3 COASTAL PROCESSES & CAUSES OF EROSION

3.1 General Considerations

A good understanding of the fundamental coastal processes affecting Woorim Beach has been developed in order to determine and assess engineering and management options such that solution strategies may be adopted with confidence of success. Only limited detailed study of the coastal processes and beach/dune dynamics has been undertaken previously. Nevertheless, considerable knowledge is available from both:

- Practical and theoretical knowledge of the principles of beach behaviour now established in the fields of coastal and ocean engineering and geomorphology;
- Geological and geomorphological investigations undertaken specifically of Bribie Island and the surrounding coastal system; and
- Measurements and modelling assessments undertaken as part of both previous studies and the present investigation of the wave, current and sand transport processes occurring at Woorim Beach.

A brief outline of this knowledge is presented in this Chapter.

The key issues affecting the most appropriate management action are those of historical and future:

- supply of sand into the beach system;
- sand movements within and through the beach system; and
- possible progressive net loss of sand from the beach system.

The natural beach system includes not only the beach itself but also:

- the dune that acts as a reservoir of sand for the beach during major erosion events and subsequently rebuilds gradually as the sand is moved onshore by wave and wind action; and
- the nearshore zone where sand movement is related to beach behaviour.

While it is known that there has been a tendency for gradual erosion of Woorim Beach superimposed on short term fluctuations of the shoreline location, the nature and rate of progressive long-term erosion has been uncertain. A comprehensive investigation over some years and involving substantial cost would be needed to gain a full understanding of those processes. However, the review of existing knowledge and additional investigations undertaken as part of this study and outlined below have provided a level of understanding sufficient to identify the most suitable engineering and management options for dealing with the erosion, as set out in this report. Within that context, relevant uncertainties and their significance are identified and discussed.

3.2 Geological Framework

The geological evolution of the Woorim coastline fits within the broader evolutionary development of Bribie Island as a whole and the adjacent areas (Figure 3-1) and needs to be considered in that regional context. Jones (1992) provides the most recent and comprehensive assessment of the geology and geomorphology of Bribie Island and the region north to Point Cartwright. Armstrong (1990) describes the geological development of the southern tip of Bribie Island in particular. Lester et al (2000) describe the geomorphological processes affecting stability of the northern tip of Bribie Island. Key findings of those research and investigation publications are summarised below.

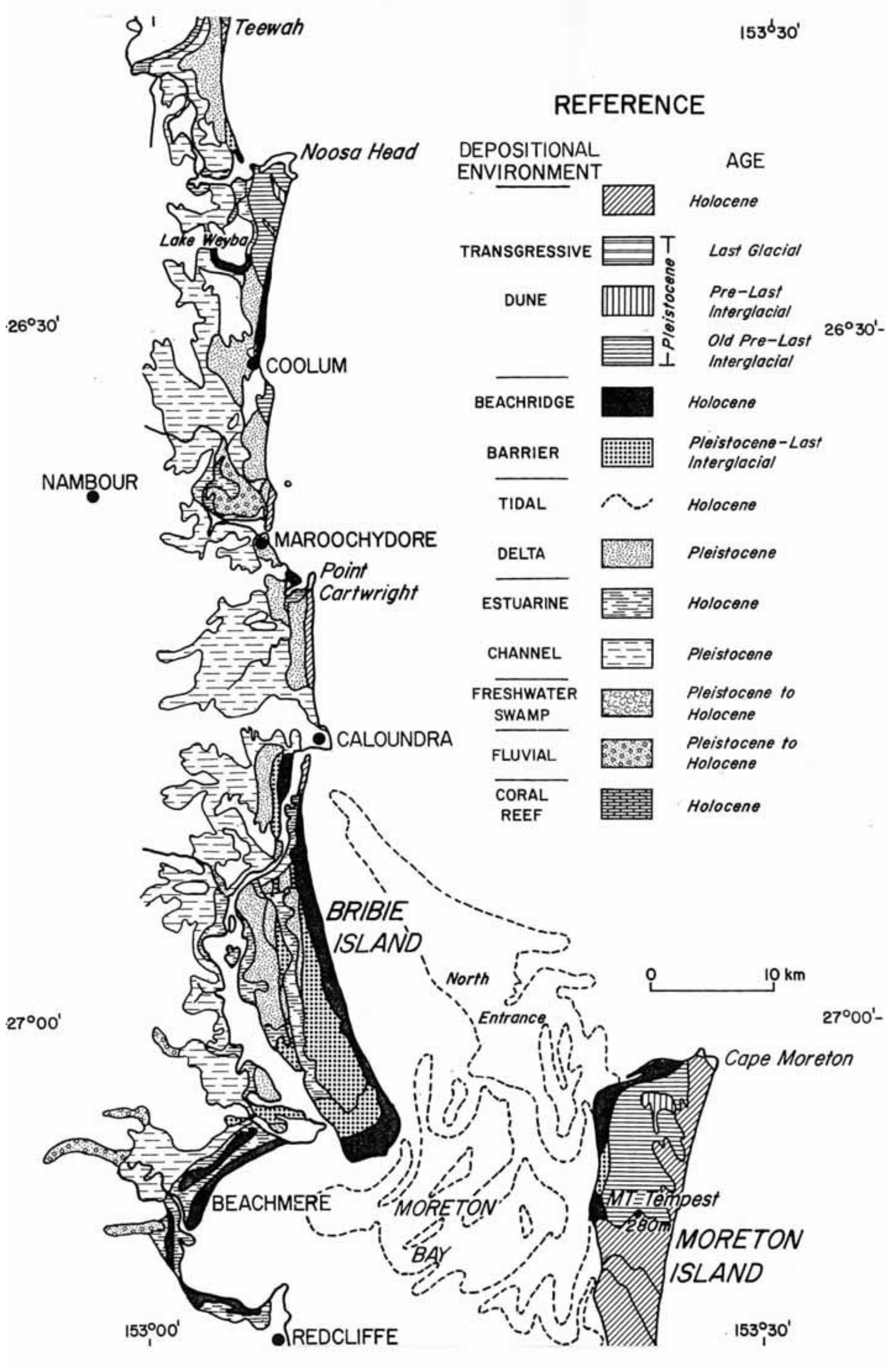


Figure 3-1 Moreton Island & Bribie Island Onshore Geology (from Stephens 1982)

Bribie Island has formed through transport and deposition of unconsolidated sand during the late Quaternary period, including several episodes of rising and falling sea level. The most recent post-glacial sea level rise was about 120 metres from 18,000 to 6,000 years BP. The oldest sand deposits are of Pleistocene age and occur as stranded dunes, beaches and tidal deltas accumulated about

120,000 years ago when the sea was previously at the present level. Holocene (last 10,000 years) sand bodies similar to but less extensive than those of the Pleistocene were formed over the past 6,000-7,000 years.

Offshore from Bribie Island, large deposits of marine sand moved north along the coastal system mainly at times of lower sea level have formed the North Banks and Hamilton Patches (Figure 3-1), between Moreton Island and Caloundra. At present sea level, those banks are submerged and being remoulded by the tides and waves while the coastal sand supply is feeding into Moreton Bay in the NE Passage region near Combuyoro Point. A well-defined natural channel along the western side of the banks separates them from Bribie Island.

Further south, the alternating channels and banks of a large tidal delta occupy the entire entrance to Moreton Bay between Bribie Island and Moreton Island. There, tidal currents produce a dynamic environment for the evolution of ebb and flood tide dominated channels. Along Bribie Island, both wave and tidal currents are active in transporting sand, with tides becoming progressively more dominant to the south.

Offshore from Woorim, well developed tidal channels to depths of 22m are separated by banks shallowing to less than 5m, with bed forms characteristic of strong tidal flows and active sediment transport. The profiles and sediments there indicate:

- The seafloor sediments are predominantly clean quartzose sands;
- A major tidal channel directly abuts the Bribie Island shoreline at Woorim;
- Along the western margin of this channel, estuarine muds are exposed at depths of 8-14m, believed to have formed prior to 6,000 years ago during the post-glacial transgression and forming the substrate of Bribie Island. Their exposure suggests that erosion at Woorim may relate to westward migration of the channel;
- The surficial sediments of the nearshore zone form a veneer less than 1m thick overlying the transgression age deposits, evidenced also by tree stumps and peaty deposits exposed at times on the lower beach south of Freshwater Creek (between Woorim and Skirmish Point).

Onshore (Figure 3-2), the Holocene deposits on Bribie Island lie mainly at the northern and southern ends of the Pleistocene core deposits. In the north, they represent the tidal delta, narrow barrier peninsula and superficial swamp environments greatly influenced by the mobile channels of the Caloundra Bar. In the south, the Holocene deposits are mainly foredune ridges and their net accumulation in episodes of accretion and erosion has extended the island to the south-southeast by up to 2.5km.

The southern end of the older Pleistocene deposits is located just north of the Bongaree-Woorim Road. South from there, the island has evolved by extensive deposition of Holocene dune barriers in a sequence of units that can be distinguished by differences in alignment and truncation of crests as mapped by Armstrong (1990) (Figure 3-3). This deposition occurred initially at the southern end of the island (Units 1-6) and subsequently expanding the width of the southeastern part, including Woorim (Units 7-8), unconformably truncating the seaward edge of the earlier units, followed by more recent deposits at the southern end of the island (Units 10-11).

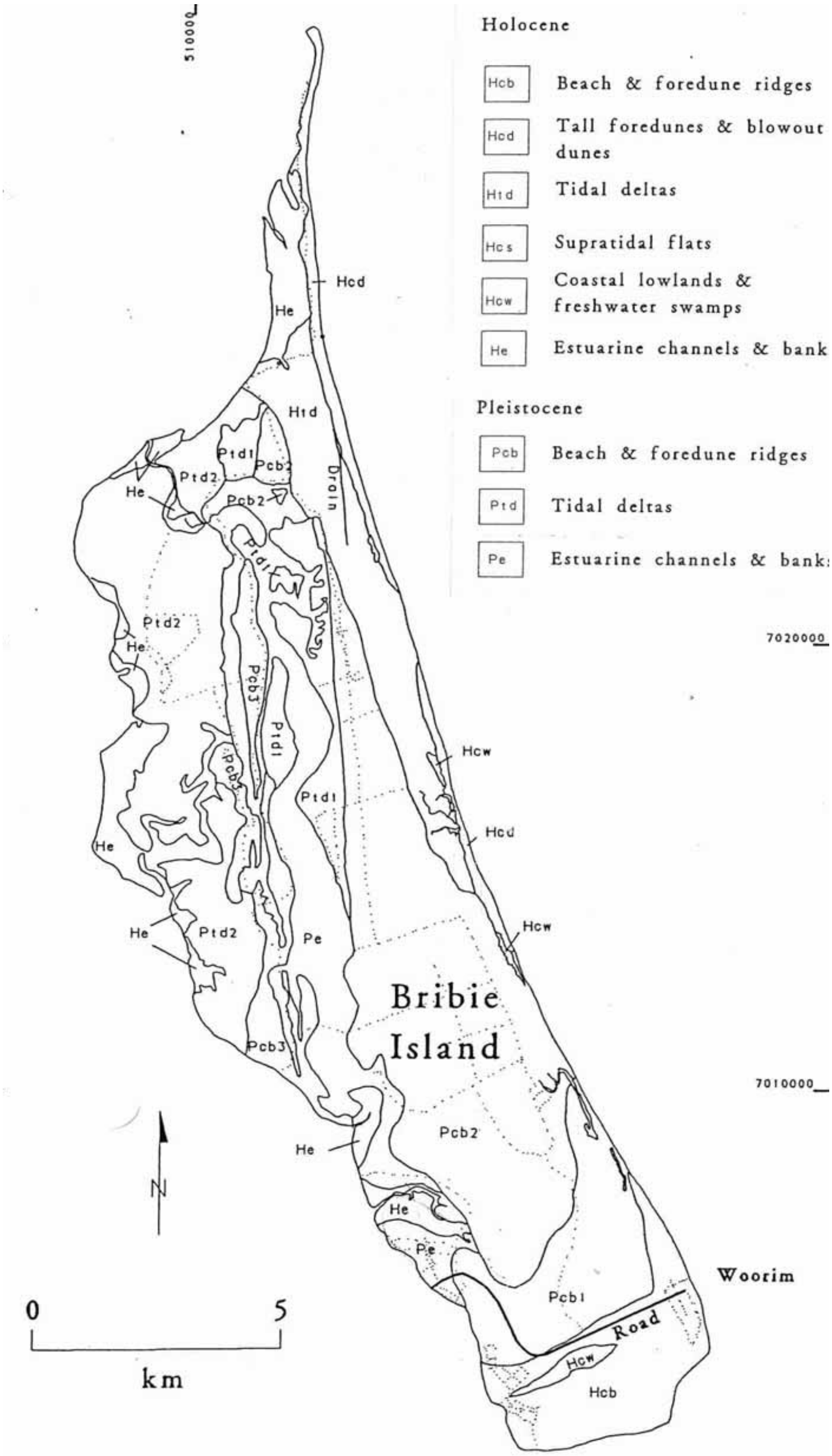


Figure 3-2 Geology of Bribie Island – from Jones (1992)

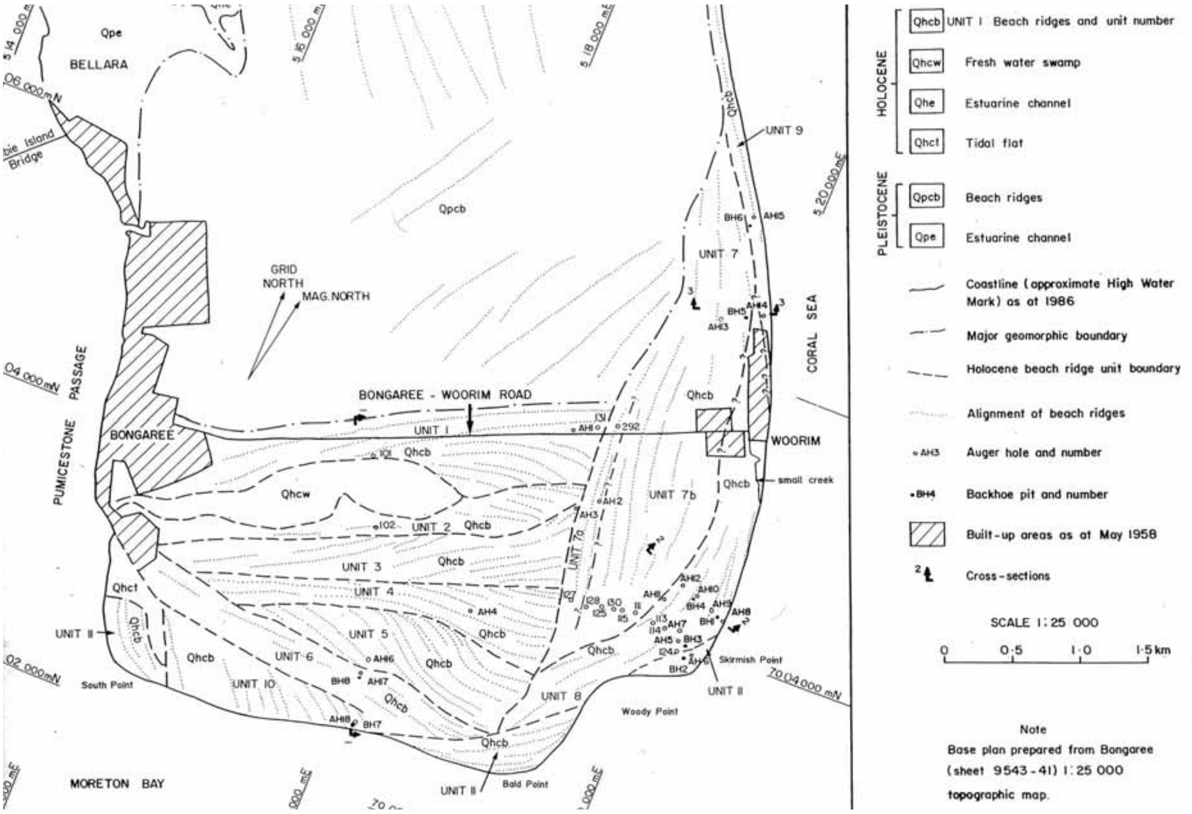


Figure 3-3 Holocene Evolution of Southern Bribie Island – from Armstrong (1990)

Despite this accretionary pattern of the past 6,000 years, the shoreline at Woorim is believed to be eroding at present. Exposure of old soil horizons in the dune scarp at Woorim indicates continuing erosion. Radiocarbon dating of charcoal from a buried soil profile at Woorim shows that, during the past 750 years:

- the coastline prograded seawards and topsoil developed;
- subsequent erosion occurred with a younger fore-dune blown inland over the soil; and
- continued erosion has exposed the soil horizon in the dune scarp at Woorim.

This behaviour pattern appears to be part of a complex cyclical process of accretion and erosion over time. Although accretion and erosion have alternated during the build up of southern Bribie Island, this does not preclude erosion occurring at one location simultaneous with accretion at another. Presently, the sand eroded from the shoreline at Woorim is mostly transported southwards enabling accretion at Skirmish Point.

Further north, along the central part of Bribie Island, a residual old Pleistocene shoreline and dune barrier aligned towards the NW is evident across the island, with a continuation of that Pleistocene alignment occurring as the boundary between Pleistocene and Holocene deposits on the mainland at Golden Beach (Figure 3-1). The present Bribie Island shoreline thus cuts into this Pleistocene barrier.

Thus, at the beginning of the sea level stillstand period around 6,000-7,000 years BP, the ocean shoreline most likely lay at the rear of Golden Beach, Caloundra. The northern tip of Bribie Island developed later in the Holocene and overlies a Pleistocene humic sandrock layer that is exposed in the side of the channel on the mainland side of Bribie Island. Dating of shell deposits suggests that this humic sandrock layer may be much younger than the sandrock exposed in the nearshore zone to the east of Bribie Island.

There is little evidence for any present day onshore supply of sand either from the tidal delta at the southern end of Bribie Island or in the northern area near Caloundra. While the northern part of Hamilton Patches is undergoing tidal and wave transport, resulting in a northwestward displacement of about 13m/yr, those deposits appear to be independent of the sediment budget of the beaches on the mainland and Bribie Island. Jones (1992) suggests that an onshore supply may have occurred during the sea level rise at lower sea level, but has subsequently ceased.

As such, the late Holocene evolution of Bribie Island has occurred predominantly by re-cycling of the older Pleistocene and younger Holocene sand deposits forming the island itself. Lester et al note that the northern Bribie Island spit exhibits a number of features consistent with a receding barrier, particularly exposures of estuarine sediments and tidal flat deposits in the inter-tidal zone along the eastern shore of the spit. Further evidence is the encroachment of foredunes into Pumicestone Passage on the mainland side of the spit and their subsequent erosion by tidal currents there.

3.3 Contemporary Coastal Processes at Woorim

3.3.1 Sand Transport Mechanisms and Beach Dynamics

Sand is transported along Woorim Beach by the combined action of waves and currents there. The prevailing waves are both ocean swell and locally wind-generated ‘sea’. The swell waves are of long period (typically 7-12 seconds) and propagate to the shoreline from the deep ocean across North Banks. They experience significant modification by refraction, bed friction and shoaling. The sea waves are of relatively very short period (generally less than 4 seconds) and are not substantially affected by the offshore bathymetry prior to breaking nearshore.

The waves have three key effects on sand transport, namely:

- They break and generate so-called radiation stresses, particularly within the wave breaker zone where wave-driven longshore currents may result;
- Their orbital motion impacts on the seabed causes bed shear stresses that mobilise and put into suspension the seabed sand. Their asymmetry in shallower water causes a significant differential in the forcing on the bed sediments, stronger towards the shoreline in the forward direction of wave travel leading to an onshore mass transport of sand; and
- They cause a bottom return current in the surfzone, strongest during storms when they typically dominate over the mass transport and move sand off the beach to the offshore area.

Currents generated by the tide, waves and wind provide the primary mechanism for the transport of the sand that has been mobilised and put into suspension by the wave/current action. It has been noted in Section 3.2 (Jones, 1992) that both tide and wave forces strongly affect sand transport along Bribie Island, with the tidal influence on currents becoming relatively more significant towards the southern end. Thus, Woorim Beach is likely to be subject to a combination of those factors from time to time, with waves dominant near the beach face and tidal currents dominant further offshore, leading to complex sand transport behaviour. The longshore direction of sand movement by those processes may be opposite at any given time. Comprehensive 2-dimensional modelling is required to investigate these processes.

Generally, at a typical beach location, sand transport may be regarded in simple terms as involving longshore and cross-shore sand movement processes. These act concurrently and interact.

Cross-shore sand transport involves:

- Erosion of sand from the upper beach and dune area during large storm wave events, with the sand being taken offshore where it is commonly deposited as one or more shore-parallel sand bars located in the vicinity of the wave break area;
- Subsequent slow transport of the eroded sand back to the beach, often over many months or several years; and
- Transport by the wind of the accreting beach sand back to the dune system where dune grasses act to trap it and build the dune back to its former condition.

Thus, on dynamically stable beaches, there is a balance in the amount of sand that is taken offshore and is subsequently returned to the beach and dune. The wind plays an important role in the natural balance of sand movements and beach and dune stability. If the dune is poorly vegetated, the sand may be blown landward and lost from the active dune system.

Longshore sand transport results predominantly from waves breaking at an angle to the shore with an alongshore component of their radiation stress that drives an alongshore current and carries the sand along the coast. The wind and tide may also contribute to generation of alongshore currents near the beach. This longshore sand transport is distributed across the surfzone and is greatest in the area near the wave break point where the wave height, longshore current and bed shear are greatest. That is, it occurs across a limited zone most probably in water depths less than about 5-8m along Bribie Island. Longshore sand movements at water depths greater than 8m are likely to be associated with tidal currents.

The beach may remain stable (without net recession or accretion) where the longshore sand transport is uniform along the coast. However, where there are differentials in the rates of longshore transport, including any interruption of the sand supply to an area, the beach will erode or accrete in response.

Wave effects on longshore transport are expected to be complex and variable because the dominant ocean swell waves propagate over the shallow North Banks in reaching the Bribie Island shoreline and thus are subject to variable refraction patterns associated with both varying tide level and changes in the shoal bathymetry of North Banks over time (Figure 3-4). This is reflected in a highly uneven shoreline alignment along the island (Figure 3-5).

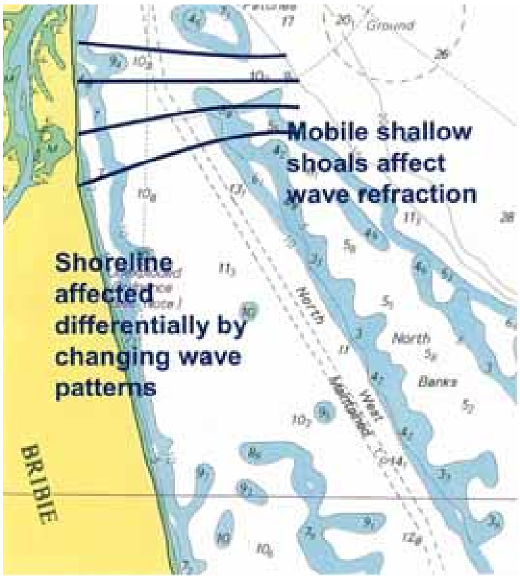


Figure 3-4 Wave Propagation to Bribie Island is affected by North Banks

Figure 3-5 Irregular Shoreline Alignment of Bribie Island

Because longshore and cross-shore transport co-exist, a net sand loss of sand in the nearshore part of the beach profile caused by a negative longshore transport differential may not manifest immediately as erosion of the upper beach. However, more sand would be taken from the beach when storm erosion occurs and, to maintain the normal equilibrium profile shape within the active zone, less sand is subsequently returned to the beach/dune than was previously there. This leads to a recession of the shoreline.

The only quantitative assessment of coastal processes and erosion along the ocean shoreline of Bribie Island has been for the northern peninsula spit area (EPA 1992). There, detailed assessment of shoreline change has been made based on both survey data since 1970 and photogrammetric analysis of aerial photography dating back to 1940, with the following conclusions:

- Photogrammetry indicates typical recession of the mean water line (RL 0.0m AHD) in the range 55m-75m over the 52 years covered, equivalent to shoreline recession at an average rate of about 1.1-1.44m/yr;

- Surveys indicate recession of the shoreline at a rate of about 2m/yr after 1970

This recession is consistent with the geological history in that it is considered likely that the spit, although a Holocene accretion feature, has been migrating landward for many years as a receding barrier. Lester et al (2000) calculated erosion of the eastern shore of the spit at approximately 144,000 m^3/yr with about 80% of the sand deposited in the flood tide delta of Caloundra inlet and about 30,000 m^3/yr lost by littoral drift towards the south.

The geological evolution of the shoreline suggests that there is only a limited direct link between the processes occurring at the spit and those at Woorim, although it is likely that there is a net southward longshore sand transport along the island. The balance between wave and tidal forcing of sand transport varies significantly along the island with tidal currents increasingly dominant towards the south.

BMT WBM has undertaken further investigations including analysis of available aerial photography, current measurements, assessment of wave climate, analysis of longshore sand transport rates from both the recorded directional wave climate and the Coastal Observation Program – Engineering (COPE) data, together with 2-dimensional modelling of currents and tide-related sand transport as part of the present study. Details of those investigations are outlined in the ensuing sections of this report. They have confirmed the expected general processes of wave propagation, current patterns and longshore sand transport. However, they show that the processes are complex and difficult to quantify reliably on the basis of available information. Nevertheless, they provide a sound basis for considering the effects and feasibility of the various management options.

3.3.2 Assessment of Historical Shoreline Erosion

The primary research and information drawn upon in this study includes:

i. Geological research reports as referenced and discussed in Section 3.2;

ii. Historical and site information derived from:

    - Library and historical society sources;
    - Local residents and Steering Committee members; and
    - Analysis of aerial photography obtained from the Department of Natural Resources.

At Woorim, the historical erosion is considered the result of a negative longshore transport differential in which:

- More sand is moved away along the beach towards the south than is supplied from the north or offshore;
- The deficit in sand transport is 'made up' by permanent erosion of the beach and dune.

These are the result of natural processes that are part of the long-term geological evolution of this section of coastline. However, it is noted in Figure 3-3 that this behaviour is not simple or consistent over the geological time-frame. Woorim is located at the junction of Units 8 and 9 (illustrated in that figure). Armstrong (1990) notes:

- There were at least three phases of accretion of beach ridges normal to the alignment of Units 1 to 6 (Units 7a, 7b and 8). The inner part of Unit 7 (7a) is significantly older than the outer part (Unit 7b), indicating a long hiatus in deposition between them, possibly accompanied by erosion of part of 7a.
- Units 7b and 8 are of similar age but there is a disconformity between them in their ridge alignments indicating a period of erosion and slight change in shoreline orientation between them.
- The eastern side of Units 7 and 8 was eroded before deposition of Unit 9.
- It is likely that erosion of Units 7, 8 and (possibly) 9 contributed to the sediment deposited in Unit 10 at the southern end of the island, but subsequently largely eroded.
- Sand has accreted in modern times in Unit 11 at Skirmish Point, Bald Point and South Point. Deposition is continuing with shoreline accretion of several hundred metres since the 1970s evident at some locations (Figure 3-6).

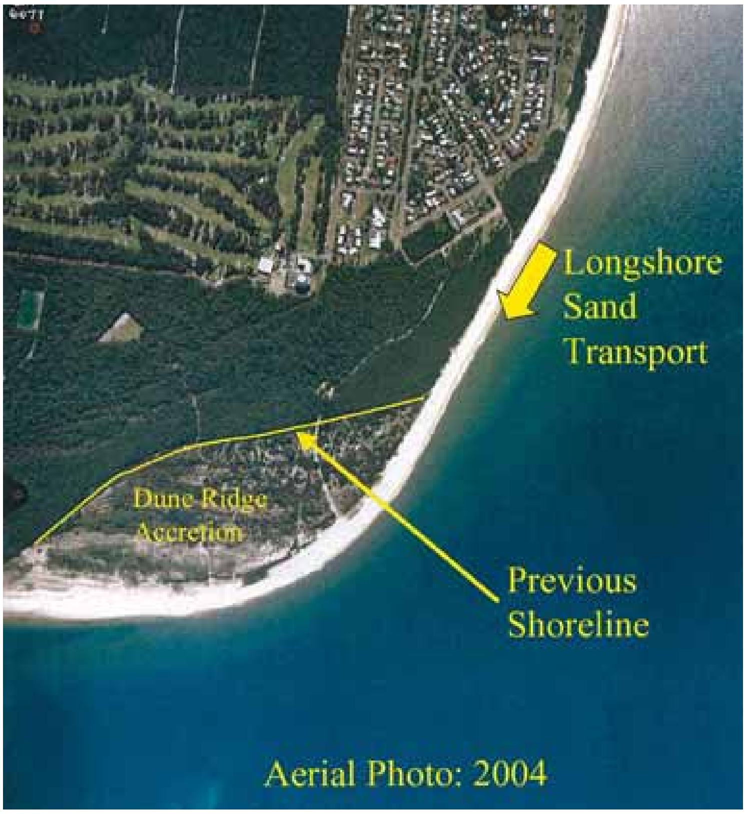


Figure 3-6 Recent Accretion of Skirmish Point, Southern Bribie Island

The indications from observations and Armstrong (1990) are that Woorim Beach is eroding predominantly at the southern end of the township but is relatively stable at the northern end (Figure 3-7, Figure 3-8 and Figure 3-9).

Figure 3-7 Erosion and Limited Beach Width at the Southern Area

Figure 3-8 Northern End of Woorim Presently in Good Condition

BMT WBM

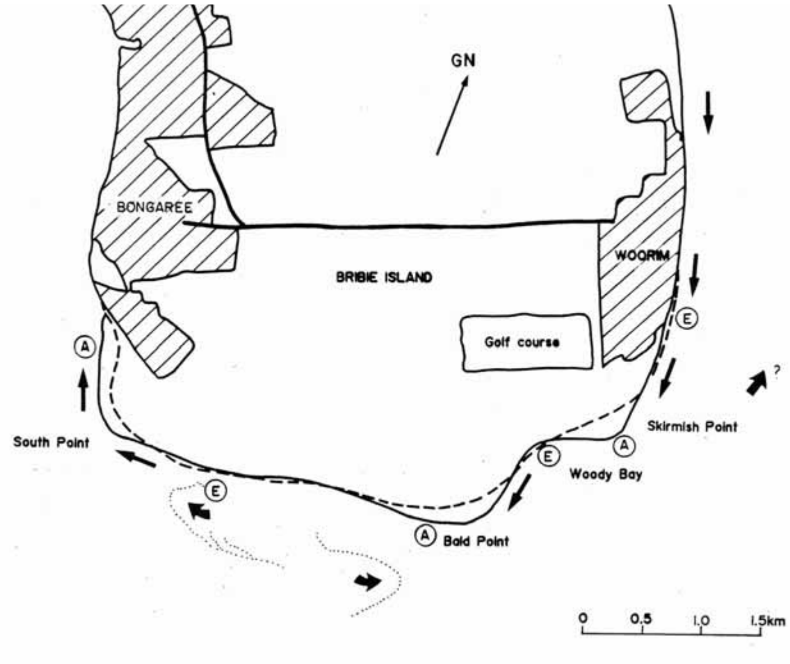


Figure 3-9 The Armstrong (1990) Interpretation of Sediment Movement and Shoreline Erosion/Accretion. (E = erosion; A = accretion)

3.3.3 Analysis of Aerial Photography

3.3.3.1 Shoreline and Dune System Changes

Aerial photography sourced for this study extends from 1940 to present. Analysis of this photography has involved:

- Qualitative assessment of the state of the beach and dune system along Woorim Beach to determine changes in use and stability of the dunes, as indicated by the dune vegetation; and
- Measurement of changes in the seaward extent of the dune vegetation at nine (9) locations along the beach for various dates.

Dune edge movements were determined by reference to fixed features (eg. roads) common to successive dates of photography. An accuracy of about ±2m was possible for each case. In that regard, rectified aerial photography for selected dates from 1961 to 2004 was provided by EPA, allowing accurate comparison of those photographs without image distortion.

The analysis indicated:

- In 1961 (Figure 3-10), damage to the dune vegetation in the surf club area is evident along a section of about 250 metres where wind erosion was causing dune sand to blow landward across the carpark and roads;
- By 1967 (Figure 3-11), although the photography is unclear, considerable adverse impact on the dune vegetation was evident over a wide area, with extensive areas of disturbance and blow-outs occurring, allowing loss of sand from the beach by wind erosion, with sand blowing inland over previously hind-dune areas – particularly evident at the main surfing beach area;

- Considerable effort by Council in conjunction with the (then) Beach Protection Authority to stabilise the dunes with respect to wind erosion during the early 1970s led to significant improvement in dune vegetation and, by 1978 (Figure 3-12 and Figure 3-13), that problem was largely under control.
- Subsequent erosion issues to 2004 (Figure 3-14 and Figure 3-15) related predominantly to shifts in high water mark, erosion of the base of the dune and changes in beach width associated with wave/current action rather than wind erosion.
- The aerial photo analysis (Figure 3-10 to Figure 3-15) shows the broad-scale changes that indicate a long-term trend of shoreline recession, particularly towards the southern parts of Woorim, as follows:

  1961 to 2004

  The change in position of the vegetation line shown in Figure 3-16 indicates varying recession from essentially nil at the northern end of Woorim to about 1.7m/yr south of Freshwater Creek. Between Second to Third Avenue south to the southern end of the SLSC carpark the erosion distance is about 12m over the 43 years, a rate of 0.3m/yr.

  The former mouth of Freshwater Creek has been substantially eroded, the rate immediately south of the creek being about 0.9m/yr, leaving the present mouth some 150m north of its 1961 position, while further southward recession of about 75m (1.7m/yr) is evident.

  1979 to 2004

  Assessment of changes in the interpreted base of the dune scarp between 1979 (fence line visible) and 2004 (dune base unclear) indicates:

  - general stability north from around Third Avenue;
  - localised slight accretion of the foredune in front of Fourth Avenue area;
  - erosion between Third Avenue and the surf club of up to about 5m, equivalent to 0.2m/yr;
  - erosion south of the surf club area to Freshwater Creek of about 8m (0.3m/yr);
  - relative stability at and immediately south of Freshwater Creek following considerable recession (about 40m at 2.2m/yr) there between 1961 and 1979;
  - erosion of the dune by up to about 45 metres (1.8m/yr) further south, along about 400m of the shoreline in the area immediately north from Skirmish Point; and
  - at Skirmish Point, a progressive accretion of the shoreline, extending the width of the dune ridge barrier towards the south by up to about 400 metres between 1979 and 2004, as evident in Figure 3-16. The estimated growth of sand volume in that area is about 2.7-3.3 million m^3, providing a basis for estimating the rate of net southward sand transport at Skirmish Point over that time, as discussed in Section 3.3.5.2.

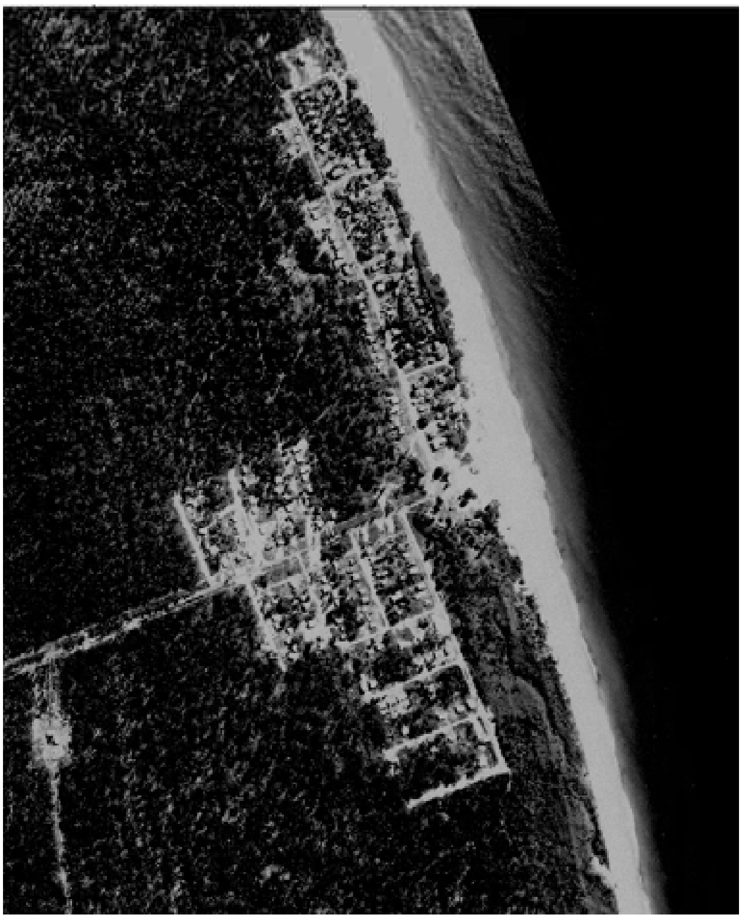


Figure 3-10 Dune instability associated with vegetation loss evident near the surf club in 1961

Figure 3-11 Extensive clearing, vegetation loss and dune instability associated with wind erosion evident in 1967

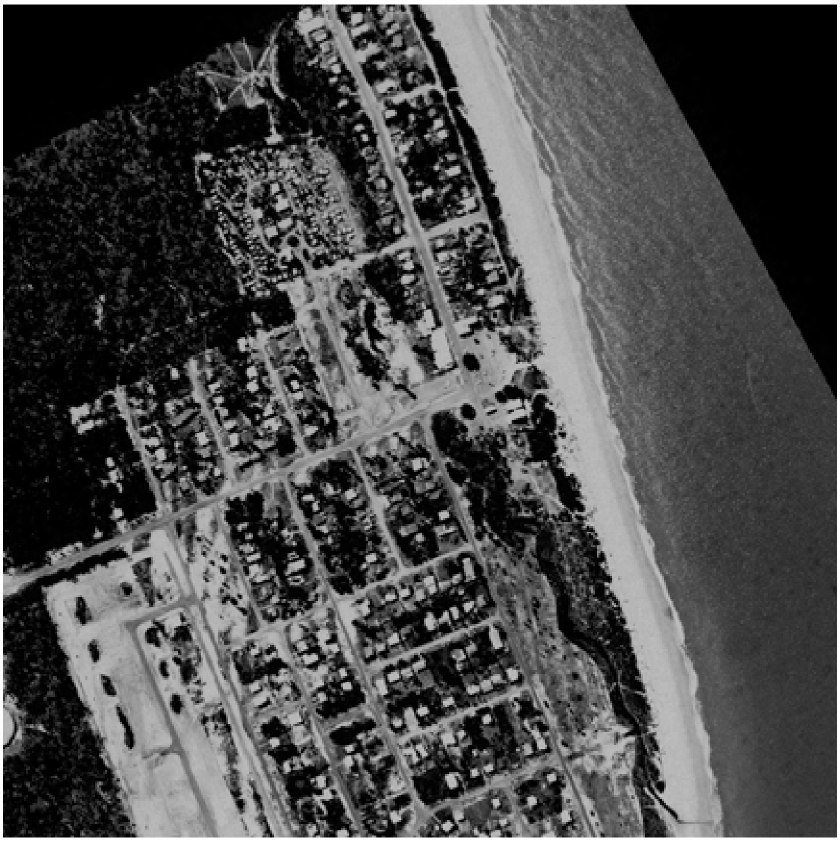


Figure 3-12 Vegetation regrowth and improved dune stability evident in 1973

Figure 3-13 General dune vegetation stability evident in 1978

Figure 3-14 Stabilised dune vegetation along the whole coastal unit and accretion at Skirmish Point evident in 2004

Figure 3-15 Present status of Woorim Beach near the surf club (2004)

3.3.3.2 Longshore Sand Transport from Aerial Photography

It is feasible to derive an indication of the total wave and tide induced longshore transport rates and gradient along the shoreline from the erosion pattern and rates identified from the aerial photography. This requires knowledge of the relationship between the linear distances of shoreline change and the volumetric change in across the whole active profile, from the dune crest to the offshore limit of the active profile.

The Woorim region shoreline has been subject to both erosion and beneficial beach nourishment. The combined action of waves and tidal currents has affected profile change to different degrees along the shoreline. The survey data suggests a shallower water depth of profile change at the northern end (4-6m) than at the south (10-15m). This would suggest greater tidal influence towards the southern areas towards Skirmish Point. However, the accretion zone beyond Skirmish Point is likely to have deposited across a zone of water depth less than about 5-6m, based on the prevailing offshore depths there now.

The area of accretion at Skirmish Point from 1979 to 2004 has been derived from the photography to be 300,000 m^2, corresponding to about 2.55 – 2.85 million m^3. Thus, on the basis that there was no transport out of that area to the west, the average annual net longshore transport rate from the north to Skirmish Point would have been in the range 100,000 to 115,000 m^3/yr.

The rates of total wave and tide induced net longshore transport rates at various locations along the shoreline between Skirmish Point and Woorim for the period 1979 to 2004 may be estimated from the rate determined for Skirmish Point with appropriate allowance for both:

- The measured distances of shoreline change; and
- The beach nourishment quantities of sand added into the system over that period.

The nourishment record is as listed in Table 3-1. It indicates that about 0.62 million m^3 sand has been placed on Woorim Beach since June 1988 at an average rate of about 32,700 m^3/yr.

Table 3-1 Beach Nourishment Quantities

Date	Dredge	Quantity (m^3)	Cumulative Quantity (m^3)
June 1988	"Sir Thomas Hiley"	50,000	50,000
Sept 1988	"Sir Thomas Hiley"	150,000	200,000
Sept 1989	"Sir Thomas Hiley"	65,000	265,000
Feb 1991	"Sir Thomas Hiley"	40,000	305,000
Feb 1997	"Sir Thomas Hiley"	86,000	391,000
Nov 2000	"Sir Thomas Hiley"	60,000	451,000
May 2004	"Brisbane"	45,000	496,000
July 2006	"Brisbane"	65,000	561,000
Dec/Jan 2006/07	"Brisbane"	60,000	621,000

Analysis of the likely transport rate at Woorim on this basis indicates a southward total wave plus tide transport of about 75,000 to 90,000 m^3/yr. This is about 10,000 to 25,000 higher than that calculated for waves alone, potentially representing the tidal current contribution there. This analysis also suggests that the tidal current contribution at Skirmish Point could be as high as 50,000 to 60,000 m^3/yr. This is reasonably consistent with the modelling undertaken (Section 3.3.5).

Figure 3-16 Assessed change in position of the vegetation line 1961-2004

3.3.4 Analysis of Wave-Induced Longshore Sand Transport

3.3.4.1 COPE Data Analysis

The Coastal Observation Program – Engineering (COPE) of the former Beach Protection Authority (BPA) operated at a station at Woorim over the period 1986 to 1996. A range of beach, wave and current parameters were measured each day, providing a most useful database for analysis of coastal processes. In particular, the breaking significant wave heights, longshore currents and longshore sand transport rates have been determined from the data using the simple techniques developed by the BPA (Patterson & Blair, 1985). Patterns of beach erosion and accretion in terms of beach berm width have also been assessed (Figure 3-17), indicating increased width following commencement of regular nourishment in 1988.

The calculation method determined by the BPA as described in Patterson (1985) was used. It involves a modified form of the CERC relationship that eliminates the wave angle and includes the direct measure of longshore current available from COPE. A time series of longshore transport has been determined for each location from which annual average net transport results have been derived. This is considered to be a relatively accurate approach, particularly for the reasonably small and accessible surfzone at Woorim. While the absolute results contain some uncertainty, the relative transport results should give a reliable indication of any significant gradients and differentials.

COPE Reading of Longshore Current at Woorim (approx 1985)

Erosion at stairs near COPE station in 1988

The COPE wave and current data together with the analysis of daily sand transport rates are illustrated in Figure 3-7. They yield an average annual net sand transport rate over the ten year period of 65,600 m^3/yr, with clearly some variability from year to year.

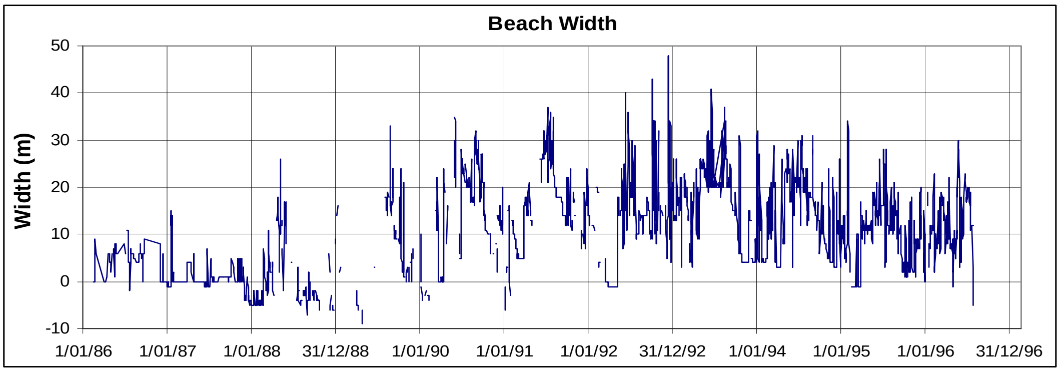


Figure 3-17 Measured Beach Width at Woorim COPE Station: 1986 – 1996

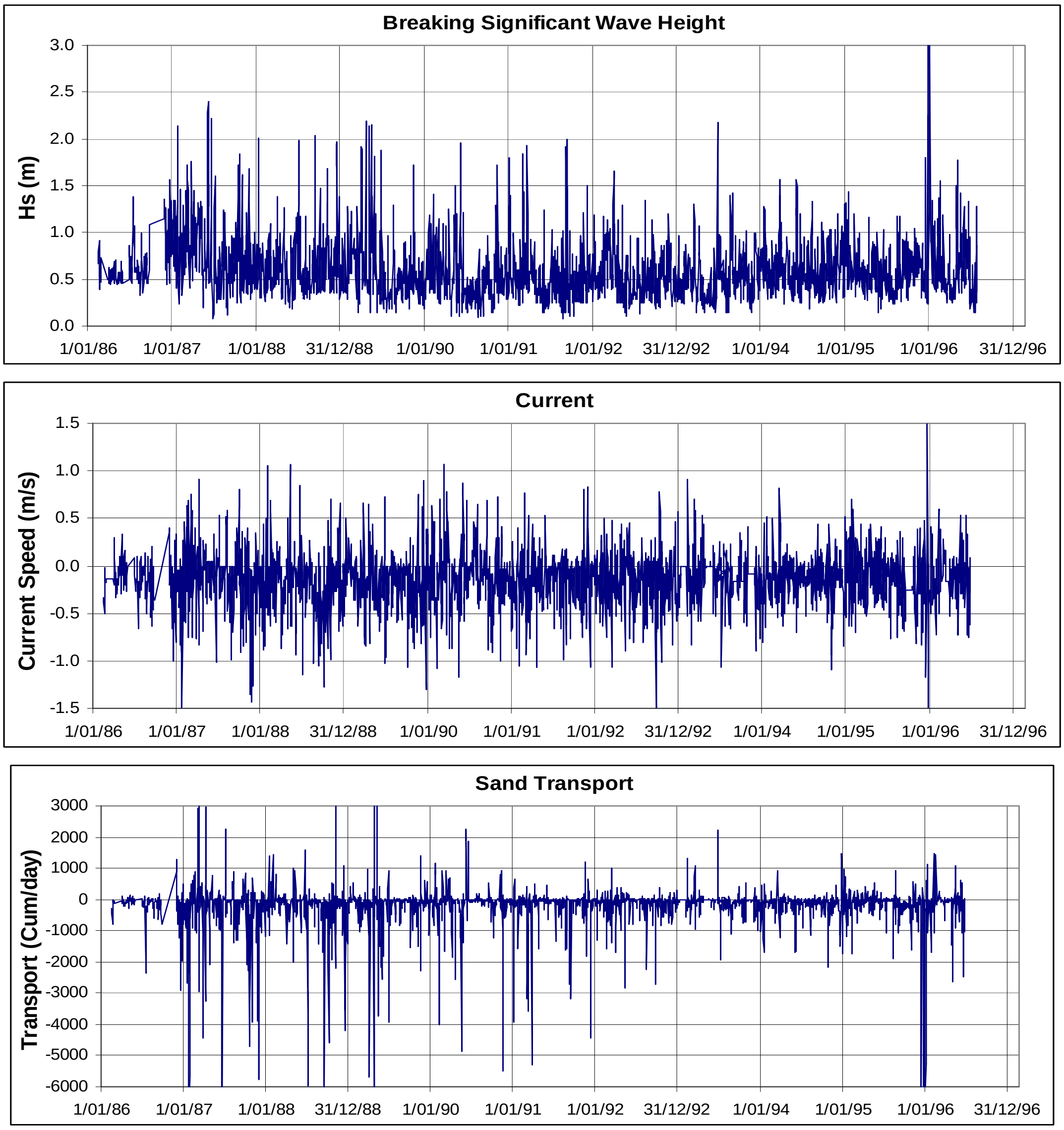


Figure 3-18 Analysis of Longshore Sand Transport from COPE Data

3.3.4.2 Longshore Transport from Directional Wave Climate

Comprehensive wave propagation analyses and calculation of longshore sand transport rates associated with both the ocean waves and the local wind-generated waves have been carried out for several sites from north of Woorim to Skirmish Point using:

- the recorded Brisbane directional wave data; and
- recorded wind data from Spitfire Channel.

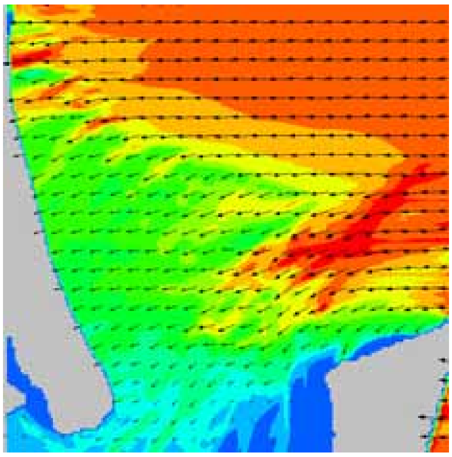
The available directional ocean wave data covers the period 1997 to 2005, with no overlap with the COPE data. Wind data for the period August 2002 to July 2005 were used.

A conventional calculation methodology has been followed, applied to each record in the wave time series, involving:

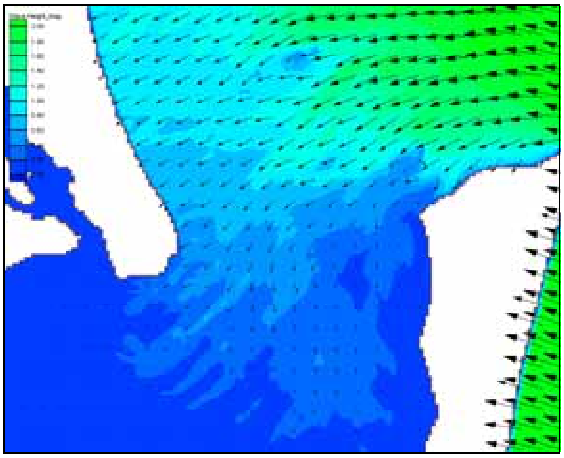
- For the ocean waves, analysis of spectral wave propagation from deep water using SWAN to provide refraction transformation relationships to various nearshore locations in 10m depth along the coast;
- For the wind waves, hindcasting of the nearshore wave heights and periods;
- For each wave record in the data time series:
    - Representation of wave conditions in terms of the significant wave height (H_s), spectral peak period (T_p) and direction at the spectral peak as routinely analysed by the respective agencies (no spectral resolution of sea and swell);
    - Further propagation to the break point to estimate breaker height and angle on the basis that the nearshore contours shallower than 10m are essentially straight and parallel;
    - Calculation of the longshore transport rate for that time increment;
    - Filling of gaps in the data with transport at rates equivalent to the average annual rate for that year over the gap duration.

Typical wave patterns for ocean swell and local wind-generated ‘sea’ are shown in Figure 3-8. Modelled wave propagation indicates that the longer period ocean swell is refracted and arrives essentially shore-normal along most of the Bribie Island shoreline, although subject to minor variations associated with the incident deep-water direction and the effects of North Banks. However, the swell reaches the southern part of the island, south from around Woorim, at an angle to the shoreline consistent with causing a southward longshore sand transport.

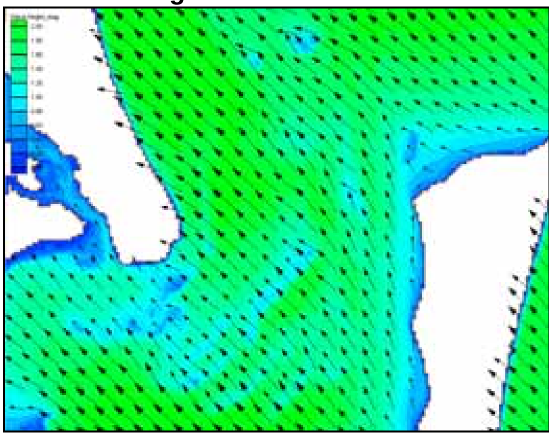
For the locally generated sea waves that are of short period (generally less than 6 seconds), their direction and angle at the shoreline are determined predominantly by the wind direction. Northerly wind/waves cause a southward transport and east to southeast wind/waves cause an upcoast northerly sand transport.



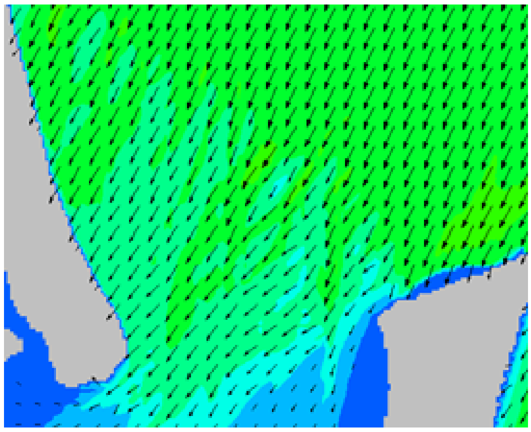
Large East Ocean Swell



ESE Ocean Swell



SE Swell and Local Wind Waves



NE Waves

Figure 3-19 Modelled Wave Patterns

Thus, sand is transported in both directions along the shoreline from time to time, at varying rates. The wave-induced transport near the beach may occur independently of the tide-induced transport further offshore.

The results of the analyses are summarised in Table 3-2. in terms of average annual net longshore transport rates for both ocean waves and local wind waves.

Table 3-2 Longshore Sand Transport Rates from Recorded Wave & Wind Data

Location	Net Transport (m^3/yr)		
	Ocean waves	Wind waves	Resultant
North Woorim	-61,400	7,000	-54,400
Woorim Surf Club	-77,900	13,000	-64,900
South Woorim	-113,000	21,000	-92,000
Skirmish Point	-75,000	26,000	-49,000

Note: Transport to north is +ve; to south is –ve

The resultant southward net transport rate of about 64,900 m^3/yr at the Woorim Surf Club site corresponds very closely to the value of 65,600 m^3/yr derived from the COPE data. Further, a gradient in the net transport rates is identified, increasing towards the south through Woorim, consistent with the observed pattern of progressive erosion, but with a reduction in the wave-related net transport in the southern area at Skirmish Point.

There is an additional influence of the tide in transporting sand along the coast. This is discussed further in Section 3.3.5 (modelling of tidal processes) and Section 3.3.3.2 in which longshore transport rates are deduced also from the shoreline changes identified in the analysis of aerial photography.

3.3.5 Hydrodynamic Modelling of Tide-Related Processes

Hydrodynamic modelling has been undertaken as part of the present study to gain a better understanding of the role that tidal currents play in the movement of sand along the coastline of Bribie Island and its interaction with wave-induced sand transport near the shoreline. The modelling has been based on the hydrodynamic and wave models established and validated by BMT WBM for a range of investigations over many years, most recently for the Moreton Bay Sand Extraction Study and Brisbane Airport Corporation New Parallel Runway impact assessments.

The computational layout of the hydrodynamic model is shown in Figure 3-20. This has been substantially refined specifically for this study along the coastline of Bribie Island, particularly around Woorim in order to provide a suitable level of detail with respect to the cross-shore distribution of the longshore tidal current and sand transport potential.

Additional bathymetric data from BPA/EPA profile surveys and a hydrographic survey undertaken by Queensland Transport in 2001 was utilised for the model refinement. It is noted that large differences were found between bathymetric chart data (AUSCHARTS) and these data sources in the vicinity of Bribie Island.

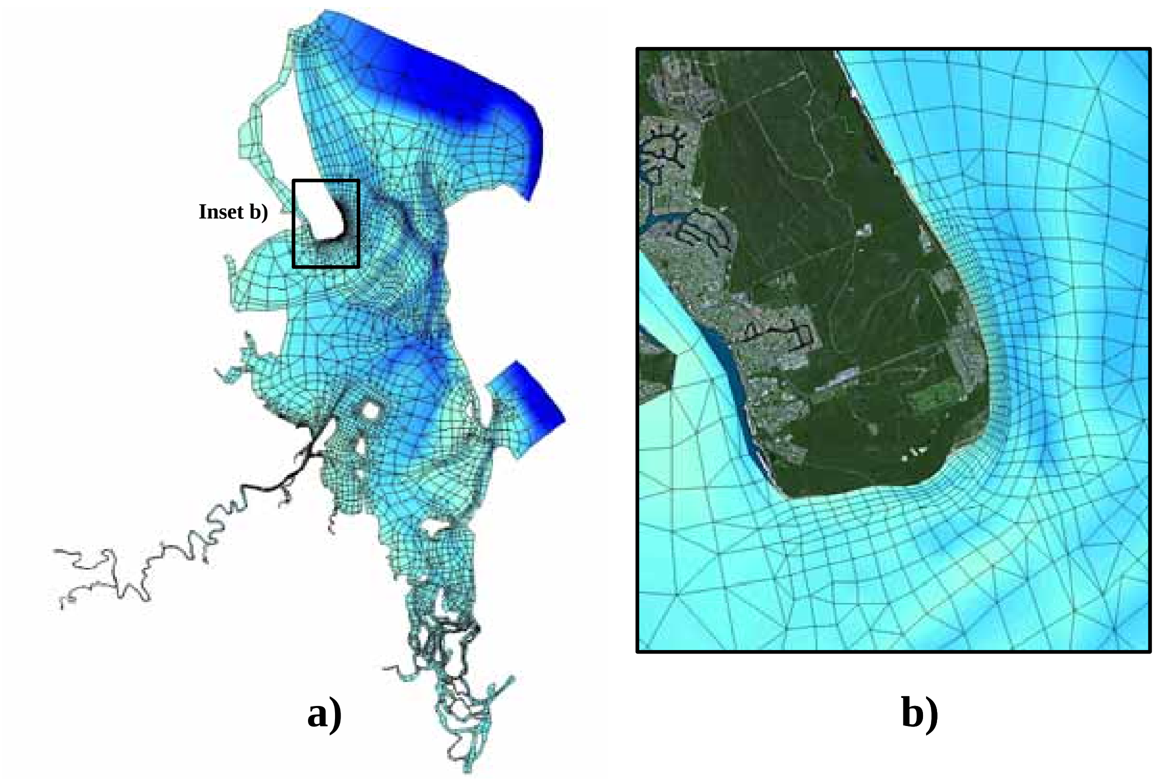


Figure 3-20 Hydrodynamic Model – Bathymetry and Computational Grid Mesh

It must be recognised that modelling of coastal processes remains an imperfect science and obtaining a high level of quantitative accuracy depends to a large degree on:

- Accurate representation of the area being modelled (bathymetry, seabed characteristics, computational grid mesh, etc)
- The accuracy and representativeness of the boundary conditions applied (wave conditions, winds, tides);
- Validation to ensure that all of the 'physics' of the processes important in any particular area are being properly simulated in the model.

The models applied to this study provide an invaluable 'tool' for providing both qualitative insights and quantitative information about the processes taking place. The level of modelling and analysis undertaken is considered sufficient for the purposes of this study given that the wave, current and sand transport processes occurring at Woorim are understood sufficiently well for a reasonable assessment of the key processes and erosion mechanisms that occur.

Typical model results in terms of regional and local nearshore tidal current patterns are shown in Figure 3-21 and Figure 3-22 respectively.

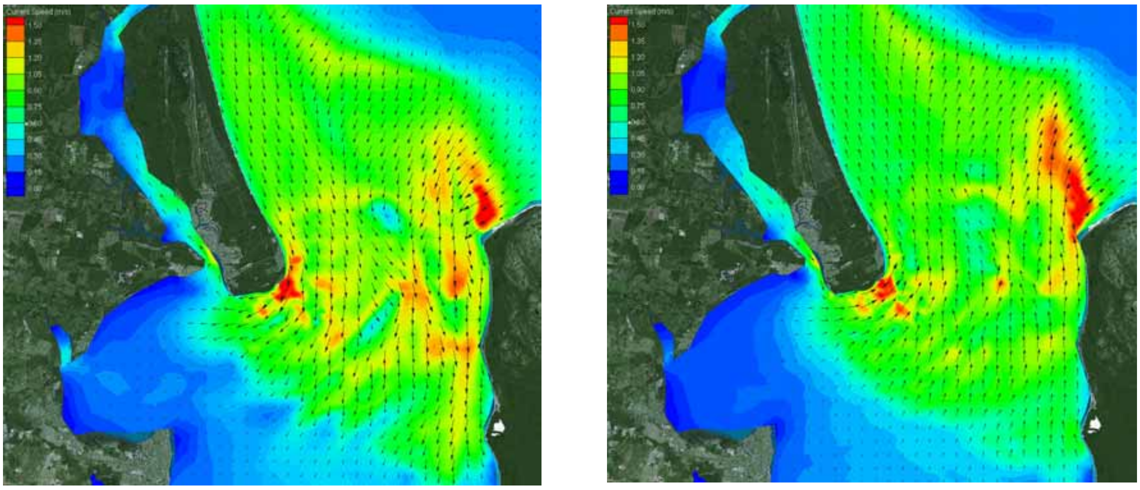


Figure 3-21 Typical Tidal Current Patterns – Left: Flood tide; Right: Ebb tide

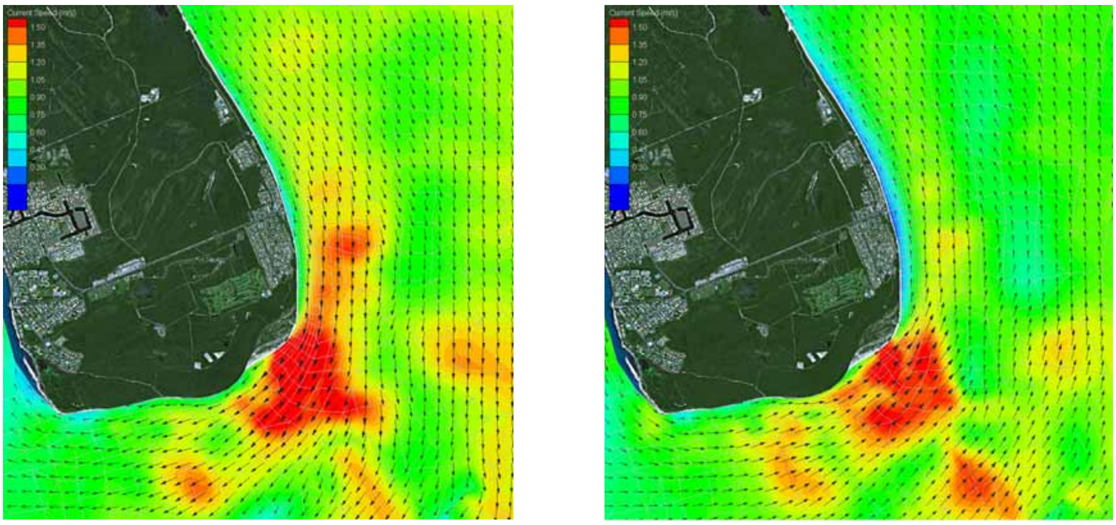


Figure 3-22 Nearshore Tidal Patterns – Left: Flood tide; Right: Ebb tide

The model shows flood tide dominant tidal currents close to the shoreline at Woorim, consistent with the geological interpretation. Tidal currents have been measured by BMT WBM offshore from Woorim for this study. The data obtained is presented in Figure 3-23 and also confirms:

- Flood tide dominance; and
- Current speeds in excess of 0.5m/s, sufficient to transport sand, particularly in conjunction with wave action.

The refined RMA hydrodynamic model has been validated against the S4 current meter data collected for this study, with the model predictions also shown in Figure 3-23. In general the model does a good job of predicting the phasing and amplitude of the tidal currents offshore of Woorim.

The model has been used to determine net tide-induced sand transport adjacent to the southern Bribie Island coastline. The van Rijn model for total sand transport has been used for this purpose, with net transport calculated by averaging over two neap–spring tidal cycles. The pattern of net sand transport is illustrated in Figure 3-24 and Figure 3-25, indicating:

- Flood tide dominance;
- Increasing transport towards Skirmish Point consistent with a net deficit sand budget for Woorim;
- Skirmish Point and its offshore shoals is a convergence (deposition) zone for sand transported from the north and west.

The alongshore distribution of the net tidal sand transport is shown in Figure 3-25 and illustrates the strong increase in transport potential between Woorim and Skirmish Point.

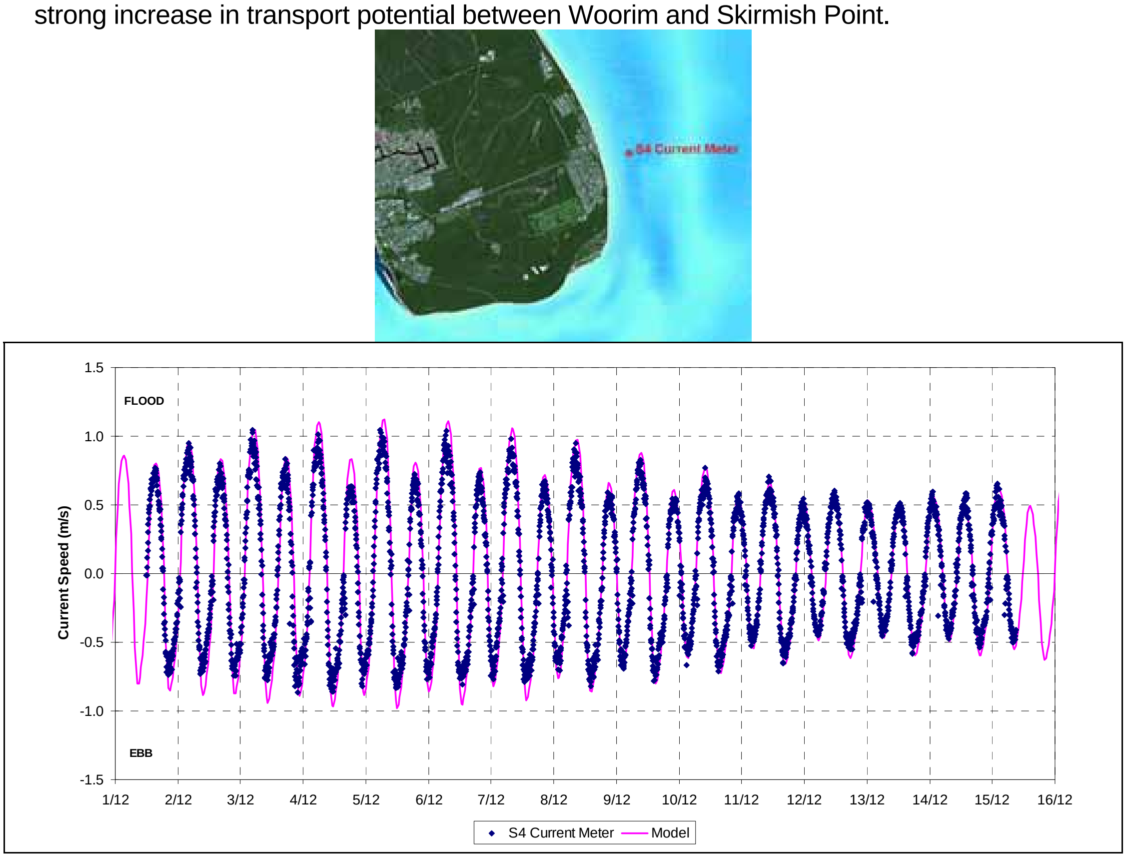


Figure 3-23 Measured and Modelled Currents Off Woorim

Figure 3-24 Modelled Net Sand Transport Induced by Tidal Currents Alone.

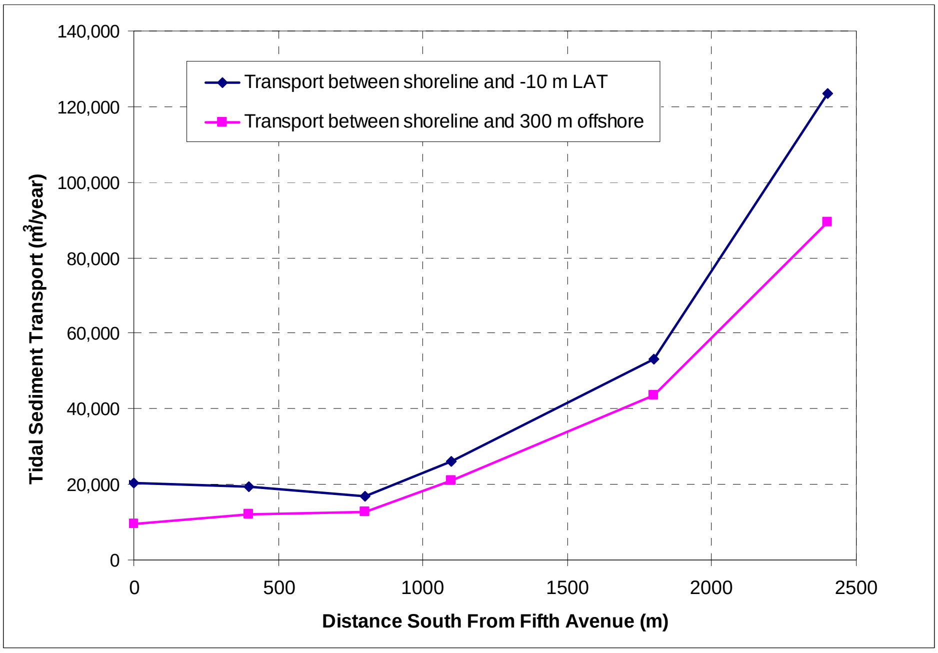


Figure 3-25 Alongshore Distribution of Net Tidal Sand Transport.

3.3.6 Net Longshore Sand Budget

As shown in Sections 3.3.5 and 3.3.4 both wave-induced and tidal-current-induced net sediment transport gradients are potentially contributing to the long-term progressive erosion at Woorim, which was analysed from aerial photography in Section 3.3.3. A summary of the modelled transport due to both waves (ocean and local wind waves) and tidal currents is given below. These results show the dominance of wave induced transport to the north of Woorim and the increasingly significant contribution from tidal current induced transport to the south.

Table 3-3 Calculated Total Longshore Sand Transport Rates

Location	Net Transport (m^3/yr)		
	Waves	Tidal Currents	Resultant
North Woorim	-54,400	-9,600	-64,000
Woorim Surf Club	-64,900	-12,600	-77,500
South Woorim	-92,000	-43,000	-135,000
Skirmish Point	-49,000	-89,500	-138,500

Note: Transport to north is +ve; to south is –ve

In Figure 3-26 the sediment transport model predictions are compared with net alongshore transport rates derived from the analysis of historical aerial photography (and taking into account sand nourishment) that was discussed in Section 3.3.3. The combined model results are in reasonably good agreement with the derived transport rates between 5th Avenue and 800 m south at Woorim Surf Club. At the southern end of Woorim the combined model results are higher than the derived rates. This may be due to the tidal transport being only partially coupled with the upper beach sand budget (and hence shoreline change).

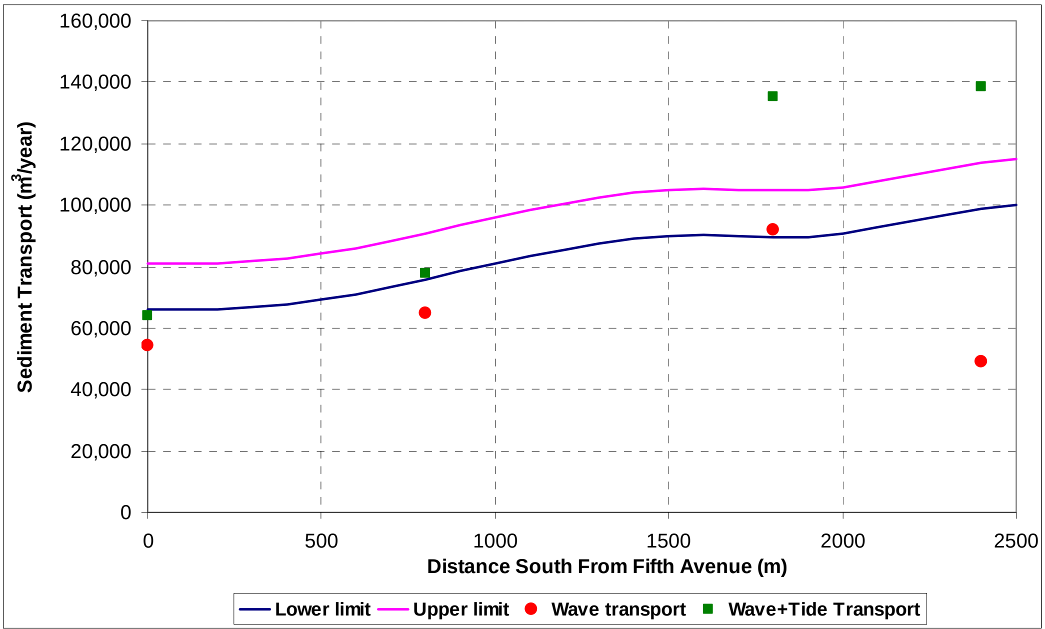


Figure 3-26 Comparison of Upper and Lower Limit Longshore Transport Rate Derived From Historical Shoreline Change With Model Predictions.

In order to investigate this further the cross-shore distribution of the wave and tidal-current related sediment transport are shown in Figure 3-27. This plot shows that at Woorim the wave transport is focussed in a narrow surfzone of less than 50 m width. On the other hand the magnitude of tidal transport is relatively insignificant in the nearshore region. This result indicates that the tidal-current induced sand transport is much less significant to shoreline erosion than the wave induced transport process.

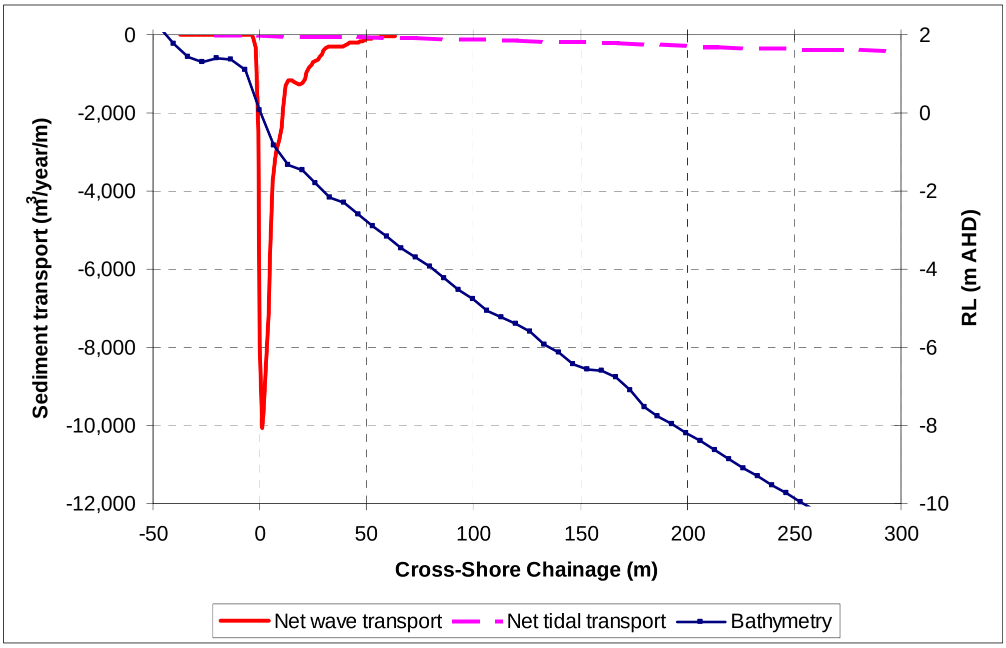


Figure 3-27 Cross-Shore Distribution of Wave and Tidal-Current Sand Transport at South Woorim.

3.3.7 Storm Erosion

The potential for short-term erosion due to severe wave and ocean surge conditions has been modelled using simple cross-shore equilibrium profile models. The models of Kriebel and Dean (1993) and Vellinga (1983) have been applied for this purpose. These methods require an input initial beach profile as well as wave and storm surge conditions during the storm event. The models predict the volume of dune erosion and corresponding shoreline recession that will result from these conditions.

A significant wave height of approximately 9 m at the Point Lookout waverider buoy has been transferred inshore to Woorim using the SWAN model discussed in Section 3.3.4.2. A significant wave height at Woorim of 3 m, and peak period of 12 s has been used for the storm erosion modelling. A super-elevation of the mean shoreline water level of 1.6 m above the average equilibrium conditions has been derived for a corresponding storm event. It is considered that these conditions are conservatively representative of a single 100 year ARI erosion event at Woorim.

The cross-shore equilibrium profile models predict that if such an event were to occur with the current beach profile that approximately 60 to 70 m^3/m of short-term erosion would occur. This would translate to a short-term recession of the dune toe of 12–14 m.

Vellinga model results for the profiles corresponding to the BPA survey line ETA 408.0, which is situated at the southern end of Rickman Parade, are shown in Figure 3-28. The same model results for ETA 409.0, which is 400 m further north along Rickman Parade, are shown in Figure 3-29.

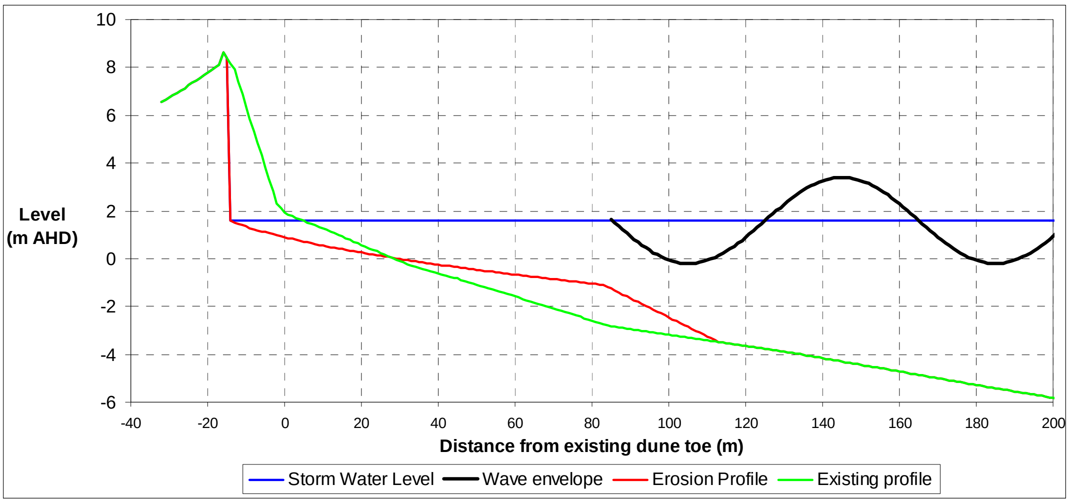


Figure 3-28 Vellinga Storm Erosion Profile at ETA 408.0.

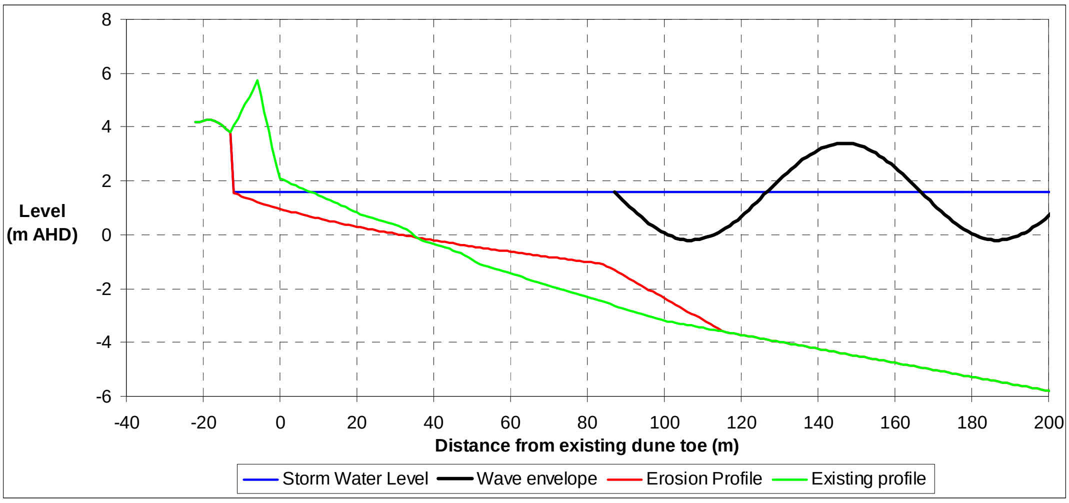


Figure 3-29 Vellinga Storm Erosion Profile at ETA 409.0.

3.3.8 Present and Future Shoreline Erosion

3.3.8.1 Historical Erosion Trend

As is evident in Figure 3-30 and Figure 3-31, continuing shoreline erosion is occurring at Woorim. This has been evident for many years. The analysis of aerial photography undertaken for this study shows that the erosion is more acute further south, most probably because beach nourishment has helped to minimise the erosion along the northern areas. Nevertheless, it is apparent that the placement of over 30,000 m^3/yr of nourishment sand on average since 1988 has not been sufficient to prevent the shoreline erosion, indicating that the potential erosion exceeds that quantity along the nourished area.

Figure 3-30 Old gravel road base horizon exposed below wind blown sand and mature vegetation in the eroding dune scarp adjacent to the surf club area

Figure 3-31 Old bitumen surface exposed below wind blown sand and mature vegetation in the eroding dune scarp adjacent to the surf club area

The aerial photography evidence required to quantify the rates of shoreline recession along the study area is confused somewhat by the extensive wind erosion that occurred through the 1960s to early 1970s. As well, the beneficial effects of the nourishment must be accounted for in deriving the likely erosion rates that would have occurred without the nourishment.

These factors, together with consideration of the calculated sand transport rates and differentials have been used to determine likely present and future potential trends of shoreline change in the absence of management intervention such as nourishment or other coastal works. This forms the basis of determination of the need for and nature of management action required.

The sand budget based on the longshore transport calculations shows that, over the period 1979 to 2004, there has been a natural differential of about 45,000 to 60,000 m^3/yr between North Woorim (5^{th} Avenue) and Skirmish Point. This is equivalent to a gradient of 18-24 m^3/m/yr, which equates to a linear shoreline recession of about 1.4 to 1.8 m/yr. This has been offset by beach nourishment at Woorim such that the recession along the northern areas has been minimal. However, erosion of this order has occurred along the southern areas.

Despite that, the period 1961 to 1979 also experienced only relatively minor erosion north of the Surf Club and extensive erosion further south, particularly south from Freshwater Creek. While there is evidence in the survey data of placement of an unknown quantity of sand on the beach at Woorim in 1973, it appears that this earlier period did not experience the same extent of shoreline recession along the northern area as is indicated for the period after 1979.

Why the erosion is varying in that spatial and temporal pattern is not clear. It most probably relates to the specific present stage of natural evolution of this part of southern Bribie Island as a whole with both tidal currents and wave action having significant effects on the processes involved. As such, there can be no prognosis of any likely easing of the more recent erosion potential in the foreseeable future.

3.3.8.2 Climate Change Impacts

Research on likely climate change indicates that two fundamental impacts may affect the shoreline, namely:

- Changes to storm occurrences and storm winds together with their effects on storm surges, and
- Sea level rise.

Little is known about likely changes to prevailing winds or extreme storm behaviour, although it is likely that cyclones would extend further south under warmer sea temperatures. This may slightly increase the extent of future storm erosion of the beach and dunes, but not at an extent that would influence the outcomes of this study.

Sea level has been rising at about 1.0-1.5 mm/year for many years. It is expected that this rate of rise will accelerate in the future due to the effects of climate change.

There are uncertainties as to the actual magnitude and rate of future sea level rise. This has lead to various scenarios being adopted by the Intergovernmental Panel on Climate Change (IPCC), based on the range of model results available and dependent upon the amount of future emissions assumed. The Institution of Engineers, Australia, National Committee on Coastal and Ocean Engineering recommends that these values be used for planning and design.

Table 2.1 presents the low, mid (best), and high estimates of global mean sea level rise from IPCC (2001) for the years 2040 and 2090, relative to 1990.

Table 3-4 IPCC Estimates of Sea Level Rise (m)

Year	Low	Best Estimate	High
2040	0.03	0.12	0.30
2090	0.09	0.48	0.88

The most recent IPCC information from its meeting in 2007 does not present sea level rise predictions in this format, but indicates various ranges of possible sea level rise for a number of scenarios assessed. These indicate rises of 0.18 to 0.59m by the end of the present century, with a possible upper limit of about 0.79m. Thus, planning for a sea level rise of the order of 0.3-0.5m over the planning timeframe of 50-100 years for the Woorim SEMP appears appropriate in the context of the present understanding of these processes.

For this study, this involves, as a minimum, recognition that the present situation at Woorim will become worse over time if no action is taken and management action will need to cater for a progressively increasing sea level. Based on an offshore slope of about 1:30, an additional shoreline recession of about 5m by 2040 and 15m by 2090 could be expected, over the prevailing trend associated with other factors.

Using the past trend of behaviour to predict the future shoreline recession is made more complex by the fact that sea level has been rising at a rate of about 1.7 mm/yr over many decades and there would be some small tendency for shoreline recession associated with that rise, equivalent to about 0.05 m/yr. That is, even if there were no net losses of beach/dune system sand due to a differential in longshore sand transport or by wind erosion, there would have been a small but relatively insignificant shoreline retreat due to sea level rise that has occurred to date.