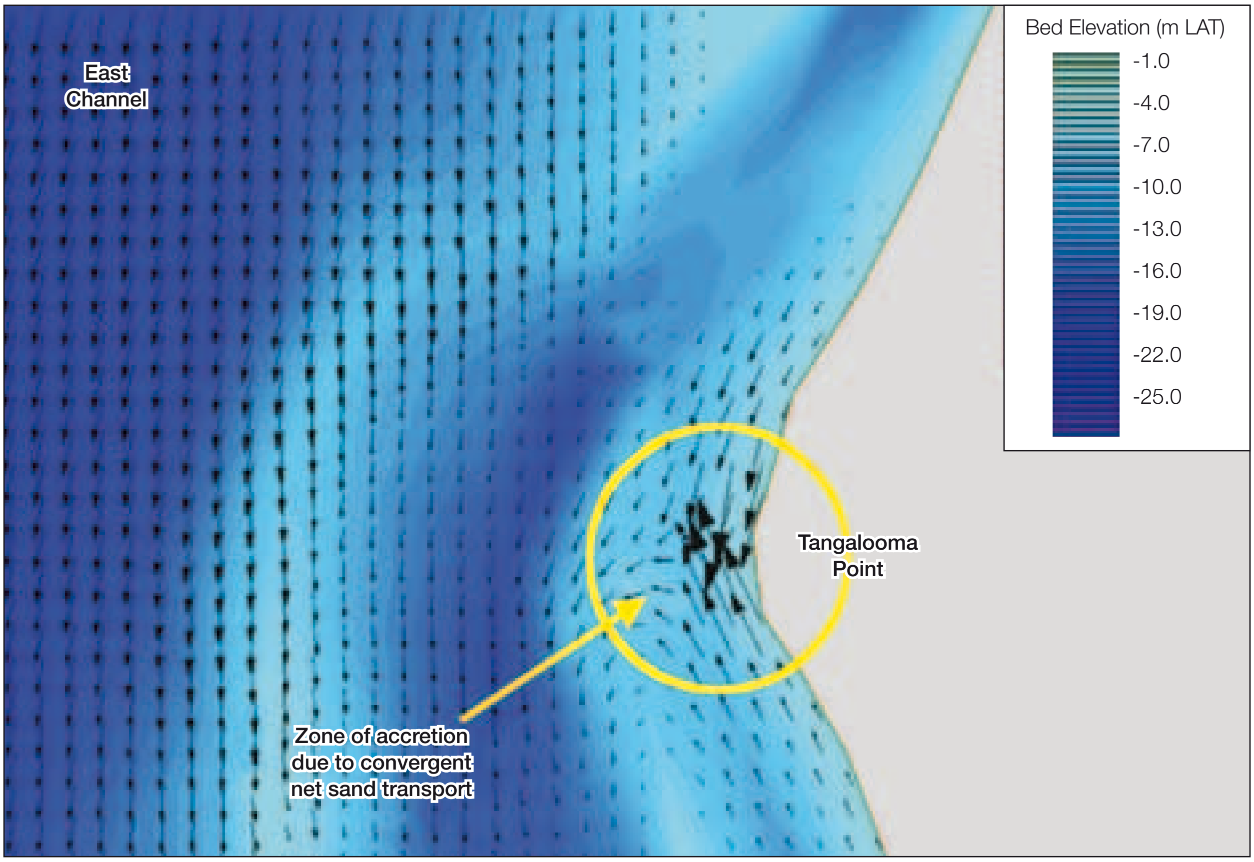


Photo 3.10a: *Accreting Sand Point at Tangalooma Point.*

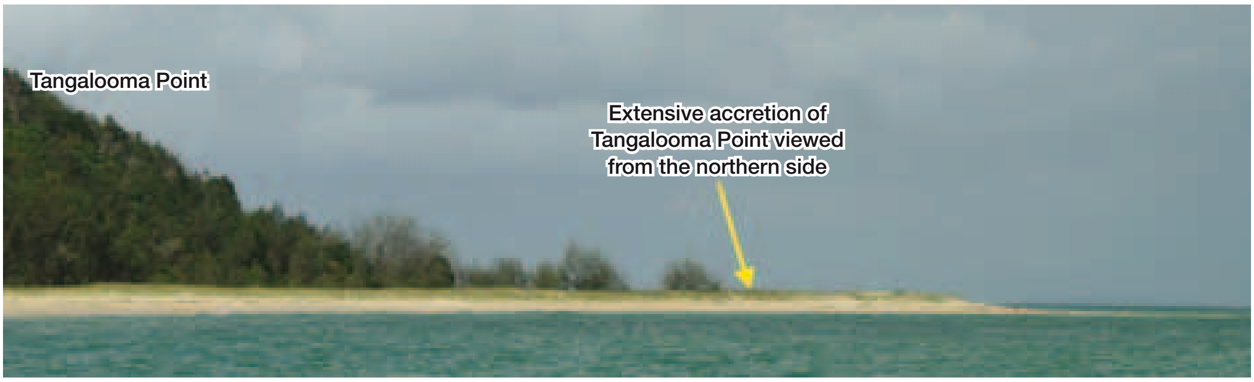
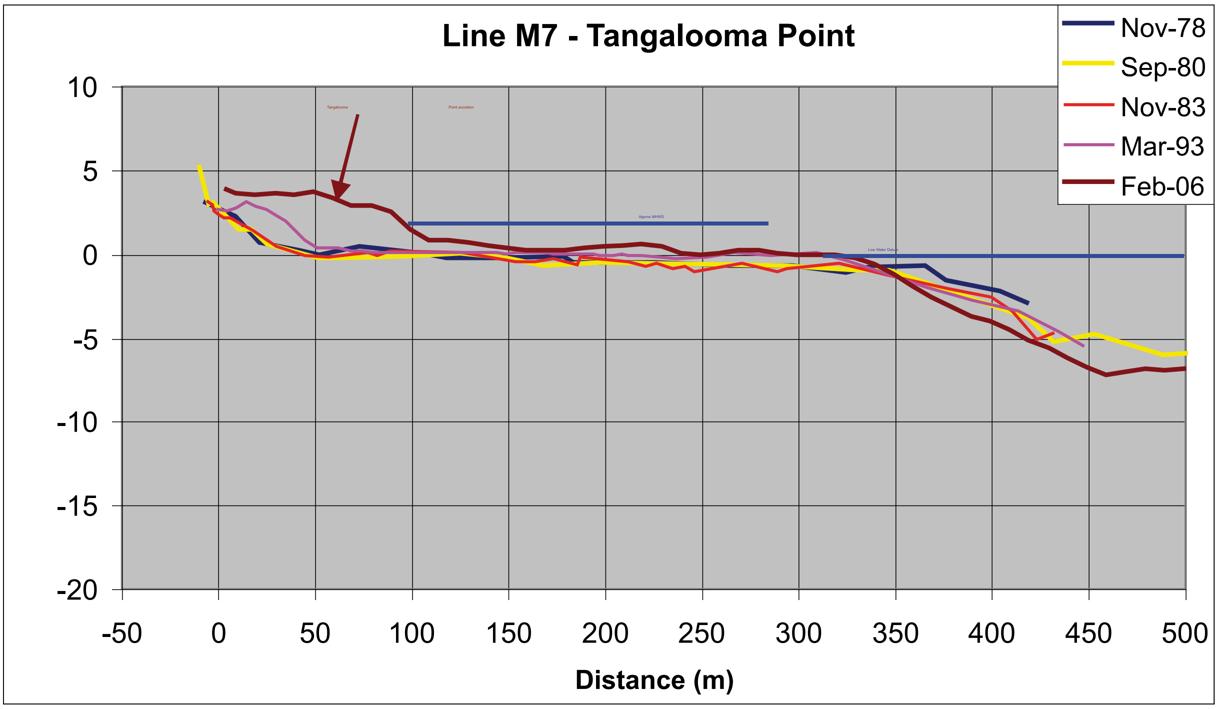


Photo 3.10b: *Southern Side of Accreting Sand Point at Tangalooma Point.*

Figure 3.10d: *Surveyed Beach Profile at Tangalooma Point Showing Progressive Accretion.*



- 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.
- Mainland beaches, sheltered almost completely from the ocean swell by both the blocking effect of Moreton Island and the considerable attenuation of wave energy by breaking and bed friction across the Northern Entrance Tidal 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 adjacent 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 particular respect to 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, 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 term 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 when a predominant swell exists (eg Bribie Island) or lost from the immediate shoreline beach system 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 northeast 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 illustrating the naturally dynamic behaviour of the western shoreline of Moreton Island.

3.11.1 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".*

3.11.2 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. 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. Fortunately, although the position worsened steadily, there were no cyclones or gales of unusual severity to cause catastrophe. By 1901 the position of both the lighthouse and the keeper's cottage were within only 10 ft of the sea and in danger of being swept away. To save them they had to be removed 635 ft across a creek 40 ft wide and, as it was important that this light, which formed one of the sectored lights leading into Moreton Bay, should be exhibited nightly, arrangements had to be made to remove the tower without interfering with the light." (Harbours and Marine 1986).

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.

Despite the dynamic nature of the shoreline and adjacent shoals and channels at a local scale, the regional shape of the bathymetry along the western shoreline of Moreton Island has remained the same since the earliest surveys. **Figure 3.11a** shows the navigation chart of 1893, with the coastline shape as well as Middle Banks, Ridge Shoal and Dring Bank shown much then as they are today.

Investigations of the nature and behaviour of the western shoreline of Moreton Island were undertaken as part of impact assessment studies prior to the previous airport redevelopment dredging exercise (NEDECO 1974, Reidel 1979, Foster 1979). As well, survey monitoring of the beaches was undertaken over the period from 1978 through to 1993 to assess beach profile behaviour and identify any changes that occurred, particularly any changes that might be attributable to the dredging. Those surveys have been augmented in the present study with a further survey at each of the profile locations in February 2006 to extend the assessment and establish the present baseline status of the shoreline.

The locations of the beach survey profile lines are shown in **Figure 3.11b.**

The findings of the investigations undertaken for the previous dredging indicate that the processes taking place are complex, with:

- A strong inflow of sand around Comboyuro Point and southward along the northern part of the island shoreline, driven primarily by the tidal currents and, in the immediate shoreline area, by refracted ocean swell waves.
- A net southward movement of sand in the tidal channels adjacent to the western shoreline of Moreton Island, driven by the tidal currents.
- Sand movements in both directions along the western shoreline of Moreton Island from time to time, driven by the local 'sea' waves from north-west to south-west directions, with the south-west waves being dominant.

Figure 3.11a: *Moreton Bay Navigation Chart - 1893.*

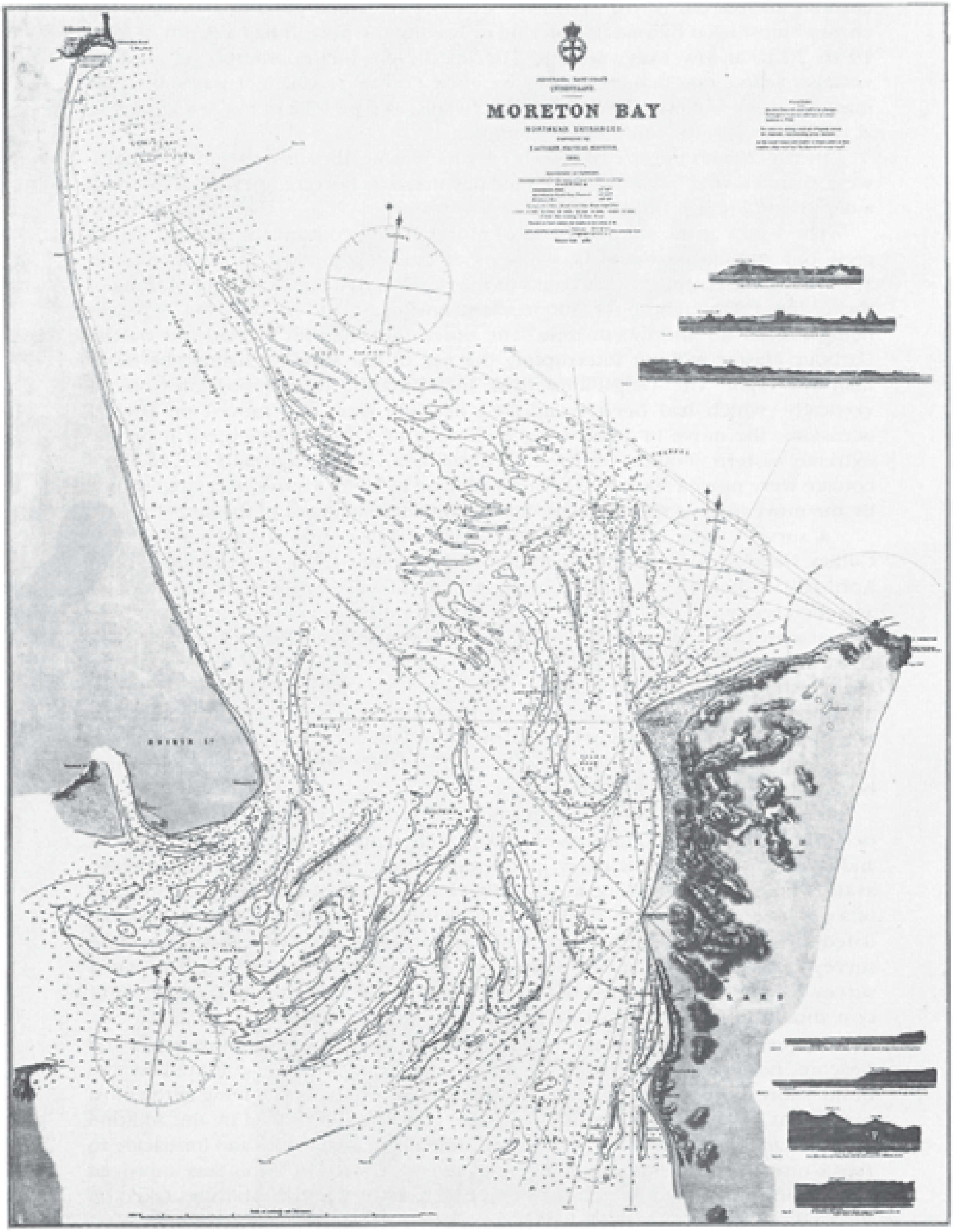


Figure 3.11b: *Locations of Moreton Island Beach Survey Profiles.*

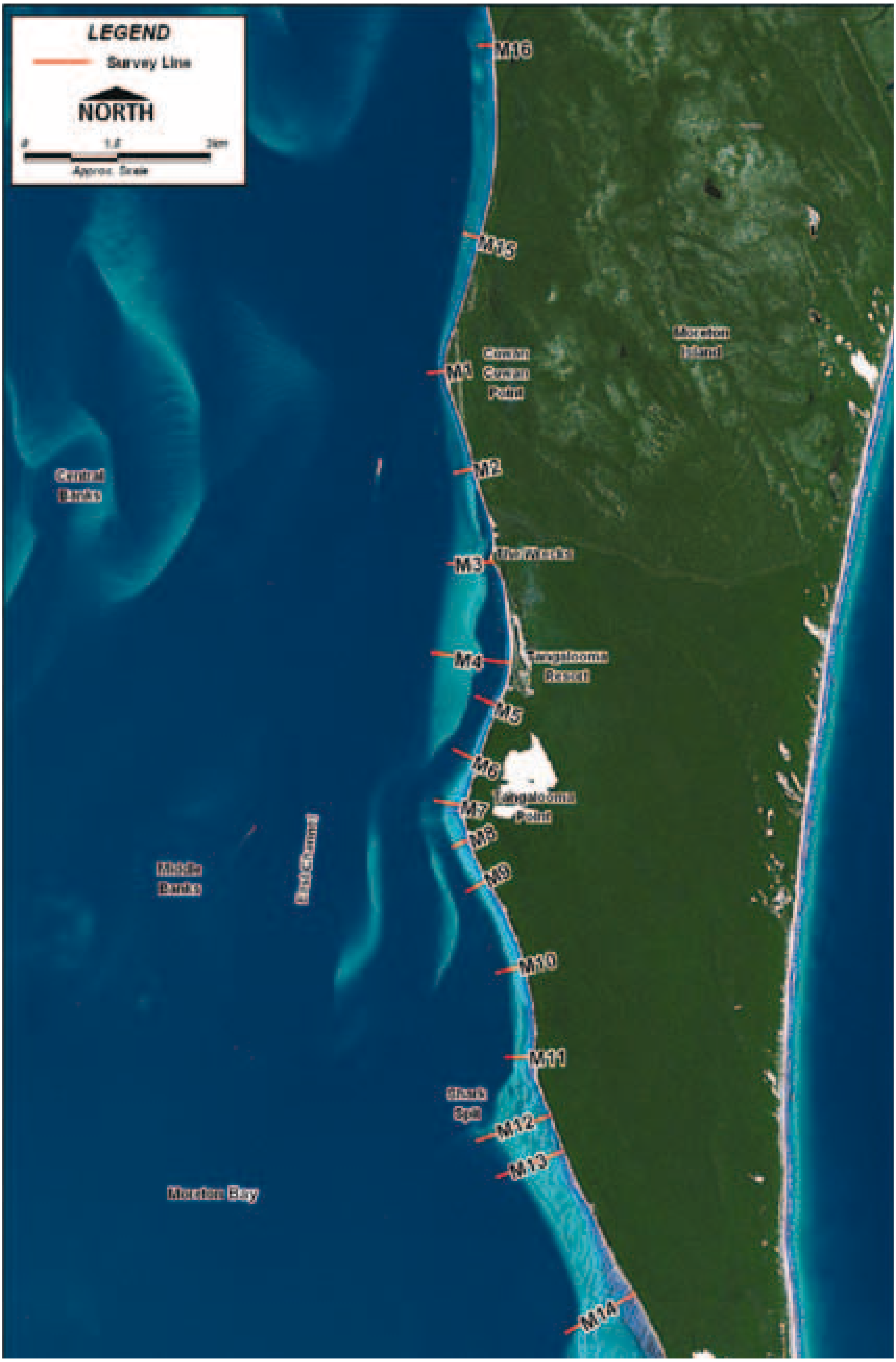
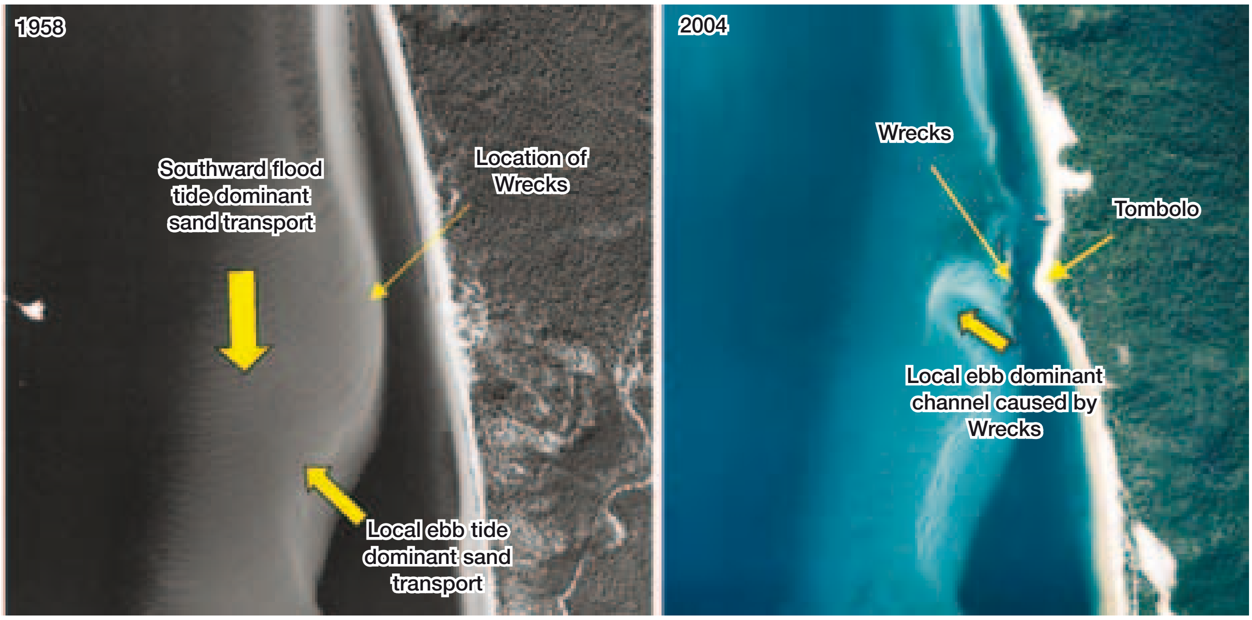


Figure 3.11c: *Shoreline Changes at The Wrecks, Tangalooma – 1958 to 2004.*



It is apparent that the net sand movement along the beach itself is probably northward along much of the western shoreline of Moreton Island, as a result of the predominant south-westerly wind-generated local sea waves. Despite that, the location and orientation of the spits and/or southward projecting shoals to the south of the prominent points at Cowan Cowan and Tangalooma Point indicate persistent southward net sand transport in the main tidal channels due to the tidal currents.
Reidel (1979) notes that:

> *"According to the ripple and dune patterns on the Salamander and Yule Banks, this material is moved in a southward direction due to the predominant southward current. This southward sand movement most probably continues over Middle Bank, Ridge Shoal and the western slope of Dring Bank, as evidenced by the dune pattern observed on these banks. From the rather steep slopes of the channels it is clear that these banks are mainly formed by the current."*

Reidel (1979) describes the nature and behaviour of the shoreline system between Cowan Cowan and Shark Spit as follows:

> *"The controlling feature for most of the beach is the existence of steep dunes, often more than 50 metres high, with their toe at the high water line. Consequently, wave action accompanying high tides will cause erosion which is readily visible in the form of scarps or slips on the dune face. Taking the Moreton Bay shoreline as a whole .....it is apparent that many of the dunes have old slip faces which have revegetated and at present the dune faces are a succession of current and recent slippages, revegetated slip faces of varying ages and dunes that are completely intact. The shoreline may thus be described as being in dynamic equilibrium in terms of engineering time scales (order of 50 years) although in terms of longer (geological) time scales the shoreline may be eroding."*

Reidel (1979) notes further:

- The local impact that 'The Wrecks' have had on the adjacent shoreline in developing a tombolo as a result of changes to the pattern of incident waves, with accretion of the beach in the lee of The Wrecks and erosion of the beach to the immediate north and south. He reports that the Tangalooma Resort is constructed on a section of coast where the steep dune system is set back 100 metres from the high water line and *"This beach has been in dynamic equilibrium since 1944 (date of earliest aerial photography), however the shoreline is vulnerable to storms from the west and severe storms from the west occurring during high spring tides could damage some of the hotel development."*

- *"Just along the beach north of Cowan Cowan Point the movement of the material in the surf zone is northward as a result of waves generated by the wind, which blows predominantly from the SW direction in Moreton Bay."*

Aerial photography confirms the reported behaviour at The Wrecks, as shown in **Figure 3.11c**. This also shows that the tombolo formation has tended to reduce the capacity for ebb tide flow along the inner channel and has forced a new ebb channel immediately adjacent to the southern side of The Wrecks.

This accretion is illustrated in the beach profile survey (M3) at The Wrecks (**Figure 3.11d**). The survey indicates that the adjacent channel has tended to maintain its dimensions and has migrated in the offshore direction by a distance commensurate with the extension of the beach, potentially beginning to undermine some of the wrecks themselves.

Aerial photography also shows persistent beach accretion against the southern side of the Bulwer Wrecks, as illustrated in **Figure 3.11e**. This is clear evidence of northward net sand transport there, despite the influence of refracted ocean swell that is likely to be stronger there than further south along the island.

Thus, along most parts of the western shoreline of the Island, the wave-induced net sand transport along the beach system is in the opposite direction (northward) to that of the current-induced net transport in the main tidal channels (southward).

The geological record indicates geologically recent (centuries) progressive erosion of the Holocene accretion deposits along the shoreline south from Comboyuro Point to at least Cowan Cowan. The shape of the dune ridges at Comboyuro Point and Cowan Cowan suggests that the early Holocene shoreline may once have featured a protruding point extending into the present Bay area between those two locations. This indicates that, while there has been a surplus of sand supply to that shoreline over the longer geological term, other processes of shoreline change, possibly affected by 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.

The site visit and investigation by Foster (1979) confirms these findings and observed that the beaches were not stable with some areas showing erosion and others slight accretion. Erosion was evidenced by:

- The high water reaching the toe of the dunes.
- Dune slides, both old and new.
- Dead tress along the beach.
- Wartime fortifications at Cowan Cowan Point on the exposed beach.

Comparison of the hydrographic surveys of 1869 and 1946 (Foster 1979) show marked changes in the shoreline over the 76 years as:

- Advancement of Shark Spit northward at a rate of 2 to 2.5 m per year.

Figure 3.11d: *Profile Survey of Shoreline Change at Tangalooma Wrecks.*

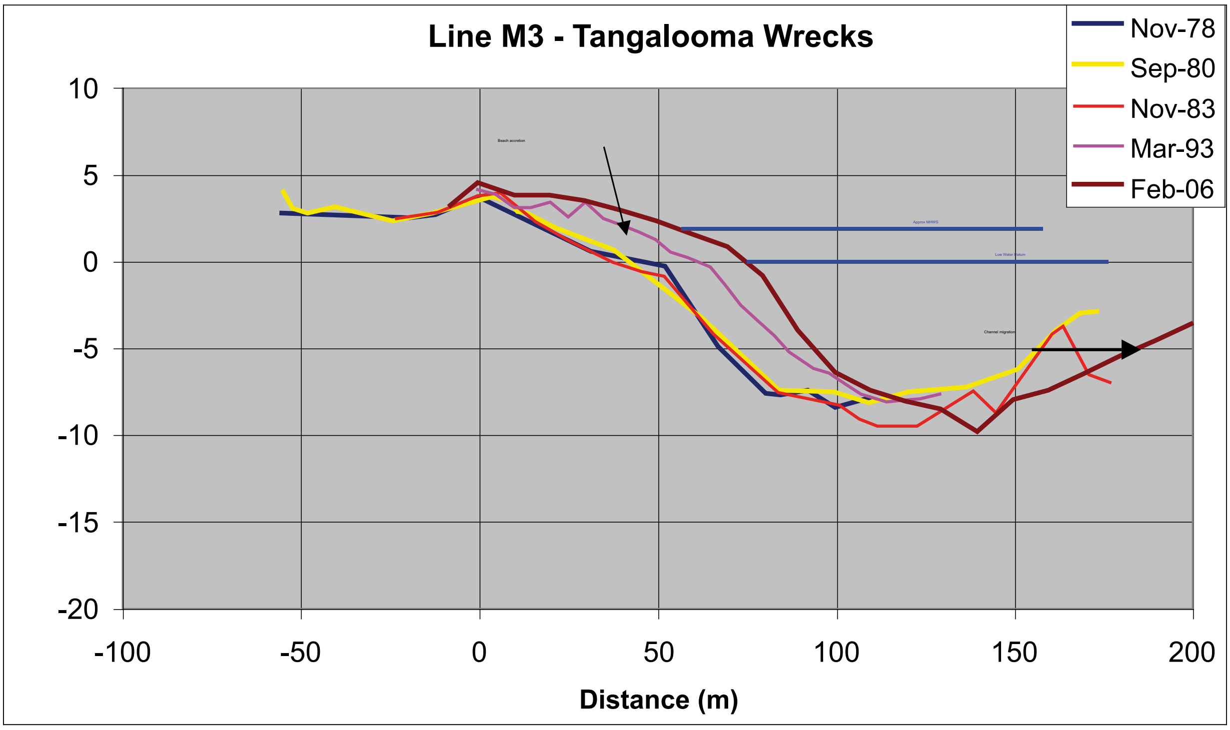


Figure 3.11e: *Beach Accretion at Bulwer Wrecks.*

- Erosion and northward advancement of Tangalooma Point, with erosion on its southern side of about 2 to 2.5 m per year.
- Tangalooma Beach showing little change or possibly slight accretion.
- Cowan Cowan Point eroded and advanced southwards, with erosion on the northern side up to 1 m per year.
- Within the accuracy of the soundings, little change in the location and depths of the offshore channels except at the northern end of Tangalooma Road where siltation of some 2-3 m had occurred, and to Dring Bank which reflects the shoreline change.

Foster's assessment of more recent changes based on aerial photography indicated:

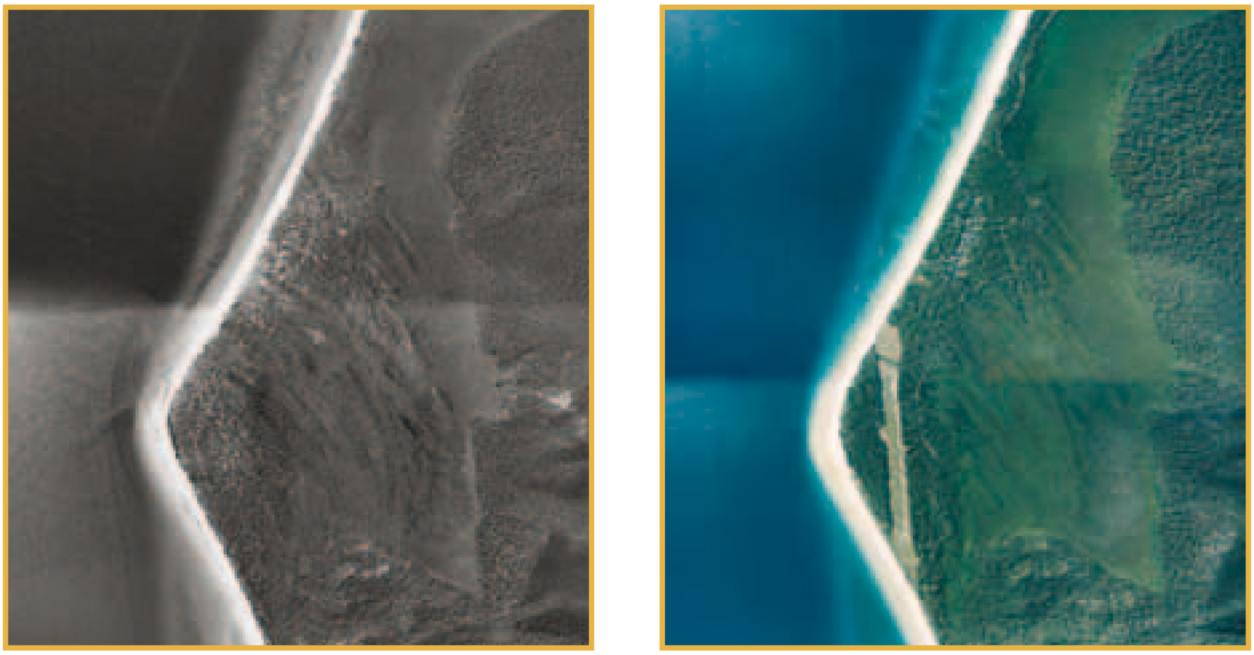
- At Tangalooma and on the northern side of Tangalooma Point, no major changes occurred between 1952 and 1978.
- Continuing erosion of 1-1.5 m/yr occurred south of Tangalooma Point.
- On the northern side of Cowan Cowan Point, a retreat of the beach at Moreton Bay Boat Club observation tower of 0.6 m/yr since 1951.

Foster (1979) considered it most unlikely that Tangalooma Point is a tombolo formed in the lee of Middle Banks, based on his assessment of its effects on wave propagation.

Updated assessment of shoreline changes at both Cowan Cowan and Tangalooma confirm ongoing trends as previously determined in the earlier studies. For Cowan Cowan, examples of the aerial photo record are presented in **Figure 3.11f to Figure 3.11h**. Those photos have been analysed in enlarged format to determine shoreline change. The results of that analysis are presented in **Figure 3.11i**, indicating a progressive shoreline recession of about 0.57 m/year. Note that the accuracy of such an analysis for each individual date of photography is limited to within about 2-4 m, depending on the photo resolution and ability to clearly identify key marks such as houses and the edge of vegetation along the shoreline. Nevertheless, the trend pattern is considered reliable and is consistent with the earlier findings.

It is considered that the erosion of the shoreline at Cowan Cowan is related primarily to wave effects in eroding the dune and transporting the sand along the shoreline towards the north. There is probably some net southward transport of sand by tidal currents in the nearshore zone and extending to the deeper water in the East Channel. The influence of tidal currents in undercutting the shoreline does not appear to be a factor here, possibly because of the

Figure 3.11f: *Aerial Photography of Cowan Cowan Point for 1958 (left) and 2004 (right).*



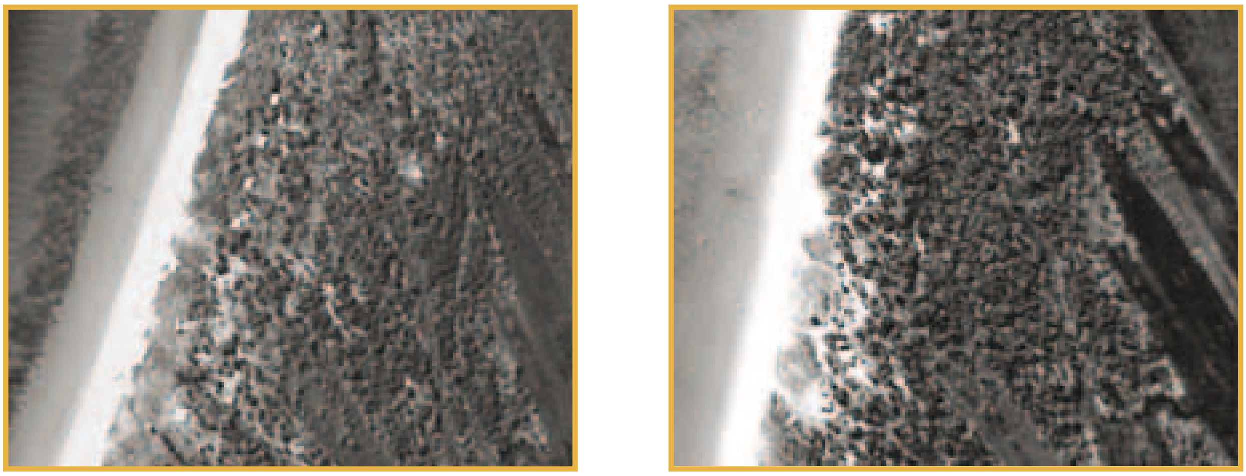
existence of underlying stiff clay and hard "coffee rock". Stephens (1978) reports:

> *"The main channels which exist at present have been deepened to between –18 m and –23 m, but between Cowan Cowan Point and East Knoll a maximum depth of –57 m below mean sea level has been recorded. Scuba investigations to –42 m in this locality have shown that the channel sides consist of stiff blue-grey clay (presumably Pleistocene estuary fill), which is covered by a thin layer of sand. ……. The only other hard substrates so far discovered are layers of coastal sandrock ("coffee rock") which crop out as ledges usually at depths between –7 m and –14 m, as at Bulwer Ledge. Intermittent outcrops occur between Comboyuro Point and Cowan Cowan Point. Other known outcrops lie in Pearl Channel and on the eastern side of East Channel between Tangalooma Wrecks and Cowan Cowan Point."*

In addition, the profile surveys at locations M15 (Cowan Cowan North) and M16 as presented in **Figure 3.11j** and **Figure 3.11k** respectively confirm that there has been no change in the level of the nearshore shelf that extends out from the beach at either location. The shoreline erosion appears to be occurring at the upper part of the nearshore profile, associated predominantly with wave-induced longshore sand transport, probably together with some direct storm wave erosion that distributes some of the sand across the nearshore shelf. This latter process appears to be essentially non-reversible as the lower non-storm waves have only limited capacity to move the sand back onshore and sand deposited in the nearshore area may be further distributed by the tidal currents, predominantly towards the south.

Thus, the erosion mechanism appears to be complex and part of the natural long term evolution of the shoreline. Less sand is being transported by waves north from Cowan Cowan Point towards the Cowan Cowan township area than is being transported away from there towards the north. There may be some 're-cycling' of some of the sand eroded by the storm waves southward towards Cowan Cowan Point by the tidal current. There is no evidence in the monitoring surveys or the aerial photo analysis to suggest that the shoreline erosion has been influenced by the previous dredging.

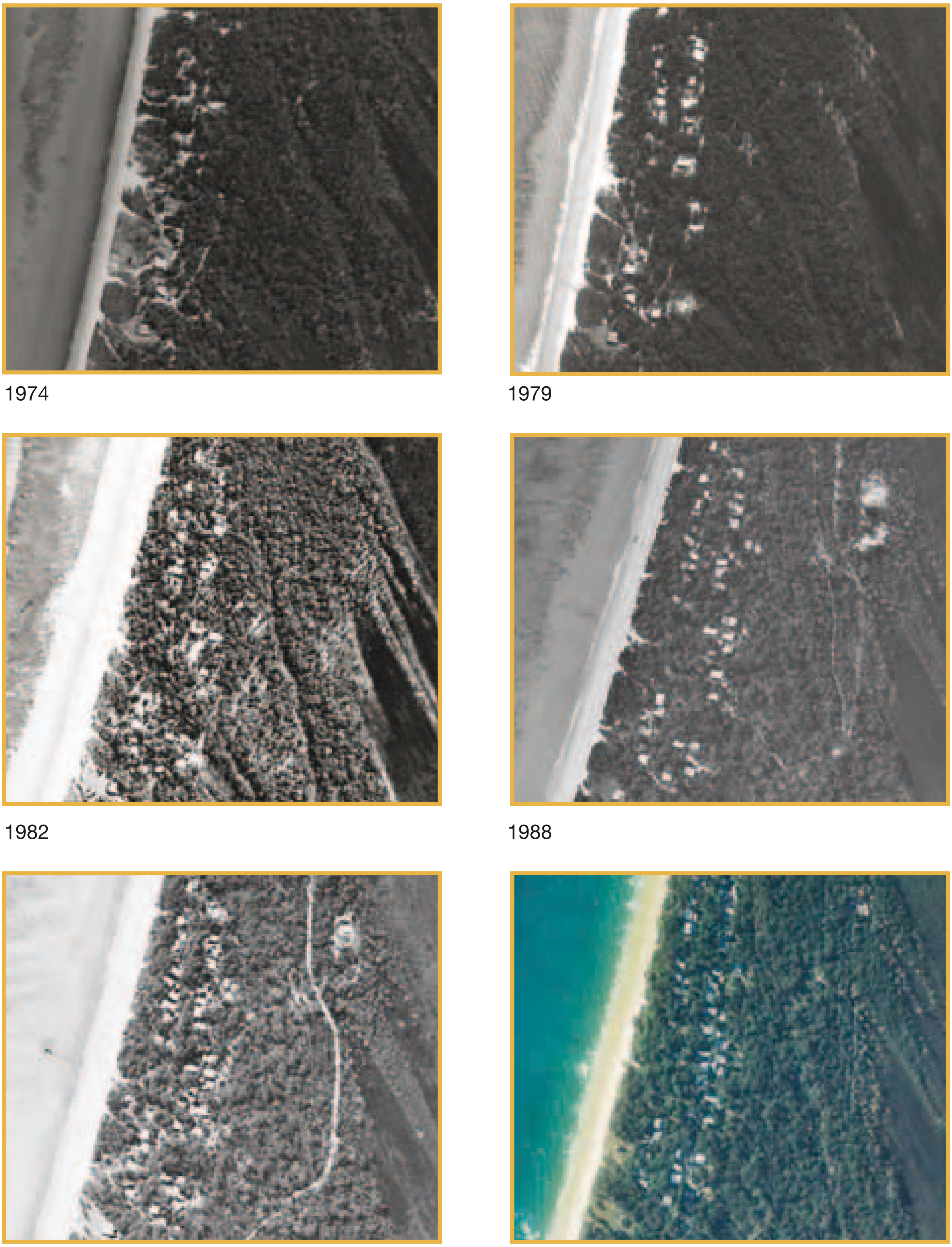
Figure 3.11g: *Historical Aerial Photos at Cowan Cowan – 1958 to 1999.*



1958

1972

Figure 3.11g: *Historical Aerial Photos at Cowan Cowan – 1958 to 1999.*



1974

1979

1982

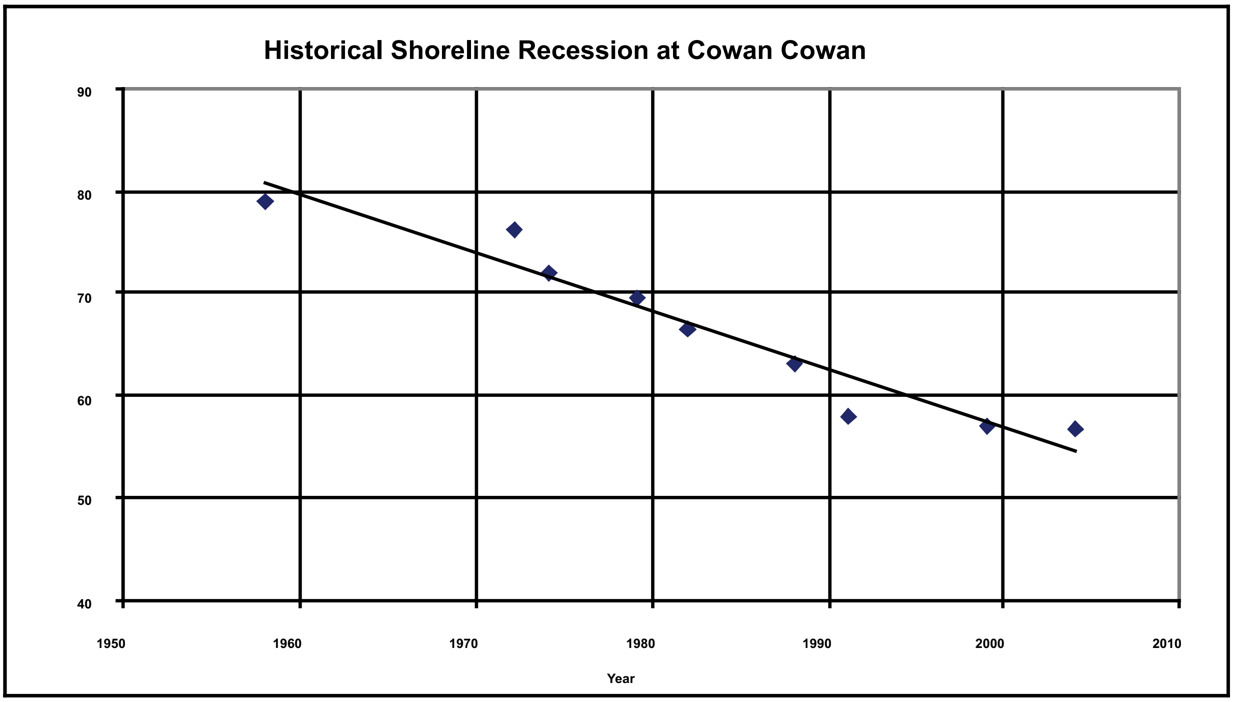
1988

1991

1999

Figure 3.11h: *Aerial Photo of Cowan Cowan - 2004.*

Figure 3.11i: *Historical Shoreline Recession at Cowan Cowan – 1958 to 2004.*



Recent photographs (**Photos 3.11a** and **3.11b**) taken at Cowan Cowan on 15 March 2006 illustrate the continuing erosion, with high erosion scarps and old wartime gun emplacements collapsing onto the beach.

Photo 3.11a: *Cowan Cowan Foreshore: 15 March 2006.*

Photo 3.11b: *Cowan Cowan Foreshore: 15 March 2006.*

Figure 3.11j: *Profile Survey at Cowan Cowan North (Location M15).*

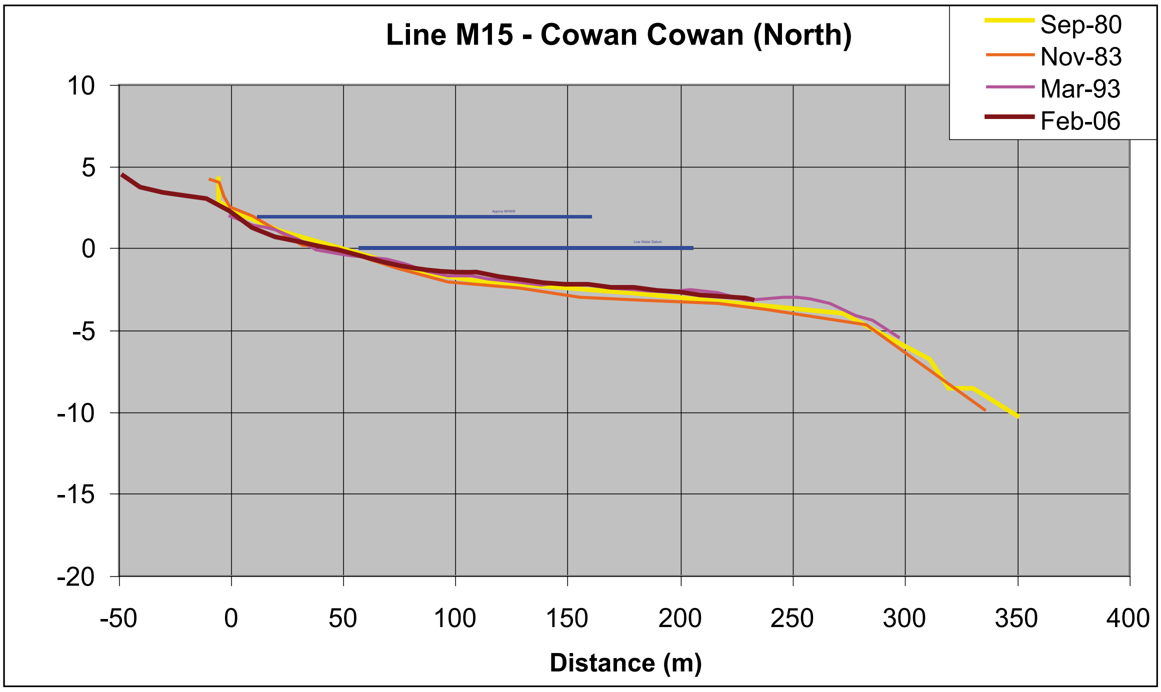
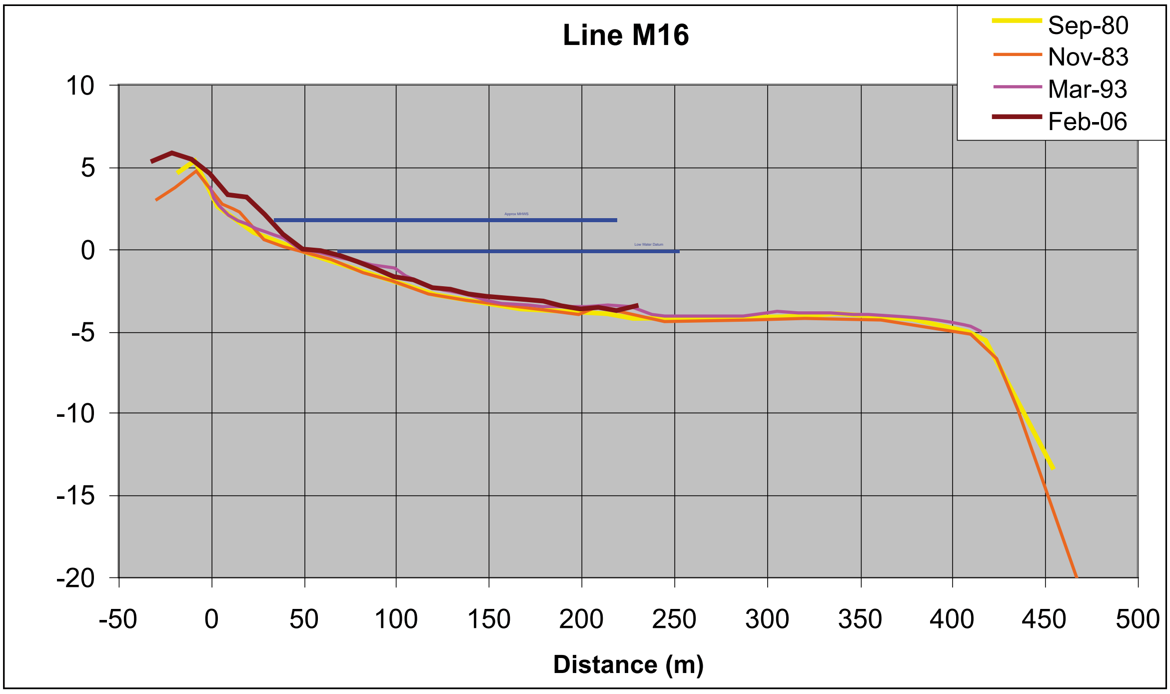


Figure 3.11k: *Profile Survey at Location M16.*

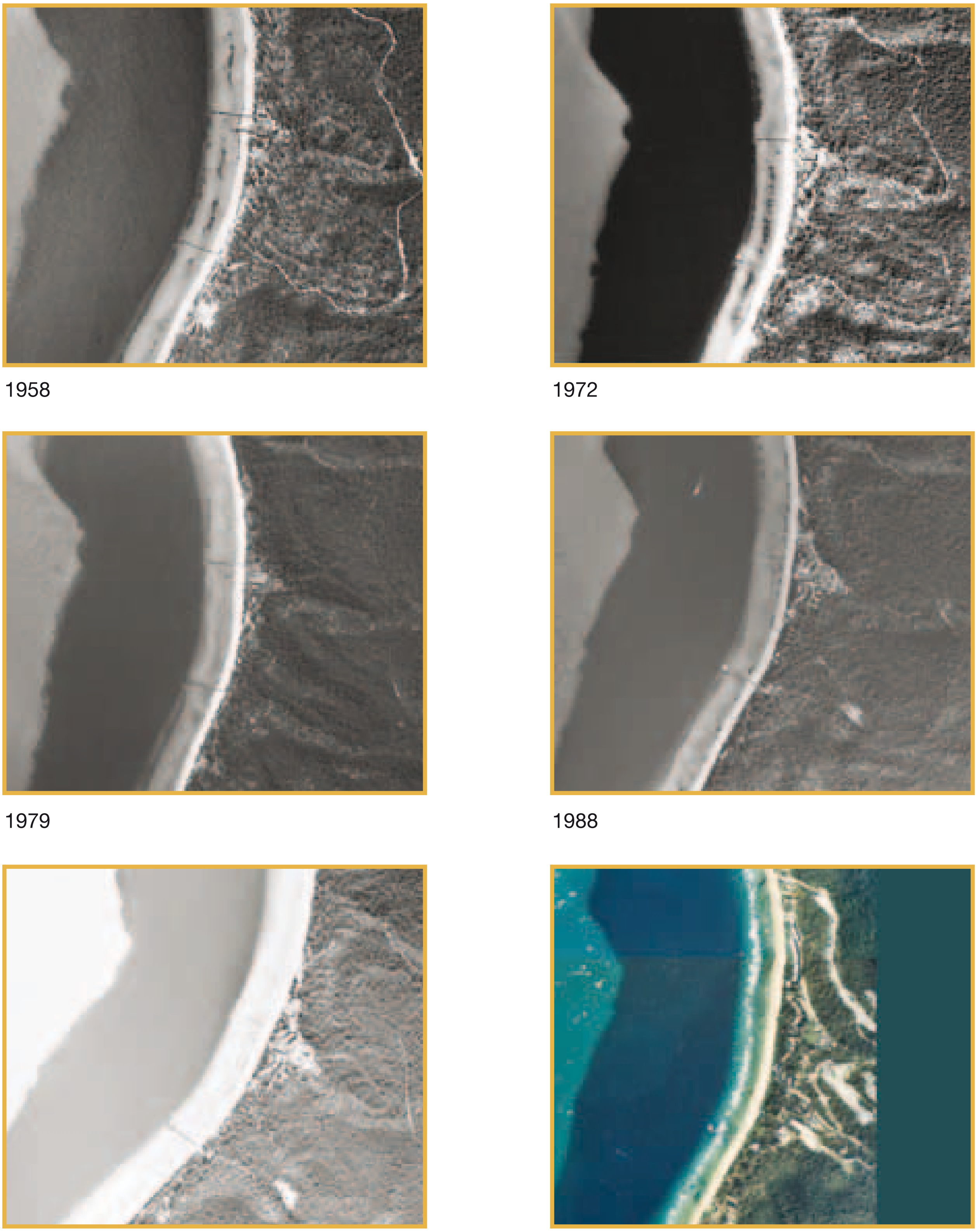


An equivalent shoreline movement analysis has been undertaken for Tangalooma Resort, with the aerial photo record presented in **Figure 3.11l** to **Figure 3.11o** and the historical shoreline movement shown in **Figure 3.11p**. These show that, apart from the substantial change in the shoreline caused by installation of The Wrecks and some placement of sand at Tangalooma Resort, this section of coast has experienced little change in the longer term, consistent with the previous findings.

Figure 3.11l: *Historical Shoreline Change: Tangalooma to Cowan Cowan Point – 1958 to 2004.*

Figure 3.11m: *Historical Shorelines at Tangalooma Point – 1958 to 2004.*

Figure 3.11n: *Historical Aerial Photos of Tangalooma Resort – 1958 to 1999.*



1958

1972

1979

1988

1991

1999

Figure 3.11o: *Aerial Photograph of Tangalooma Resort - 2004.*

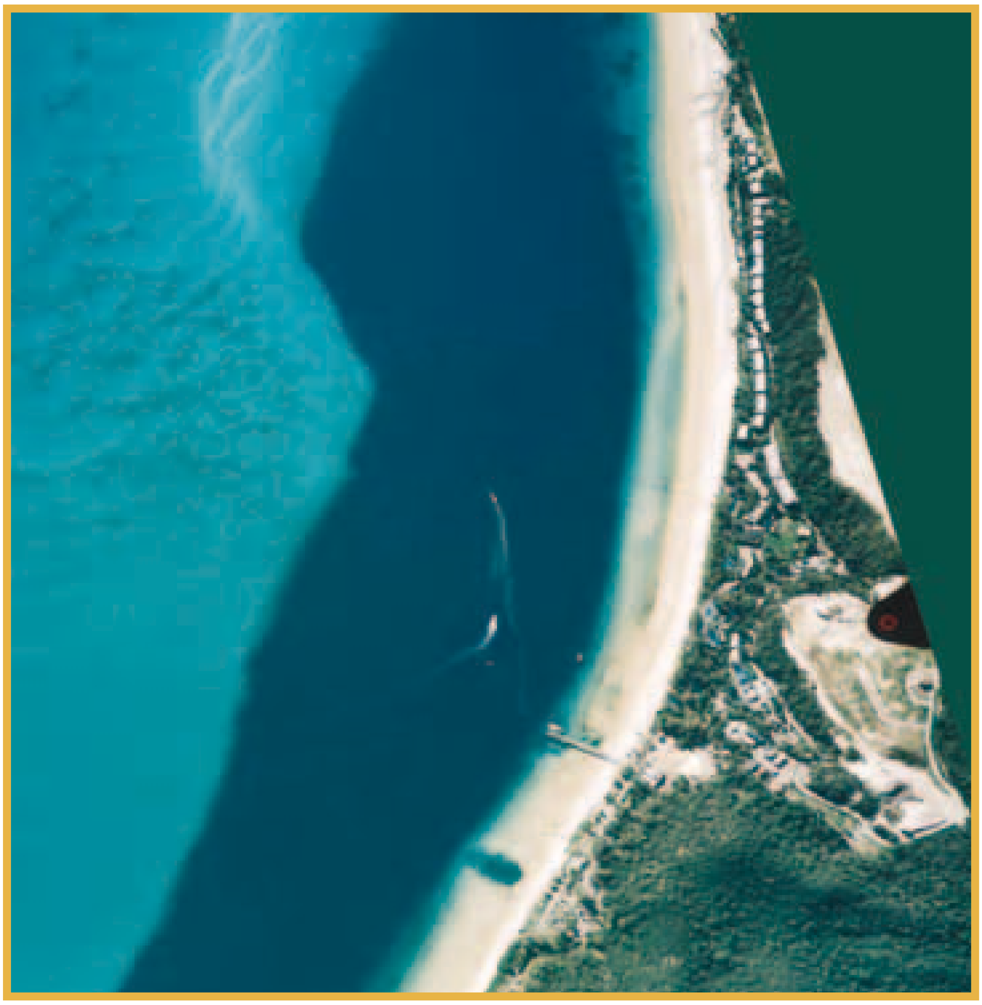


Figure 3.11p: *Historical Shoreline Movement at Tangalooma – 1958 to 2004.*

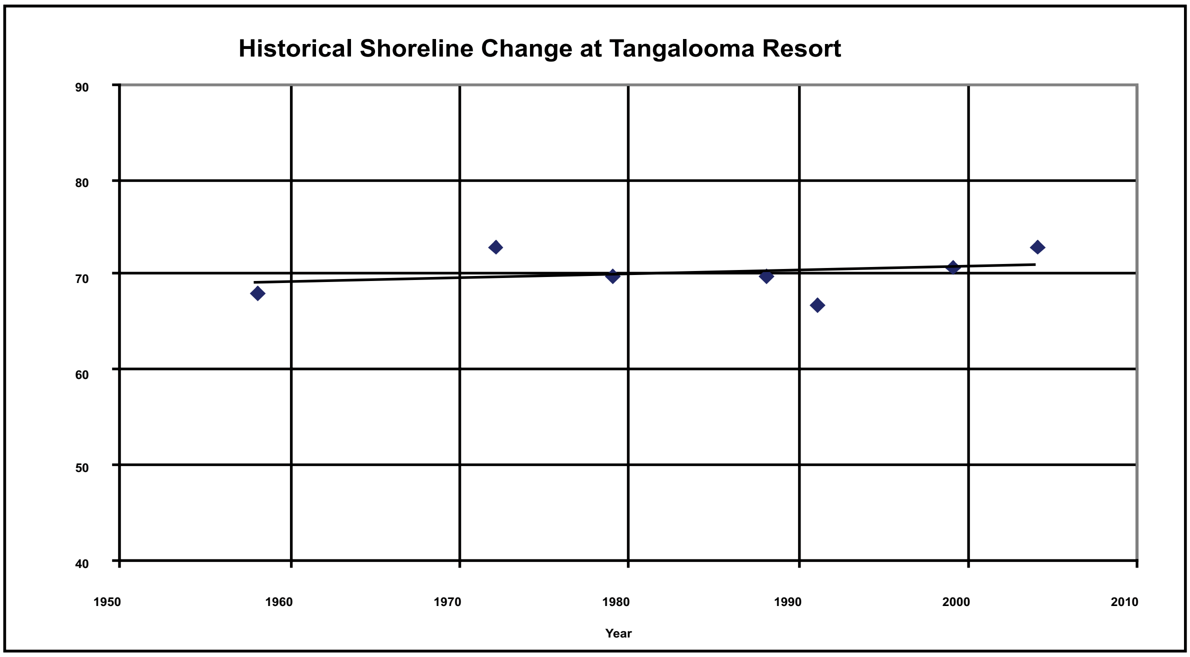
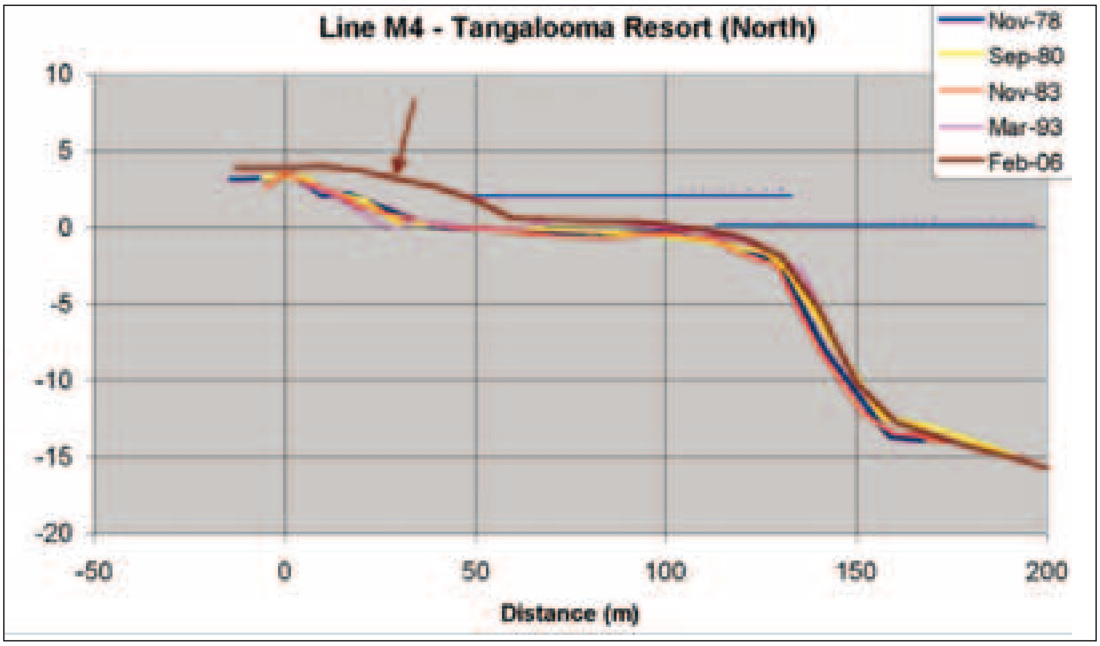


Figure 3.11q: *Profile Surveys at Tangalooma Resort Showing Sand Placement.*



It is noted that there has been some placement of sand on some parts of this beach, elsewhere from the location of the above analysis, to improve recreational amenity. This is evident in the survey data (eg Profile M4) as illustrated in **Figure 3.11q**. This shows that the beach has remained essentially stable and that the placement of sand at that location has resulted in a larger width of beach.

3.11.3 Interaction with Natural Features and Environmental Values

As outlined above, the shorelines of northern Moreton Bay are all sandy beaches in nature. They are naturally dynamic and subject to continuing change in response to natural variations in the prevailing wave and current action. Natural sandy beaches retain their dynamically stable form when left to respond naturally to the prevailing wave/current regime. Only when disturbance in the form of works that prevent natural beach movements, such as seawalls, are constructed will the beach form potentially be lost. Their inclusion in the Moreton Bay Ramsar site under these existing natural conditions indicates that their habitat value is maintained over time and does not depend on shoreline stability, but on preservation of the dynamic sandy beach form, whether it is eroding, accreting or stable in the longer term.

3.12 Consultation

A source of the considerable information for the present studies relating to coastal processes has been the investigation reports and monitoring data relating to the previous dredging of Middle Banks for the airport reclamation at that time. These were sourced largely via Dr M Gourlay of the University of Queensland.

3.13 Policies and Guidelines

Potential impacts from development activities on coastal processes such as shoreline erosion are assessed under the *Integrated Planning Act 1997* pursuant to the *Coastal Protection and Management Act 1995.*

In particular, this chapter addresses matters in policy 2.1.6 of the *State Coastal Management Plan 2001* and South East Queensland *Regional Coastal Management Plan 2006* related to potential impacts on shoreline processes and other natural coastal processes from sand extraction.

3.14 Impact Assessment

3.14.1 General Considerations and Impact Significance Criteria

The North Entrance Tidal Delta, including the Middle Banks area, and the adjacent northern shorelines of Moreton Bay have evolved over the past 6,000 years in response to the sand transport processes associated with the strong north-south oriented tidal currents and prevailing wave conditions. Correspondingly, the hydrodynamics of Moreton Bay are controlled substantially by the continually changing sand shoals and flow channels within the Northern Entrance Tidal Delta.

The processes and stability of the western shoreline of Moreton Island in the Middle Banks region are determined by sand supply and transport that are controlled by tidal currents and predominantly locally generated sea waves impinging on that area. 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 significant permanent 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 behaviour.

Thus, for dredging of the Middle Banks to adversely affect either the hydrodynamics of Moreton Bay or the sediment transport regime and stability of the adjacent foreshores of Moreton Island, it would have to:

- Alter the tidal flow of water to and from the Bay, thereby affecting the tidal range throughout the Bay,
- Significantly change the prevailing tidal currents immediately adjacent to the foreshores,
- Alter the prevailing wave conditions at the foreshores, i.e. altered wave heights and/or wave directions, and/or
- Alter the supply of sand, if any, directly to the foreshore.

The impact assessment undertaken herein has been based on these considerations, as outlined in this Chapter. Specifically, each of the processes described above has been assessed in detail, involving comprehensive computer modelling, such that the nature and extent of any impacts have been identified quantitatively and the consequences determined.

To assist in determining the local and regional significance of any impacts that may be caused by the proposed sand extraction from Middle Banks, a set of significance criteria has been developed as presented on the following page. (see **Table 3.14a**)

Table 3.14a: Significance Criteria for Coastal Processes.

Significance	Criteria: Coastal Processes
Major Adverse	Direct or indirect adverse impact on the hydrodynamics of Moreton Bay to the extent that tide levels, major flow patterns or wave propagation are altered over extensive regional areas of the Bay, such that there would be potential for consequent adverse impacts elsewhere in the Bay. In particular, extensive or acute disturbance (major impact) occurring to the shorelines bordering Moreton Bay, causing increased erosion that would affect township property and/or significant environmental habitat values.
High Adverse	Irreversible changes to tides, currents and/or waves causing adverse impacts on significant parts of the shorelines bordering Moreton Bay, causing increased erosion that would affect township communities and/or significant environmental habitat values. Also, substantial changes to the morphology of Middle Banks such that: • The majority of the regional distribution of a habitat type for ecological communities protected by national or state legislation is lost or substantially depleted; or • The sediment pathway for sand flow to important other areas of the Bay is intercepted.
Moderate Adverse	Changes to tides, currents and/or waves affecting parts of the shorelines bordering Moreton Bay, causing short term increased erosion that would affect township communities or habitat values, such that natural recovery or mitigation measures would alleviate adverse impacts. Also, substantial changes to the morphology of Middle Banks such that the local distribution of a regionally uncommon seabed habitat type is permanently lost or substantially depleted.
Minor Adverse	Lesser disturbance than moderate adverse (moderate impact) to tide levels, currents and/or wave processes causing changes in shoreline stability of limited or temporary nature, or potentially increased shoreline erosion in areas where such erosion is of little consequence. Also, significant changes to the seabed morphology that would be temporary or of only local spatial extent with no impacts elsewhere.
Negligible	No perceptible impacts on regional Moreton Bay hydrodynamics beyond the immediate works area. Local hydrodynamic changes that have no consequent adverse impacts elsewhere. Little or no changes to water level, current or wave processes at shorelines such that any impacts to shoreline stability would be imperceptible.
Beneficial	Any effects or measures that are expected to result in reduced shoreline erosion where that is presently a problem, or design features or management activities that would make a long term positive contribution to shoreline amenity or coastal environmental values.

3.14.2 Previous Studies

The Moreton Bay Sand Extraction Study Phase I (WBM Oceanics Australia, July 2002) examined the potential effects of several indicative options for extraction of sand from northern Moreton Bay, in the vicinity of Central, Middle, Spitfire and East Banks. The options assessed provided for extraction of 30 million cubic metres of sand in each area. Indicative preliminary modelling undertaken in that study indicated that all of the four options considered would cause only a localised redistribution of water flow with no overall change in tidal regime or levels in Moreton Bay.

While impacts varied somewhat between options, the overall impacts were generally low with any adverse affects able to be managed by the design of the dredging works.

The Moreton Bay Sand Extraction Study Phase II – Hydrodynamic Impacts Review (WBM Oceanics Australia, December 2003) included modelling to assess potential hydrodynamic effects of sand extraction involving removal of (approximately) 20 Mm^3 sand from any of four (4) locations, including Middle Banks. The modelling indicated that impacts are likely to be relatively local re-distributions of current flow, with indiscernible effects beyond the immediate dredging area and on the tidal regime of the Bay as a whole. There would be no change in tidal flushing of the Bay generally or tidal levels at surrounding shorelines or the Brisbane River.

Specifically of significance to this proposal, dredging of Middle Banks would have some local impact on tidal current patterns, particularly for the deeper levels of dredging, however, there would be no discernable impact at adjacent shorelines.

The Moreton Bay Sand Extraction Study Phase II – Wave Penetration Study (WBM Oceanics Australia, January 2004) focused on assessment of potential impacts to wave processes associated with extraction of up to 20 Mm^3 sand from any one of the four areas assessed, including Middle Banks. The results of the study demonstrated that, for the dredging scenario adopted at Middle Banks, involving excavation along the western side of the East Channel without interference to the shallower areas:

- In ambient day to day swell conditions and strong wind ‘sea’ conditions, there would be no discernible changes in the wave conditions at the shorelines around northern Moreton Bay, including the mainland, Bribie Island and Moreton Island.
- Under higher ocean swell conditions (greater than 3 m offshore), there could be minor impacts to the incident swell conditions along the northern part of the western shoreline of Moreton Island. However, these changes relate to low absolute wave heights, generally less than 0.2 m and would be of negligible significance for shoreline stability.

Overall, it was found that neither the tidal currents nor this wave-related sediment transport processes would be adversely affected. Thus it was concluded that shorelines of northern Moreton Bay will not experience any changes in sand transport or shoreline stability as a consequence of the dredging scenarios assessed.

3.14.3 Assessment of Impacts of the Proposed Middle Banks Dredging

The proposed dredging of Middle Banks (see Volume C, Chapter 1 for details) will immediately deepen the local bathymetry within the dredging footprint that extends along the western side of the East Channel for a distance of approximately 5 - 6 km. This will involve deepening by about 10 m at the western margin reducing to about 1 m in the East Channel. The shallower parts of Middle Banks, less than 10 m depth, will not be affected.

Detailed numerical modelling has been used to assess the potential impacts of the proposed Middle Banks dredging on the local and regional hydrodynamics (tidal processes and waves), the seabed morphological processes and the related processes and stability of the adjacent Moreton Island shoreline. The modelling includes:

- Two-dimensional finite element hydrodynamic modelling of potential impacts on tidal currents using the RMA10S model established previously and refined and further validated as part of the present study, as described in section 3.8.
- Two-dimensional wave modelling of wave propagation and impacts at shorelines using the SWAN model established and validated as described in section 3.8.
- Two-dimensional finite element morphological modelling of sand transport processes in the Middle Banks region using the RMA10S model.

Assessment of potential effects on shorelines is determined on the basis of the modelled impacts on the wave/current processes there. The existing situation and the proposed dredging design, involving extraction of 15 Mm^3 from an area along the western margin of the East Channel immediately adjacent to Middle Banks, have been modelled. By using identical model setup and boundary conditions in each case, the impacts of the dredging may be identified by direct comparison of the model results.

The dredge footprint modelled for the purposes of the hydrodynamic and coastal processes assessment assumes a shape that is similar but not identical to the dredge footprint identified in Chapter C1. This is because a number of additional considerations have been taken into account in the dredge footprint presented in Chapter C1 such as the exclusion of areas with unsuitable fine sediments and avoidance of seagrass habitat areas in shallow water above -10 m LAT. However, key factors such as the proposed depth of the dredge profile are identical between the proposed and modelled footprint. As such, for the purposes of the assessment of changes to hydrodynamic processes and coastal processes these minor differences between the footprint shapes would not lead to detectable changes in the modelling results or in the interpretation of potential impacts.

Impact assessment results for these scenarios have been derived in terms of:

- Spatial plots of changes in hydrodynamic processes (currents, waves), identifying where any potentially significant impacts may occur.
- Tabulated wave height and direction values at particular representative and/or relevant locations along the Moreton Island shoreline.
- Tabulated water level values at particular representative and/or relevant locations.
- Spatial plots of morphological processes (sand transport), identifying where any potentially significant impacts may occur.
- Consideration of the absolute values of current speed and wave height at particular representative locations to provide a context for assessing the significance of any relative impacts.

A range of representative local ‘sea’ wave conditions have been modelled, specifically including wind scenarios that might have maximum potential for impacts to Moreton Island, as listed in **Table 3.14b**.

Table 3.14b: Wave and Wind Scenarios.

Typical Condition		Offshore Wave Condition			Local Wind Condition	
		Hs (m)	Tp (s)	Dir (deg)	Vel (m/s)	Dir (deg)
1	High ocean swell with no wind	3	8	SE	–	–
2		3	8	ESE	-	-
3		3	8	E	-	-
4		3	8	ENE	-	-
5	Medium to strong winds from the SW to NW sectors in Moreton Bay				15	SSW
6					15	SW
7					15	W
8					15	NW

Note: Hs = Significant wave height; Tp = Spectral peak period; Dir = Wave/wind direction; Vel = Wind speed.

Table 3.14c: Tidal Amplitude Impacts in Moreton Bay.

Location	Existing	Dredged
Ocean	0.680	0.680
Comboyuro	0.704	0.704
Tangalooma	0.783	0.783
West Inner Bar	0.872	0.873
Russell Island	0.930	0.931

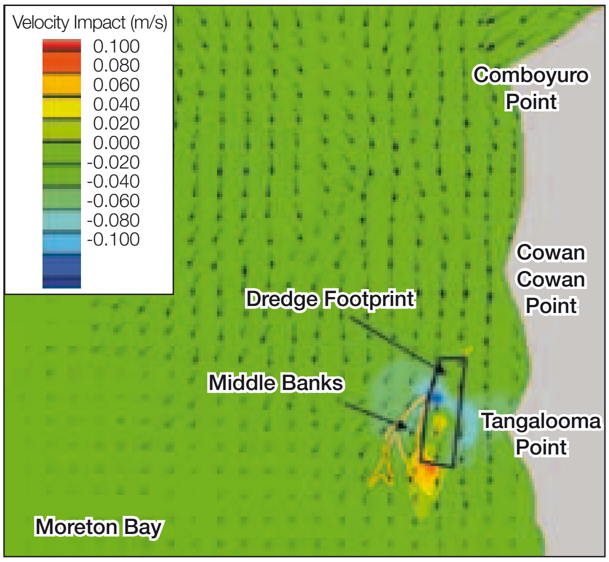
3.14.3.1 *Hydrodynamic Impacts*

The Northern Delta shoal and channel bathymetry, and associated bed friction forces, play a major role in determining the flow and tidal level regime of Moreton Bay. Some parts of the Delta have more effect than others in that regard, with the North East Channel area being potentially the more critical. However, previous studies have shown that the vast size of the Delta is such that even quite large-scale sand extraction of the scale proposed has relatively insignificant effect in modifying the bathymetric and frictional controls on flow to and from the Bay.

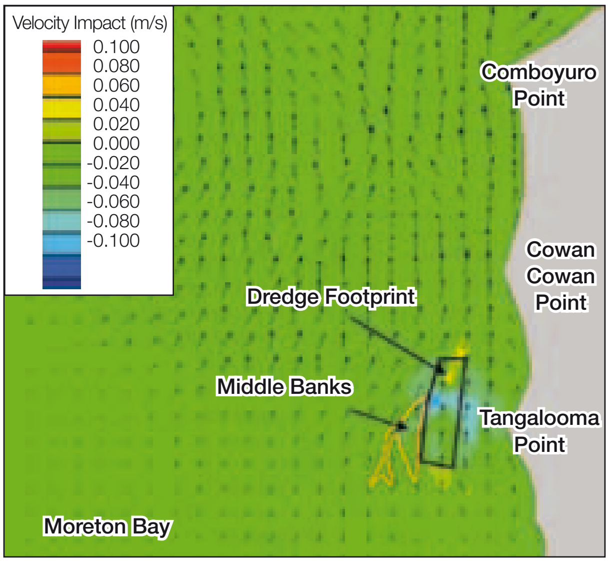
The hydrodynamic modelling results showing potential impacts on tidal levels for a Spring Tide for the proposed dredging of Middle Banks are shown in **Table 3.14c** in terms of tidal amplitude from harmonic analysis for the existing and dredged cases, indicating less than 0.1 mm (0.1%) increase. Such change would be undetectable and of no consequence.

As well, plots showing the spatial distribution of changes to the peak flood and ebb tide currents are presented in **Figure 3.14b**. These changes have been interpreted in conjunction with absolute current speeds in determining the potential impacts of the works on tidal flows, as described below.

Figure 3.14a: *Spatial Distribution of Impact on Tidal Currents.*



(a) Flood Tide Current Speed Difference Plot.



(b) Ebb Tide Current Speed Difference Plot.

The hydrodynamic modelling shows that the dredging will alter the tidal flow pattern in the local area by attracting some additional flow into the East Channel and away from the adjacent un-dredged areas to the east and west, thereby:

- Increasing the tidal flow within the East Channel, and
- Decreasing the tidal flow over the adjacent undredged areas to the east and west.

The increase in flow in the East Channel will increase the tidal current speeds in the un-dredged parts of the channel to the north and south of the dredged area. However, within the dredged area itself, despite the increased flow, the increase in depth is such that total flow area will be increased relatively more and the tidal current speeds there will decrease.

These results show that:

- The impacts to the tidal current patterns are confined to the local area in the immediate vicinity of the dredging footprint and do not extend broadly across Moreton Bay. Tidal currents would be increased in some areas and reduced in others, as shown in **Figure 3.14a** and as described below:
    - Flood and ebb tide current speeds would be reduced by less than 0.1 m/s (equivalent to approximately 10 percent) in the local area immediately north of Middle Banks, and reduced by less than 0.05 m/s (5 percent) over a somewhat larger area north of and to the east of Middle Banks towards Tangalooma Point.
    - Flood and ebb tide current speeds would be increased slightly (by about 0.04 m/s – 4 percent) immediately north along the East Channel from the dredged area. This increase in current speed is relatively small (less than 1 - 2 percent) as far north as Cowan Cowan Point.
    - Tidal current speeds would be increased in the shallower un-dredged area of Middle Banks to the south-west of the dredged footprint by up to about 0.08 m/s (8 - 10 percent) on the flood tide and 0.04 m/s (4 percent) on the ebb tide.
- In no area does any discernible change in current speed impinge close to any section of the shoreline.
- There are no discernable impacts on the tidal regime of the Bay as a whole.
- There are no impacts on circulation patterns of the Bay.
- There are no discernible impacts on tidal elevations at any locations.

Thus, impacts on the hydrodynamics are likely to be of significance only in the immediate Middle Banks and East Channel area. The impacts identified are likely to increase the rate of southward sand transport in the East Channel immediately to the south and north of the dredged area. Such impact reduces northward towards Cowan Cowan Point.

3.14.3.2 Wave Impacts

In principle, increased water depths associated with dredging may potentially impact on wave propagation processes through:

a) Altered wave focusing around shallow shoals affected by the dredging.

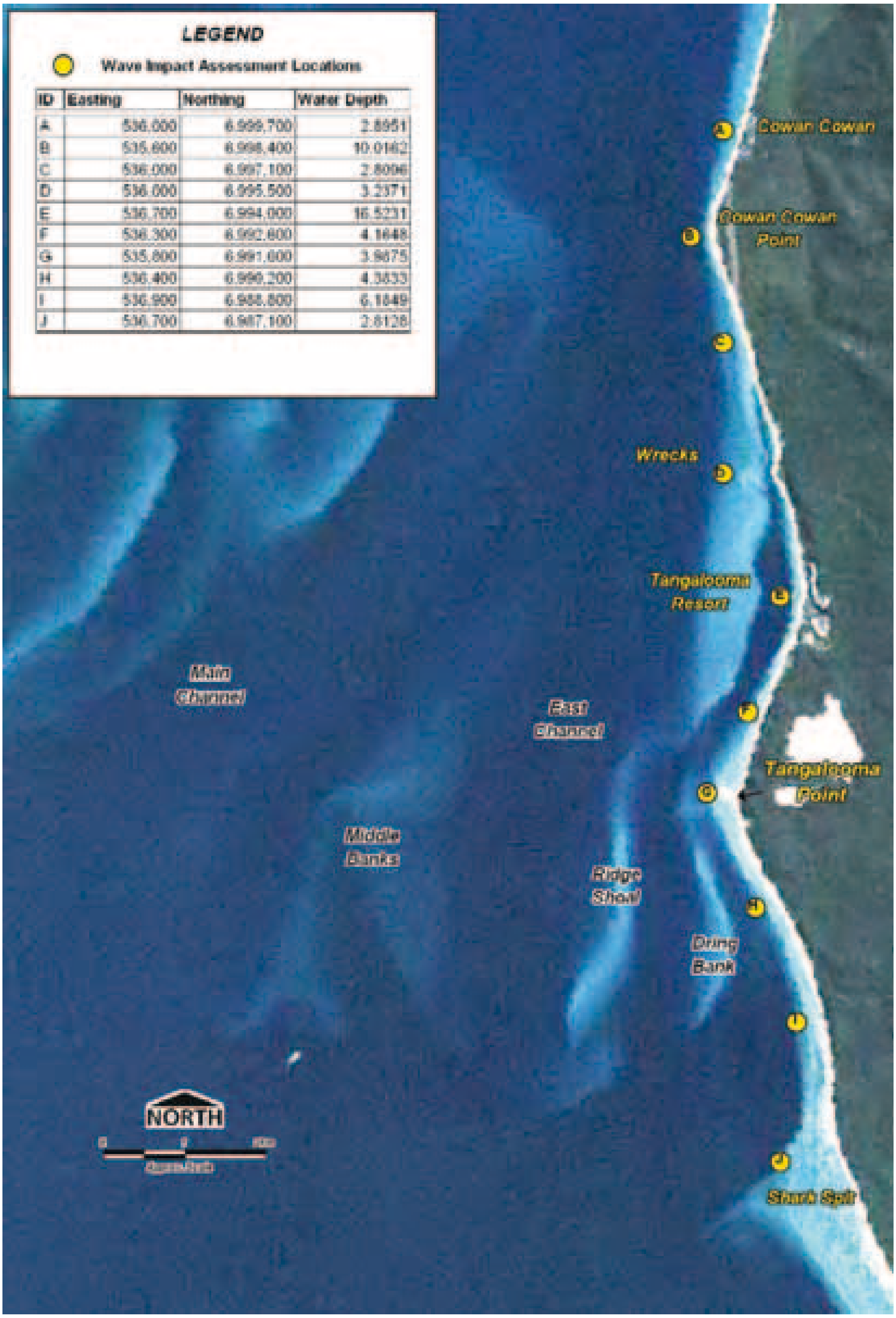
b) Reduced wave energy loss across the dredged area due to reduced bed friction.

Longer period swell wave propagation is likely to be affected more than that for short period sea waves as they ‘feel’ and are affected more by the seabed. However, it has been shown (Section C3.5) that such swell waves propagating to the Middle Banks area from the ocean are typically of insignificant height and any such impacts would be of indiscernible consequence. Only those locally generated sea waves of period large enough to be affected by the seabed at the depths involved in the dredging may be impacted to any significant degree.

In that regard, it is known that waves begin to be affected by the seabed at water depths less than half the ‘deep water’ wave length. Thus, for a minimum dredging depth of about 8 m, only those waves of period greater than about 3.2 seconds would be affected to any degree, corresponding to sea waves typically occurring at Middle Banks of height greater than about 0.65 m. Such waves occur about 7 percent of the time (refer **Table 3.5b**).

Tables containing the wave height and direction impacts for the Moreton Island shoreline locations shown in **Figure 3.14b** are given in **Tables A** and **B** in **Appendix C3: A**.

Figure 3.14b: *Moreton Island Shoreline Locations for Wave Impact Assessments.*



LEGEND

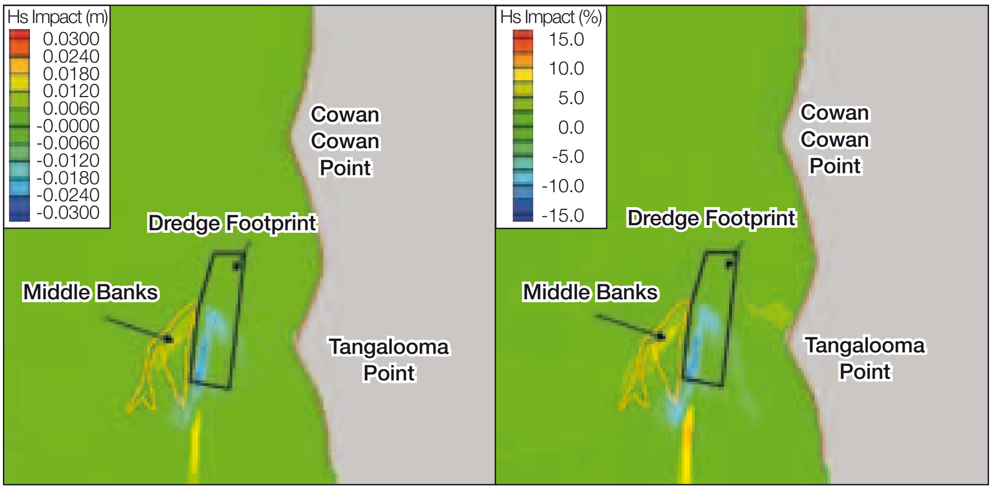
● Wave Impact Assessment Locations

ID	Easting	Northing	Water Depth
A	536,000	6,999,700	2.8951
B	535,600	6,998,400	10.0162
C	536,000	6,997,100	2.8096
D	536,000	6,995,500	3.2371
E	536,700	6,994,000	16.5231
F	536,300	6,992,600	4.1648
G	535,800	6,991,600	3.9675
H	536,400	6,990,200	4.3833
I	536,900	6,988,800	6.1849
J	536,700	6,987,100	2.8128

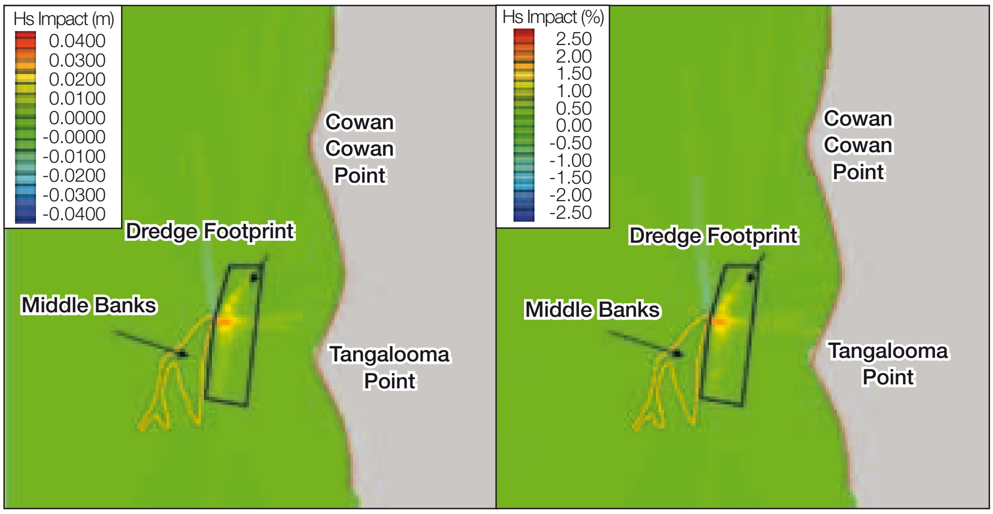
The results indicate that:

- Generally there would be only isolated local changes in wave heights in the vicinity of Middle Banks, typically less than 10 percent at the nearby shoals. For the very low swell waves confined to the open waters of the Bay, changes of up to about 0.02 m may occur but would not be discernible. For the wind waves that may reach up to about 1.5 m in significant wave height, local height changes of up to about 0.03 m (1.0-2.0 percent) may occur primarily associated with changed shoaling coefficients within the dredged area and, similarly, would not be discernible there.
- The Middle Banks dredging will have less than 0.25 percent impact on the predominant wind waves at adjacent Moreton Island shoreline.
- The dredging could increase swell wave heights by up to 3 percent at the shoreline locations near Tangalooma Point (Locations F and G), however this is relative to extremely small existing heights of less than 0.2 m and would be of negligible significance to shoreline processes.
- Changes in wave direction at the shoreline will be negligible (less than 0.1 degree for local sea and less than 0.4 degrees for the swell).

Figure 3.14c: *Spatial Extent of Impacts to Waves (refer also tables in* ***Appendix C3: A****).*

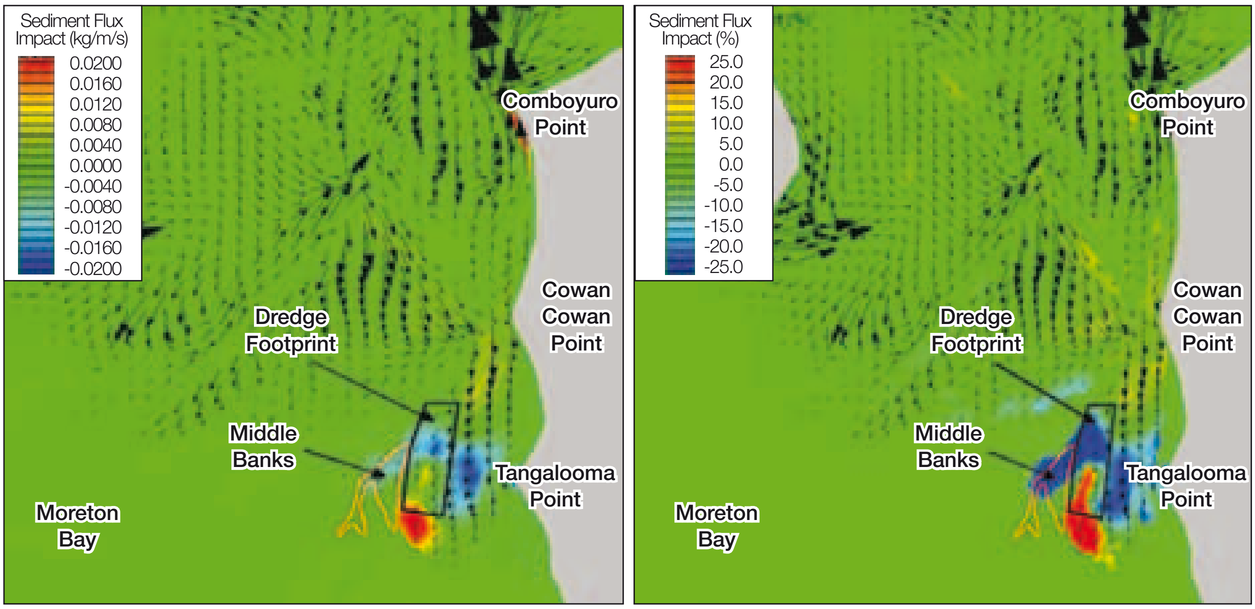


A. Difference Plots (left in metres; right as %) for Wave Case 3 (Ocean Swell).



B. Difference Plots (left in metres; right as %) for Wave Case 6 (SW Wind Wave).

Figure 3.14d: *Zone of Impact on Net Sand Movement – Left as Kg/m/s; Right as Percent Change (Green: No Change; Orange: Increase; Blue: Decrease).*



Wave height impact (difference) plots for typical sea and swell propagation (wave cases 3 and 6) are presented in **Figure 3.14c** to illustrate the results as described above and summarised in **Appendix C3: A**.

3.14.3.2 Impacts on Seabed Morphology

The morphological response to the dredging is commensurate with that of the tidal currents. It is noted that sand transport rates are non-linearly proportional to current speed, typically related to velocity raised to the power 5. Thus, changes in sand transport rates are more acute than those in current speed.

The modelled impact on the net sand transport in the northern Moreton Bay region is illustrated in **Figure 3.14d** in terms of absolute transport rate changes (Kg/m/s). In that figure, the zone in which no significant change would occur is shown as green while yellow/orange indicates an increase and blue indicates a decrease.

These results must be interpreted carefully in that, at Comboyuro Point (where there is a noticeable change in the absolute net transport rate) they represent only a very minor relative change (<2 percent) compared to the existing high transport there.

The modelling shows that there will be:

- A substantial (up to 100 percent) increase in the net sand transport southwards along the un-dredged parts of the East Channel south of the dredging footprint. This will occur across a width of about 400 m along the alignment of the dredged footprint and will not affect the shallower parts of Middle Banks.
- An increase of up to 10 - 12 percent in the southward net sand transport in the area north from the dredged area towards Cowan Cowan Point, reducing to about 5 - 6 percent in the vicinity of Cowan Cowan Point.
- A decrease in sand transport in the dredged part of the East Channel and in the areas to the immediate east and west of the dredged area.

This will result in subsequent progressive changes to the seabed involving:

- A slight increase in the gradual accretion in the East Channel at the northern part of the dredged area, with sand derived from the area immediately north of the dredged area, as appears to have occurred following the previous dredging.
- Erosion immediately south of the dredged area due to reduction in the southward supply and increase in the rate of transport south from

there, with a commensurate increase in the flow of sand to the southern drop-over margin of the Middle Banks shoal along the alignment of the dredged footprint.

- A slight reduction in the rate of sand transport over the shallower parts of Middle Banks, unlikely to have any discernible impact on the bathymetry or behaviour of those areas.

It is noted that the general shape of the seabed formed by the previous airport dredging exercises in the 1980s and 1990s remains evident today, indicating only relatively slow morphological response to those works over the past 20 years.

The modelling suggests that a similar slow morphological response to the proposed works will occur and that the seabed bathymetry essentially as formed by the dredging is likely to persist for many years. Nevertheless, the sand forming the seabed will continue to be mobile and transported by the prevailing tidal currents with a net southward movement. Mobile seabed ripple and dune forms will continue to be a feature of the area, as at present.

The increased sand transport south of the dredged footprint will result in a gradual deepening of that area and an increase in the rate of sand migration to the southern drop-over margin of the shoal there. Current speeds there are presently up to about 1 m/s in spring tides and are likely to increase by about 8-10 percent on flood tides and 4 percent on ebb tides. There is evidence that this drop-over area is presently quite active and extending southward at a rate of the order of 200 m over the past 25 years (8 m/yr). Migration of the drop-over margin is likely to increase as a result of the dredging to up to twice the existing rate. As stated in the assessment of ecological impacts in Chapter C5, the predicted increase in bed transport rates is unlikely to result in major changes in the structure of benthic communities.

3.14.3.3 Impacts on Stability of Adjacent Shorelines

In principle, three factors may adversely affect shoreline stability along the coastlines of Moreton Bay, particularly the western shore of northern Moreton 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.
and/or
- Direct storm wave attack causing beach erosion with sand being moved offshore from the foreshore, either to be returned to the beach when a predominant swell exists 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 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 of the Middle Banks to adversely affect the sediment transport regime and stability of the adjacent foreshores of Moreton Islands, it would have to:

- Significantly change the prevailing tidal currents immediately adjacent to the foreshores,
- Alter the prevailing wave conditions at the foreshores, i.e. altered wave heights and/or wave directions, and/or
- Alter the supply of sand, if any, to the foreshore.

The wave propagation modelling shows that there would be no changes in wave heights of any significance at any shoreline location as a result of the proposed dredging. Both the present and all previous investigations (WBM 2001, WBM 2003) have indicated that there is no regional impact to tidal currents from large-scale sand extraction from the Northern Delta region generally, and Middle Banks dredging in particular. However, the detailed modelling now available indicates some increase in tidal currents and associated net sand transport along the East Channel as far north as Cowan Cowan. The increase in southward tide-related sand transport in the channel is likely to be around 5-6 percent. No other nearshore areas would be so affected.

It is known that the shoreline at Cowan Cowan is presently eroding. The mechanism is considered to be predominantly wave processes in transporting sand northward along the shoreline and not the tidal current. The tidal current is not presently undermining the shoreline there, clearly evidenced by the relatively flat shallow shelf that extends out from the beach for a significant distance before dropping down to the deeper East Channel.

Accordingly, the processes that influence the present shoreline erosion at the township of Cowan Cowan will not be affected in any discernible way, either adversely or beneficially. This is consistent with the findings of the assessments and monitoring relating to the previous dredging.

Further, while the dredging will remove sand from the system, there is also an ongoing supply of sand to the overall northern delta region and southward along the East Channel towards Middle Banks, at a rate of about 300,000 m^3/yr. This has persisted over the past 6,000 years and will continue into the future. The vast size (approximately 4,000 million cubic metres of sand), natural mobility and changing nature of the Northern Delta dominate the overall processes relative to any impacts likely to result from the proposed dredging.

It is concluded that there is negligible risk that the proposed Middle Banks dredging will affect any shoreline areas of Moreton Bay.

3.15 Cumulative and Interactive Effects

The Moreton Bay Sand Extraction Study (MBSES) identified the potential impacts of undertaking large-scale sand extraction from the Bay, involving quantities of up to 60 million cubic metres from various parts of the Northern Delta in the vicinity of Central, Middle, Yule and Spitfire Banks. The study concluded that:

- Extraction of large volumes of sand from the northern banks would have no potential for change to the overall hydraulics of the Bay, therefore no changes in tidal flushing or tidal levels at surrounding shorelines are likely.
- Extraction of large volumes of sand would have only localised effects on the prevailing tidal flows in adjacent areas.
- Taken together, only localised changes would occur as shallow sand banks are removed however only small changes to wave climates or tidal currents close to the shoreline would be expected.

It was inferred that the likely impacts on sediment supply and shoreline stability of adjacent coastal areas would be negligible.

Based on the findings of the MBSES, it may be concluded that any additional sand extraction within the scope of activities considered in that study, either as part of proposed dredging of Spitfire Channel or extraction for industry purposes undertaken in conjunction with the proposed dredging at Middle Banks, would have indiscernible impacts on the regional hydrodynamics of Moreton Bay and the shorelines of the Bay. In that context, the relatively minor sand extraction presently being undertaken ay Middle Banks by the extractive industry is insignificant in terms of impacts on hydrodynamics and sedimentation processes.

As such, it is considered that the cumulative and interactive effects of the various dredging activities in the Bay are minimal and present no constraint to the proposed level of sand extraction from Middle Banks.

3.16 Mitigation Measures

Mitigating measures to ensure minimal impacts on adjacent shorelines have been incorporated into the dredge footprint design. Specifically, by excavating along the western fringe of the East Channel, essentially in the same location as the previous dredging in the 1980s, the shallow banks will be left intact and changes to wave propagation will be indiscernible at the shoreline.

The assessment has shown that the dredging will have only local discernible impacts, with no adverse impacts to the shoreline of Moreton Island or the broader Moreton Bay hydrodynamic regime. As such, no other mitigating measures are considered feasible or warranted.

3.17 Residual Effects

It is apparent from the historical surveys that the residual seabed from the previous dredging remains essentially intact after more than 20 years. There is evidence of some infilling in the northern area within the East Channel, consistent also with the modelling of the proposed dredging. As such, it is expected that the deepened bathymetry formed by the proposed dredging will remain relatively unchanged for many years (decades).

The investigation of shoreline processes undertaken in this study shows that sand transport in the nearshore beach areas is dominated by wave action. The historical erosion of the shoreline at Cowan Cowan has been occurring for over a century and there is no evidence that the previous or presently proposed dredging would affect the rate of erosion. Thus, while there will be some minor residual effect on the net rate of sand transport in the deeper water along the East Channel adjacent to Cowan Cowan, it is not likely that this will impact on shoreline stability. It is expected that the historical rate of shoreline erosion will continue into the foreseeable future, with no adverse impact from the proposed dredging.

Nevertheless, the seabed will continue to be active, with substantial sand movement occurring, as at present. This will tend to smooth out any sharp irregularities in the seabed formed by the dredging. It is likely that large mobile sand dune bed forms will again develop along the dredged area, as exist now.

There will also be an increase in the southward migration of the sand to the southern drop-over margin of the Middle Banks shoal south of the dredge footprint. This is likely to persist for many years, with increased sand flow over the drop-over.

3.18 Assessment Summary Matrix

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

Table 3.18: Coastal Processes Assessment Summary Matrix.

EIS/MDP Area: **Coastal Processes** **Feature/ Description**	**Current Value** **+** **Substitutable Y:N**	**Description of Impact**			**Additional Compensation (beyond standard practice)**	**Residual impacts**
		Impact	**Mitigation inherent in design/standard practice amelioration**	**Significance Criteria**		
Moreton Bay hydrodynamics	Impacts would affect other parts of Moreton Bay. Not substitutable	Regional changes in tide levels and/or tidal currents as well as wave heights and/or wave propagation processes	Dredge footprint determined to avoid shallow parts of Middle Banks and confined to area adjacent to existing East Channel. Avoids impacts on wave propagation.	Negligible, -ve, LT, D	Nil	Negligible
Moreton Bay Morphology	Bay bed bathymetry and sand transport regime	Local change to bathymetry with associated impact on sand transport and bathymetry in local adjacent areas	Design adopted to coincide with previous dredged footprint – no intrusion into other areas.	Refer ecology impacts (Chapter C5), LT,D	Nil	Refer to C5.
Moreton Island Shoreline	Socio-economic value to owners and residents of adjacent properties; Coastal amenity value; Ramsar value.	Increased erosion or change in character of shorelines	Dredge footprint determined to avoid shallow parts of Middle Banks and confined to area adjacent to East Channel, thereby minimising impacts to wave propagation.	Negligible, -ve, LT, D	Nil	Negligible

Key:

Significance Criteria: Major, High, Moderate, Minor Negligible
+ve positive; -ve negative
D – direct; I – indirect
C – cumulative; P – permanent; T – temporary
ST – short term; MT – medium term; LT long term

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