Coastal erosion investigation and management options for South Mission Beach, Cardwell Shire

Queensland Government
Environmental Protection Agency
Queensland Parks and Wildlife Service

RE508 August05
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1.0 Introduction

Since 1971 beach erosion has been reported at the very southern end of South Mission Beach in the vicinity of the boat ramp. The erosion has progressively extended north and now visibly affects the coastline for some 800m to the north. The erosion is affecting the narrow strip of parkland and the scarp face is close to the sealed roadway, which is the only legal access to many residential properties.

South Mission Beach has been identified in the Cardwell Hinchinbrook Regional Coastal Management Plan (Environmental Protection Agency, 2003) as a priority area for erosion management (see Policy 2.2.2 Erosion prone areas). This involves investigating the cause of the erosion and determining a scheme of works that can be implemented within environmental, economic and social constraints.

The Environmental Protection Agency EPA (and previously the Beach Protection Authority) and Cardwell Shire Council have discussed the erosion issue on a number of occasions over the years. In 1999, the EPA prepared a report entitled Management of the Dune/ Beach Ridge system at South Mission Beach for Council. This report recommended options for the management of the dunal areas, but beach erosion was only discussed generally, and did not quantify the problem or give specific solutions.

As a result of discussions with officers of the Cardwell Shire Council, the EPA agreed to undertake a study of the beach erosion at South Mission Beach to assist Council in managing the erosion problem along this section of coast.

The aims of the study are to:

- examine and describe the coastal processes occurring in the vicinity of South Mission Beach;
- identify the cause and magnitude of the erosion problem;
- discuss the various strategies for managing the erosion problem; and
- provide recommendations on a specific program for addressing the erosion problem for consideration by Cardwell Shire Council.

2.0 Study area and site description

South Mission Beach is the southern-most section of a coastal plain extending from Tam O'Shanter Point in the south to Clump Point in the north. This beach compartment also includes Wongaling Beach and Mission Beach and, for this study, is called the Mission Beach compartment. South Mission Beach is a low lying 2km section of coast located between a rocky outcrop at its southern end and Wheatley's Creek to the north. In the vicinity of Wheatleys Creek sand has accumulated in a broad, moderately convex salient caused by the sheltering effects of Dunk Island to the southeast. This acts as a controlling feature on the coast, and South Mission Beach has formed as a slightly indented embayment between this point and the rocky outcrop at the southern end. A locality plan of the site is presented as figure 1(next page).

The beach profile consists of a broad gently sloping intertidal area of about 100m in width backed by a narrow high tide beach 10m to 20m in width. Behind this is a relatively low and narrow sandy beach ridge plain forming a barrier to the Hull River estuary. South Mission beach has been extensively developed for residential purposes. A 30m wide esplanade has been designated over its entire length. The original foredune and swale now covered by the Esplanade has, for most of its length, been graded, filled and developed for road and park, and is typically only 1m above highest astronomical tide level (HAT). The erosion scarp is within 6m to 10m of the constructed road in some places. Behind this area is a narrow beach ridge plain, which is higher and broader than the foredune. Housing and other residential infrastructure has been established along these beach ridges. Estuarine and freshwater wetlands associated with the Hull River back this western side of the beach ridge plain.

Photo 1. Kennedy Esplanade showing the relatively narrow width of undeveloped esplanade seaward of the road. (source: EPA)

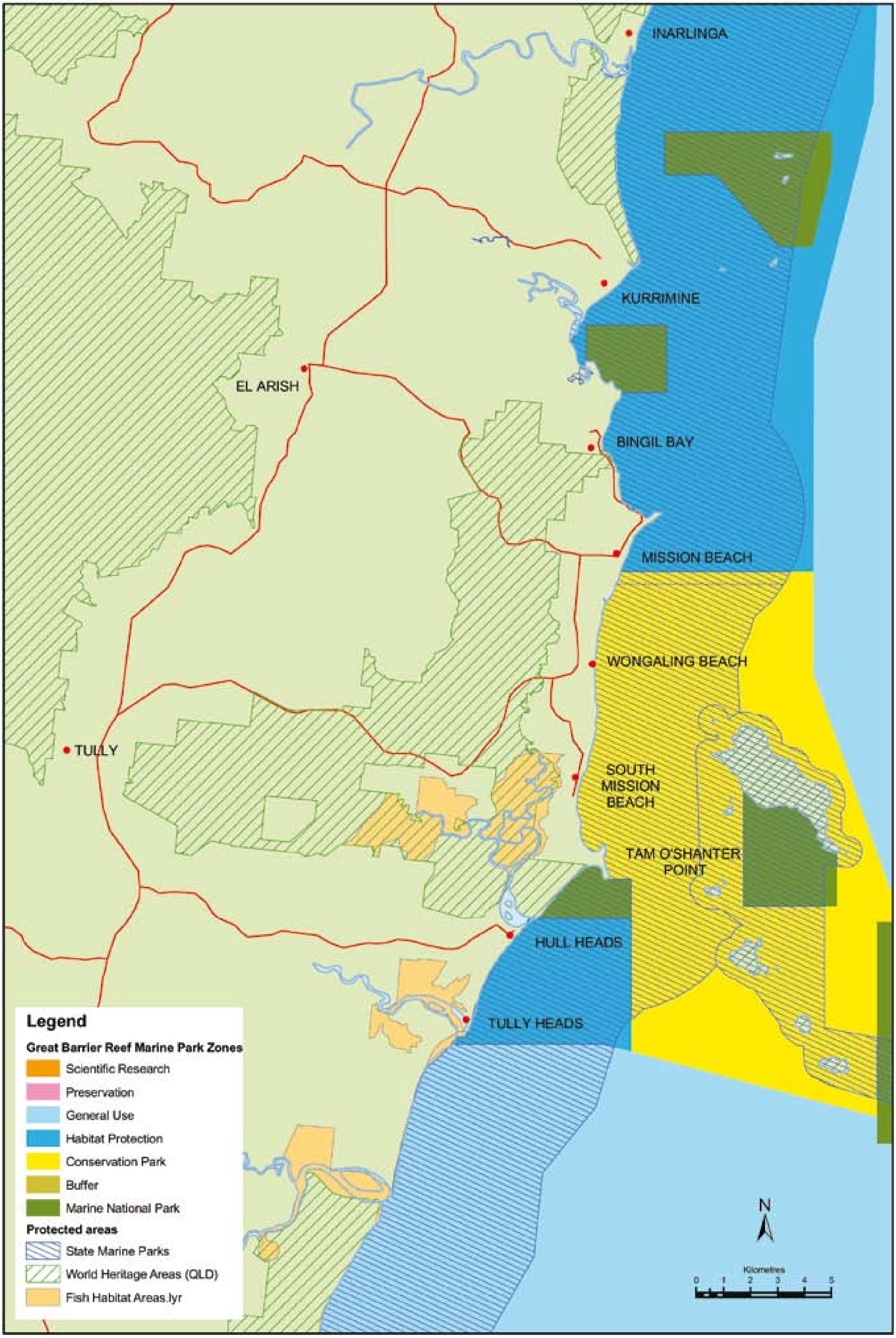

Figure 1. Locality plan of South Mission Beach including marine park and other protected areas.

3.0 Coastal erosion issue

The southern end of the beach has experienced a slow but persistent trend of erosion for at least 30 years. Following construction of a concrete boat ramp in 1968, localised erosion immediately north of the ramp emerged as a problem in 1971. The Council responded by constructing a rock wall on the scarp face to protect the immediately adjacent road and toilet facility. The rock wall has been progressively extended northward following the migrating erosion scarp. The rock wall appears to have had the undesirable effect of transferring the erosion problem northwards. The rock wall presently extends approximately 600m along the beach and a persistent erosion scarp is evident for approximately 200m further north of the rock wall.

The problem with the current erosion management strategy is threefold as described below.

- The rock wall, for most of its length, has been poorly constructed in terms of footing depth, armor size and wall porosity, and for much of its length consists simply of dumped rock. It is considered that it would neither halt the present trend of coastline recession nor provide protection against the effects of a severe storm event. In some places the wall has slumped, smaller rock has been dispersed across the beach and the erosion scarp has retreated behind the wall alignment.
- Construction of the wall on the erosion scarp means that there is little, if any, sand dune buffer left between the rock wall and the beach. This leaves the wall continuously exposed, which reduces the visual amenity of this prime recreational asset.
- The ongoing construction and maintenance, and the required upgrading of the rock wall will be an increasing financial liability to the Council. At the same time the recreational value of the beach will decline as the beach level decreases and the useable beach narrows.

Photo 2. Poorly constructed rock wall at the southern end of South Mission Beach. (source: EPA)

Photo 3. Beach condition in June 2001 following sea erosion. (source: EPA)

Photo 4. Beach condition in November 2003 following sea erosion. (source: EPA)

Photo 5. Beach condition in May 2004 following sea erosion in March 2004. (source: EPA)

4.0 Data collection and analysis

4.1 Investigation of local coastal geomorphology and implications for present day coastal processes

To understand the erosion problem at South Mission Beach, an overview of the geomorphology and the large-scale sediment transport pathways and coastal processes in the region were investigated.

Holmes (1993) assessed the geomorphology and erosion vulnerability of the Mission Beach coast as part of a larger regional study. This coast consists of a narrow sand plain extending from the boat ramp at South Mission Beach to Clump Point. This coastal plain consists of both Pleistocene sands deposited during a previous sea level high >100,000 years before present (BP), and Holocene beach ridges, deposited up to 6000 years BP. These landforms are detailed in figure 2. The Holocene beach ridges directly onlap the Pleistocene ridges. The coastal plain is narrowest at South Mission Beach and widest at Wongaling Beach. South of Tam O'Shanter Point is a wide Holocene beach ridge barrier. The Holocene barrier is between 350m and 460m in width and extends from Tam O'Shanter Point to the Hull River mouth as a continuous series of ridges. Three major ridges occur along the length of the barrier. The Holocene barrier onlaps Pleistocene beach ridges which extend south from Tam O'Shanter Point.

Holmes (1993) indicated that the Mission Beach embayment did not have an external source of sand and could essentially be considered a pocket beach with a finite sand resource. This was based on the fact that the Tully River is the only possible external source of sediment and that no transport pathway could be found around Tam O'Shanter Point. It was also determined that the Mission Beach sand had a lower Potassium-feldspar content than Tully River sand indicating that the Mission Beach sand has undergone some form of weathering and is not recently derived from the Tully River. He concluded that most likely source of sand along Mission Beach was from the continental shelf. This sand was probably transported onshore during the marine transgression (10,000 to 6000 years BP) and early stillstand (post 6000 years BP).

Further investigation of the stratigraphy and geomorphology of the area was undertaken in December 2002 to determine the history and age of geomorphic units of the site. This investigation included an analysis of aerial photographs and a soil profile examination by backhoe trenching. The purpose of the work was to confirm whether a sediment supply from south of Tam O'Shanter Point to South Mission Beach once existed in relatively recent geological times and if so, at what time over the Holocene had the formation of the Tam O'Shanter tombolo cut off the sand supply, resulting in the observed trend of erosion. This would assist in determining whether erosion at South Mission Beach is caused by a geologically recent disruption in sand supply from the Tully River/ Hull Rivers compartment to South Mission Beach causing a long-term realignment of the coast, whether it is caused by an episodic redistribution of sand within the Mission Beach compartment, or by some other cause.

Four trenches up to 5m deep were excavated on the tombolo west and south of Tam O'Shanter Point, and a recent septic tank excavation and soil test bore log on a seaward residential lot at South Mission Beach were examined. The location of these is indicated on figure 2 (next page). Unfortunately, no shell material that could be used for dating the dune emplacements was recovered from any of the trenches. This was probably due to the age and extensive weathering of these soils in a tropical climate. A description of the soil profiles is given in figure 3 (following page).

The age of the dune sands could only be inferred from the characteristics of the soil profile and barrier morphology. The dune soils examined had well developed profiles indicative of extensive weathering, except for the South Mission Beach profile. The soil profile characteristics of an increasing width of the organically enriched A-horizon and development of an orange brown B-horizon deepening with depth are consistent with increasing age of the barrier sequence landward. Pye (1981) has indicated that in humid tropical conditions the observed reddening of dune sands may occur within 10,000 to 100,000 years, but with a diverse nature of controls on reddening, time alone is not the determining factor.

Soil profile characteristics as shown in figure 3 indicate the Holocene barrier formed rapidly after the end of the postglacial marine transgression (estimated at 5600-6100 years BP). The soil profile of the tombolo immediately west of Tam O'Shanter Point (location no. 2) indicated that it is probably Pleistocene, but may be Holocene in part. In any event, it is inferred that the tombolo closed the sand transport pathway behind the Point to South Mission Beach from at least the mid Holocene.

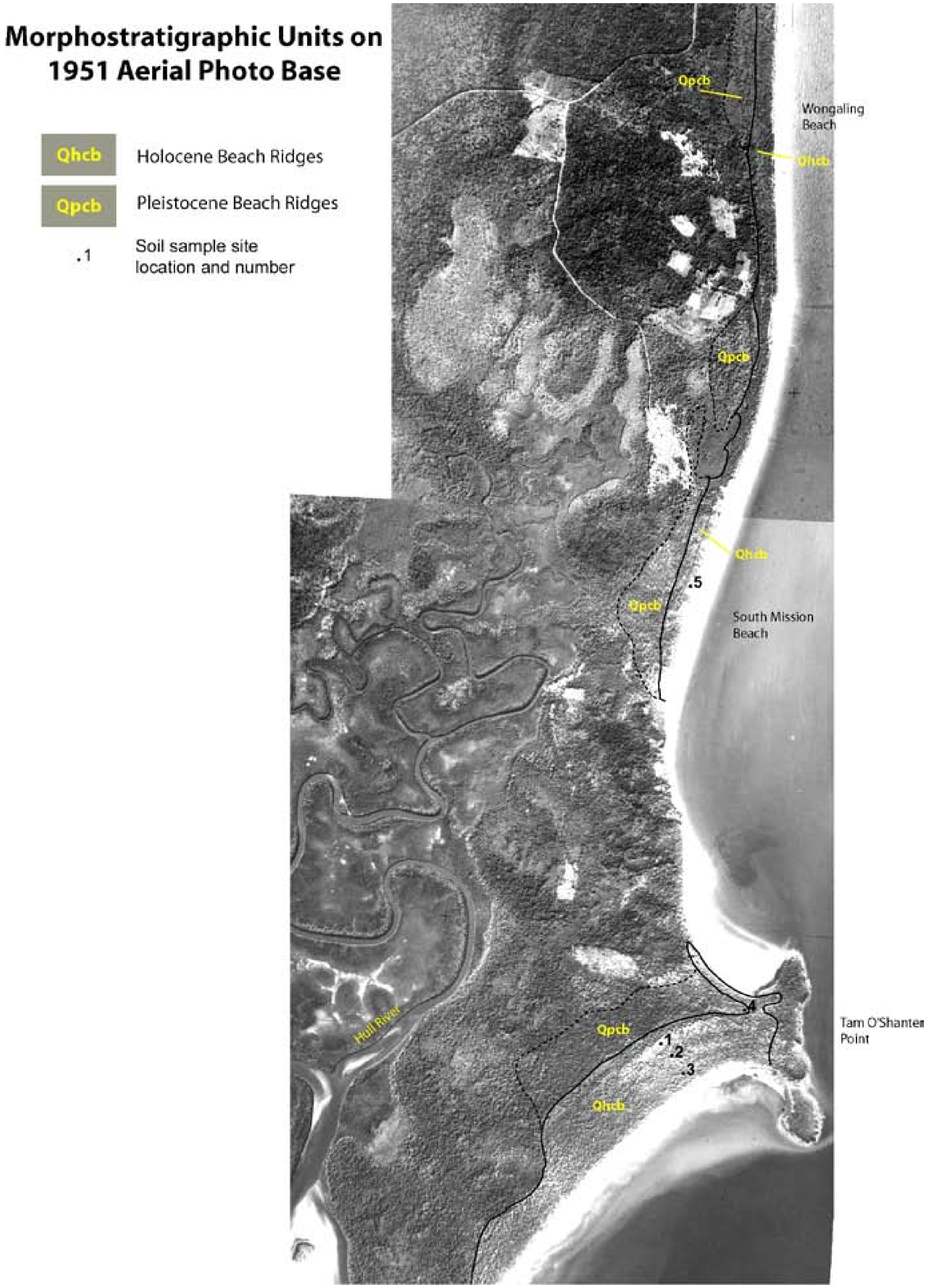

Figure 2. Morphostratigraphic units of the dune areas from the Hull River to Wongaling Beach – 1951 photography. (source: EPA)

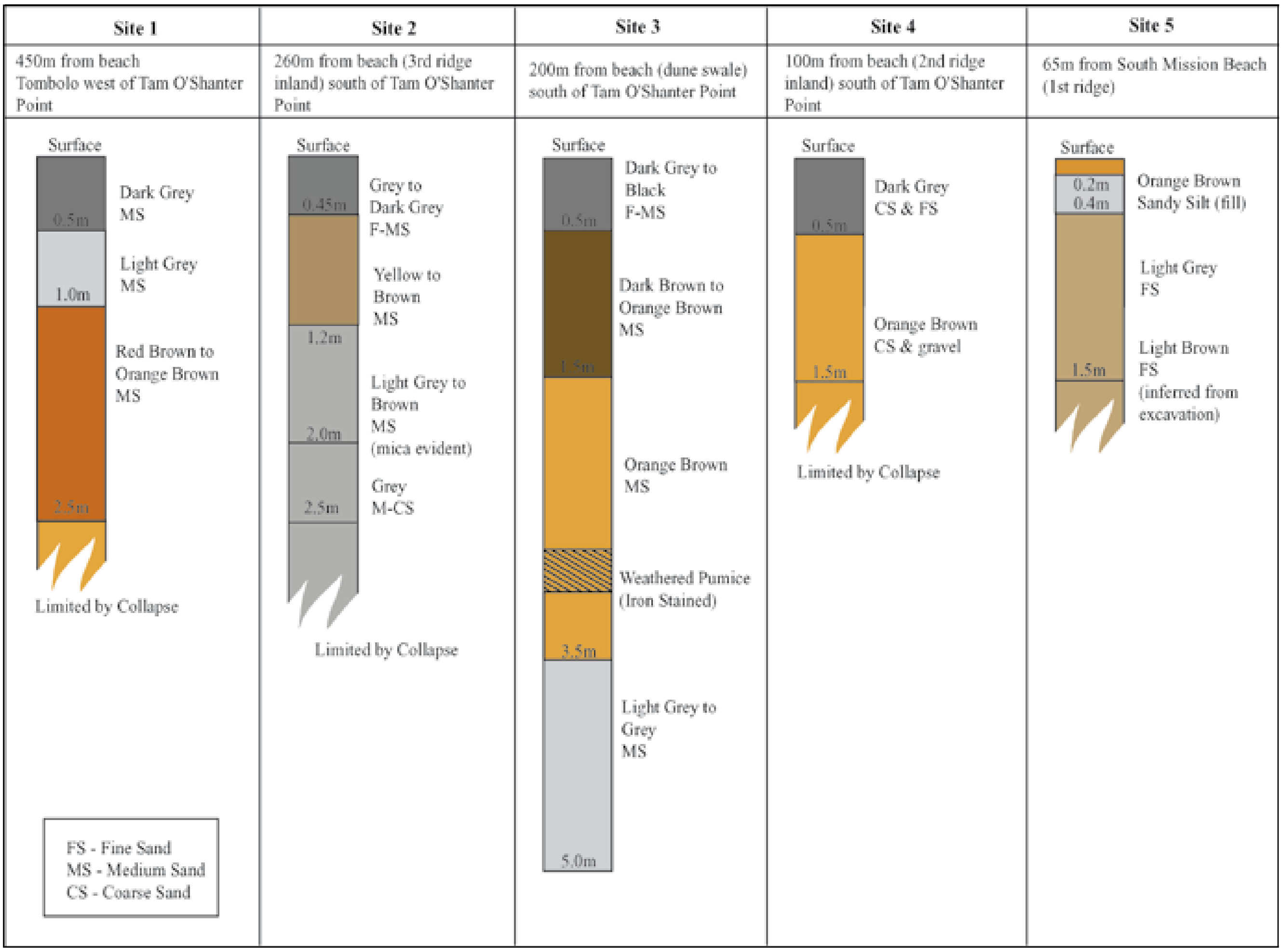

Figure 3. Soil profiles of the Tam O'Shanter Point dune field. (source: EPA)

An interesting feature of the dune morphology in the vicinity of Tam O'Shanter Point was the increasing elevation of the dune crests and swale troughs landward. This is consistent with findings from other research on morphostratigraphy of barrier systems in north Queensland (Masselink and Lessa, 1995) which indicate sea level at the end of the post glacial marine transgression was 1.5 to 2m higher than at present, probably due to isostatic rebound, where the land level is raised and there is a relative drop in sea level.

The undifferentiated soil profile from South Mission Beach indicates a relatively short period of weathering due to its young age. However, if this barrier was formed in the mid Holocene by the onshore migration of shelf sands, the apparent young age can only be interpreted as reworking of the existing sand by sea erosion and dune reconstruction.

The findings from this component of the investigation were:

i) The gap between the mainland and Tam O'Shanter Point has been closed by a tombolo since at least the mid Holocene, and there is little likelihood of any significant longshore transport of sand around Tam O'Shanter Point. Therefore there is no significant modern day sand supply to the Mission Beach compartment from the Hull or Tully Rivers.

ii) The Mission Beach compartment is a large pocket beach with a finite sand resource held between Tam O'Shanter Point and Clump Point. Sand in the compartment was probably derived from offshore marine deposits and emplaced during the early Holocene.

iii) The South Mission Beach Holocene beach ridges are relatively uniform and intact over most of the compartment with no evidence of long-term reworking or erosion, such as barrier truncation. However, evidence suggests a recent (50 to 500 years) reworking of the most seaward beach ridge. This was thought to result from cyclone activity, where sand from the beach ridge is eroded and stored in an off-shore bar. During subsequent calm weather the sand is transported onshore and a beach ridge rebuilt (Taylor and Stone, 1996).

- The long-term net littoral drift for this coastal sector is assessed to be close to zero.
- The large most seaward beach ridge that occurs along the length of the Esplanade of South Mission Beach appears to be relatively young and was probably formed by a major event reworking existing deposits in the recent past (<500 years BP).

4.2 Comparison of historical shoreline positions

Historical aerial photography of the region captured in 1951 (figure 2) was sourced from the Department of Natural Resources and Mines to determine the state of the coastline at South Mission Beach before significant residential development occurred, as shown on the most recent aerial photography taken in 2002 (figure 4).

High-resolution aerial photography of the South Mission Beach area taken in 1974, 1991 and 2002 were rectified using permanent features such as houses and roads common to each time series, and compared to quantify the horizontal changes in shoreline position over this 28-year period. Aerial photography from 1951 was also assessed but accurate comparisons of shoreline position could not be made due to the low number of permanent features from which to rectify the images. These historical views of South Mission Beach are shown in figure 4. The spatially referenced shoreline positions obtained from each date were overlaid on the 2002 rectified image and measurements of shoreline change are presented in figure 5. Some limited comparisons have been included from the 1951 aerial photography where permanent features were identified, but accuracy is reduced.

Shoreline comparisons over 28 years from 1974 to 2002 indicated that the beach behaviour has been complex, as described below:

- in the southern section shoreline retreat has been minor and in the order of 3m. Progressive construction of a rock wall on the scarp face has limited further retreat;
- in the southern to central section shoreline retreat has been more rapid, particularly in the past 10 years, with typical retreat of 4m to 7m and the greatest retreat of 13m at an area of storm water discharge near Douglas Street; and
- in the central to northern section, minor accretion of approximately 7m has occurred, mainly as a low lightly vegetated dune terrace that probably comes and goes over time.

At the central part of South Mission Beach the rate of shoreline retreat increased between 1991 and 2002 up to 0.88m per year. Erosion has probably been accelerated by construction of the rock wall to the south, which has concentrated erosion in this area.

Photo 6. Northern end of South Mission Beach following erosion in March 2004. Note the broad intertidal zone and high-tide bar. It would be expected that this bar will move up the profile in calm weather and rebuild the dunes. (source: EPA)

Figure 4. Historical aerial photos of South Mission Beach 1951 to 2002. (source: EPA)

Rate of Shoreline Change

1974 - 2002	+0.35m/yr	+0.16m/yr	+0.16m/yr	-0.24m/yr	-0.48m/yr	0.0m

Change in shoreline position (+ is accretion, - is erosion)

1974 - 2002	+9.8m	+4.3m	+4.4m	-6.7m	-13.4m	0.0m
1991 - 2002	+6.8m	+9.8m	+10.5m	-3.7m	-9.7m	-3.0m
1974 - 1991	+3.0m	-5.5m	-6.1m	-3.0m	-3.7m	+3.0m
1951 - 1974 (Low reliability due to poor quality 1951 photography)	+8.8m	+3.8m	+5.0m	0.0m	+2.5m	-1.5m

Figure 5. Changes in shoreline position 1951 to 2002.

Shoreline changes between 1951 and 1974 could not accurately be determined due to the poor quality of the earliest photography available and lack of permanent features to reference the photos at various dates. The only obvious trend was significant accretion on the northern part of the beach. This is based on the assumption that the centre line of Kennedy Esplanade was constant between 1951 and 1974.

While horizontal recession along this coast is only minor, the recession relative to the park width back to the edge of the sealed road has been significant, with 25 to 50 percent of the vegetated park seaward of the road having been lost at some locations.

4.3 Water levels

Table 1 provides the tidal planes for the region, based on published data for Clump Point. Table 1 also provides estimated storm tide levels (Rust PPK, 1995).

	Level relative to AHD
1:500 year Average Recurrance Interval (ARI) storm tide*	3.20m
1:100 year ARI storm tide*	2.64m
Highest Astronomical Tide (HAT)	1.91m
Mean High Water Springs (MHWS)	0.93m
Mean Low Water Springs (MLWS)	-1.00m
Lowest Astronomical Tide (LAT)	-1.68m

Table 1 Storm Tide Statistics – Cardwell Region

* Note: Estimates for Tully Heads - does not include an allowance for wave setup.

4.4 Wave climate

On long sandy beaches such as South Mission Beach, the overall wave climate has a strong influence on the alignment of the coast. In general, the beach alignment responds to the "average" wave direction and significant local changes may be caused by variations in the wave climate.

The site is exposed to relatively low to medium wave conditions. These are locally generated wind waves driven mainly by predominant southeasterly trade winds and the sea breeze. The offshore islands (particularly Dunk Island) and Tam O'Shanter Point provide a degree of sheltering that reduces the energy of the inshore wave climate. The occasional impact of tropical cyclones can result in the generation of extreme waves. These are in the form of swell waves, propagating from near the centre of the cyclone, and locally generated windwaves. A direct assessment of the wave climate affecting South Mission Beach has not been made as part of the present study.

The James Cook University Marine Modeling Unit (JCU, 2003) has undertaken a program of numerical modeling and associated statistical analysis of tropical cyclone waves for the majority of the Great Barrier Reef area. This work was funded through the Cooperative Research Centre for the Great Barrier Reef World Heritage Area. For a location approximately 35km east of Dunk Island, the significant wave height corresponding to a 50 year average recurrence interval is estimated as 4.5m. The results do not allow an accurate estimation of likely extreme wave conditions in the lee of Dunk Island, however an indicative estimate is in the order of 3.5m.

4.5 Sediment transport

Sediment transport on the coast at South Mission Beach occurs by two principal mechanisms.

Longshore sediment transport:

This is a response of a beach to incoming wave energy reaching the shallow water near the shore at an angle to the beach. The waves will move sand along the beach as they stir up sediment on the bottom. Over a given period and depending on wave energy and direction the total (or gross) longshore sediment transport may be significant as sand is moved on both directions along the coast. However, the net longshore sediment transport may be small. Over relatively long time scales this is likely to be the case at South Mission Beach, based on the assessment of geological controls.

Cross-shore sediment transport:

The most important form of cross-shore sediment transport is the response of a beach to elevated water levels (storm tides) and storm waves. During storm conditions the beach profile flattens causing a recession of the upper beach. Generally the sand eroded from the upper beach is deposited in the near-shore area and is slowly returned during calmer wave conditions.

A direct assessment of the longshore sediment transport rates affecting South Mission Beach has not been made as part of the present study. Contributions to longshore transport are made by:

- southeasterly trade winds;
- the daily seabreeze. This has the effect of rotating the wind-wave direction towards the perpendicular to the coastline;
- seasonal north-easterly winds; and
- the effect of sea and swell waves generated by the occasional tropical cyclone.

The analysis of the longshore sediment transport at South Mission Beach is complicated by the lack of representative wind records for the region that are required to assess the locally generated wind-wave climate. Applicable recorded wind data, from a preliminary review, appear to be influenced by topographic factors.

Small changes to the longshore sediment transport may be caused by relatively subtle climate variations (for e.g. a typical year-to-year variability of the strength and net average direction of the trade winds may cause changes to the equilibrium alignment of the beach). Over a long section of beach this can cause marked effects on the coastal alignment near each end. In the case of South Mission Beach this is likely to be noticeable at the southern end of the beach.

During years when the south-easterly winds are frequent, the net annual longshore transport would be to the north. This is probably balanced by years when strong north-easterly winds occur or a tropical cyclone occurs north of the region, when net annual longshore transport would be to the south.

Figure 6. Location and number of survey lines.

4.6 Beach profile analysis and changes

As part of the present study, Cardwell Shire Council completed an initial set of 16 beach profile surveys for the length of South Mission Beach in September 2002. The surveys extend from the backshore area out to approximately the lowest astronomical tide level (figure 6).

Beach profiles recorded at each survey line are presented in figure 7. Profiles 1 to 3 are within the beginning of the salient feature, and profiles 4 to 5 display a small nearshore bar. Profiles 6 to 9 indicate an actively eroding section of coast and profiles. Profiles 10 to 14 are on the section of the coast where a rock wall has been constructed. Profiles 15 and 16 are within an area modified by construction of a boat ramp. Typical profiles for each of these areas are shown in figure 8.

4.6.1 Comparison of survey profiles

No historical beach profile or hydrographic survey data are available for the South Mission Beach area. In the absence of historical survey data, some information on sand volume lost over time from the beach by erosion may be derived by a comparison of current survey lines. As an approximation, it can be assumed that the profiles at the northern end of the beach represent the un-eroded, "natural" state of the beach. The relative loss of volume from the beach profiles at the southern end of the beach can be determined by comparing the profile data, taking profile 4 as the base.

Figure 7 shows all the survey data overlaid to a common underwater point (-1m AHD). It can be noted that, apart from profiles 1 and 3, there is little change between profile shapes particularly in the lower beach sections. Differences are noticeable at around the +1m level, which is approximately mean high water springs tidal level.

To investigate this further the relative position of the +2m contour (approximately HAT or the level of the toe of the frontal dune) relative to the –1m contour (MLWS) has been derived (figure 9) and provides a simple measure of the overall erosion and retreat of the upper beach. The most landward position of the +2m contour occurs at profile 9, 600m north of the boat ramp. This is the profile immediately north of the end of the rock wall.

This finding illustrates the mode of erosion occurring at the southern end of the beach. The upper beach (represented by the +2m contour) shows recession of up to 7m compared to profiles further north, but the lower section of the beach is relatively unaffected. The beach in front of the rock wall has constrained landward retreat and the foreshore immediately seaward exhibits a lowered level. Therefore, erosion occurs primarily on the upper beach above MHWS, but where recession is prevented by the construction of a rock wall, erosion continues seaward of the wall resulting in a lowering of the beach level.

The volume of sand eroded over time can be estimated by comparing profile 4, representing a typical equilibrium beach profile, and all other profiles. Sand volume differences between the -1m contour and a point 80m landward of the –1m contour is shown in table 2.

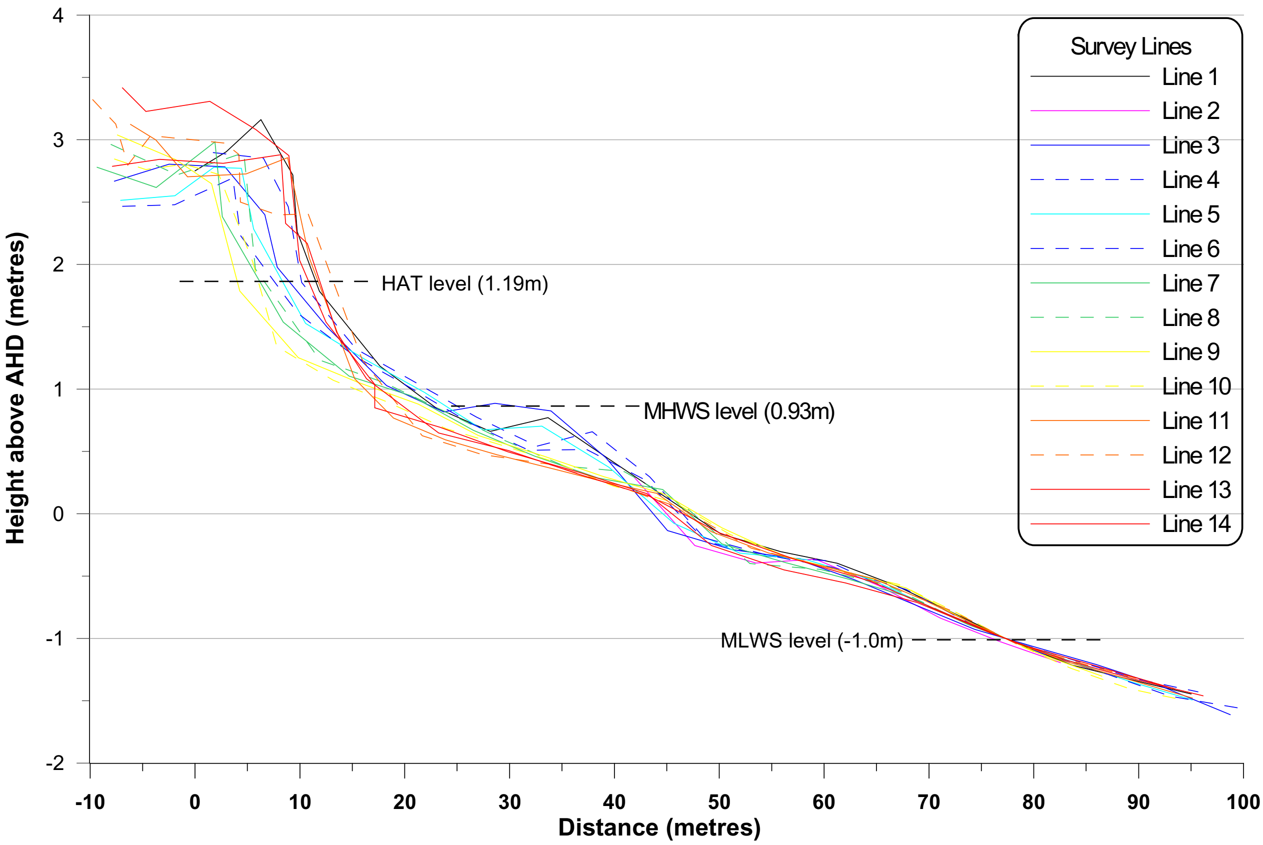

Figure 7. Beach profile at each survey line recorded on 22 September 2002

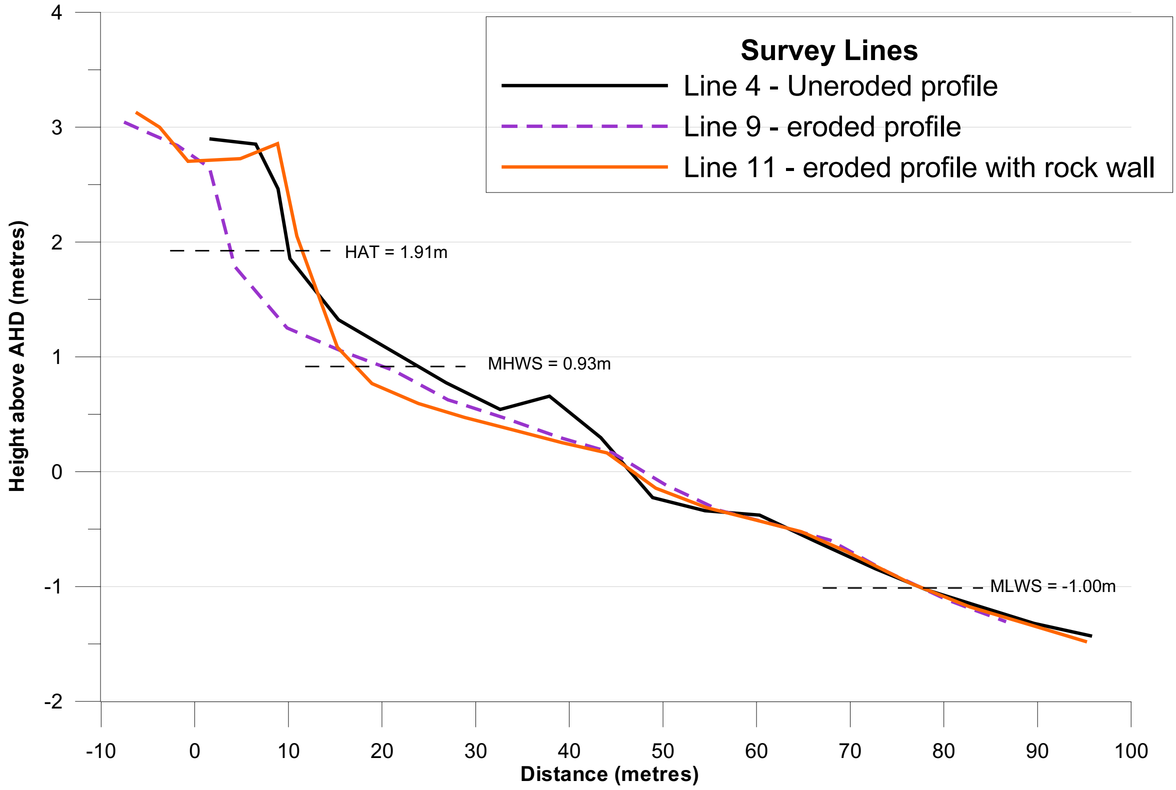

Figure 8. Typical beach profile

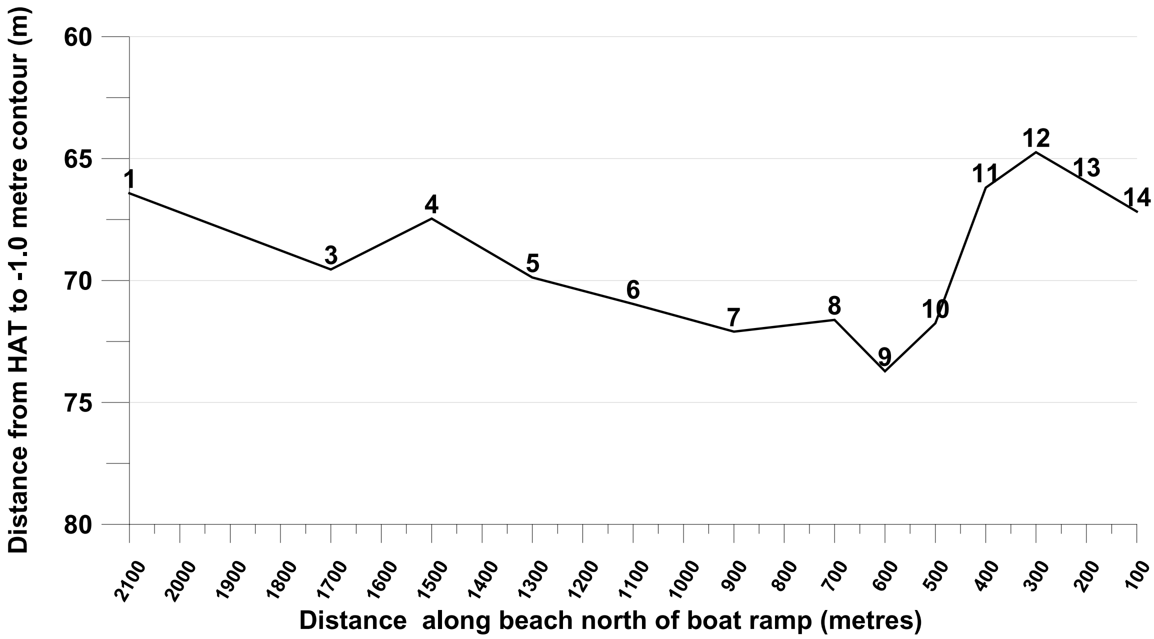

Figure 9. Distance of the highest astronomical tide level to the -1.0m contour at September 2002.

The total volume determined through summation of sand lost over the entire beach is estimated at 14,639m³, with the bulk of this coming from the southern to central section of this beach. The most eroded section of this beach has experienced a sand loss of 14m³/m of coast.

It should be noted that the above estimation of sand loss assumes that the beach profile at the –1m contour is stable and has not changed over time. As no previous survey data to this level is available, this assumption cannot be tested. Therefore, it would be prudent to include a safety factor of 40 percent in any calculation of sand loss to minimize the risk of an underestimation of sand loss. Sand loss is therefore recalculated at 20,494m³ and for convenience is rounded to 20,000m³.

Assuming that this erosion has occurred over a 28 year time period, the average annual loss from erosion is calculated at about 700m³ per year. This is a relatively small amount compared to other sites along the Queensland coast (e.g. Woorim in Caboolture Shire is a similar moderate wave energy coast and is losing about 30,000m³ of sand per year).

Survey line (profile) number	Chainage north from boat ramp	Sand volume difference between each profile and profile 4	Section length	Sand volume change per 100m of beach
	(m)	(m^3/m)	(m)	(m^3)
1	2100	2.3	200	230
	2000			230
2	1900	-1.95	200	-195*
	1800			-195*
3	1700	-6.21	200	-621#
	1600			-621#
4	1500	0	200	0
	1400			0
5	1300	-7.65	200	-765
	1200			-765
6	1100	-9.22	200	-922
	1000			-922
7	900	-14.07	200	-1407
	800			-1407
8	700	-11.16	100	-1116
9	600	-15.35	100	-1535
10	500	-15.35	100	-1535
11	400	-7.65	100	-765
12	300	-6.08	100	-608
13	200	-6.37	100	-637
14	100	-6.23	100	-623
Total of losses (-)				**-13,628**

Table 2 Sand loss from beach sections compared to an uneroded beach section represented by survey line 4.

* Profile data of poor quality hence calculated volumes may be inaccurate
# Profile affected by creek mouth hence calculated volumes may be inaccurate
Note 1. Profiles 15 and 16 were no included due to distortions in the beach profile introduced by construction of the boat ramp.

4.6.2 Potential shoreline recession from future storm erosion

An estimate of short-term beach erosion from a storm event may be determined by the method of Vellinga (1983). This method assumes an equilibrium beach profile that develops in response to elevated water levels and wave action. The computed profile is a function of wave height and beach sediment properties. The Vellinga method is limited, as it doesn't take into account time varying conditions during a storm and describes the response of the upper beach only. Despite its shortcomings, it is an accepted empirical method widely used for estimation of erosion potential on other sections of the Queensland coast.

A Vellinga analysis has been undertaken on profile 13, which represents the beach at the southern end of the study area. Key parameters used in the analysis were:

- average recurrence interval for storm event = 100 years (extreme cyclonic event);
- peak storm water level = 2.99m AHD;
- peak significant wave height = 3.5m; and
- median sediment diameter D_{50} = 0.21mm.

The analysis results show a recession at the toe of the frontal dune in the order of 45m is required to achieve an equilibrium beach profile at the elevated water level (figure 10). The actual amount of recession will depend on the duration of the elevated water level and the tidal influence at the time. Such a recession event may not occur as a single event and could result from the cumulative effect of a series of events over a short time period. This would provide the opportunity for short-term remedial actions, such as sand pushing from the intertidal zone to the upper beach.

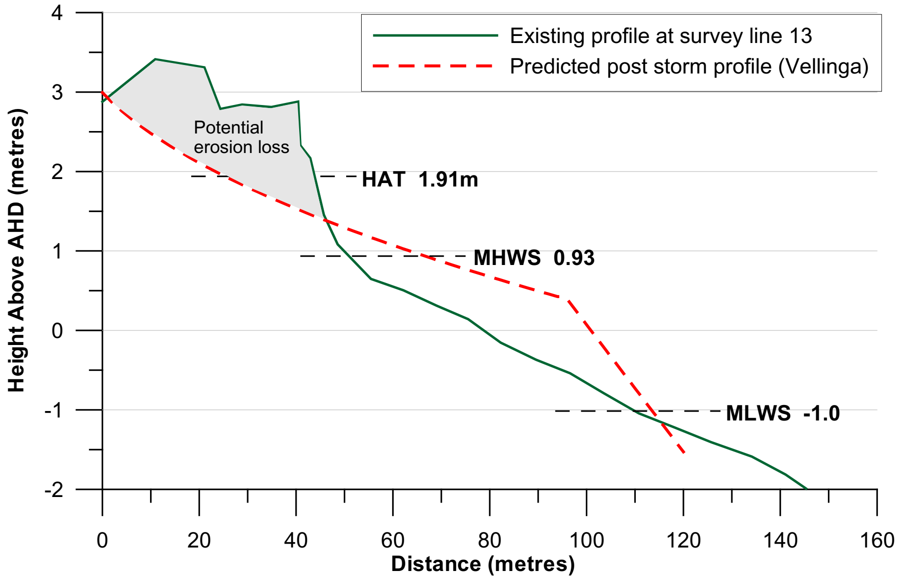

Figure 10. Estimated short-term beach profile response to a 1 in 100 ARI storm event based on Vellinga 1995).

4.7 Effects of storm water discharge on beach erosion

Storm water from the roadway along South Mission Beach is discharged to sumps or soakage pits on the foredune seaward of the roadway and allowed to percolate into the sand. Beach erosion along this coast appears to be worsened generally seaward of storm water disposal sumps.

The sump type disposal system does not appear to have the capacity to handle intense rainfall events which cause system overflows. This is observed to result in ponding of water behind the dune crest, and locally concentrated surface flow. This system may also have a limitation in that the sump will locally elevate ground water levels and where this is near the erosion scarp face, the sand becomes fluidised and is more susceptible to erosion. As ponded water breaches the dune crest significant scour holes are formed, which can further concentrate wave erosion (see photo 7).

Photo 7. Scour channel through the foredune caused by stormwater overflow, May 2004. (source: EPA)

The direct discharge of storm water to the ocean across the beach appears to be the only viable alternative at this location to minimise this impact. However, unless managed correctly, disposal of storm water to the upper beach has the potential to cause extensive local scour. Suitably designed outlet structures would be required to minimise problems.

Council will need to seek further design advice regarding this matter. It is noted that a number of new products have been developed utilizing geotextile materials that may be of use including sand filled containers, and scour aprons.

5.0 Key findings on erosion

i) The coastline at the southern end of South Mission Beach is experiencing a relatively small but persistent trend of erosion. The erosion trend appears to have started at the southern end and has steadily progressed northward. A rock wall has stopped the coastline recession at the southern end of the beach but has effectively transferred the erosion to the north. Active beach erosion is now apparent near the center of the embayment adjacent to the end of the wall. The northern coast of South Mission Beach has experienced sand accretion and coastline progradation.

ii) The most eroded section of coast around profile 9 (figure 6) has experienced shoreline recession in the order of 4m to 7m which is a annualise rate of 0.24m. The maximum point of recession at the end of the rock wall was 13.4m which is an annualised rate of 0.9m.

iii) Based on a comparison of beach profiles, a total loss of 20,000m^3 of sand is estimated along the southern and central section of this beach over the last 28 years.

iv) A review of the geomorphological factors affecting sediment supply to South Mission Beach has determined that the Tam O'Shanter to Clump Point compartment is a closed system with no longshore supply of sand from the Hull or Tully Rivers. The only significant sand supply was offshore marine deposits in the mid-Holocene associated with the ending of the postglacial marine transgression. The present beach has formed in response to zero net sediment supply and therefore the long-term average longshore sediment transport rate at any point along the beach is negligible.

v) The most probable cause of the present beach erosion problems is therefore an episodic response to a change in the prevailing wave climate, which has resulted from a subtle shift in the balance between the various climatic factors that drive longshore sediment transport. It is likely that the erosion at the southern end of the beach has resulted in an associated accretion of the salient feature at the northern end of the beach near Wheatley's Creek.

vi) The factors that can cause changes to the prevailing wave climate include inter-annual variability of the south-easterly trade winds and the effects of occasional tropical cyclone events.

vii) The esplanade, constructed on the foredune and close to the erosion scarp, is vulnerable to storm erosion. A storm event, producing water levels corresponding to a 100 year average recurrence interval may potentially cause up to 45m of recession. This would potentially destroy most of the road and may threaten adjacent houses.

viii) The present rock wall is generally poorly constructed and has been damaged by small to moderate erosion events. For the most part, it would offer little protection against a severe storm event.

ix) Erosion has been locally aggravated by the discharge of storm water to soakage pits on the frontal dune and the overland flow of ponded storm water overtopping the dune crest.

6.0 Erosion management options for South Mission Beach

There are a range of options available to the Council to manage the erosion at South Mission Beach. These are detailed below with the pros and cons of each provided. Specific recommendations on the favored erosion management options are provided in section 8.0.

6.1 Managed retreat

Managed retreat allows coastal erosion to continue unhindered, by relocating assets further landward as erosion progresses, to avoid loss. It is commonly referred to as the buffer zone concept, where sand eroded from the dunes during storms is moved offshore and returns to build the dunes during calm weather. This is a low-cost strategy but requires the dunal buffer areas to be of adequate width, and is most applicable when erosion is cyclical.

At South Mission Beach, the slow erosion along sections of coast is expected to continue in the short to medium term, and at the current rate, the existing dunal area can only accommodate erosion for the next 5 to 10 years before the road is directly affected. There is also insufficient land between the road and the foreshore to accommodate short-term cyclical erosion without directly threatening to the road and other public infrastructure, and there is insufficient space for these to be relocated. Furthermore, the suspected presence of fill material in the dune swale undermines the value of this area as a source of sand for natural beach replenishment.

Photo 8. Rock and soil fill material on the esplanade exposed by dune erosion. (source: EPA)

The loss of parkland amenity is also of concern to the Council as some residents have identified this parkland amenity as an important feature of South Mission Beach. Managed retreat therefore is not considered a viable option for most of the actively eroding sections of the study area.

6.2 Beach nourishment

Beach nourishment is the replenishment of beaches with imported sand and is one of the best available means of restoring beaches where erosion has become a problem. It widens the beach and dunes thereby preserving existing beach amenity and increases the buffering capacity of the dunes against storm attack to protect development. Sand nourishment increases the width of land available to accommodate erosion, while at the same time allowing the beach to continue to behave naturally.

Sand placed in only a few selected areas of a generally eroding coastline or placed to form only the upper (visible) part of the beach will usually be dispersed quickly through the beach system. The sand is not lost but remains in the active beach system, resulting in some gain overall but a less-than-desired gain for individual beaches. To achieve successful beach restoration, expectations of the result must be clearly articulated and sand requirements must be carefully calculated to achieve these.

The one disadvantage of beach nourishment is that the sand will continue to be eroded and ongoing top-up nourishment may be required to maintain the desired beach profile. This may be seen by some as a temporary solution and a waste of money.

An important aspect of beach nourishment is that any sand added to the beach comes from a source outside of the active beach system. The active beach system includes the areas of present day sand movements including the dunes, beach and offshore sand bars. The sand introduced thereby represents a gain in the quantity of sand contained within the beach system rather than just a transfer from one part of the system to another.

It is also important that the grain size of nourishment sand is similar to that of the existing sand. This ensures that the slope of the beach profile remains compatible with the pre-nourishment profile, and that sand movements as a result of natural profile adjustments are minimised.

A low-cost alternative to purchasing sand from an outside source is to use clean sand surplus to requirements from Council projects such as road works or pipeline installations, or from private development sites or maintenance dredging. Council can also impose a requirement on certain development approvals that all surplus clean sand from such sites is placed on beaches and dunes. Within the designated erosion prone area, building works involving the excavation of clean sand can be required to place this material elsewhere within the erosion prone area.

Beach nourishment works may attract a 25 percent State subsidy through the Local Governing Bodies' Capital Works Loan Subsidy Scheme administered through the Department of Local Government and Planning

Application to South Mission Beach

Beach nourishment can be used at South Mission Beach to:

i) replace erosional losses and restore the beach to the preexisting profile. South Mission Beach is experiencing moderate erosion over more than 1000m of coastline with a calculated annual sand loss of 700m^3, and a long-term loss since 1974 of 20,000m^3 (table 2). These quantities are considered relatively small compared to other areas of the coast and are therefore amenable to remediation by beach nourishment. The sand volumes required to offset the historical erosional losses is presented in table 3, and the required post nourishment beach profiles are presented in figure 11.

ii) increase the width of the dunes to create a wider buffer zone seaward of the road. Figure 10 demonstrates that an extreme cyclonic event (1 in 100 ARI) may cause erosion of the dunes and a landward recession of the coast by up to 45m. An analysis of the existing dune width indicates that the dunes would have to be increased in width seaward of the road by up to 35m so that this erosional loss could be accommodated within the dunal zone. The sand volume to construct this buffer zone is estimated at 180,000m^3 for the length of South Mission Beach. A lesser sand volume could be considered to increase the level of protection against lower intensity storm events, and would also assist in protecting the remaining trees on the Esplanade. An increase in dune width to 20m seaward of the road edge is considered to be a reasonably functional width increase. This would require an additional 20,500m^3 of sand placed on the southern and central section of the beach. A detailed description of sand quantities required and placement location for an increase in dune width is given in table 3.

The problem will be in finding a supply of suitable sand and at a reasonable cost. Four sand sources have been identified and are briefly described below.

i) Offshore sand either from the river deltas to the south or shelf sand several kilometres offshore. The most prospective source of this sand is considered to be the nearshore areas between the Hull River mouth and Tam O'Shanter Point, due to its accessibility, modern accumulative history, minimal adverse impact on local coastal processes and expected low fines content. This source of sand may not be economically viable for obtaining small quantities (<20,000m^3) due to the high costs of resource identification, approval processing, dredge commissioning and environmental management in the Great Barrier Reef Marine Park. The economics of using nearshore sand may improve if larger quantities of sand were needed for both erosion mitigation and widening of the dunal buffer. Preliminary discussions will be required with the Great Barrier Reef Marine Park Authority and the Queensland Parks and Wildlife Service to determine if access to this sand is possible. Following on from this, a geotechnical investigation of potential sand sources would be required to confirm the suitablility of the sand in the borrow areas, and discussions held with dredge operators to evaluate practicality and cost.

ii) Onshore sand from beach ridge plains such as that behind Tam O'Shanter Point. Much of this sand is on freehold land and extraction therefore requires the consent of the owner. A recent trial beach nourishment project at South Mission Beach using such sand demonstrated the viability of this option in terms of cost and practicality.

iii) River sand dredged from the Tully River. While this is a viable option as the Council currently holds dredging licenses for the Tully River, or could obtain sand from commercial operators, the cost of transport to South Mission Beach could prove prohibitive.

iv) Surplus sand from private or local government projects, including installation of sewerage pipes, road upgrading, excavation for private development such as buildings or prawn farm ponds.

Any sand source needs to be of a similar or moderately larger size grading and to have a fines content of less than 5 percent to be suitable.

A disadvantage of beach nourishment is the perception of its high cost and its temporary nature, that is, it is not seen as a permanent solution. However, in the present case, a relatively small volume of sand imported to the affected section of the beach would provide significant benefits. Any nourishment sand eroded from the placement area at the southern end of South Mission Beach would be transported north and therefore of benefit to the beaches to the north of the existing rock wall.

Artificially placed sand is generally not as stable as a natural beach due to its tendency to be redistributed across the intertidal zone and alongshore. A nourished beach has an abnormal alignment (the high water mark is formed seaward of the pre-existing coastline) and an over-steep profile. Due to these factors, there is typically an advantage to slightly overfill a nourished beach and to place some or most of the sand in the intertidal zone.

Beach nourishment works could be completed in stages. This may have advantages in terms of resources and funding, and the monitoring of the initial stages would provide valuable information to assist in improving the design of further stages.

The nourishment sand will be vulnerable to wind erosion and may be blown landwards onto the park or road. The sand surface should be vegetatively stabilised with native dune grasses and runners soon after being placed. A 5m wide “starter strip” of plants including sand spinifex grass and goatsfoot should be established on the landward edge of the new sand. Plants should be established at 1m to 1.5m centres. This can be combined with fertilizing the existing native dune vegetation with a nitrogenous fertiliser at a rate of 50kg of nitrogen per ha per application, repeated every two to three months as required.

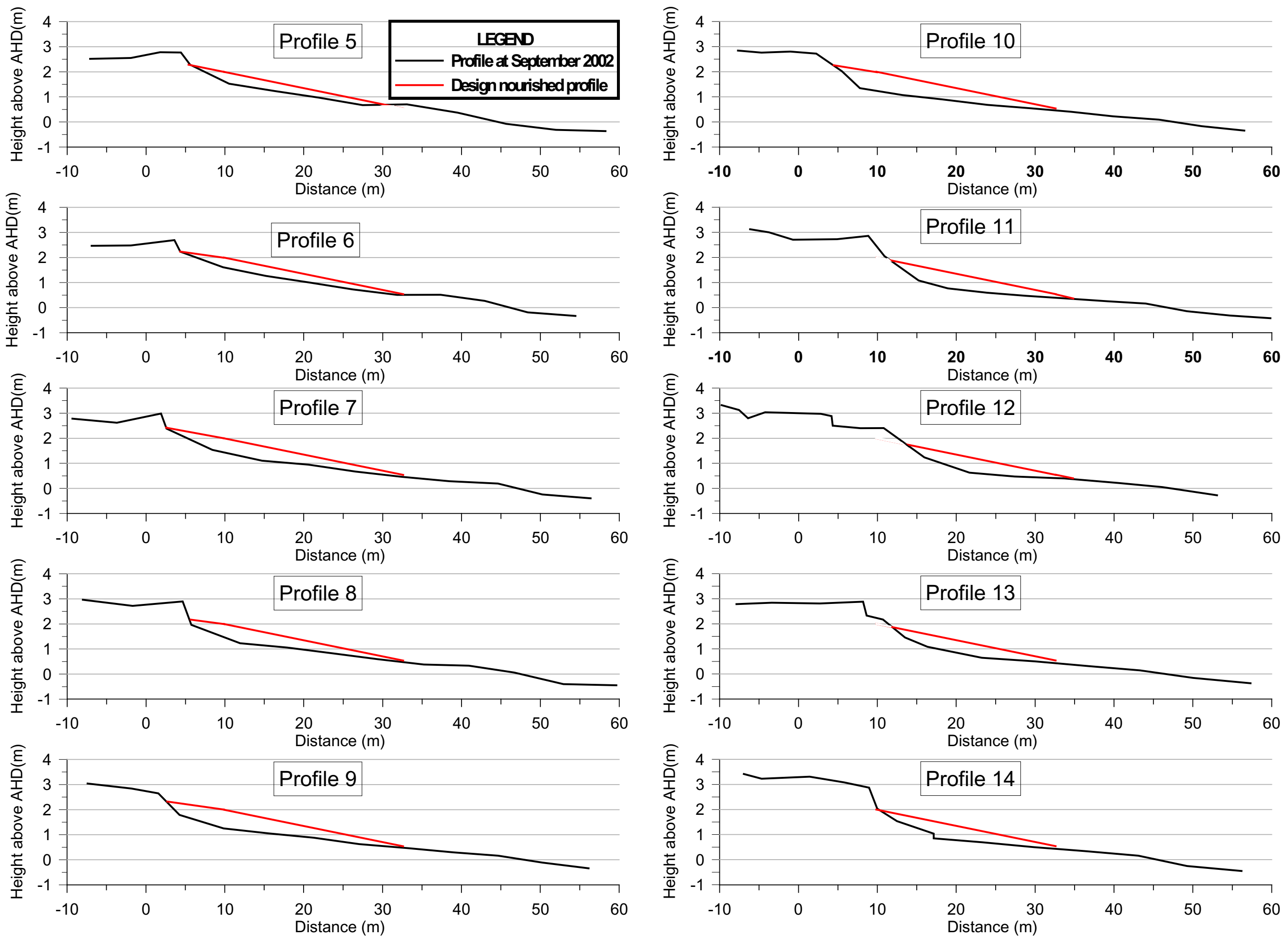

Figure 11. Indicative design nourishment profiles based on sand nourishment volumes provided in table 3 to fill erosional loss.

Survey line/ profile number	Chainage north from boat ramp	Current distance from road edge to HAT	Nourishment sand required to fill erosion loss	Estimated HAT extension Seaward	New distance from road edge	Additional sand required to extend distance from road edge to HAT to 20m	Additional sand required to extend distance from road edge to HAT to 45m
	(m)	(m)	(m^3)	(m)	(m)	(m^3)	(m)
1	2100						
	2000				>45		
2	1900				>45		
	1800				>45		
3	1700	43			43		1000
	1600	31			31		7000
4	1500	37			37		4000
	1400	35			35		5000
5	1300	33	500	0	33		6000
	1200	29	500	<2	29		8000
6	1100	25	500	<2	25		10,000
	1000	25	1000	4	29		8000
7	900	15	1500	5	20		12,500
	800	15	2000	5	20		12,500
8	700	12	2500	5	17	1500	14,000
9	600	11	3000	7	18	1000	13,500
10	500	10	3000	5	15	2500	15,000
11	400	14	2000	0	14	3000	15,500
12	300	11	2000	0	11	4500	17,000
13	200	14	1000	0	14	3000	15,500
14	100	10	500	0	10	5000	15,500
Total sand volume			**20,000**			**20,500**	**180,000**

Table 3 Effects of sand nourishment volumes on increasing the width of the dune system (HAT extension seaward)

6.3 Local sand relocation

Where erosion is considered as localised, where the sand is moved only a relatively short distance offshore or along the coast, some relief from erosion can be gained from mechanically relocating the sand back to where it was eroded from. In the simplest example, sand can be scraped from the intertidal area or adjacent sand bars immediately offshore and moved to the upper beach. This usually has only short to medium-term benefits as the placed sand will be redistributed by wave and tidal action to reform the original equilibrium profile. That is, it will want to get back to its original shape. The further offshore the sand is taken from and the shallower the material is skimmed, the slower the redistribution process will be.

Sand can also be moved from accumulation areas up coast or down coast from the eroded area, usually at spits or creek mouths. This may involve longer and more complex transport arrangements.

Local sand relocation is usually more useful for managing short-term erosion events associated with storms or extreme tides, and pockets of erosion associated with stormwater washouts.

Application to South Mission Beach

At South Mission Beach sand is sometimes pushed from the upper beach to erosion scarps or around the base of trees to protect against king tides or other short-term events. This technique provides only short-term benefit.

This study has indicated that sand eroded from the southern end of South Mission Beach tends to accumulate to the north in the vicinity of Wheatleys Creek. Therefore this area could potentially be used as a source of sand to replenish the southern beach. This is considered as local sand relocation rather than beach nourishment, as the sand borrow area is still part of the active beach system. Two options for removing sand are identified below:

i) Wheatleys Creek mouth is occasionally opened to the south to overcome channel migration to the north, which affects freehold properties. There may be an opportunity for sand removed to be relocated south at the same time.

ii) The beach area for 500m immediately south of Wheatleys Creek could be considered as a source of nourishment sand, as this area is slowly building up. However, it is suggested that the borrow quantity be limited to 5000m^3 and be removed from the upper intertidal zone to limit beach recession adjacent to the borrow area. Beach recession should be less than 1m and as this site is well north of residential development, the erosion should not be of concern. Observation of the beach response would be required before further sand removal is considered. This source will therefore only provide a portion of the nourishment sand requirement.

Relocation of sand is usually achieved using scrapers and or truck transport. A relative new dredging technique known as the Sand Shifter may also be worth considering at this site. This is a relatively low cost, method where sand is extracted using a submerged suction head and pumped as a sand slurry to the replenishment area. Significant investigation would be required to establish the applicability of this technique to this site, including core sampling to identify an adequate resource of suitable sand at depths of up to 6m.

The use of sand from this location would be subject to an assessment of environmental impacts.

6.4 Revetments

Revetment walls are generally successful at controlling shoreline recession. However, revetments can transfer erosion of the adjoining beach by locking up sand reserves in the dunes, and prevent a new beach from building up. By constructing a revetment wall along the existing erosion escarpment, sand landward of the wall is isolated from the active beach system and the volume of sand available for normal beach movements is limited to that seaward of the wall. During a storm event when sand is washed offshore, limited sand supply can be quickly eroded, resulting in the reduction of beach levels. When waves break against the wall, the loss of sand is further hastened as wave energy is partially reflected from the wall and the rate of sand transport along the beach is increased as the walls induce or increase nearshore currents.

Revetment walls do not necessarily prevent the accumulation of sand onto the beach during periods of accretion. However, revetments almost always lead to increased erosion effects at the downdrift end of the wall. Accordingly, revetments should only be considered when private property or public infrastructure that cannot be relocated is under direct threat, and should be located as far landward as practicable to maintain a dunal buffer zone and beach amenity.

Application to South Mission Beach

In discussing the applicability of revetment walls to address the erosion problem at South Mission Beach two matters need to be considered:

- Whether rock walls are an appropriate solution to stop erosion; and
- An appropriate design and alignment of any such revetment.

It is considered that the continued use of rock wall protection to mitigate the long-term trend of erosion is not an effective option. As already evident, this simply results in the transfer of the problem further northward, thus leading to a need to further extend the wall. This approach also lowers the beach profile seaward of the wall causing progressive loss of the usable beach. Furthermore, a wall constructed on the scarp face is likely to become a permanent visual feature on the beach, degrading the amenity value of the area.

It is recognised that the present configuration of the beachfront area of South Mission Beach is vulnerable to damage from extreme waves and elevated water levels associated with a severe tropical cyclone. The road and other infrastructure such as the Council toilet block near Jackey Jackey Street are at risk of damage.

The existing revetment walls at South Mission Beach have been constructed by end dumping rock over the scarp face in response to localised erosion events. The walls have not been designed to withstand a specific event, which determines armor size, and do not include toe scour protection, or a filter layer and significant crest elevation to prevent collapse from the washing of sediments from behind the wall. The existing revetment wall, in its present condition, would probably provide only limited protection.

An upgraded revetment wall would be required to reduce the present erosion risk, and if the Council decided to proceed, the EPA would recommend that the wall be designed to withstand a minimum one in 50 year average recurrence interval storm event (see Table 1). The Council would need further structural design advice before proceeding to actual construction of a wall. As a cost indicator of an adequately designed revetment, a recently constructed rock revetment wall at Holloways Beach at Cairns cost approximately $3000/m. Optimizing this design to local conditions as detailed below may reduce this cost to under $2000/m.

It may be cost prohibitive to construct a wall over the entire 1600m length of Kennedy Esplanade at an indicative cost of $3.2million. Due to the present trend of erosion, it may not be feasible to maintain a dune and beach along the southernmost section of South Mission Beach at all times. Accordingly, the section of wall (e.g. south from Jackey Jackey Street) should be retained and upgraded.

If construction of a rock revetment wall along the length of Kennedy Esplanade is contemplated, the wall should be designed so that it remains buried as far behind the active beach profile as possible. The wall would therefore function principally as a backstop to limit coastal recession only during severe storm events. In general terms, the alignment of a rock revetment wall should be located as far landward as possible. The intention is to encourage the maintenance of a sandy beach seaward of the wall and therefore reduce the exposure of the wall to direct wave action. This increases the effectiveness of the wall during storms, minimises adverse impacts to the adjacent beach and avoids excessive ongoing maintenance costs.

In this scenario, the design of an upgraded revetment wall could be optimised by accepting a limited amount of damage to the wall during a severe event. This would reduce the initial costs while still providing an acceptable level of protection, as follows:

- The wall is intended to protect the road from wave attack only, and not adjacent private development from storm surge.
- The wall crest level would be set at about the road surface height. The wall may be overtopped during design conditions, and therefore some inundation and damage to the road surface may be expected.
- The armor size could be reduced such that the wall would partially "fail" during the worst of the storm conditions although the bulk of the wall will remain in place to limit the amount of subsequent erosion. (The likely failure mode of this type of sea wall is the dislodgement of armor units by wave action followed by slumping). A typical armor size range is 500-2000kg with a median size of 1500kg is indicated. In the present case the median armor size could be reduced to say 1000kg, although the minimum size of 500kg should be retained. This could also reduce costs of sourcing material and subsequent handling.
- The depth of the toe of the wall should be set to a level that would withstand undermining during the design storm conditions. Typically the toe of a seawall would be constructed to at least the lowest astronomical tide level. However, assuming the volume of sand on the beach seaward of the structure has been maintained via a nourishment program, a higher toe level (say mean low water springs tidal level) could be used.

It should be noted that the above remarks are preliminary advice only and the Council should seek detailed structural design advice.

6.5 Groynes and artificial reefs

Groynes constructed perpendicular to the coastline can be used to trap longshore sediment transport, producing an accumulation of sand on the updrift side of the groyne. However, the downdrift beach is correspondingly starved of sand, resulting in an erosion problem being transferred to and concentrated in this area. Unless this downdrift erosion is acceptable, the construction of groynes without associated beach nourishment will not solve erosion problems. Accordingly, the construction of groynes without associated beach nourishment should not be considered, as the erosion problem will be transferred further along the beach. At South Mission Beach where there is no new sand entering the beach compartment from the south, virtually all sand would have to be imported to reconstruct the beach.

Groynes are often built in conjunction with beach nourishment programs where the groyne acts as an end structure to retain the nourishment sand and extend the life of the works. However, there is no natural end point for such a structure on this beach. In the above situations groynes with beach nourishment will have a significantly higher cost than beach nourishment alone.

Groynes are not considered an acceptable solution for the erosion at South Mission Beach for the reasons listed above, and for the significant changes they would cause to the visual amenity and usability of the beach.

Artificial reefs can modify the local wave climate and extend the life of beach nourishment. But they may have similar disadvantages to groynes, and it is expected that they would have a significantly higher investigation and establishment cost.

7.0 Conclusions

It is concluded that:

i) The southern end of South Mission Beach is experiencing slow but chronic long-term erosion, where sand is being transported from the southern and central ends of the beach and deposited on the northern end. This is considered to be a natural coastal process redistributing sediment within this beach compartment, with transport currently to the north.

ii) Kennedy Esplanade fronting South Mission Beach, is relatively narrow and has been developed for road and park use. This road and associated infrastructure are vulnerable to loss or damage from sea erosion and shoreline recession that may occur during a severe tropical cyclone due to the limited dunal buffer zone seaward of the road and park facilities.

iii) The revetment wall constructed along the southern section of this coast is considered inadequate to prevent erosion during a severe tropical cyclone, and in some sections the wall has been completely ineffective against erosion, with the scarp face retreating behind the wall, and material from the collapsed wall being spread over the beach.

iv) The revetment wall has led to an acceleration of erosion and shoreline retreat in the southern part of South Mission Beach, and continuation of the wall north will accelerate the progression of the erosion problem further north. Furthermore, construction of the wall has isolated sand behind it from active coastal processes. As the erosion process continues and sediment continues to be removed, the upper beach in front of the wall will narrow and the beach level will generally drop, affecting beach amenity and usability. It is considered that the continued use of a revetment wall alone to provide protection and mitigate the long-term trend of erosion is not an effective strategy if beach amenity is to be retained.

v) The relatively slow rate of erosion of this section of coast makes beach nourishment an attractive erosion management strategy if a source of sand at reasonable cost can be identified. Beach nourishment can both increase the width of the dunal buffer zone, increasing the level of protection to infrastructure on the Esplanade, and maintain or improve beach amenity.

vi) Infrastructure behind the beach is vulnerable to loss by erosion during extreme cyclonic events. Beach nourishment, in addition to that required for the replacement of erosional losses, could be used to widen the beach and dune system to increase the buffering capacity of the dune system against sea erosion during storm events.

vii) Rock revetment protection works for the entire length of Kennedy Esplanade (constructed to an adequate standard) would be expensive. Based on an indicative cost of $2,000-$3,000/m, total costs could exceed $3M. The cost could probably only be justified if the present level of risk of storm erosion damage to the road was considered unacceptable. The section of wall from the boat ramp to Jackey Jackey Street is of a significant size and close to the road, and should be upgraded to an appropriate standard. Rubble revetment walls further north should be removed prior to the placement of nourishment sand. It should be noted that a rock revetment wall east of the Esplanade should only be considered for the protection of Council assets. Works for the protection of private property should be constructed within or adjacent to the freehold property boundary.

viii) The current method of disposing of storm water into soakage pits in the foredune has had the effect of raising groundwater levels, fluidizing the sand and locally accelerating the erosion of the upper beach. An alternative storm water disposal method, which discharges storm water directly to the beach, is required to overcome this problem.

8.0 Recommendations

Provided below are recommendations on preferred actions for managing sea erosion at South Mission Beach for consideration by Cardwell Shire Council:

i) Beach nourishment should be undertaken on the central and southern sections of the beach to replace historical sea erosion losses, thereby re-establishing a dunal zone and raising the beach level. This will offset the present sand loss from this area and increase the protection from future storm events provided by the foredune. A minimum 20,000m^3 of imported sand is required to restore the beach to the state that existed some 30 years ago, and would provide for the widening of the upper beach by up to 7m in the most eroded section of this coast.

ii) Average annual beach renourishment at an annualised rate of 700m^3 should be undertaken to match ongoing losses. This can be achieved by inclusion in the initial nourishment program of a 10-year loss provision, or by periodic top ups.

iii) Widening of the dunal zone by beach nourishment in addition to i) and ii) above should be considered as a means of minimizing the impact of future erosion events on infrastructure on the esplanade. A minimum of 20,000m^3 of sand would be required, depending on the level of protection required.

iv) The southern section of rock revetment wall from the boat ramp to Jackey Jackey St should be upgraded to a standard appropriate to withstand damage from a severe storm event with an ARI of 50 years minimum. Rubble walls to the north should be removed and the reconstructed dune relied upon as the primary protection against wave attack and sea erosion.

v) The use of soakage pits on the foredune for storm water dissipation should be discontinued, with storm water being discharged directly across the beach. The number of storm water outlets should be minimised as is practical and storm water flow impacts managed by the use of energy dissipaters, and water quality managed through the use of litter traps. Due regard should be given to the requirement of the Environmental Protection (Water) Policy 1997 for urban storm water quality management.

vi) The placement of permanent development on the Esplanade should be avoided, but where this is not possible, located as far landward as is practical.

vii) All public infrastructure, including power, water and sewerage should be located on the landward side of the road to minimise risk of loss during future erosion events.

viii) Park facilities should be located as close to the road edge as is practical, or designed to be relocatable in the event of an erosion threat.

ix) Monitoring of beach profiles should be undertaken annually to monitor movement of the nourishment sand and improve estimates of renourishment volumes.

x) Any sand nourishment program should include revegetation works to reinstate the sand trapping dune vegetation to stabilise the dunes and prevent wind erosion. This would also need to include control of pedestrian access to the beach and replacement of trees previously lost to erosion.

9.0 Additional information

9.1 Statutory obligations

Any works undertaken at South Mission Beach may require an approval under the *Coastal Protection and Management Act 1995*, *Integrated Planning Act 1997* and a permit under the *Marine Parks Act 1982* administered by the Environmental Protection Agency. The use of offshore sources of sand may be constrained by being located in the Great Barrier Reef Marine Park world heritage area and a State Marine Park, as described in the relevant Marine Park Zoning Plan.

9.2 State assistance with funding

Certain works for beach protection purposes, including beach nourishment and revegetation, may be eligible for a State Government subsidy of 25 percent of the cost of the works under the Local Governing Bodies' Capital Works Loan Subsidy Scheme administered by the Department of Local Government and Planning. Other types of works may be eligible for a lower level of subsidy.

10.0 References

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