COASTAL ENGINEERING SOLUTIONS

BOWEN COASTAL EROSION INVESTIGATION & MITIGATION PLAN

FINAL REPORT

prepared for

Whitsunday Regional Council

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Coastal Engineering Solutions Pty Ltd
P.O. Box 677
59 Hulcombe Road
Samford QLD 4520
Australia
tel : + 61 7 3289 7011
fax : + 61 7 3289 7022
email : *obrien@coastengsol.com.au*

Coastal Engineering Solutions Pty Ltd
600 Burwood Road
Hawthorn East
VIC 3123
Australia
tel : + 61 3 9882 2298
fax : + 61 3 9882 7232
email : *riedel@coastengsol.com.au*

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EXECUTIVE SUMMARY

The complex interaction of waves, tides, winds and creek flows have continually shaped and reshaped the shorelines of the Bowen region. The dynamic nature of the coastal environment means that sections of the foreshore are experiencing erosion which is threatening essential infrastructure and adversely affecting social and environmental values.

In recognition of the need to preserve this foreshore as a natural resource and to accommodate the ever increasing pressures of urban development on an eroding shoreline, Whitsunday Regional Council has commissioned the *Bowen Coastal Erosion Investigation and Mitigation Plan* (the Study).

OBJECTIVES

Objectives of the Study are:

- To provide Council with information on coastal erosion occurring in the Bowen region.
- This information will be used by Council to develop natural disaster action plans for each of the beaches within the study area.
- Assist Council with identifying appropriate erosion mitigation works and strategies.
- Be used to develop community brochures to improve community preparedness.

These objectives are to be achieved through appropriate consideration of the physical coastal processes that are shaping local foreshores.

The Study is to address five coastal precincts, namely

- Kings Beach at Rose Bay
- Port Dennison West Beach
- Queens Beach
- The Pocket Beach
- Horseshoe Bay

KINGS BEACH AT ROSE BAY

Following consideration of local physical processes and the nature of the erosion threat, the recommended erosion mitigation strategy for Kings Beach at Rose Bay is as follows:

- The recommended strategy is beach nourishment. It is also a flexible foreshore management process that can be tailored to suit future climate change impacts as they gradually evolve.
- It entails placing sand as initial beach nourishment on the foreshore south of the informal beach track (approximately midway along the Bluewater Parade ocean frontage). The sand is to be placed against the foredune above approximately RL+1.5m AHD. The required volumes being:
  - 7,000 m^3 to provide protection against the 50 year ARI storm event; or
  - 8,000 m^3 to provide protection against the 100 year ARI storm event.
- Implement appropriate dune management practices on the newly nourished foreshore. As a minimum, this entails the planting and protection of native dune vegetation, the on-going clearing of noxious weed species and ensuring adequate controlled access is maintained through new dune areas.
- Undertake ongoing beach renourishment along this section of Bluewater Parade ocean frontage through the average annual placement of 750m^3 of sand. This is to recharge the erosion buffer established by the initial beach nourishment exercise. Annual volumes and placement areas may need to be amended in response to the results of ongoing monitoring of beach performance - particularly as future climate change effects manifest themselves.
- Replace the damaged beach access ramp at the northern end of the beach with a board and chain walkway.
- Existing shoreline transect lines to be formally surveyed to accurately establish their vertical and horizontal datums. Surveys of these three transects should occur at least twice a year (at the same times each year); as well as immediately after significant erosion events.

Summary of Recommended Strategy for Kings Beach at Rose Bay

Cost Estimate for Erosion Mitigation of Kings Beach at Rose Bay:

Activity	Cost	Annual Cost
Project Design and Approvals		
Design of initial beach nourishment	$7,500	
Obtain appropriate approvals	$2,500	
Project Monitoring		
Establish & undertake initial pre-project surveys	$2,500	
Twice annual survey of 3No. beach transects		$4,000
Allow additional survey after erosion event, say		$2,000
Beach Nourishment		
Establish / reinstate beach access for initial sand placement	$25,000	
Modify stormwater drainage system, say	$17,500	
Implementation of initial beach nourishment :		
for 50 year ARI immunity (place 7,000 m^3)	*$105,000*	
for 100 year ARI immunity (place 8,000 m^3)	*$120,000*	
Implementation / maintenance of dune management program	$15,000	$2,000
On-going renourishment (average of 750 m^3 annually)		$12,000
Totals (for various initial beach nourishment options)		
for 50 year ARI immunity	**$175,000**	**$20,000**
for 100 year ARI immunity	**$190,000**	**$20,000**

PORT DENNISON WEST BEACH

Following consideration of local physical processes and the nature of the erosion threat, the recommended erosion mitigation strategy along Port Dennison West Beach is as follows:

Beach alongside the Jetty

- Place approximately 850 m^3 of sand as initial beach nourishment.

Existing rock seawall opposite the Catalina Interpretative Centre

- The integrity and future performance of the existing seawall should be checked by a structural audit to ensure that it can provide appropriate protection to the foreshore during severe storms / cyclones.
- Implement appropriate structural rectification / upgrading if the structural audit identifies that its function might be compromised.

Adhoc rubble seawall alongside concrete ramp

- Remove all building debris / rubble from the eastern side of the ramp and all of the damaged concrete wall and part of the concrete pavement on the western side.
- Place approximately 1,200m^3 of sand on the foreshore as initial beach nourishment.

Sandy foreshore west of the sailing club

- Place approximately 1,200m^3 of sand as initial beach nourishment on the section of foreshore between the sailing club and the un-named creek some 150 metres further west.
- Place approximately 2,600m^3 of sand as initial nourishment on the 300 metre long section of foreshore between the un-named creek and Doughtys Creek.
- Undertake ongoing beach renourishment along the shoreline between the un-named creek and Doughtys Creek through the average annual placement of 200m^3 of sand. This is to recharge the erosion buffer established by the initial beach nourishment exercise. Annual volumes and placement areas may need to be amended in response to the results of ongoing beach performance monitoring.

Dune Management

- Implement appropriate dune management practices on existing and newly nourished foreshores. As a minimum, this entails the planting and protection of native dune vegetation, the on-going clearing of noxious weed species and ensuring adequate controlled access is maintained through beach crest / dune areas.

Monitoring surveys

- Shoreline transect lines are to be formally established along the Port Dennison West Beach foreshore. Nine transect lines are envisaged.
- Surveys of these transects should occur at least twice yearly (at the same times each year); as well as immediately after significant erosion events.

Summary of Recommended Strategy for Port Dennison West Beach

Cost Estimate for Port Dennison West Beach:

Activity	Cost	Annual Cost
Project Design and Approvals		
Design of proposed works	$17,500	
Obtain appropriate approvals	$4,000	
Project Monitoring		
Establish & undertake initial pre-project transect surveys	$7,500	
Twice annual survey of 9 No. beach transects		$10,000
Allow additional survey after erosion events, say		$2,500
Foreshore Works for Mitigation Strategy		
Undertake structural audit of existing rock seawall	$17,500	
Place 850 m^3 of sand on beach alongside Jetty	$12,000	
Remove rubble & trim foreshore alongside ramp	$17,500	
Place 1,200 m^3 of sand alongside concrete ramp	$17,500	
Place 1,200 m^3 of sand between sailing club & creek	$17,500	
Place 2,600 m^3 of sand between creek & Doughtys Creek	$36,000	
On-going renourishment between creek & Doughtys Creek		$3,500
Modify various stormwater drainage outlets, allow say	$8,000	
Implementation / maintenance of dune management program	$30,000	$4,000
Totals	$185,000	$20,000

QUEENS BEACH

Following consideration of local physical processes and the nature of the erosion threat, the recommended erosion mitigation strategy along the various foreshore precincts of Queens Beach is:

Queens Beach South

- Either Planned Retreat or Beach Nourishment - the most appropriate to be determined by Whitsunday Regional Council in conjunction with other stakeholders - since the selection will depend upon important community considerations of what constitutes non-essential and essential infrastructure.
- The best way to approach these considerations is through the application of a Coastal Defence Line. Defining the position of a Coastal Defence Line along Queens Beach requires stakeholders to determine what assets are to be defended. The Line forms the landward boundary of erosion buffers to protect the shoreline at any particular site. Property and infrastructure landward of the Coastal Defence Line remains protected throughout the planning period, whereas foreshore areas seaward of the line lie within the active beach system (ie. within the erosion buffers).
- Under a Planned Retreat strategy, all park infrastructure and amenities such as paths, barbeques and picnic shelters, would be relocated beyond the threat of future erosion by a nominated ARI storm. This would allow the natural coastal processes that are shaping the foreshore to continue unimpeded. However it would likely result in an adverse impact on adjoining private properties that would result in a requirement for these landowners to instigate their own foreshore protection measures.
- Alternatively, under a Beach Nourishment strategy:
  - Place 22,000 m^3 of sand as initial beach nourishment. The sand should be placed against the foredune, typically above RL+0.5m AHD.
  - Implement appropriate dune management practices on newly nourished foreshores. As a minimum, this entails the planting and protection of native dune vegetation, the on-going clearing of noxious weed species and ensuring adequate controlled access is maintained through new dune areas.
  - Undertake ongoing beach renourishment through the average annual placement of 3,000m^3 of sand. This is to recharge the erosion buffer established by the initial beach nourishment exercise. Annual volumes may need to be amended in response to the results of ongoing monitoring of beach performance.
- Seven beach transect lines be established at approximately 200 metre spacing. These transects are to be surveyed at least twice annually at the same time of year. Additional surveys should be undertaken on these transects immediately following significant erosion events.

Queens Beach Central

- Either Planned Retreat or Beach Nourishment - the most appropriate to be determined by Whitsunday Regional Council in conjunction with other stakeholders. Again this could be facilitated by the selection of a Coastal Defence Line in this precinct (refer discussions above).
- A Planned Retreat strategy would allow the natural coastal processes that are shaping the foreshore to continue unimpeded. It effectively means:
    - Relocating some putting greens and accepting narrower fairways on the golf course as a consequence of the increasing risk associated with future foreshore recession.
    - At the Queens Beach Surf Lifesaving Club, relocation of the clubhouse and associated facilities under a Planned Retreat strategy would significantly hinder the function of this facility. A buried seawall is recommended on the condition that:
        - The seawall structure is not constructed along the current alignment of the beach, but is located further inland - buried within the existing buffer between the clubhouse infrastructure and the beach so as to act as a "last line of defence"; and
        - That the wall be designed by an appropriately qualified and experienced coastal engineer, irrespective of whether it is of rock or geotextile sand bag construction. The design must address the structural implications of undermining, overtopping and out-flanking as well as directly accommodating cyclone wave loadings in the event of its exposure.
- Alternatively, under a Beach Nourishment strategy:
    - Place 14,000 m^3 of sand as initial beach nourishment. The sand should be placed against the foredune, typically above RL+1.0m AHD.
    - Implement appropriate dune management practices on newly nourished foreshores. As a minimum, this entails the planting and protection of native dune vegetation, the on-going clearing of noxious weed species and ensuring adequate controlled access is maintained through new dune areas.
    - Undertake ongoing beach renourishment through the average annual placement of 3,000m^3 of sand. This is to recharge the erosion buffer established by the initial beach nourishment exercise. Annual volumes may need to be amended in response to the results of ongoing monitoring of beach performance.
- Seven beach transect lines be established at approximately 200 metre spacing. These transects are to be surveyed at least twice annually at the same time of year. Additional surveys should be undertaken on these transects immediately following significant erosion events.

Queens Beach North

- Given the adequate width of natural erosion buffers, in conjunction with the provisions of the Queens Beach Foreshore Management Plan, a strategy of Do Nothing is recommended.

- Nevertheless, eight beach transect lines be established at approximately 200 metre spacing. These transects are to be surveyed at least twice annually at the same time of year. Additional surveys should be undertaken on these transects immediately following significant erosion events.

Cost Estimates for Queens Beach:

Activity	Cost	Annual Cost
Queens Beach South - Planned Retreat		
Project Monitoring		
Establish & undertake initial pre-project transect surveys	$10,500	
Twice annual survey of 7 No. beach transects		$10,500
Allow additional survey after erosion events, say		$5,500
Foreshore Works for Mitigation Strategy		
Relocate existing park infrastructure, allow say	$200,000	
Modify various stormwater drainage outlets, allow say	$75,000	
Sub-totals	$285,500	$16,000
Queens Beach South - Beach Nourishment		
Project Design and Approvals		
Design of proposed works	$22,500	
Obtain appropriate approvals	$3,500	
Project Monitoring		
Establish & undertake initial pre-project transect surveys	$10,500	
Twice annual survey of 7 No. beach transects		$10,500
Allow additional survey after erosion events, say		$5,500
Foreshore Works for Mitigation Strategy		
Establish / reinstate beach access for initial sand placement	$3,500	
Place 22,000m^3 of sand as initial nourishment for buffer	$330,000	
On-going renourishment of approximately 3,000m^3		$45,000
Modify various stormwater drainage outlets, allow say	$10,000	
Implementation / maintenance of dune management program	$50,000	$4,000
Sub-totals	$430,000	$65,000

Activity	Cost	Annual Cost
Queens Beach Central - Planned Retreat		
Project Design and Approvals (Surf Club seawall)		
Design of proposed works	$17,500	
Obtain appropriate approvals	$5,000	
Project Monitoring		
Establish & undertake initial pre-project transect surveys	$10,500	
Twice annual survey of 7 No. beach transects		$10,500
Allow additional survey after erosion events, say		$5,500
Foreshore Works for Mitigation Strategy		
Modify various stormwater drainage outlets, allow say	$50,000	
Buried seawall at Surf Club	$75,000	
Note : excludes costs of any relocation of golf greens		
Sub-totals	**$158,000**	**$16,000**
Queens Beach Central - Beach Nourishment		
Project Design and Approvals		
Design of proposed works	$22,500	
Obtain appropriate approvals	$3,500	
Project Monitoring		
Establish & undertake initial pre-project transect surveys	$10,500	
Twice annual survey of 7 No. beach transects		$10,500
Allow additional survey after erosion events, say		$5,500
Foreshore Works for Mitigation Strategy		
Establish / reinstate beach access for initial sand placement	$10,000	
Place 14,000m^3 of sand as initial nourishment for buffer	$210,000	
On-going renourishment of approximately 3,000m^3		$45,000
Modify stormwater drainage, allow say	$6,000	
Implementation / maintenance of dune management program	$27,500	$4,000
Sub-totals	**$290,000**	**$65,000**

Activity	Cost	Annual Cost
Queens Beach North - "Do Nothing"		
Project Monitoring		
Establish & undertake initial pre-project transect surveys	$10,500	
Twice annual survey of 8 No. beach transects		$8,000
Allow additional survey after erosion events, say		$4,000
Sub-totals	**$10,500**	**$12,000**

THE POCKET BEACH

Following consideration of local physical processes and the nature of the erosion threat, a Planned Retreat strategy is recommended at The Pocket Beach. This will entail:

- Design and implement road works to relocate an approximately 120 metre long section of Horseshoe Bay Road, including modifications to its intersection with Murrays Bay Road.
- This road relocation work to be supplemented by the structural upgrading of the existing seawall consisting of sand-filled geotextile bags.
- The effectiveness of this Planned Retreat strategy needs to be considered more widely in the context of providing a trafficable route to the Horseshoe Bay community in the event of severe cyclone erosion of local foreshores. The causeway crossing the rear of the beach at Greys Bay could be damaged and made impassable by waves/erosion irrespective of the strategy adopted at The Pocket Beach.
- Evaluate, design and implement road works if necessary to structurally upgrade the road pavement and associated causeway at Greys Bay.
- Should damage to Horseshoe Bay Road occur at The Pocket Beach as a consequence of cyclone erosion prior to implementation of the strategy, it is recommended that reinstatement works should consider an alternative more landward alignment of the road.

It is estimated that the road relocation works at The Pocket Beach would cost around $500,000. The extent and nature of associated upgrading of the causeway crossing at Greys Bay is unknown at this point.

HORSESHOE BAY

Following consideration of local physical processes and the nature of the erosion threat, the recommended erosion mitigation strategy at Horseshoe Bay is Planned Retreat.

- In the event of damage occurring as the shoreline gradually recedes due to future climate change, Council implement a strategy of retreat rather than simply reinstating any damage to the foreshore park and associated car parking area.
- The additional width this creates between the car park and the beach should be reformed and revegetated into a small coastal dune system to act as a buffer and allow coastal processes to continue unaffected.

It is estimated that the relocation works associated with the seaward edge of car park would cost $75,000. However such works would only be undertaken as actual climate change influences manifest themselves.

PROJECT DESIGN AND APPROVALS

- Whitsunday Regional Council (in consultation with other stakeholders) to select the Design Event for which the erosion mitigation strategies recommended by this Study are to accommodate. This requires consideration and acceptance of the risk that such an event will occur (or be exceeded) within a 50 year planning period. Guidance on risk is offered in this report. Nominating the Design Event requires selecting the Average Recurrence Interval (ARI) cyclone for which immunity is required.
- Should an event occur that is more severe than the selected Design Event, then the strategies and engineering works implemented in accordance with the recommended strategies may be compromised and coastal infrastructure could be damaged or destroyed as a consequence. The selection of an appropriate Design Event is therefore an important consideration.
- Whitsunday Regional Council (in consultation with other stakeholders) to select the alignment of an appropriate Coastal Defence Line along sections of Queens Beach. Throughout the planning period, property and infrastructure landward of the Coastal Defence Line remain protected from long-term erosion effects; short-term erosion caused by the Design Event; and recession as a consequence of future climate change. Foreshore areas seaward of the Coastal Defence Line lie within the active beach system (ie. within the erosion buffers).
- Undertake engineering designs for works associated with the recommended erosion mitigation strategies.
- Prepare and submit appropriate approval applications based on the engineering designs for the proposed works.

SOURCES OF SAND FOR BEACH NOURISHMENT

- During project implementation, the detailed engineering design of proposed beach nourishment works needs to consider the following physical properties of available sand sources:
  - grading of the sand - ideally uniformly graded, rather than widely graded;
  - size of the sand - ideally the same size as that already on local beaches; however sand that is somewhat finer or coarser than this can be used, but the volumes to be placed need to account for this variation.
- An assessment of the grading and the size of sand that is commercially available from various extraction points in the Don River has been undertaken for this Study. It is evident that these Don River sources are suitable for beach nourishment purposes throughout the Bowen region - however specific specifications as to grading and size requirements need to be made during the detailed design phase of project implementation.

SUMMARY OF RECOMMENDATIONS

LOCATION	EXISTING 50 year ARI cyclone erosion threat	EXISTING 100 year ARI cyclone erosion	recession due to long-term erosion processes over 50 years	predicted shoreline recession over 50 years due to climate change	FUTURE overall erosion threat (50 year ARI cyclone)	FUTURE overall erosion threat (100 year ARI cyclone)	RECOMMENDED MITIGATION STRATEGY	initial sand nourishment volume	annual sand re-nourishment volume	initial capital cost for implementation (including survey setup)	annual cost to maintain strategy (including surveys)
Kings Beach at Rose Bay	30m	36m	32m	11m	76m	80m	**Beach Nourishment**	*see Note 1*	750m³	*see Note 2*	$20,000
Port Denison West Beach											
beach alongside jetty	N/A	N/A	0	4m	N/A	N/A	**Beach Nourishment**	850m³	0m³		
existing rock seawall	N/A	N/A	0	0	N/A	N/A	*see Note 3*			$195,000	$26,000
at concrete ramp	N/A	N/A	0	0	N/A	N/A	**Beach Nourishment**	1,200m³	0m³		
west of sailing club	N/A	N/A	12m	4m	N/A	N/A	**Beach Nourishment**	3,800m³	200m³		
Queens Beach											
South	33m	33m	0	12m	46m	46m	**Planned Retreat OR Beach Nourishment**	22,000m³	3,000m³	*see Note 4*	*see Note 4*
Central	26m	43m	0	7m	38m	51m	**Planned Retreat OR Beach Nourishment**	14,000m³	3,000m³	*see Note 5*	*see Note 5*
North	33m	48m	0	9m	49m	57m	**Do Nothing**			$10,500	$12,000
The Pocket Beach	24m	24m	0	8m	33m	35m	**Planned Retreat**			$500,000	
Horseshoe Bay	N/A	N/A	0	4m			**Planned Retreat**			$75,000	

N/A denotes insufficient data to determine.

NOTES:

1. For 50 year ARI cyclone immunity require 7,000 m³ of sand.
   For 100 year ARI cyclone immunity require 8,000 m³ of sand.

2. For 50 year ARI cyclone immunity, implentation cost is $180,000.
   For 100 year ARI cyclone immunity, implementation cost is $195,000.

3. Undertake a structural audit & upgrade the seawall if necessary.

4. Planned Retreat strategy : Implementation cost $285,500. Annual cost to maintain the strategy $16,000.
   Beach Nourishment strategy : Implementation cost $430,000. Annual cost to maintain the strategy $65,000.

5. Planned Retreat strategy : Implementation cost $158,000. Annual cost to maintain the strategy $16,000.
   Beach Nourishment strategy : Implementation cost $290,000. Annual cost to maintain the strategy $65,000.

1 INTRODUCTION

The complex interaction of waves, tides, winds and creek flows have continually shaped and reshaped the shorelines of the Bowen region. The dynamic nature of the coastal environment means that some local foreshores are experiencing erosion that threatens essential infrastructure and adversely affects social and environmental values.

In recognition of the need to preserve the local foreshore as a natural resource and to accommodate the ever increasing pressures of urban development on eroding shorelines, Whitsunday Regional Council has commissioned this study (the Study). Its purpose is to identify the risk of coastal erosion at a number of key sites; and to identify appropriate strategies that Council can implement to reduce this risk and to increase the community's preparedness to confront erosion threats. These objectives are to be achieved through appropriate consideration of the physical coastal processes that are shaping these foreshores.

The five coastal precincts selected by Council to be considered by the Study are:

- Kings Beach at Rose Bay
- Port Dennison West Beach
- Queens Beach
- The Pocket Beach
- Horseshoe Bay

1.1 Objectives of the Study

The specific objectives of the Study are defined in Section 2.2 of the Project Brief[1], namely:

- *"To provide Council with information on the coastal erosion occurring in the Bowen region.*
- *This information will be used by Council to develop natural disaster action plans for each of the beaches within the study area.*
- *Assist Council with identifying appropriate erosion mitigation works and strategies.*
- *Be used to develop community brochures to improve community preparedness."*

[1] "*Bowen Coastal Erosion Investigation and Mitigation Plan - Project Brief*" prepared by Whitsunday Regional Council, dated 14th January 2010.

1.2 Structure of this Report

This report on the findings of the Study has been structured as follows:

- This Section 1, which consists of an introduction and provides some background to the *Bowen Coastal Erosion Investigation and Mitigation Plan.*
- Section 2 provides a brief description of the natural physical processes that have in the past, are currently, and will in the future, shape local shorelines.
- This is followed in Section 3 by a discussion of the erosion threat that these various natural processes represent to local infrastructure, and to environmental and social values.
- Section 4 then offers a number of possible generic strategies that could be applied to mitigate these risks.
- Section 5 provides a ranking of the generic solutions - leading to the establishment of a preferred erosion management strategy for each of the five coastal precincts addressed by the Study.
- Section 6 provides specific details as to the recommended erosion mitigation strategy for each site, including costs.
- The process of implementing the preferred strategy is then briefly presented in Section 7.
- An Appendix is provided containing an outline of the commonwealth, state and local government planning and legislative framework affecting the implementation of the proposed strategies.

1.3 Regional and Local Setting

As illustrated in Figure 1.1, the five sites in the study area are located on either side of Cape Edgecumbe. Consequently they have quite different exposures to the waves and storm tides that considerably influence erosion processes on these shorelines.

1.3.1 Kings Beach at Rose Bay

This coastal reach is at the northern end of Kings Beach. It is approximately 5 kms by road from the central business district of Bowen. The residential precinct fronting Edgecumbe Bay is known as Rose Bay - despite Rose Bay itself being the small sandy embayment to the immediate north of the rocky headland which forms the northern limit of Kings Beach.

The Rose Bay shoreline considered in the Study is the approximately 325metre frontage opposite Bluewater Parade. The foreshore in this area has receded in recent years as a consequence of a number of severe storm events, causing damage to a beach access ramp and heightening the concerns of property owners in Bluewater Parade.

The foreshore faces directly east across the entrance to Edgecumbe Bay. Consequently the persistent south-easterly trade winds that blow across the Bay during the North Queensland dry season generate waves that propagate to the northern end of Kings Beach.

Figure 1.1 : Extent of the Study Area

The open water fetches to the north and north-east of Cape Edgecumbe are quite long, with the main Great Barrier Reef system being some 70kms offshore. It is from across these open northerly and north-easterly fetches that the largest waves can propagate into Edgecumbe Bay, from where they can refract and diffract so as to also reach the project foreshore of Kings Beach at Rose Bay.

1.3.2 Port Denison West Beach

The beach on the shore of Port Denison is known locally as Bowen's Front Beach and is close to the central business district. The foreshore precinct along its eastern end has been developed into a community recreational area that includes an outdoor amphitheatre and information centre, grassy picnic areas and paths.

The 800 metre long beach to the west of the jetty has experienced erosion in recent years, particularly in the vicinity of the concrete hardstand and boat ramp alongside the Port Denison Sailing Club. Sections of this foreshore have been armoured by the adhoc placement of rock and other materials. It is this western section of the local foreshore which is considered in the Study.

The foreshore faces south-east across Edgecumbe Bay; but there is a somewhat narrow window of wave exposure between Stone Island and Adelaide Point (which forms the South Entrance into Port Denison) through which waves can propagate.

The seabed approach slope onto the foreshore is very flat and incorporates quite wide intertidal flats. These flat shallow approach slopes, in conjunction with the surrounding land features of Stone Island and Dalrymple Point, provide natural protection and wave energy attenuation for the foreshore precinct of Front Beach - particularly during extreme storms and tropical cyclones.

Nevertheless, the persistent south-easterly trade winds that blow across the Bay can generate waves that propagate to the Port Denison West beach and strongly influence local erosion processes.

1.3.3 Queens Beach

Queens Beach is the approximately 4.3kms long shoreline that stretches west of the Cape Edgecumbe headland to Yasso Point at the Don River entrance. It is directly exposed to the long open water fetches that extend out to the Great Barrier Reef, some 70kms offshore. Consequently Queens Beach can experience quite severe storm and cyclone erosion. Indeed the cyclones that occurred in the late-1950's reputedly caused 150 metres recession of the Queens Beach foreshore.

The orientation of the shoreline varies significantly along its length, with the eastern half facing almost directly north and the western half facing north-east. The entrance to an un-named ephemeral creek is located near the confluence of these two shoreline orientations. This varying alignment of Queens Beach with respect to incoming wave energy means that there is also variability in the littoral processes that account for the movement of sand along the shoreline - and the erosion threat that this poses.

The eastern-most end of Queens Beach is referred to by local residents as "the Pocket". This sub-reach has its own particular erosion problems and has therefore been included as one of the five sites to be investigated by the Study.

The nature of the foreshore elsewhere along Queens Beach is quite variable. Seawalls of varying structural form and condition have been constructed along the foreshore frontages near the end of Soldiers Road, including two caravan parks and private properties.

Further to the west (beyond the ephemeral creek entrance), the foreshore consists of a natural beach system which incorporates a frontal dune. The eastern end of this sandy foreshore (adjacent to the creek entrance) has been experiencing erosion in recent years, causing concern to the Golf Club that fronts onto this section of Queens Beach.

A Draft Foreshore Management Plan has been prepared by Council for the foreshore reserve on the approximately 1.4km long western-most end of Queens Beach, adjacent to the Don River entrance.

1.3.4 The Pocket Beach

The Pocket Beach is located at the eastern-most end of Queens Beach, immediately adjacent to the Cape Edgecumbe headland.

The foreshore behind the beach consists of parkland; however the alignment of Horseshoe Bay Road at the eastern end of The Pocket Beach is such that a section of the road pavement is located only some 10 - 12 metres from the top of the beach slope.

This, in conjunction with storm erosion over the years, resulted in foreshore stabilisation work (consisting of sand-filled geotextile containers) being implemented in 2004 to protect Horseshoe Bay Road and its intersection with Murrays Bay Road. These two roads provide the only land access to the local communities of Horseshoe Bay and Murray Bay respectively. Consequently any erosion that causes these roads to be unserviceable will seriously compromise access during or after a severe cyclone event.

The foreshore protection work undertaken in 2004 has largely been effective to date; however this area has been included for consideration by the Study to determine its erosion vulnerability during severe storm / cyclone events.

1.3.5 Horseshoe Bay

Horseshoe Bay is located near the tip of Cape Edgecumbe. It is a small 110 metre long pocket beach contained between high rocky shores at either end. There is a grassed picnic area and sealed car parking immediately behind the beach.

Its picturesque nature, along with the proximity of a nearshore coral reef for snorkelling/diving opportunities, makes Horseshoe Bay a popular destination for residents and visitors to the Bowen region. Given the high social and environmental values of the Horseshoe Bay foreshore, it has been included for consideration by the Study of erosion vulnerability.

2 LOCAL COASTAL PROCESSES

The term "*coastal processes*" refers to the complex interaction of ocean water levels, currents and waves that collectively move coastal sediments – including the sand on beaches.

There are five coastal sites considered by the Study. It is important to have an appreciation of the local coastal processes at each location. Otherwise there is a very real risk that any future strategies to mitigate local erosion will be ineffectual, costly and potentially compromise the environmental and social values of these foreshores.

Some discussion of each of these various influences is offered in this section of the report. This is followed in Section 3 with a discussion of how these particular processes affect each of the five study sites.

2.1 Ocean Water Levels

When considering the processes that shape shorelines it is necessary to consider the ocean water levels that prevail from time to time. This appreciation not only relates to the day-to-day tidal influences, but also to the storm surges which occur as a result of extreme weather conditions. The expected impacts of climate change on sea level also need to be considered.

Ocean water levels will have a considerable influence on the wave climate of each of the five study locations. As ocean waves propagate shoreward into shallower water, they begin to "feel" the seabed. The decreasing depths cause the waves to change direction so as to become aligned to the seabed contours and to also shoal up in height until such time as they may break - dissipating their energy as they do so.

Just how much wave energy reaches the shoreline is therefore determined significantly by the depth of water over the seabed approaches. Ocean water levels and the seabed bathymetry are important aspects in this process of wave energy transmission.

Consequently it is necessary to have a thorough understanding of the following ocean levels on local foreshores:

Astronomical Tide - this is the "normal" rising and falling of the oceans in response to the gravitational influences of the moon, sun and other astronomical bodies. These effects are predictable and consequently the astronomical tide levels can be forecast with confidence.

Storm Tide - this is the combined action of the astronomical tide and any storm surge that also happens to be prevailing at the time. Surge is the rise above normal water level as a consequence of surface wind stress and atmospheric pressure fluctuations induced by severe synoptic events (such as tropical cyclones).

2.1.1 Astronomical tides

The tidal rising and falling of the oceans is in response to the gravitational influences of the moon, sun and other astronomical bodies. Whilst being complex, these effects are nevertheless predictable, and consequently past and future astronomical tide levels can be forecast with confidence at many coastal locations. Tidal planes have been published for the Bowen region (MSQ, 2010) and these are presented in Table 2.1 below.

Tidal Plane	to AHD	to Chart Datum
Highest Astronomical Tide (HAT)	1.95 metres	3.73 metres
Mean High Water Springs (MHWS)	0.99 metres	2.77 metres
Mean High Water Neaps (MHWN)	0.38 metres	2.16 metres
Mean Sea Level (MSL)	-0.06 metres	1.72 metres
Mean Low Water Neaps (MLWN)	-0.39 metres	1.39 metres
Mean Low Water Springs (MLWS)	-1.00 metres	0.78 metres
Lowest Astronomical Tide (LAT)	-1.78 metres	0.00 metres

Table 2.1 : Tidal Planes at Bowen[2]

In a lunar month the highest tides occur at the time of the new moon and the full moon (when the gravitational forces of sun and moon are in line). These are called "*spring*" tides and they occur approximately every 14 days. Conversely "*neap*" tides occur when the gravitational influences of the sun and moon are not aligned, resulting in high and low tides that are not as extreme as those during spring tides.

As can be seen in Table 2.1, the maximum possible astronomical tidal range at Bowen is 3.73 metres, with an average range during spring tides of 1.99 metres and 0.77 metres during neap tides.

Spring tides tend to be higher than normal around the time of the Christmas / New Year period (ie. December - February) and also in mid-year (ie. around Jun - Aug). The various occurrences of particularly high spring tides are often referred to in lay terms as "*king tides*" - in popular terminology meaning any high tide well above average height.

The widespread notion is that king tides are the very high tides which occur early in the New Year. However, equally high tides occur in the winter months, but these are typically at night and are therefore not as apparent as those during the summer holiday period - which generally occur during daylight hours.

[2] These tidal planes refer to Port Denison and are consequently representative of the tides at the project sites of Port Denison West Beach; Kings Beach at Rose Bay; and Horseshoe Bay. The more distant and more exposed ocean frontages of The Pocket and Queens Beach are likely to have tidal planes with slightly lower ranges.

However since tidal predictions are computed on the basis of astronomical influences only, they inherently discount any meteorological effects that can also influence ocean water levels from time to time. When meteorological conditions vary from the average, they can cause a difference between the predicted tide and the actual tide. This occurs at the five project sites to varying degrees. The deviations from predicted astronomical tides are primarily caused by strong or prolonged winds, and/or by uncharacteristically high or low barometric pressures.

Differences between the predicted and actual times of low and high water are primarily caused by wind. A strong wind blowing directly onshore will "pile up" the water and cause tides to be higher than predicted, while winds blowing off the land will have the reverse effect. Clearly the occurrence of storm surges associated with tropical cyclones can significantly influence ocean water levels.

2.1.2 Storm tide

The level to which ocean water can rise on a foreshore during the passage of a cyclone or an extreme storm event is typically a result of a number of different effects. The combination of these various effects is known as *storm tide*. Figure 2.1 illustrates the primary water level components of a storm tide event. A brief discussion of each of these various components is offered below.

- Astronomical Tide

As discussed earlier, the astronomical tide is the normal day-to-day rising and falling of ocean waters in response to the gravitational influences of the sun and the moon. The astronomical tide can be predicted with considerable accuracy.

Astronomical tide is an important component of the overall storm tide because if the peak of the storm/cyclone were to coincide with a high spring tide for instance, severe flooding of low lying coastal areas can occur and the upper sections of coastal structures can be subjected to severe wave action.

The quite high spring tides that typically occur in summer are of particular interest since they occur during the local cyclone season.

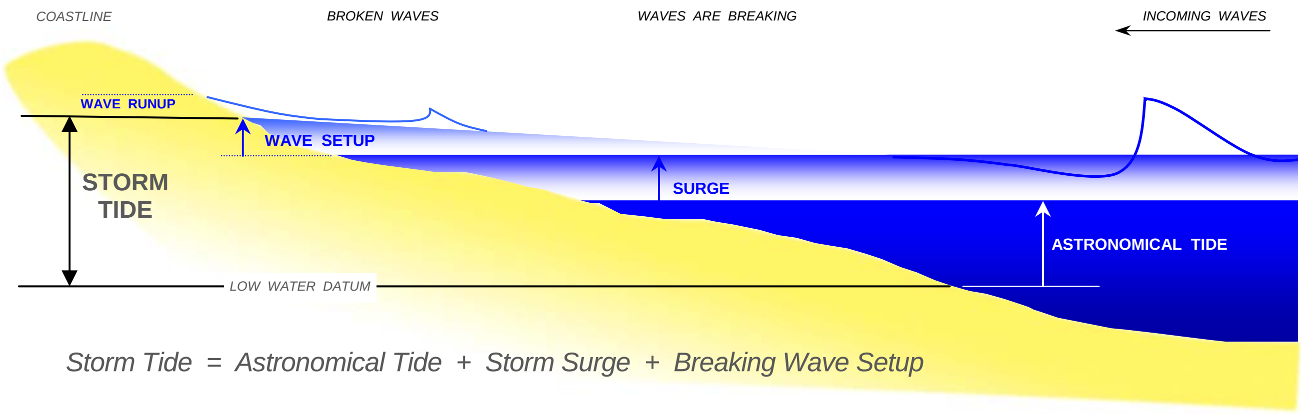


Figure 2.1 : Components of a Storm Tide Event

- Storm Surge

This increase in the ocean water level is caused by the severe atmospheric pressure gradients and the high wind shear induced on the surface of the ocean by a tropical cyclone. The magnitude of the surge is dependent upon a number of factors such as the intensity of the cyclone, its overall physical size, the speed at which it moves, the direction of its approach to the coast, as well as the specific bathymetry of the coastal regions affected.

In order to predict the height of storm surges, these various influences and their complex interaction are typically replicated by numerical modelling techniques using computers.

- Breaking Wave Setup

The strong winds associated with cyclones or severe storms generate waves which themselves can be quite severe. As these waves propagate into shallower coastal waters, they begin to shoal and will break as they encounter the nearshore region. The dissipation of wave energy during the wave breaking process induces a localised increase in the ocean water level shoreward of the breaking point which is called *breaking wave setup*.

Through the continued action of many breaking waves, the setup experienced on a foreshore during a severe wave event can be sustained for a significant timeframe and needs to be considered as an important component of the overall storm tide on a foreshore.

- Wave Runup

Wave runup is the vertical height above the local water level up to which incoming waves will rush when they encounter the land/sea interface. The level to which waves will run up a structure or natural foreshore depends significantly on the nature, slope and extent of the land boundary, as well as the characteristics of the incident waves. For example, the wave runup on a gently sloping beach is quite different to that of say a near-vertical impermeable seawall.

Consequently because this component is very dependent upon the local foreshore type, it is not normally incorporated into the determination of the storm tide height. Nevertheless it needs to be considered separately during the assessment of foreshore erosion vulnerability.

- *Storm Tide Events at Bowen*

A number of studies have previously been undertaken with regard to storm tides that may occur in the Bowen region. The most recently published being the *Bowen Shire Storm Tide Study* (Connell Wagner, 2004). That study also addresses the effect of enhanced Greenhouse conditions on sea level rise and tropical cyclone occurrences.

The storm tides reported by that study have been used in this investigation of cyclone erosion threat and are summarised in Table 2.2 for the present day climate scenario.

Average Recurrence Interval	Rose Bay	Front Beach	Queens Beach	The Pocket	Horseshoe Bay
50 years[3]	2.36	2.51	2.36	2.30	2.30
100 years	2.58	2.77	2.59	2.51	2.51

Table 2.2 : Storm Tide Levels (metres above AHD) at the Project Sites

These levels exclude the effects of breaking wave setup, since this particular component varies at each site. Its value is determined in later considerations of the effects of storm tide on erosion processes by this Study.

The duration of the storm tide is also a critical consideration when determining effects on sandy shorelines. The surge component of the storm tide typically builds to a peak over several hours, then drops away over a similar or even shorter timeframe as the cyclone influences pass.

2.2 Wave Climate

Given that sand is predominantly transported by wave action on these foreshores, wave characteristics are important considerations when assessing local coastal processes.

Waves arrive in the nearshore waters of the project sites as a consequence of several phenomena - any of which can occur simultaneously, namely;

- Swell waves - generated by weather systems in the distant waters of the Coral Sea and Pacific Ocean out beyond the Great Barrier Reef. In order to propagate to Bowen's foreshores, these waves must pass through and over the extensive reefs and shoals that constitute the Barrier Reef. There is considerable attenuation of wave energy during this propagation process. Nevertheless, whilst inshore swell wave heights are quite low and may be imperceptible at times, because of their relatively long wave periods (typically in excess of around 12 seconds) they contribute to local sediment transport processes.

- Distant Sea waves - generated by winds blowing across the open water fetches between the mainland and the outer Great Barrier Reef system (some 70 kms offshore). The significant distances between the mainland and the Great Barrier Reef means that quite sizeable waves can be generated by winds blowing across these fetches - particularly during cyclones which are a common synoptic event in these waters.

  Whilst some of the project sites are on the sheltered western shores of Edgecumbe Bay, Distant Sea waves can nevertheless diffract and refract around

[3] For ARI of less than 50 years, the maximum local storm tide level may not necessarily be associated with tropical cyclones. Other more frequent meteorological or synoptic events may combine with particularly high spring tides to result in potentially greater levels than that listed here for 50 year ARI.

the northern tip of Gloucester Island, Cape Edgecumbe and around Stone Island to reach these sites. The attenuating effects of diffraction and refraction mean that the energy of these waves is diminished. Nevertheless, because they are driven by the predominant seasonal weather systems, waves approaching Edgecumbe Bay from the south-east and east sectors represent an important component of the ambient wave climate within the Bay. Their persistent nature and relatively long periods (typically greater than 8 seconds) mean that they strongly influence beach processes in the region.

- Local Sea waves - the same winds that blow across the open water fetches between the mainland and the Great Barrier Reef (to generate Distant Seas) also blow across the enclosed waters of Edgecumbe Bay. Consequently they generate waves within the Bay itself – these waves are called Local Seas. Whilst the fetches are relatively short and shallow, they still enable substantial wave energy to be generated and propagate to Port Denison West Beach, Kings Beach at Rose Bay and Horseshoe Bay.

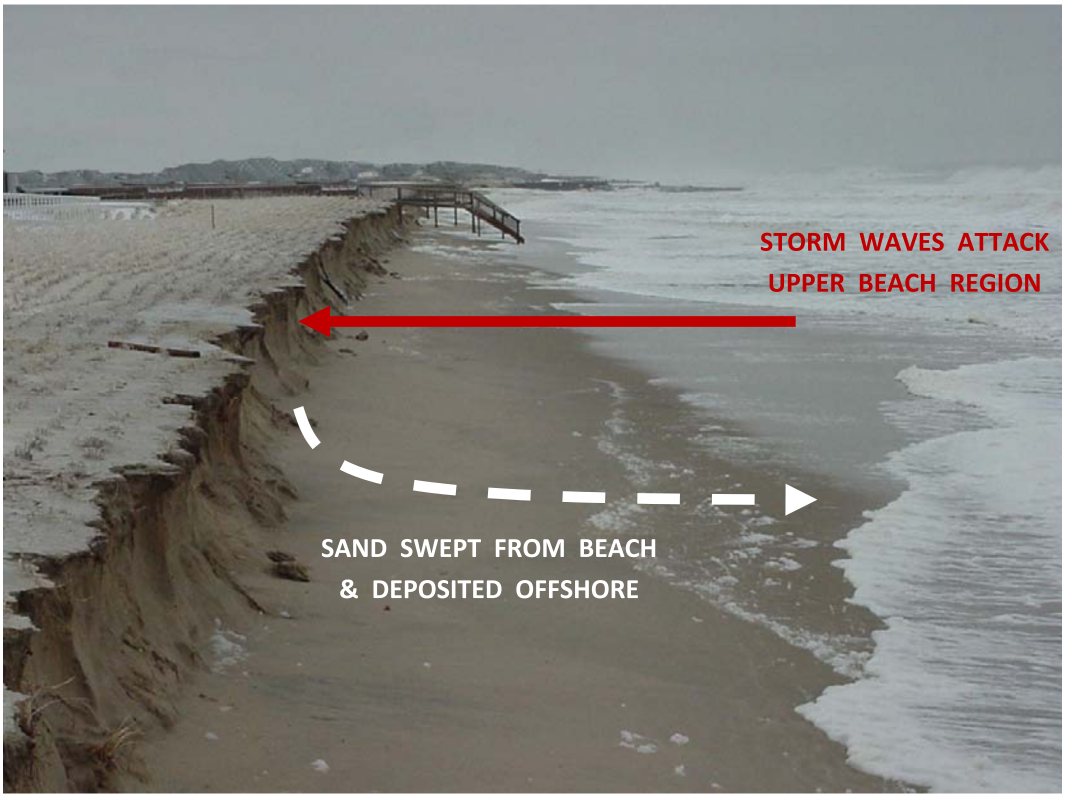
The generation of the various wave types and how they are modified by wave refraction, diffraction, seabed friction, shoaling and breaking as they propagate from their offshore generation areas to local beaches is considerably complex. In the absence of any site specific long-term directional wave measurements, the only way of obtaining an appreciation of the wave climate on local beaches is to apply numerical modelling techniques.

Such an approach is beyond the scope of the Study, however some beach response modelling to predict the erosion associated with extreme events has been undertaken. The results and implications of that modelling are discussed in later sections of this report.

2.3 Sediment Transport

Before considering the sediment transport processes on the five project foreshores in Section 3 of this report, it would be informative to firstly outline how waves move sand on shorelines. This occurs as a consequence of two fundamental mechanisms; cross-shore transport and longshore transport. These are illustrated conceptually in Figure 2.2.

Both processes can occur simultaneously, but both vary significantly in their intensity and direction in response to prevailing wave conditions.



(a) Cross-shore Sand Transport

(b) Longshore Sand Transport

Figure 2.2 : Wave-induced Sand Transport Mechanisms

2.3.1 Sand Transport Processes

2.3.1.1 Cross-shore transport

This is the movement of sand perpendicular to the beach – in other words, onshore/offshore movement. Whilst this washing of sand up and down the beach profile occurs during ambient conditions (ie. the normal day-to-day conditions), it is during severe storms or cyclones that it becomes most evident and most critical.

Strong wave action and elevated ocean water levels during such events can cause severe erosion of a beach as sand is removed from the dunes and upper regions of the profile. The eroded sand is moved offshore during the storm to create a sand bank near the seaward edge of the surf zone. Subsequent milder wave conditions return this sand back onto the beach, where waves and onshore winds then re-work it so as to establish the pre-storm beach condition.

During particularly severe storms very significant erosion of sand from the upper beach can occur in only a few hours; whereas recovery of the beach by onshore transport processes may take many years, even decades.

2.3.1.2 Longshore transport

This is the movement of sand along the beach and occurs predominantly within the surf zone. Of all the various processes that control beach morphology, longshore sand transport is probably the most influential. It determines in large part whether shorelines erode, accrete or remain stable.

Waves arriving with their crests at an angle to the plan alignment of the shoreline create an alongshore current which initiates and maintains sand transport along the beach.

The angle at which the incoming waves act on the beach face may only be very small (as may be the waves themselves), nevertheless their continual and relentless action is sufficient to account for notable volumes of sand to be moved annually on local shorelines.

On most coasts, waves arrive at the beach from a number of different offshore directions - producing day-to-day and seasonal reversals in transport direction. At a particular beach location, transport may be to the left (looking seaward) during part of the year and to the right during other times of the year. If the volumes of transport are equal in each direction then there is no net change in the beach position over annual timeframes. However this is not often the case.

Typically longshore movement is greater in one direction than the other – which results in a net annual longshore movement.

Whilst there may be a net longshore transport along a section of foreshore, this does not mean that sand is being lost and therefore the beach is eroding. So long as sand is being supplied at the same rate as it is being transported along the shore at any particular location, then there will be no net change to the beach over annual timeframes.

The importance of cross-shore and longshore sand transport to the development and implementation of foreshore management strategies can perhaps best be summarised as:

- Cross-shore transport needs to be understood so that appropriate sand reserves are maintained on a foreshore to act as an erosion buffer during severe storms or tropical cyclones. It provides insight into short-term erosion processes.
- Longshore transport needs to be understood so that the sand supply to a foreshore is maintained at a rate that will continue to naturally sustain the sand reserves acting as the erosion buffer. Where natural supply is deficient, it may need to be augmented with placement of extra sand through beach nourishment works. Longshore transport provides insight into ongoing long-term erosion processes.

2.3.2 Beach Response Modelling of Cross-shore Transport

Technical work undertaken for this Study has included application of the SBEACH proprietary numerical model to predict the response of beach profiles to a number of different cyclone scenarios. The 50 and 100 year ARI storm conditions were investigated at those study sites where adequate shoreline and nearshore bathymetric survey information was available - namely at Rose Bay, Queens Beach and The Pocket Beach.

The fundamental approach to this beach response modelling has been to:

- utilise cyclone wave information for the deep waters offshore of Cleveland Bay using data generated for the *Atlas of Tropical Cyclone Waves in the Great Barrier Reef* (MMU, 2001);
- utilise storm tide levels for extreme events which has been previously determined by modelling of storm tides in the Bowen region (DNRM, 2004 and Connell Wagner Pty Ltd, 2004);
- transform these offshore wave and storm tide conditions to each of the five study locations using desk-top wave transformation modelling;
- apply the local wave / storm tide conditions and the most recent shoreline transect surveys as input to the SBEACH model to determine the eroded profile at each location.

This provides the basis for determining the extent of the erosion threat at each site, as well as the requirements for the reinstatement of any erosion buffers as part of an erosion mitigation strategy. The results of the beach response modelling are presented in Section 3 of this report where the specific erosion threat at each of the study locations is discussed.

2.3.3 Overwash

During severe storms and cyclones, there is considerable overwash of some foreshores in the Bowen region. This phenomenon occurs when the storm tide progressively builds during a severe cyclone event to be so great that waves no longer dissipate their energy directly on the beach slope or on the dunes - ocean water levels are such that the waves wash over the beach slope since it is substantially submerged.

This occurs at locations where the back-beach area is quite low - for example along the ocean frontages of Port Dennison West Beach, Horseshoe Bay and The Pocket Beach.

Once overwash commences at these sites, further recession of the foreshore still occurs; however it tends to be somewhat diminished. Instead of being carried offshore, sand in the upper beach is swept up over the slope and carried inshore. Despite shoreline recession then effectively stopping, there can nevertheless be devastating consequences to nearshore areas during overwash - since the foreshore is not only inundated by storm surge, but destructive cyclonic waves can wash over the dunes and penetrate inland.

Unfortunately the extent of profile change and damage caused by overwash cannot be confidently predicted by current mathematical modelling techniques. Consequently when overwash occurs, the erosion characteristics predicted by beach response modelling should be considered as indicative only.

2.4 Future Climate Change

Climate change will cause environmental changes to ocean temperatures, rainfall, sea levels, wind speeds and storm systems. If climate changes develop as predicted, the foreshores of the Bowen region will be subjected to potentially greater storm and cyclone energy, higher waves, stronger winds and increased water levels.

In its Fourth Assessment Report released in 2007 the *Intergovernmental Panel on Climate Change* (IPCC, 2007) has presented various scenarios of possible climate change and the resultant sea level rise in the coming century. There is still considerable uncertainty as to which of these various scenarios will occur. The oceanographic and atmospheric processes involved are complex, and numerical modelling of these processes is far from precise.

Because of these complexities, there is a wide range in the predictions of global sea level rise for the coming century. A rise of between 0.18 metres and 0.59 metres by the year 2100 is predicted by the IPCC investigations, with a possible additional contribution of 0.1 to 0.2 metres from melting ice sheets.

At this stage there is no agreed pattern for the longer-term regional distribution of projected sea level rise offered by the IPCC predictions. Nevertheless, in the Australian region a common feature in many model projections of sea level rise is an increase on the east coast of Australia that is potentially higher than the global average. In the Bowen region, this is estimated to be approximately 0.15 metres above global averages (CMAR, 2008).

The projected sea level rise currently adopted for planning purposes by Queensland's *State Coastal Management Plan* is 0.3 metres over 50 years. Whilst this is still within the range of projections in the IPCC Fourth Assessment Report, it is now at the lower end of these recent predictions and is therefore being reviewed. Under the provisions of the Coastal Act, a review of the 2002 *State Coastal Management Plan* was initiated in 2009.

As a consequence of that review, the draft coastal plan has adopted an updated sea level rise of 0.8 metres by the year 2100. This is based on the upper limit of the most recent projections released by the IPCC in its Fourth Assessment Report, in conjunction with the expectation that sea levels along the east coast of Australia will be higher than the global average.

The Department of Environment and Resource Management currently uses a planning period of 50 years when considering the requirement for coastal setbacks (ie. erosion prone area widths) under the current State Coastal Management Plan. Reference to the upper limit of the range in predictions offered by IPCC (2007) indicates that a 0.4m allowance for Greenhouse-induced sea level rise should be included when planning over a 50 year timeframe.

In addition to sea level rise, there is speculation that the intensity of tropical cyclones may increase - although it is also acknowledged that there is a possibility that the overall number of cyclones affecting coastal regions may decrease. However estimating any changes to the intensity and occurrence of cyclones is particularly problematic since their formation and subsequent track are dependent upon the complex interaction of a number of natural phenomena (such as the El Nino - Southern Oscillation) which themselves are not yet well understood.

However to accommodate any such adverse impacts on future erosion vulnerability, the effects of a 10% increase in offshore wave heights and a 5% increase in offshore wave periods have been considered in this Study - along with a 0.4m sea level rise. This increase in wave characteristics equates very approximately to a 10% increase in the intensity of cyclones for any given ARI.

The rate of any sea level rise as a consequence of climate change will be very gradual, and the timescales associated with the coastal processes shaping the nearshore and foreshore regions will keep pace with the slow sea level rise. Consequently the basic form of the beach profile on local foreshores will be maintained in relation to the gradually rising sea level in front of it.

Nevertheless, there will be a gradual recession of the position of the shoreline, which will effectively reduce sand buffers in front of existing foreshore infrastructure. The seabed on the wave approaches to each site will likely remain at much the same levels and slopes as they are now - which means that waves will be approaching the shore through slightly deeper water.

Numerical modelling of beach response (using the SBEACH model) has been undertaken for this Study using the expected increases in sea levels and more severe wave conditions.

Given the present uncertainties associated with the extent and nature of future climate change, when developing and assessing appropriate erosion mitigation strategies there is considerable merit in applying strategies that are flexible and can be tailored to suit climate change impacts as they gradually evolve.

3 THE EROSION THREAT

3.1 Designated Erosion Prone Areas

In recognition of the threat of shoreline erosion, the establishment of Erosion Prone Areas along Queensland's coastline has been an intrinsic part of the state's coastal management policy since 1968. The concept is to set aside undeveloped buffer zones thereby implementing a philosophy that biophysical coastal processes are to be accommodated rather than prevented. The most basic form of accommodation is to avoid locating development and vital infrastructure within dynamic coastal areas affected by the natural processes of shoreline erosion and accretion.

An adequate buffer zone allows for the maintenance of coastal ecosystems (including within littoral and sublittoral zones), visual amenity, public access and the impacts of natural processes - without the high cost and potentially adverse effects of property protection works.

The Department of Environment and Resource Management currently has an Erosion Prone Area Plan for the Bowen region. It was first established by the Beach Protection Authority in December 1984[4]. Its purpose is to define the width of local foreshores that might be susceptible to erosion over the coming 50 years. At the time it was prepared, no specific allowances for potential future climate change were directly incorporated into the designated widths, although a 40% factor of safety was applied to the widths calculated by the Beach Protection Authority.

This safety factor was applied in recognition that there are uncertainties and limitations associated with predictions of future erosion, including those that might arise as a result of what was then identified as emerging Greenhouse effects.

Some amendments have been made to the Erosion Prone Area Plan since it was established; however the designated erosion prone areas along the five project foreshores are currently as follows:

- Kings Beach at Rose Bay : 95 metres (or to the location of any outcropping bedrock);
- Port Denison West Beach : 80 metres;
- Queens Beach : 110 metres (except for a section of foreshore immediately south of the ephemeral creek entrance which is 70 metres);
- The Pocket Beach : 110 metres;
- Horseshoe Bay : 55 metres.

[4] Plan number SC 3388, titled "*Bowen Shire Erosion Prone Areas*"; originally dated 03rd December 1984. It has subsequently been amended a number of times to the current Revision G.

The erosion prone area is measured landward from the seaward toe of the frontal dune, or from the line of permanent terrestrial vegetation if a dune feature is not well established or identifiable.

As with designated erosion prone widths along the entire Queensland coastline, these areas have served in the past as planning and legislative tools when considering development on the state's foreshores.

3.2 Planning Period

When considering appropriate erosion mitigation measures it is necessary to select the timeframe (or planning period) over which erosion influences are to be considered. The threat of erosion to most foreshores can be summarised as being a result of:

- long-term erosion – due to a shortfall in sediment supply over time;
- short-term erosion – due to the direct effects of severe cyclone events; and
- future climate change – primarily sea level rise and increased severity/occurrence of cyclones.

The selection of a planning period determines the effects of these phenomena when considering erosion mitigation options. Some comment is therefore offered in relation to these phenomena.

- Long-term erosion

  Long-term erosion manifests itself as a gradual recession of the average position of the shoreline due to a deficit in the supply of sand from updrift foreshores. When considering the threat that this poses and the measures required to mitigate the threat, it is necessary to select a planning period.

  For example, an average long-term recession of 0.5m / year represents a potential shoreline recession of 25m over a 50 year planning period. A different planning period represents a different recession.

  It is therefore necessary to have a planning period established in order to quantify the extent of future long-term erosion and an appropriate strategy to address it.

- Short-term erosion

  The selection of a planning period also has an effect on the threat posed by short-term cyclone induced erosion. For example, the likelihood of a 100 year ARI cyclone occurring in (say) a 50 year planning period is quite different to that for shorter or longer timeframes. Consequently when determining risk, the implications of a 100 year ARI cyclone could be considered unlikely for short planning periods – or alternatively, very likely for longer periods.

- Future climate change

  The nominated planning period also has implications to the extent that climate change influences are to be incorporated into erosion mitigation works. Current projections of sea level rise and the severity / frequency of cyclones and storm tides vary - depending upon when in the future such issues are considered. Clearly such effects are different in 20 years time as opposed to 50 or 100 years into the future.

The Department of Environment and Resource Management currently uses a planning period of 50 years when considering the requirement for coastal setbacks (ie. erosion prone area widths) under the current State Coastal Management Plan. Indeed this planning period has been the State Government's policy since the establishment of the Beach Protection Authority in 1968. A 50 year planning period was considered appropriate given the practical life of coastal management projects and the maximum reasonable forward projections of present and past erosion trends.

For the purposes of the Study, a 50 year planning period has been adopted.

3.3 The Design Storm Event

When considering viable erosion mitigation strategies at each of the study sites, it will be necessary to consider the implications of varying storm / cyclone events. These events are typically categorised by an Average Recurrence Interval[5] (or ARI).

The probability of events having various ARI occurring or being exceeded within a 50 year planning period can be predicted using established mathematical techniques, thereby quantifying the risk associated with each such event. Table 3.1 presents these various probabilities of occurrence for storms and cyclones of varying intensities (ie. various ARI).

When subsequently preparing detailed designs for the implementation of the preferred erosion mitigation strategy at each site, it will be necessary for Council to consider these probabilities and nominate an Average Recurrence Interval as the design standard. This then establishes the Design Storm Event when implementing each strategy.

[5] Average Recurrence Interval (ARI) is a statistical estimate of the average period in years between the occurrences of an event of a particular size. For example, a 100 year ARI event will occur on average once every 100 years. Such an event would have a 1% probability of occurring in any particular year.

ARI of the event	probability of the event being equalled or exceeded	probability of the event occurring in any single year
10 years	99.3%	9.5%
20 years	91.8%	4.9%
50 years	63.2%	2.0%
100 years	39.3%	1.0%
200 years	22.1%	0.5%
500 years	9.5%	0.2%
1,000 years	4.9%	0.1%

Table 3.1 : Probability of Occurrence of ARI events in a 50 year Timeframe

3.4 Kings Beach at Rose Bay

The coastal reach of Kings Beach at Rose Bay considered by this Study is shown on Figure 3.1. It extends southwards from a rocky headland to the mouth of Sandhills Creek. It forms the ocean frontage to the Rose Bay residential community.

Figure 3.1 : Foreshore of Kings Beach at Rose Bay

When considering the existing and possible future erosion threat to this particular coastal reach it is necessary to consider the following:

- Long-term Erosion;
- Short-term Erosion; and
- Effects of Climate Change

3.4.1 Long-term Erosion

As part of a comprehensive state-wide program of surveying cross-shore profiles at coastal locations throughout Queensland, the Beach Protection Authority established a number of transect lines on the shores of Kings Beach. The intent being to undertake repeated surveys on these transects to provide quantitative information regarding shoreline change.

The Beach Protection Authority's survey data for the Bowen region has been provided by the Coastal Unit of the Queensland Climate Change Centre of Excellence (Department of Environment and Resource Management) to assist with this Study.

The most relevant survey data for Kings Beach at Rose Bay is the transect line nominated as BOW 206.6, located at the southern end of Bluewater Parade. The first survey of BOW 206.6 by the Beach Protection Authority was undertaken in October 1980 with subsequent surveys undertaken in May 1989, and September 1995.

This transect line also approximately coincides with a transect line established and surveyed for Whitsunday Regional Council (Hardy, 2009) in October 2008, March 2009 and September 2009.

Consequently a comparison of these various surveys offers insight into long-term changes to the ocean frontage along the southern frontage of Bluewater Parade. Figure 3.2 presents a comparison of some historical surveys.

It is evident from the transect surveys that the crest position of the dune has remained relatively unchanged over the 28 year time span of the surveys. However the toe of the dune and the beach in front of it has receded. In earlier years the beach was flatter and much wider. The increasingly narrower beach enables storm waves to more readily access the base of the sand dune, whereas previously the dune was more protected by the wider beach. This trend of increasing vulnerability of the dune is expected to continue.

The toe of the dune has receded some 17 metres over the 29 years (ie. an average recession rate of 0.6m/year); whereas the line defining MHWS along the beach has retreated shoreward some 24 metres, and the line of MLWS has retreated approximately 57 metres. Clearly the intertidal beach is much narrower now than it has been in the past. This is primarily due to the removal of sand from this active part of the beach by longshore sediment transport processes.

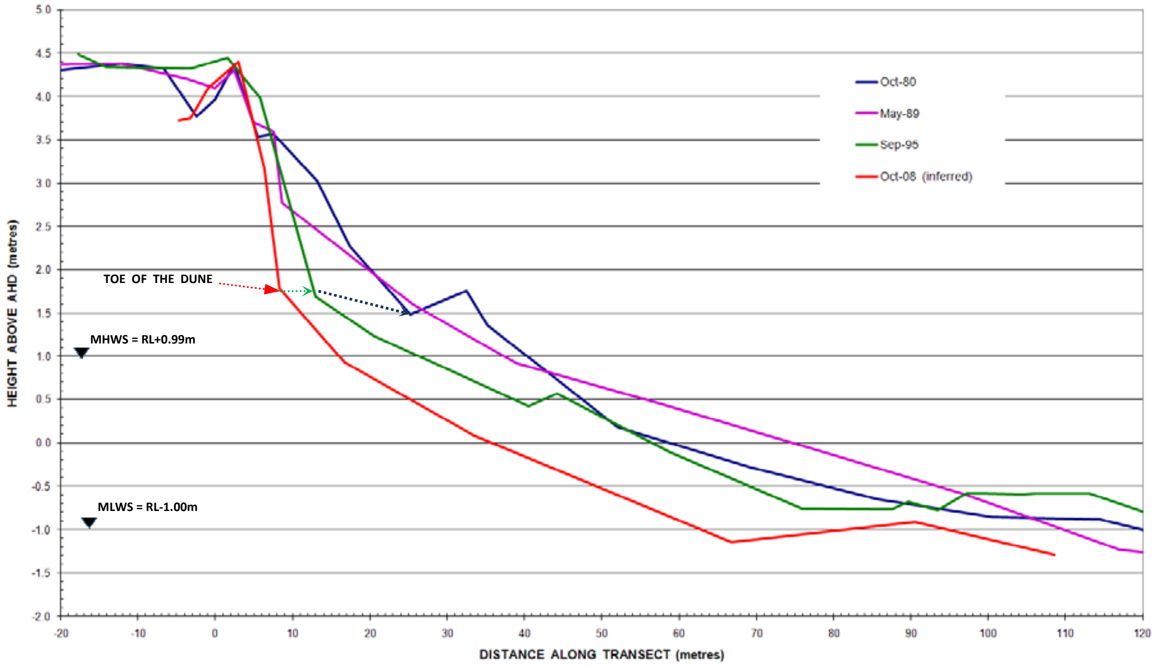


Figure 3.2 : Historical Comparison of Beach Transects - Southern End of Bluewater Parade, Rose Bay

Whilst both northward and southward transport of sand occurs along this foreshore, the surveys suggest a net southward transport of sand from the southern end of Bluewater Parade towards the ocean entrance of Sandhills Creek - at an average annual transport rate of approximately 3.5 m^3 /metre of foreshore. Inspections of historical aerial photographs - in conjunction with observations on site - suggest that this rate diminishes northwards from the rocky outcrops (that are approximately opposite No. 15 Bluewater Parade). Near the beach access at the northern end of the foreshore it appears that the net longshore transport rate has diminished to around zero.

The implication of these various considerations of historical surveys and aerial photographs suggests that the long-term average longshore sand transport rate on the foreshore of Kings Beach at Rose Bay is around 750m^3 per year. Nevertheless it is likely that the rate in any particular year will vary significantly from this long-term average.

As the sand moving southward from the Bluewater Parade frontage approaches the ocean entrance of Sandhills Creek, it accumulates in the ever-changing sandbanks and entrance shoals that are continually shaped by the complex interaction of waves and creek flows.

Indeed the creek's entrance shoals very likely influence the longshore sand transport regime on the southern beach frontage of Bluewater Parade. This is particularly so during periods of south-easterly sea conditions when approaching waves move sand northwards off the entrance shoals towards this foreshore - thereby affecting the net southerly transport volumes.

Any erosion mitigation strategy applied to the Rose Bay foreshore must accommodate the long-term erosion of approximately 3.5 m^3 /metre/ year that is occurring along this foreshore. This equates to an average recession of approximately 0.6m/year, or 30 metres over a 50 year planning period.

3.4.2 Short-term Erosion

Numerical modelling of beach response to severe cyclone events has been undertaken for Kings Beach at Rose Bay. The preceding Section 2.3.2 offers some discussion on the methodology applied to the SBEACH modelling process.

Figure 3.3 presents a summary of the SBEACH modelling for Rose Bay beach and shows the predicted eroded profile for 50 year and 100 year ARI events occurring under present day climate scenario.

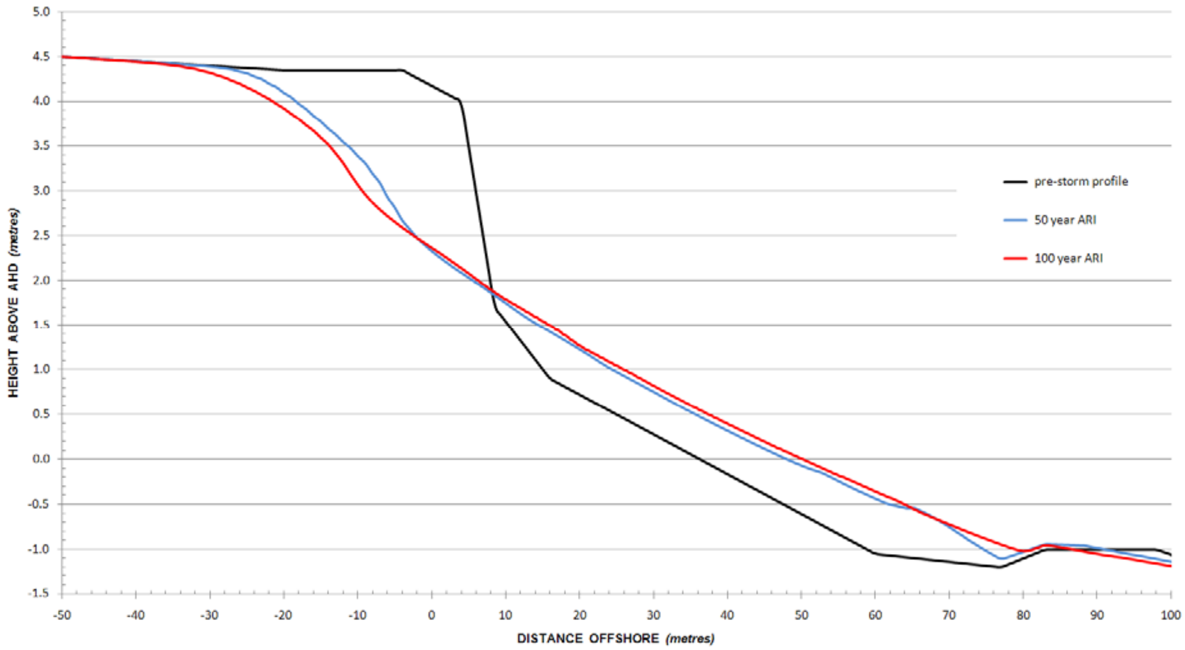


Figure 3.3 : Results of Beach Response Modelling for Rose Bay - present day scenario

The profile response for the 50 year and 100 year ARI are quite similar. This is because the waves are "depth limited". That is, the energy that reaches the foreshore during each of these events is determined by the depth of water over the seabed approaches to Kings Beach at Rose Bay. The somewhat flat approach slopes cause the larger waves in the sea state to break offshore and dissipate much of their energy as they do so.

Given that there is only some 0.22 metres difference in the level of the peak storm tide for the 50 year and 100 year ARI events (refer storm tide levels in Table 2.2), the depth limitation effects regulating the maximum waves reaching the shore are similar. This accounts for the similarity in the predicted eroded profiles for 50 year and 100 year ARI events.

Reference to Figure 3.3 indicates that the front dune above approximately RL+1.75m AHD is eroded during these severe storms, with the sand being deposited on the beach in front. Approximately 33 m^3/metre of sand would be removed from the dune by the 50 year ARI event; and 38 m^3/metre by the 100 year ARI cyclone. These correspond to potential foreshore recessions of approximately 30 metres and 36 metres respectively.

It is important to appreciate that the shoreline responses discussed above are based on foreshore characteristics representative of the southern end of the Bluewater Parade ocean frontage. The foreshore towards the northern end benefits from the protection afforded to cyclone waves by the rocky headland that separates this coastal reach from the small pocket beach just to the north. Consequently erosion is expected to be less in this northern area.

3.4.3 Effects of Climate Change

The preceding discussions of long-term erosion and beach response to cyclones are based on recent and present-day climate scenarios. Climate change will cause environmental changes to ocean temperatures, rainfall, sea levels, wind speeds and storm systems. If climate changes develop as predicted, the foreshore of Kings Beach at Rose Bay will be subjected to potentially greater storm and cyclone energy, higher waves, stronger winds and increased water levels.

3.4.3.1 Sea Level Rise

The rate of sea level rise as a consequence of climate change will be very gradual, and the timescales associated with the coastal processes shaping the nearshore and foreshore regions will keep pace with the slow sea level rise. Consequently the basic form of the beach profile will be maintained in relation to the gradually rising sea level in front of it.

Nevertheless, there will be a gradual recession of the position of beach, which will effectively reduce sand buffers in front of Bluewater Parade. On the basis of a sea level rise of 0.4 metres over a 50 year planning period (refer to discussions in the preceding Section 2.4) the future recession of Kings Beach at Rose Bay is expected to be approximately 11 metres - gradually removing approximately 22.4 m^3/metre of sand from the upper sections of the existing profile.

3.4.3.2 Increased Long-term Erosion Rate

The historical long-term erosion of approximately 0.6m/year is expected to increase as a consequence of future climate change. On the basis of detailed analyses at other similar coastal reaches, this is likely to increase by 10% to 15% over a 50 year planning period.

Adopting a 15% increase in the long-term rate of background erosion suggests that the recession is likely to gradually increase from 0.6m/year to around 0.7m/year - implying an overall recession of 32 metres by the end of the 50 year planning period.

3.4.3.3 Increased Short-term Erosion

Numerical modelling of beach response (using the SBEACH model) has also been undertaken using the increases in sea levels and more severe wave conditions that are expected to occur over the coming 50 years (refer to discussions in Section 2.4).

Figure 3.4 presents a summary of the SBEACH modelling for Rose Bay beach showing the predicted eroded profile for 50 year and 100 year ARI events occurring in 50 years' time under future climate scenario. Again the predicted profiles for 50 year and 100 year ARI events are very similar.

Approximately 36 m^3/metre of sand could be removed from the dune by the 50 year ARI event; and 40 m^3/metre by the 100 year ARI cyclone. These correspond to potential foreshore recessions of 33 metres and 37 metres respectively - which would be measured from the position of the shoreline in 50 years time.

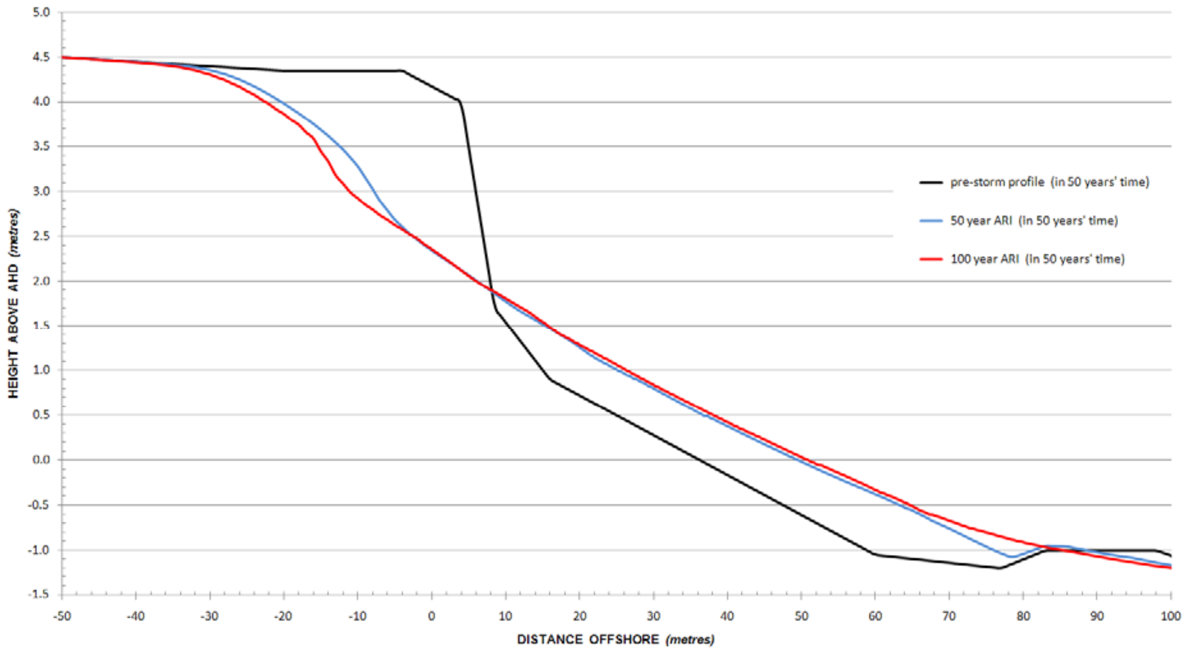


Figure 3.4 : Results of Beach Response Modelling Rose Bay - future climate change scenario

3.4.4 Overall Threat

When considering the potential erosion to the foreshore of Kings Beach at Rose Bay it is necessary to consider the threat that currently exists and that which will emerge in the future (as a consequence of ongoing long-term erosion trends and the likely effects of future climate change). As discussed in Section 3.2 a planning period of 50 years has been adopted by the Study when considering future erosion risk.

3.4.4.1 Present-day climate scenario

The current threat of erosion along the Rose Bay foreshore is due to short-term erosion caused by severe cyclones. The results of the SBEACH numerical modelling presented in Section 3.4.2 indicates potential recessions of 30 metres and 36 metres for the 50 year and 100 year ARI events respectively under a present-day climate scenario.

These Threat Lines are shown in Figure 3.5, having been plotted on a recent aerial photograph of the Bluewater Parade ocean frontage.

Reference to this figure indicates that if a 100 year ARI cyclone event was to occur, it could cause erosion that will threaten all Bluewater Parade properties except for the three northern-most properties. Bluewater Parade itself will be damaged south of the informal beach access approximately opposite No. 15 Bluewater Parade.

3.4.4.2 Future climate change scenario

When determining the threat of erosion to the Rose Bay foreshore over a planning period of 50 years, it is necessary to consider the combined effects of long-term, short-term and climate change influences.

The long-term recession rate along the southern of approximately 0.6m/year increasing to around 0.7m/year over a 50 year planning timeframe equates to a shoreline position that will be some 32 metres inland from its current position. This alone will result in the loss of Bluewater Parade and encroach into private properties.

This receding foreshore, in conjunction with the additional 11 metre recession predicted as a consequence of sea level rise as well as the increased short-term erosion threat from cyclones, means that the erosion threat extends considerably further inland than it does at present.

The Threat Lines associated with 50 year and 100 year ARI cyclones at the end of a 50 year planning period are shown in Figure 3.5.

As can be seen, the threat of cyclone erosion extends to residences in Casuarina Street behind Bluewater Parade. It is important to appreciate that the Threat Lines do not represent the position of the foreshore in 50 years time - they represent where the 50 year ARI and 100 year ARI storm erosion could reach if such events were to occur at that time.

Clearly an erosion mitigation strategy is required to protect property and road infrastructure from the increasing threat of erosion in coming years. A discussion of possible mitigation options, resulting in a recommended strategy for the ocean frontage of Bluewater Parade is presented in Section 6.2 of this report.

Figure 3.5 : Present-day Erosion Threat to Bluewater Parade Foreshore

Figure 3.6 : Future Erosion Threat to Bluewater Parade Foreshore (in 50 years time)

3.5 Port Dennison West Beach

The Port Dennison West Beach coastal reach considered by the Study is shown on Figure 3.7. It extends south-west from the jetty to the mouth of Doughtys Creek. There is a small un-named creek which discharges into the waters of Port Denison approximately midway along the shoreline. A concrete ramp crosses the foreshore in the vicinity of the Port Denison Sailing Club.

Port Dennison West Beach consists of several foreshore types - including sections of sandy beach, a rock armoured seawall and adhoc seawalls of dumped building rubble.

Figure 3.7 : Foreshore of Port Dennison West Beach

When considering the existing and possible future erosion threat to this particular coastal reach it is necessary to consider the following:

- Long-term Erosion;
- Short-term Erosion; and
- Effects of Climate Change

3.5.1 Long-term Erosion

There have been no foreshore monitoring surveys undertaken along the Port Dennison West Beach. Consequently any long-term changes to the shoreline need to be inferred from historical aerial photography - however a detailed photogrammetric analysis is beyond the scope of this Study.

Nevertheless the following is evident from a visual comparison of aerial photographs taken in October 1971, January 1980, September 1995, and April 2005:

- the sandy beach immediately alongside the Jetty shows no apparent sign of long-term recession over the 33½ years of available aerial photography;
- the rock armoured seawall (in front of the Catalina Interpretative Centre) is evident in all photographs and its position has remained stable over the 33½ years. However it is evident from site inspections that over the years wave action has removed small rocks from the seawall and consequently maintenance work has been undertaken in the past to add larger rocks to the outer armour;
- the rubble seawalls on either side of the concrete ramp only appear in the more recent photography. Observations on site indicate that this adhoc work in front of the sealed hardstand area appears to have been undertaken following storm damage to what was previously a sandy foreshore. That is, building rubble was placed in response to short-term erosion processes, rather than to mitigate any long-term background erosion.
- the sandy foreshore between the Port Denison Sailing Club and the mouth of the small un-named creek shows little sign of any long-term erosion (but does experience storm erosion from time to time);
- the more exposed sandy foreshore between the un-named creek and Doughtys Creek appears to have receded approximately 8 metres over the 33½ years between the 1971 and 2005 photographs (ie. at a rate of around 0.24m/year). A photogrammetric analysis of the photographs would confirm the actual recession more confidently. Nevertheless adopting this slow rate of long-term foreshore recession suggests that this section of Port Dennison West Beach will recede approximately 12 metres over a 50 year planning period.

3.5.2 Short-term Erosion

Given the variable form of the foreshore along Port Dennison West Beach, its response to cyclone events will also be somewhat variable. It has not been possible to investigate the performance of the foreshore using numerical modelling of beach response due to inadequate foreshore survey and nearshore bathymetric data for the Port Dennison West Beach precinct.

However the hazards associated with cyclones along this particular shoreline are primarily due to its inundation by storm tides rather than erosion causing the shoreline to recede. This is because the foreshore area on Port Dennison West Beach is quite low. Even during moderate cyclones, overwash of this foreshore will occur.

This will happen during storm/cyclone events when the storm tide rises to levels such that waves no longer dissipate their energy directly on the beach (or seawalls) - the ocean levels become such that storm waves wash over the beach slope since it is substantially submerged.

Once overwash commences, further recession of the shoreline will occur; however shoreline erosion will be somewhat diminished. Instead of being carried offshore, sand in the upper beach is swept up over the slope and carried inshore to create berms behind the beach.

Nevertheless, there can still be devastating consequences to foreshore areas of Port Dennison West Beach during overwash since the foreshore is not only inundated by storm surge, but damaging cyclonic waves can wash over the foreshore and penetrate inland.

Foreshore recession of Port Dennison West Beach as a consequence of short-term erosion processes is therefore likely to be caused primarily by non-cyclonic storms or minor cyclones.

Indeed there is evidence to suggest that this has caused the erosion of the once sandy beach on either side of the concrete ramp near the Port Denison Sailing Club. Short-term erosion has occurred at some point in the recent past to the extent that a vertical cut-off wall along the seaward edge of the large concrete hardstand area was exposed to waves (refer to Figure 3.8).

Figure 3.8 : Rubble seawalls either side of the concrete ramp

Such vertical impermeable walls do not adequately dissipate incoming wave energy and are prone to structural failure unless appropriate structural aspects are incorporated into their design. This was not the case for the lightweight shallow wall along the hardstand area to the west of the ramp. Consequently it failed and caused the scour and collapse of the hardstand area immediately behind it. This area now represents a safety hazard to foreshore users and will grow in size as the failure progressively expands as a consequence of future storms.

The erosion of the once sandy beach and the structural failure of the hardstand area alongside the concrete ramp have resulted in the placement of rubble in an effort to armour the foreshore. However as can be seen in Figure 3.8, the rubble consists primarily of building debris (particularly on the eastern side of the ramp) and appears to have been simply dumped on the foreshore. Apart from being unsightly, such materials and adhoc placement have limited structural integrity and poor functionality as a seawall.

The implementation of an appropriate erosion mitigation strategy along this particular section of Port Dennison West Beach offers the opportunity to rectify this deficiency, as well as mitigate the safety hazard posed by the failed concrete hardstand and vertical cut-off wall.

3.5.3 Effects of Climate Change

If future climate changes develop as predicted, the foreshore of Port Dennison West Beach will be subjected to potentially greater storm and cyclone energy, higher waves, stronger winds and increased water levels.

3.5.3.1 Sea Level Rise

Given the low level of the foreshore area, the biggest impact of future climate change on Port Dennison West Beach will be the anticipated increase in sea level.

The rate of sea level rise as a consequence of climate change will be very gradual, and the timescales associated with the coastal processes shaping the nearshore and foreshore regions will keep pace with the slow sea level rise. Consequently the basic form of the beach profile along the Port Dennison West Beach shoreline will be maintained in relation to the gradually rising sea level in front of it.

Nevertheless, there will be a gradual recession of the position of beaches, which will effectively reduce sand buffers in front of existing foreshore infrastructure. On the basis of a sea level rise of 0.4 metres over a 50 year planning period (refer to discussions in the preceding Section 2.4) the future recession of the sandy foreshores of Port Dennison West Beach is expected to be approximately 4 metres.

The seabed through Port Dennison will likely remain at much the same levels and slopes as they are now - which means that waves will be approaching the shore through slightly deeper water.

3.5.3.2 Increased Long-term Erosion Rate

The historical long-term erosion of approximately 0.24m/year on the foreshore between the un-named creek and Doughtys Creek (refer Section 3.5.1) is expected to increase. On the basis of detailed analyses at other similar coastal reaches, this is likely to increase by 10% to 15% over a 50 year planning period as a consequence of future climate change.

Adopting a 15% increase in long-term rates suggests that the recession is likely to gradually increase from 0.24m/year to around 0.28m/year - implying an overall recession of 13 metres at the end of the 50 year planning period. This would be in addition to the recession caused by sea level rise.

3.5.3.3 Increased Short-term Erosion

Short-term erosion (by storms/cyclones) is not expected to be appreciable greater than at present, but there will be increased occurrences of overwash.

3.5.4 Overall Threat

When considering the potential erosion to the foreshore of Port Dennison West Beach it is necessary to consider the threat that currently exists and that which will emerge in the future (as a consequence of any ongoing long-term erosion trends as well as the likely effects of future climate change).

3.5.4.1 Present-day climate scenario

As stated previously the greatest threat to foreshore infrastructure at Port Dennison West Beach is due to the potentially damaging effects of storm tide inundation in conjunction with cyclone waves. However, this Study concerns itself with the threat posed by an eroding shoreline - the threat of storm tide inundation has previously been addressed by the *Bowen Shire Storm Tide Study* (Connell Wagner, 2004).

Since Port Dennison West Beach consists of a number of foreshore types, the overall threat of erosion in each of these areas warrants separate comment.

Sandy beach immediately alongside the Jetty

> This beach has been stable over the past 33½ years. Nevertheless storms have caused short-term erosion events, and will continue to do so. Erosion events will be followed by accretionary periods of beach re-building - this is an intrinsic part of natural coastal processes.
>
> During severe storms/cyclones overwash is expected to occur. Whilst damaging non-essential infrastructure behind the beach (such as parkland vegetation and paths) such events will not cause appreciable recession of the shoreline position because of overwash.

Rock armoured seawall

> Historical aerial photographs suggest that a seawall has been in place at this site for over 30 years. Nevertheless, its current structural form and condition is relatively poor in places. Standard design principles such as appropriate rock grading and size, minimum of two layers of interlocking rocks, toe and crest protection and a filter arrangement between the rock and underlying soil are not evident in its construction.
>
> It appears that maintenance work carried out on the wall has entailed the random placement of rock of varying sizes to form a very loose matrix on the face of the seawall. Consequently it cannot be considered a robust foreshore protection structure in its current condition. It is difficult to predict its structural performance under the loadings that would be applied by a severe storm/cyclone. It is likely to be overtopped by waves and to fail in places; but it could nevertheless provide satisfactory protection to the Catalina Interpretative Centre for one such future event.
>
> However once exposed to severe wave action, the wall will then very likely require substantial rehabilitation. Appropriate structural rectification works would need to be determined at that time, however previous experience of seawall maintenance suggests that such rehabilitation is likely to be facilitated most economically by reconstruction - as opposed to simply repairing the existing structure.

Adhoc rubble seawall

The section of foreshore either side of the concrete ramp has been armoured by the placement of building debris. Whilst this can provide some erosion protection during day-to-day conditions and mild storms, such adhoc works typically have very limited value as robust seawalls during more severe events.

To date the effectiveness of this form of seawall at Port Dennison West Beach has been somewhat better than expected for such works. This is because during severe storms the seawall can be overtopped - with wave energy being dissipated behind the wall rather than directly on it. However this overtopping can cause scouring of the material behind the wall, which promotes seawall collapse and foreshore recession.

The existing damaged area of hardstand to the west of the ramp will migrate further inland during severe storms/cyclones, although it is difficult to determine the extent of this additional damage given the current deficiencies of foreshore response modelling for such arrangements.

It is also expected that the adhoc rubble walls on the eastern side of the concrete ramp will require considerable ongoing maintenance if they are to continue providing what is already only a very limited role in erosion mitigation.

Sandy beach between the Sailing Club and the un-named creek

Recent storm erosion has prompted beach nourishment activities through the placement of sand in front of private properties near the creek entrance. This sand placement has reduced the threat of storm erosion to private land.

Again, whilst significant overwash is expected along this reach during the peak of severe storms/cyclones, the foreshore itself is not expected to recede to the extent that private residences and the Sailing Clubhouse will be threatened by erosion/undermining. Numerical modelling of beach response in this area would provide greater certainty in this regard, but such modelling work would first require foreshore and nearshore surveys to be undertaken.

Sandy beach between the un-named creek and Doughtys Creek

This foreshore reach is the most exposed section of Port Dennison West Beach. Consequently it is more dynamic than the other sandy foreshores to the east. Recent storm erosion has resulted in some foreshore trees being damaged. During severe storms/cyclones overwash is expected to occur. Whilst damaging non-essential infrastructure behind the beach (such as parkland and vegetation) such events will not cause appreciable recession of this shoreline position.

3.5.4.2 Future climate change scenario

When determining the threat of erosion to Port Dennison West Beach over a planning period of 50 years, it is necessary to consider the combined effects of long-term, short-term and climate change influences. The overall threat of future erosion to each of the foreshore types are as follows:

Sandy beach immediately alongside the Jetty

Future climate change will result in increasing occurrences of storms that cause overwash of this shoreline - increasing the risk of storm tide inundation and the damage caused to foreshore infrastructure by associated wave action.

However since overwash does not cause significant recession of the foreshore, this increased occurrence does not on its own necessarily result in greater short-term erosion. Short-term erosion by storms/cyclones will not be appreciable greater than at present.

As a consequence of sea level rise, the beach is expected to recede approximately 4 metres inland from its present alignment.

Rock armoured seawall

If left in its present structural form the seawall will require increasing maintenance in order for it to fulfil its intended function as future climate change occurs. It is likely that a severe storm (or consecutive mild storms) will instigate structural failure.

Adhoc rubble seawall

Similarly, if this foreshore is left in its present form there will be increasing maintenance required in order for it to fulfil its intended function. Given that it has only limited functionality as a seawall anyway, there appears little value in committing to an increasing commitment of maintenance effort.

The existing damage to the hardstand area alongside the concrete ramp will expand, although the extent of that increased damage is difficult to estimate.

Sandy beach between the Sailing Club and the un-named creek

The comments presented above in relation to the beach alongside the Jetty are applicable to this section of the foreshore namely; an increase in the occurrences of overwash during storms (but with limited recession as a consequence),and a 4m recession of the shoreline position as a consequence of sea level rise.

These combined effects increase the risk of storm tide inundation damage to the sailing clubhouse and local residences fronting Thomas Street.

Sandy beach between the un-named creek and Doughtys Creek

As with the other sandy shorelines of Port Dennison West Beach, this foreshore precinct will experience increased occurrences of overwash.

The position of the shoreline is expected to gradually migrate 17 metres inland over the 50 year planning period. This will be as a result of long-term erosion processes (causing 13 metres recession), in conjunction with the effects of sea level rise (4 metres recession).

Foreshore parkland and trees will be lost under such a scenario. The expected recession will not reach the pavement of Quay Street, but would increase the threat of short-term erosion to that road infrastructure.

In summary

Clearly an erosion mitigation strategy is required to protect the various foreshore types along Port Dennison West Beach from the increasing threat of erosion in coming years. A discussion of possible mitigation options, resulting in a recommended strategy is presented in Section 6.3 of this report.

3.6 Queens Beach

The Queens Beach coastal reach considered by the Study is shown on Figure 3.9. It extends westward some 4.3kms from the headland of Cape Edgecumbe to Yasso Point at the mouth of the Don River.

Figure 3.9 : Foreshores of Queens Beach

The orientation of the shoreline varies along this coastal reach, with the eastern half facing almost directly north and the western half facing north-east. The entrance to an un-named ephemeral creek is located near the confluence of these two shoreline orientations.

There is a more defined frontal dune along the northern half of Queens Beach. Consequently the crest of the beach slope is approximately 1 metre higher than it is along the eastern half of the shoreline.

The eastern-most end of Queens Beach is referred to by local residents as "the Pocket". This sub-reach has its own particular erosion issues and has therefore been included as a separate site to be investigated by the Study.

The Queens Beach shoreline is primarily a sandy beach; however there is a mixture of different armoured seawalls on an approximately 420m long section of foreshore at the end of Soldiers Road. These seawalls protect two caravan parks and a number of private properties. An analysis of the structural integrity and future performance of the various seawalls is beyond the scope of this Study.

At some point in the past, rock armouring has been placed along sections of the ocean frontage of Hansen and Case Parks although (as can be seen in Figure 3.10) most of this has now been dispersed across the beach slope by wave action.

Consequently these rocks now provide negligible benefit to the mitigation of beach erosion, particularly during severe events when the elevated ocean water levels and strong wave action attack the upper beach slope, rather than the lower beach slope where rocks are now loosely scattered.

Figure 3.10 : Rock Strewn Across Foreshore at Hansen Park and Case Park

When considering the erosion threat to the entire length of Queens Beach, it is necessary to consider the following processes:

- Long-term Erosion;
- Short-term Erosion; and
- Effects of Climate Change.

3.6.1 Long-term Erosion

As part of a comprehensive state-wide program of surveying cross-shore profiles at coastal locations throughout Queensland, the Beach Protection Authority established a number of transect lines on the shores of Queens Beach. Survey data for these transects has been provided by the Coastal Unit of the Queensland Climate Change Centre of Excellence (Department of Environment and Resource Management) to assist with this Study.

Transects across the foreshore and nearshore area were surveyed by the Beach Protection Authority at several stations along Queens Beach in March 1977, December 1978, March 1980, October 1980, May 1989 and September 1995. Typically those surveys extended 50 metres inland of the frontal dune; and approximately 2kms offshore. Historical aerial photographs have been acquired for this period of surveys to further assist in their interpretation.

Long-term recession on ocean beaches can be imperceptible; and in many cases can be masked by the more dramatic erosion and accretion which accompany storm events. It can therefore be difficult to identify rates from historical data, even if that data is extensive and spans many years. Attempts to identify long-term erosion trends on the Queens Beach foreshore through comparisons of the various historical surveys (assisted by an inspection of the aerial photographs) has proved inconclusive.

It is evident from the historical data and anecdotal evidence that the Queens Beach foreshore is very dynamic - with its position and profile continually (and often significantly) changing in response to natural erosion and accretion processes. The scale and timing of dramatic short-term erosion and the subsequent slow post-storm recovery are such that any long-term gradual loss of sand from the active beach system is masked.

Given the undetectable rate of long-term recession, it is assumed for the purposes of this Study that there is no substantial long-term erosion occurring on the Queens Beach foreshore. The significant erosion that has been occurring over the years is considered to be caused by short-term events such as storms and cyclones in association with typical slow recovery.

However when formulating an appropriate strategy to accommodate storm erosion on this coastal reach (both now and in the future), a strategy that can readily accommodate underlying long-term erosion has considerable merit.

3.6.2 Short-term Erosion

Numerical modelling of beach response to severe cyclone events has been undertaken for a number of locations along Queens Beach, three representative locations have been investigated, namely:

- Queens Beach South - in the vicinity of Case Park and Hansen Park;
- Queens Beach Central - along the ocean frontage of the golf course;
- Queens Beach North - fronting the Queens Beach Foreshore Reserve.

The loose rock strewn over the beach slope along the ocean frontage of Case and Hansen Parks (refer earlier Figure 3.10) provides negligible armouring of the Queens Beach South shoreline and consequently has not been included as a robust seawall structure by the SBEACH modelling.

Figure 3.11, Figure 3.12 and Figure 3.13 present summaries of the beach response modelling for these three indicative coastal sub-reaches. Each shows the predicted eroded beach profile for 50 year and 100 year ARI events occurring under the present day climate scenario.

The volumes of eroded sand and the approximate shoreline recessions are summarised in Table 3.2.

Section of foreshore	50 year ARI		100 year ARI	
	volume	*recession*	*volume*	*recession*
Queens Beach South	20.4 m^3/m	33m	23.8 m^3/m	33m
Queens Beach Central	45.7 m^3/m	26m	58.7 m^3/m	43m
Queens Beach North	43.1 m^3/m	33m	63.4 m^3/m	48m

Table 3.2 : Queens Beach Short-term Erosion - present day climate

The predicted erosion at Queens Beach South for the 50 year and 100 year ARI events are virtually the same. This is primarily because the particularly wide and shallow seabed approach to this section of foreshore means that waves are significantly depth limited. Given that there is only 23cm difference in the storm tide levels of these events (refer Table 2.2), there is minimal difference in the wave energies that reach the shore.

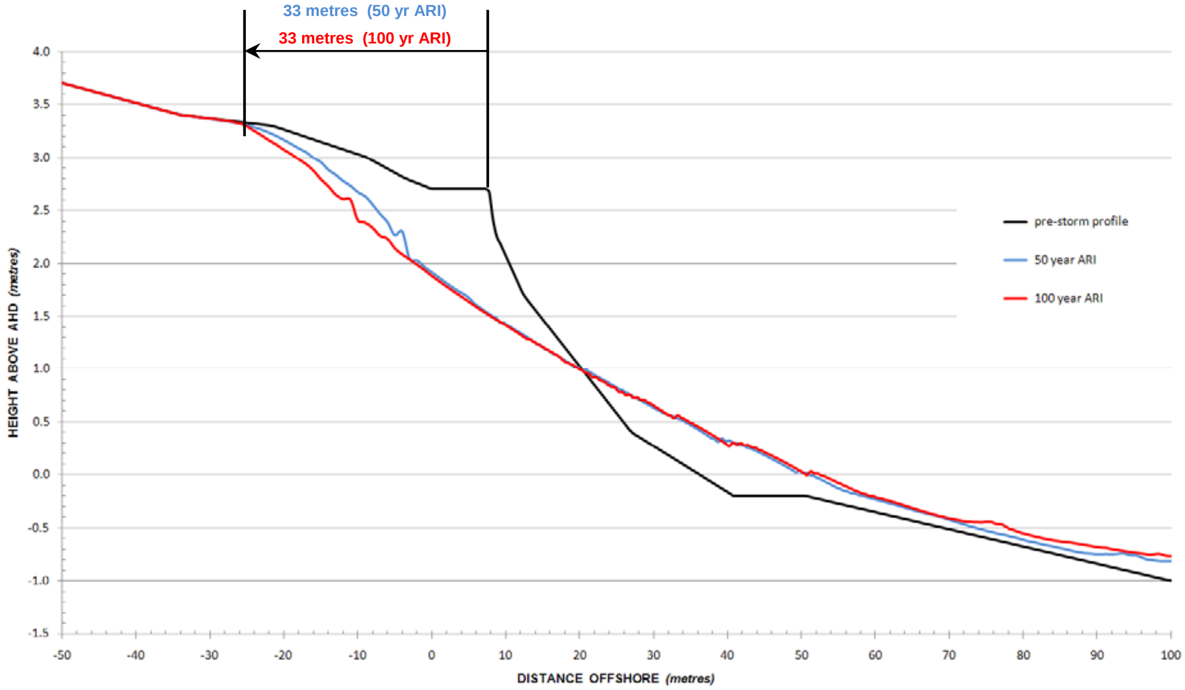


Figure 3.11 : Results of Beach Response Modelling for Queens Beach South - present day scenario

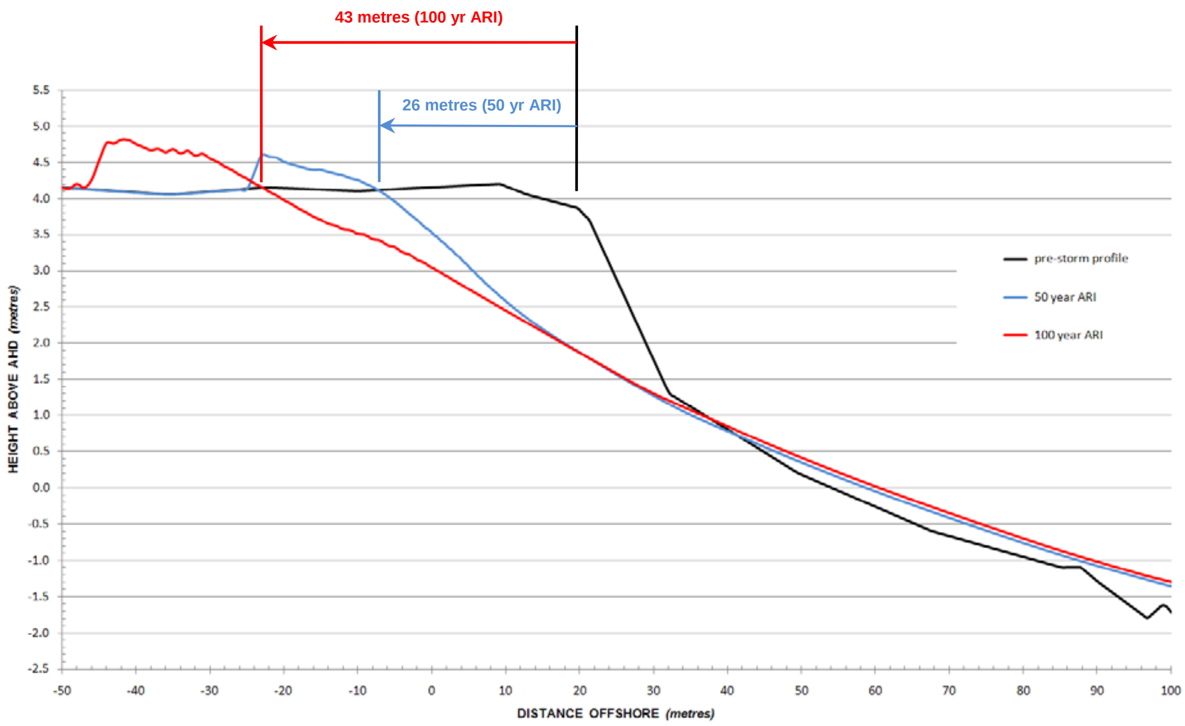


Figure 3.12 : Results of Beach Response Modelling for Queens Beach Central - present day scenario

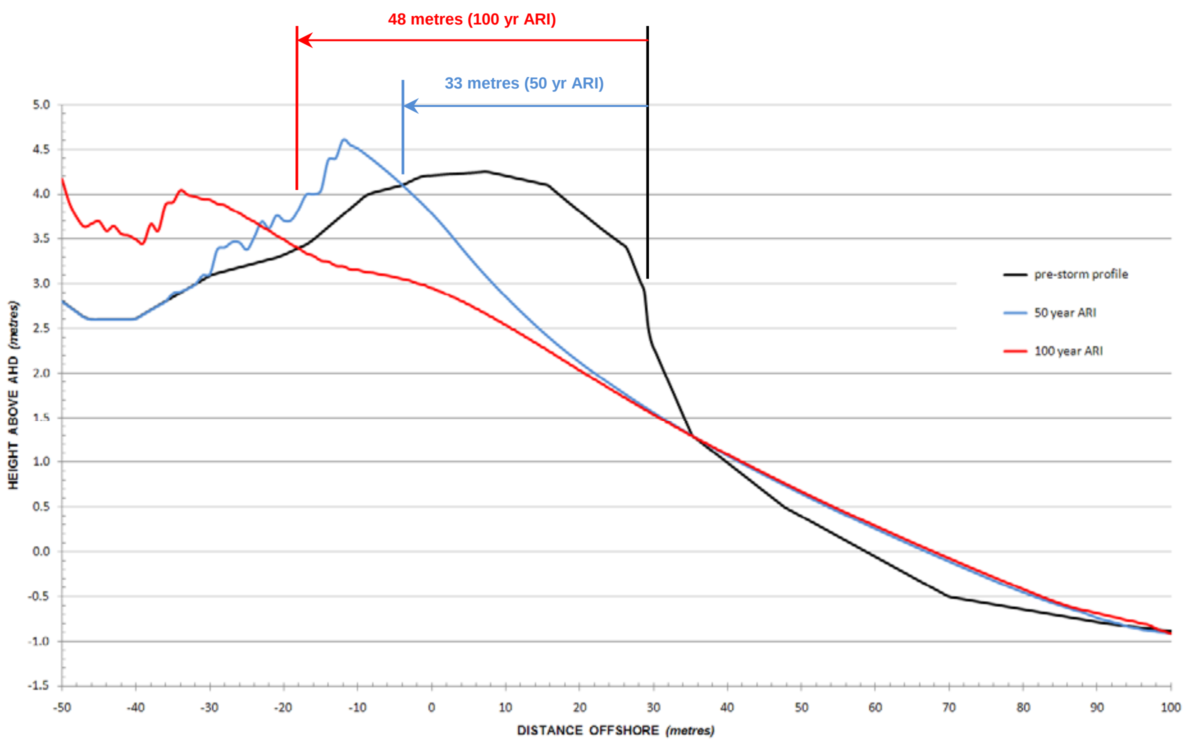


Figure 3.13 : Results of Beach Response Modelling for Queens Beach North - present day scenario

3.6.3 Effects of Climate Change

The preceding discussions of beach response to short-term erosion by cyclones are based on recent and present-day climate scenarios. If climate changes develop as predicted, the foreshores of Queens Beach will be subjected to potentially greater storm and cyclone energy, higher waves, stronger winds and increased ocean water levels.

3.6.3.1 Sea Level Rise

The rate of sea level rise as a consequence of climate change will be very gradual, and the timescales associated with the coastal processes shaping the nearshore and foreshore regions will keep pace with the slow sea level rise. Consequently the basic form of the beach profile will be maintained in relation to the gradually rising sea level in front of it.

Nevertheless, there will be a gradual recession of the position of beach, which will effectively reduce sand buffers in front of existing foreshore infrastructure. On the basis of a sea level rise of 0.4 metres over a 50 year planning period the future recession of Queens Beach is expected to be:

- *Queens Beach South* : 12 metres - removing approximately 19.8 m^3/metre of sand from the upper sections of the existing profile.
- *Queens Beach Central* : 7 metres - removing approximately 12.6 m^3/metre of sand from the upper sections of the existing profile.
- *Queens Beach North* : 9 metres - removing approximately 19.1 m^3/metre of sand from the upper sections of the existing profile.

3.6.3.2 Increased Short-term Erosion

Numerical modelling of beach response using the SBEACH model has also been undertaken using the increases in sea levels and more severe wave conditions that are expected to occur over the coming 50 years (refer to discussions in Section 2.4).

Figure 3.14, Figure 3.15 and Figure 3.16 present summaries of the SBEACH modelling for the three representative foreshore reaches along Queens Beach. The figures present the predicted eroded profile at each precinct for 50 year and 100 year ARI events occurring in 50 years' time under a future climate scenario.

The volumes of eroded sand and the approximate shoreline recessions are summarised in Table 3.3. The recessions listed in the table would be measured from the position of the shoreline in 50 years time.

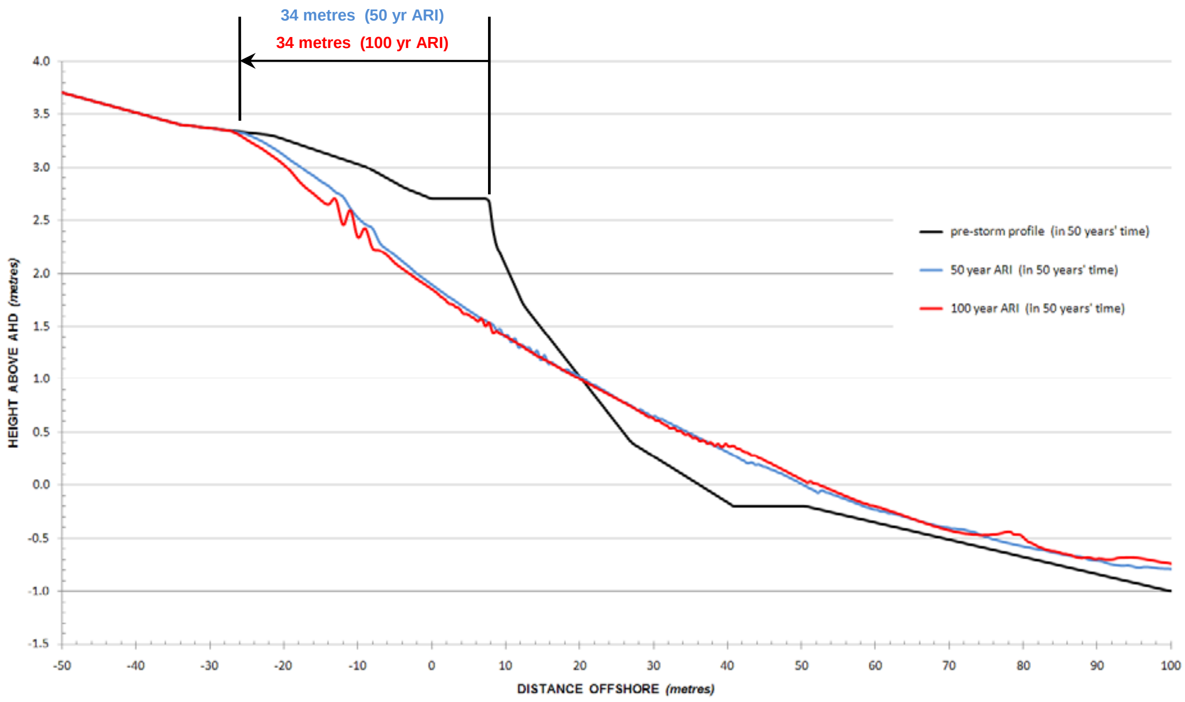


Figure 3.14 : Results of Beach Response Modelling for Queens Beach South - future climate scenario

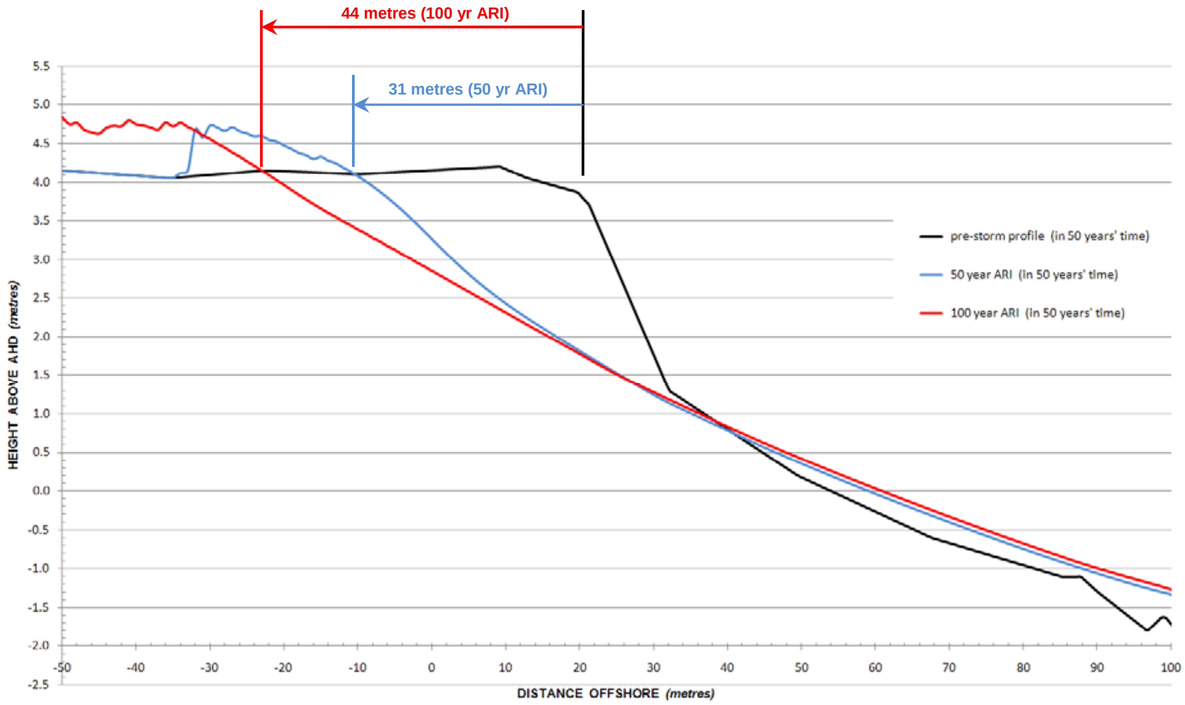


Figure 3.15 : Results of Beach Response Modelling for Queens Beach Central - future climate scenario

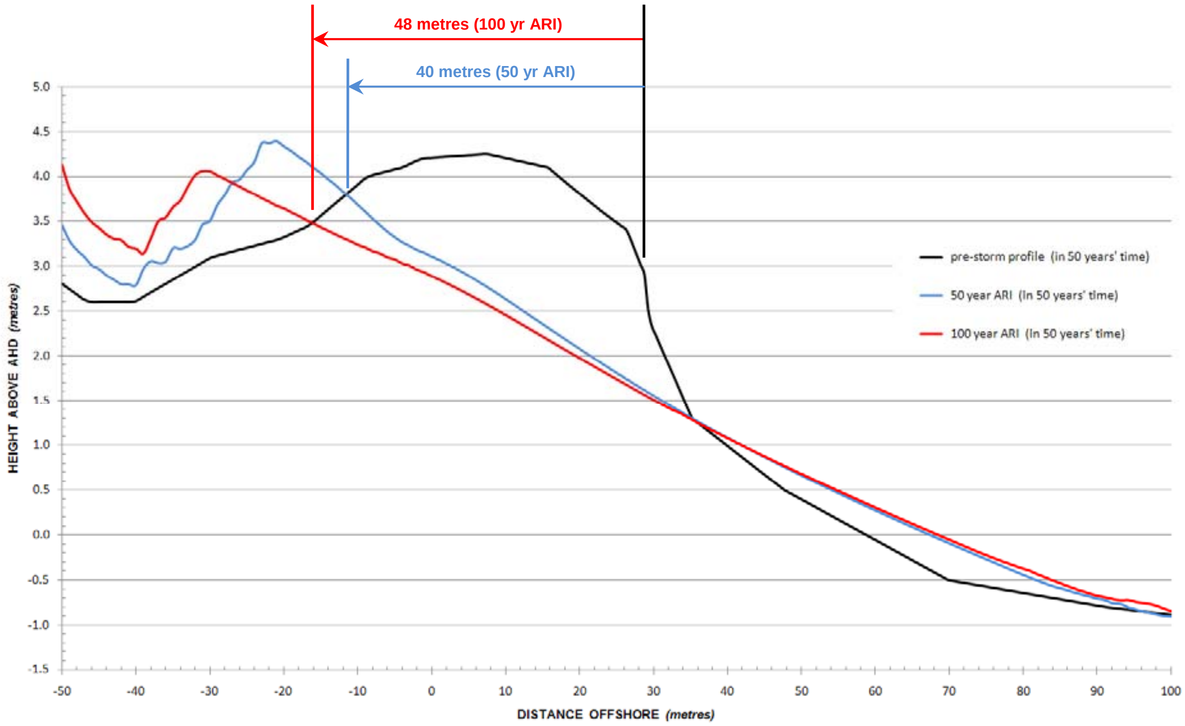


Figure 3.16 : Results of Beach Response Modelling for Queens Beach North - future climate scenario

Section of foreshore	50 year ARI		100 year ARI	
	volume	*recession*	*volume*	*recession*
Queens Beach South	22.4 m^3/m	34m	25.5 m^3/m	34m
Queens Beach Central	51.4 m^3/m	31m	64.6 m^3/m	44m
Queens Beach North	55.4 m^3/m	40m	64.6 m^3/m	48m

Table 3.3 : Queens Beach Short-term Erosion - future climate change

3.6.4 Overall Threat

When investigating foreshore erosion at Queens Beach it is necessary to consider the threat that currently exists and that which will emerge in the future (as a consequence of the likely effects of future climate change). A planning period of 50 years has been adopted for the Study when considering future erosion risk.

A summary of predicted erosion threat is offered in Table 3.4.

Section of foreshore	present-day climate		future climate change[6]	
	50 year ARI	*100 year ARI*	*50 year ARI*	*100 year ARI*
Queens Beach South	33m	33m	46m	46m
Queens Beach Central	26m	43m	38m	51m
Queens Beach North	33m	48m	49m	57m

Table 3.4 : Queens Beach - Summary of Erosion Threat

3.6.4.1 Present-day climate scenario

The current threat of erosion along the Queens Beach foreshore is due to short-term erosion caused by severe cyclones. The results of the SBEACH numerical modelling presented in Table 3.4 have been plotted as erosion Threat Lines on aerial photographs of Queens Beach as follows:

- Queens Beach South : Figure 3.17
- Queens Beach Central : Figure 3.18
- Queens Beach North : Figure 3.19

Queens Beach South

Much of the frontage of Queens Beach South is along Case Park and Hansen Park. Consequently the threat of 33 metres of foreshore recession in the event of 50 year ARI and 100 year ARI cyclones relates primarily to undeveloped parkland. Paths, barbeque facilities and shelters are at risk of damage during severe cyclones.

However there are also private properties along this reach - these being near the intersection of Horseshoe Bay Road and Rose Bay Road; as well as between Case Park and Hansen Park. As can be seen from Figure 3.11, the erosion threat presently does not encroach into private properties near the Horseshoe Bay Road and Rose Bay Road intersection. It threatens only the open space between the seaward property boundaries of these Lots.

Between Case and Hansen Parks there are approximately ten Lots with direct frontage onto the beach. The plan alignment of the beach crest currently lies within the seaward boundaries of those properties. Consequently erosion of these properties by future storms and cyclones is inevitable. When the 50 year ARI cyclone Threat Line is overlain on these properties, several structures and a private residence are seen to be directly at risk.

[6] Includes potential effects of increased severity of storm / cyclone characteristics and recession of foreshore due to sea level rise.

Queens Beach Central

As can be seen in Figure 3.18, most of the frontage of Queens Beach Central is along the Golf Course. Consequently the potential for 26 metres and 43 metres of foreshore recession due to 50 year ARI and 100 year ARI cyclones will threaten the fairways and putting greens along the shoreline.

The Queens Beach Surf Lifesaving Club is also located within the coastal reach of Queens Beach Central. The clubhouse is located only some 25 metres from the beach and is therefore currently at risk of damage by erosion associated with 50 year ARI and 100 year ARI events.

Queens Beach North

The entire frontage of Queens Beach North is along the Queens Beach Foreshore Reserve. Whitsunday Regional Council has prepared a *Foreshore Management Plan* for the reserve that sets it aside from future development pressures. The reserve is to be managed so as to protect its environmental, social and cultural values in a way that is consistent with all relevant legislation.

A fundamental objective of the management strategy is to ensure that the Queens Beach Foreshore Reserve remains as a natural coastal buffer that will accommodate physical and biological processes, preserve visual amenity, and maintain public use and access of the foreshore.

Consequently the potential for 33 metres and 48 metres of foreshore recession due to 50 year ARI and 100 year ARI cyclones will be located entirely within the buffer established by the Queens Beach Foreshore Management Plan.

Figure 3.17 : Present-day Erosion Threat to the Foreshore of Queens Beach South

Figure 3.18 : Present-day Erosion Threat to the Foreshore of Queens Beach Central

Figure 3.19 : Present-day Erosion Threat to the Foreshore of Queens Beach North

3.6.4.2 Future climate change scenario

Given the notion of negligible long-term background erosion along the Queens Beach foreshore, the future erosion threat will be due to the occurrence of severe storms/cyclones in conjunction with adverse climate change influences.

The results of the SBEACH numerical modelling presented in Table 3.4 have been plotted as erosion Threat Lines on aerial photographs of Queens Beach as follows:

- Queens Beach South : Figure 3.20 (update of Figure 3.17 for climate change)
- Queens Beach Central : Figure 3.21 (update of Figure 3.18 for climate change)
- Queens Beach North : Figure 3.22 (update of Figure 3.19 for climate change)

It is important to appreciate that the Threat Lines do not represent the position of the foreshore in 50 years time - they represent where the threat of 50 year ARI and 100 year ARI storm erosion could reach if such events were to occur at that time.

Queens Beach South

The predicted 12 metre recession of the foreshore due to sea level rise, in conjunction with the predicted increased threat of 34 metres of cyclone-induced erosion, means that the Threat Lines for the 50 year ARI and 100 year ARI events will both be 46 metres inland from the existing shoreline in 50 years time.

As can be seen from Figure 3.20, this will still only threaten non-essential infrastructure in Case and Hansen Parks. However the future threat of cyclone erosion will then include the entire width of the park behind properties at the Horseshoe Bay Road and Rose Bay Road intersection. Indeed some private properties and residences near Case Park will be directly threatened.

Between Case and Hansen Parks the position of the shoreline is expected to recede a further 12 metres into private properties as a consequence of future sea level rise. The erosion threat will therefore encroach further inland, and several residences will be at greater risk of loss by cyclone-induced erosion.

Queens Beach Central

The potential for 31 metres and 44 metres of foreshore recession due to 50 year ARI and 100 year ARI cyclones, in conjunction with the 7 metre shoreline retreat predicted as a consequence of sea level rise, means that a greater width of fairways and putting greens at the golf course will be under threat.

The Queens Beach Surf Lifesaving Clubhouse falls within the threats associated with 50 year ARI and 100 year ARI events.

Queens Beach North

The potential for 40 metres and 48 metres of foreshore recession due to 50 year ARI and 100 year ARI cyclones, in conjunction with the predicted 9 metre shoreline retreat as a consequence of sea level rise, means that the future threat of erosion is confined to the Queens Beach Foreshore Reserve. Only non-essential infrastructure is threatened.

In summary, there is currently a threat of cyclone-induced erosion along the entire length of Queens Beach. Most of the threatened shoreline constitutes foreshore parkland, the golf course or the Queens Beach Foreshore Reserve. Private properties and residences at the eastern end of Queens Beach are currently also threatened by cyclone-induced erosion.

In all cases the threat is expected to increase in coming years as a consequence of climate change.

A discussion of possible mitigation options, resulting in a recommended strategy for Queens Beach is presented in Section 6.4 of this report.

Figure 3.20 : Future Erosion Threat to the Foreshore of Queens Beach South

Figure 3.21 : Future Erosion Threat to the Foreshore of Queens Beach Central

Figure 3.22 : Future Erosion Threat to the Foreshore of Queens Beach North

3.7 The Pocket Beach

The Pocket Beach is located at the eastern-most end of Queens Beach, immediately alongside Cape Edgecumbe (refer to the earlier Figure 3.9). Being located alongside the western flank of the Cape, it is more protected than other foreshores further to the west along Queens Beach.

The area behind the beach consists of parkland; however the alignment of Horseshoe Bay Road at the eastern-most end of The Pocket Beach is such that a section of the road pavement is located only some 10 - 12 metres from the top of the beach slope.

This, in conjunction with storm erosion over the years, has resulted in foreshore stabilisation work (consisting of sand-filled geotextile bags) being implemented in 2004 to protect Horseshoe Bay Road and its intersection with Murrays Bay Road. These two roads provide the only land access to the local communities of Horseshoe Bay and Murray Bay respectively. Consequently any erosion that causes these roads to be unserviceable will seriously compromise access during or after a severe cyclone event.

For the purposes of the Study, The Pocket Beach is considered to extend some 240 metres along the shoreline and includes the entire length of foreshore that is presently armoured with sand-filled geotextile bags.

When considering the erosion threat to The Pocket Beach it is necessary to consider the following:

- Long-term Erosion;
- Short-term Erosion; and
- Effects of Climate Change

3.7.1 Long-term Erosion

As is the case with the other foreshores of Queens Beach, it is not possible to conclusively identify long-term background erosion rates of The Pocket Beach from an inspection of historical beach transects and aerial photographs.

The scale and timing of the dramatic short-term changes induced by frequent storms and cyclones are such that any long-term gradual loss of sand from the active beach system is masked. Therefore it is assumed for the purposes of the Study that there is no substantial long-term erosion occurring on The Pocket Beach. The erosion problem that has been occurring over the years (which triggered the need for armouring by geotextile sand bags) is considered to have been caused by short-term events such as storms and cyclones, in conjunction with slow recovery of the beach following such events.

Nevertheless when formulating an appropriate strategy to accommodate storm erosion on The Pocket Beach (both now and in the future), a strategy that readily accommodates underlying long-term erosion will have considerable merit.

3.7.2 Short-term Erosion

Numerical modelling of beach response to severe cyclone events has been undertaken for The Pocket Beach. Section 2.3.2 offers some discussion on the methodology applied to the modelling process. The SBEACH model can incorporate a seawall within the cross sectional profile of a foreshore as it calculates the beach's cross-shore response to storm conditions.

The structural characteristics of the seawall constructed of sand-filled geotextile bags at The Pocket Beach have been utilised in the SBEACH modelling. Those details have been obtained from drawings[7] provided by Whitsunday Regional Council and indicate the following important aspects:

- the crest level of the wall is at RL+3.0m AHD (except for the eastern-most length of 65m where the crest is at RL+2.6m AHD);
- the toe level of the wall is 0.3 metres below the naturally occurring beach level (at the time of construction in 2004); and
- the wall has been designed to accommodate a significant wave height[8] H_s of 1.5 metres.

Figure 3.23 presents a summary of the SBEACH modelling for The Pocket Beach and shows the predicted eroded profile for 50 year and 100 year ARI events occurring under the present day climate scenario. The modelling indicates that the geotextile bag wall will fail during these severe events. It therefore will not provide protection against severe storm erosion. Failure of the structure occurs as a consequence of three almost simultaneous processes, namely:

- Undermining - As the storm builds, sand on the beach in front of the seawall is eroded and transported offshore. The level of the beach drops below the founding level of the wall causing it to be significantly undermined and instigating collapse of the structure.
- Overtopping - As the storm tide approaches its peak, waves wash over the top of the geotextile bag wall. The rates of overtopping water are considerable, and well in excess of what the soil immediately behind the crest of the geotextile bag wall can accommodate. Significant scour of this material occurs, causing the unsupported top of the wall to collapse into the scour area behind. This lowers the crest, which allows even greater overtopping, causing further scour and the rapid progressive collapse of the seawall.

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[7] Design drawings prepared by International Coastal Management for Bowen Shire Council.
Project titled "*Grays Bay, Bowen : Erosion Protection Works*"
No. 2557-9000 titled Site Plan Proposed, dated 07/05/2002
No. 2558-9000 titled Typical X-Section & Plan View, dated 17/05/2002
No. 2560-9000 titled X-Section 40 & 60, dated 07/05/2002

[8] Due to the random nature and size of waves, the term "*significant wave height*" is used by engineers and scientists to quantify wave heights in a sea state. It represents the average of all of the third highest waves that occur over a particular timeframe. It is written as H_s throughout this report.

- Waves exceed the design wave height of 1.5 metres - As the 100 year ARI storm builds towards its peak, the wave height incident on the seawall itself increases. A maximum H_s of 1.7 metres occurs, which is greater than the design wave conditions nominated on the design drawings.

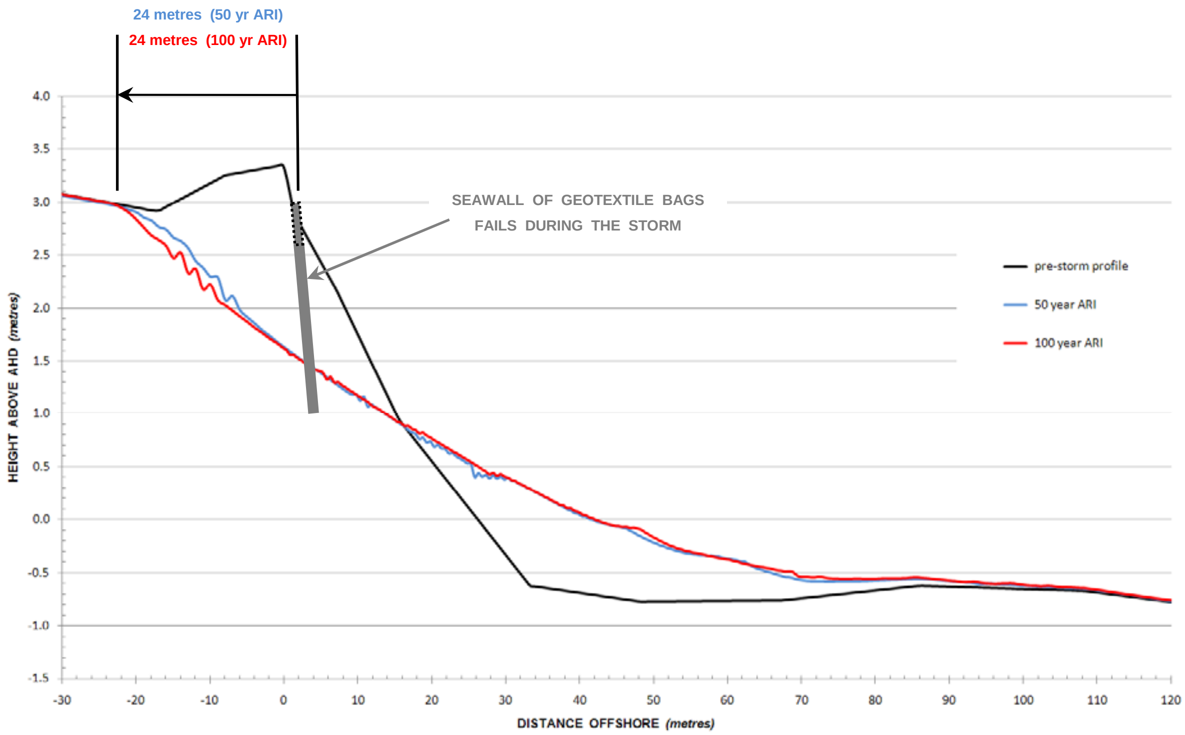

Figure 3.23 : Results of Beach Response Modelling for The Pocket Beach - present day scenario

The beach response to the 50 year and 100 year ARI events are similar. This is because the waves are "depth limited". That is, the energy that reaches the foreshore during each of these events is determined by the depth of water over the seabed approaches to The Pocket Beach. The very flat approach slopes cause the larger waves in the sea state to break offshore and dissipate much of their energy as they do so.

Given that there is only some 21cm difference in the level of the peak storm tide for the 50 year and 100 year ARI events (refer storm tide levels in Table 2.2), the depth limitation effects regulating the maximum waves reaching the shore are very similar. This accounts for the similarity in the predicted eroded profiles for 50 year and 100 year ARI events.

Reference to Figure 3.23 indicates that the foreshore above approximately RL+1.0m AHD is eroded, with the sand being deposited on the beach in front. As discussed above, the geotextile bag seawall will fail during each storm event. Approximately 30 m^3/metre of sand is removed from the dune by the 50 year ARI event; and 33 m^3/metre by the 100 year ARI cyclone. These correspond to foreshore recessions of approximately 24 metres for both storm scenarios.

3.7.3 Effects of Climate Change

If climate changes develop as predicted, The Pocket Beach will be subjected to potentially greater storm and cyclone energy, higher waves, stronger winds and increased ocean water levels.

3.7.3.1 Sea Level Rise

The rate of sea level rise as a consequence of climate change will be very gradual, and the timescales associated with the coastal processes shaping the nearshore and foreshore regions will keep pace with the slow sea level rise. Consequently the basic form of the beach profile will be maintained in relation to the gradually rising sea level in front of it. It is for this reason that the existing seawall arrangement will fail in coming years.

There will be a gradual recession of the position of beach, which will effectively reduce sand buffers in front of existing foreshore infrastructure. On the basis of a sea level rise of 0.4 metres over a 50 year planning period the future recession of The Pocket Beach is expected to be around 8 metres.

3.7.3.2 Increased Short-term Erosion

When determining the beach response in the coming 50 years it is necessary to make a determination as to whether the existing sand-filled geotextile seawall will still be in place. From a durability point of view, the service life of such a structure will be much less than 50 years. Furthermore the foreshore will be gradually receding as a consequence of sea level rise; therefore beach levels in front of the existing seawall will be gradually getting lower; with wave overtopping becoming more severe and more frequent. The wall will require increasing maintenance in future years - but will inevitably fail within the next 50 years.

Indeed at the time of report preparation, Whitsunday Regional Council is considering major repair and structural upgrading of the geotextile wall. This has come about because of damage to individual bags, as well as due to some overtopping and undermining of the structure itself. It could be assumed that the existing seawall would continue to be upgraded over the next 50 years (even possibly changed to a different structural form). However given that the primary objective of the Study is to identify an appropriate erosion mitigation strategy for The Pocket Beach (including upgrade/rebuild of the seawall), there is little merit in considering the performance of an existing structure that will have failed within the planning period.

The predicted foreshore response at The Pocket Beach as a consequence of future climate change is shown summarised on Figure 3.24.

Approximately 31 m^3/metre of sand would be removed from the dune by the 50 year ARI event; and 34 m^3/metre by the 100 year ARI cyclone. These correspond to foreshore recessions of 25 metres and 27 metres respectively - which would be measured from the position of the shoreline in 50 years time.

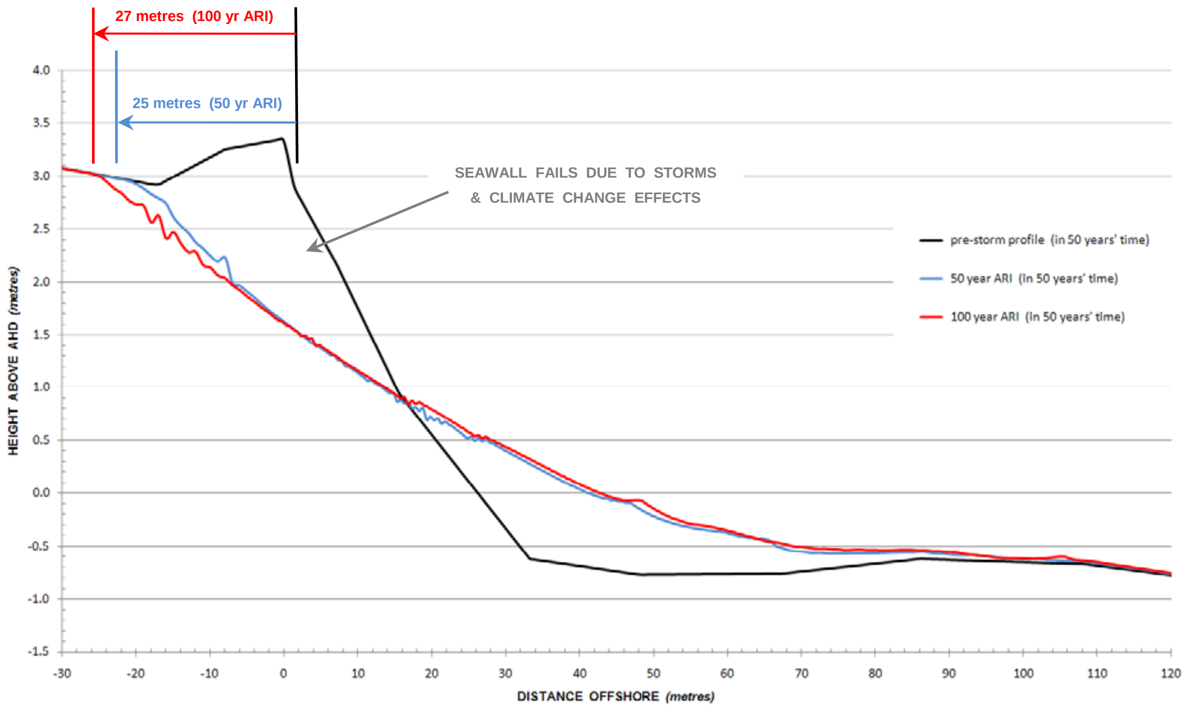

Figure 3.24 : Results of Beach Response Modelling for The Pocket Beach - future climate scenario

3.7.4 Overall Threat

When investigating foreshore erosion at The Pocket Beach it is necessary to consider the threat that currently exists and that which will emerge in the future (as a consequence of the likely effects of future climate change). A planning period of 50 years has been adopted for the Study when considering future erosion risk.

3.7.4.1 Present-day climate scenario

The current threat of erosion at The Pocket Beach is due to short-term erosion caused by severe cyclones. The results of the SBEACH numerical modelling presented in Section 3.7.2 indicates potential recession of 24 metres for both the 50 year and 100 year ARI events under a present-day climate scenario.

These Threat Lines are shown in Figure 3.25, having been plotted on a recent aerial photograph of the area.

Reference to this figure indicates that approximately 90 metres of Horseshoe Bay Road would be at risk of being lost to erosion by storms of 50 year ARI or greater. Lesser storms also represent a risk to shorter sections of this important road.

Figure 3.25 : Present-day Erosion Threat to The Pocket Beach

3.7.4.2 Future climate change scenario

When determining the threat of erosion to The Pocket Beach over a planning period of 50 years, it is necessary to consider the combined effects of short-term cyclone induced effects and climate change influences.

The predicted 8 metre recession of the current position of the shoreline as a consequence of sea level rise in conjunction with the increased threat from cyclones, means that the erosion threat extends further inland than at present.

The Threat Lines associated with 50 year and 100 year ARI cyclones at the end of a 50 year planning period are shown in Figure 3.26. As can be seen, the future threat to Horseshoe Bay Road increases to around a 120 metre length.

It is important to appreciate that the Threat Lines do not represent the position of the foreshore in 50 years time - they represent where the 50 year ARI and 100 year ARI storm erosion could reach if such events were to occur at that time.

Clearly an erosion mitigation strategy is required to protect road access to communities at Horseshoe Bay and Murrays Bay from the increasing threat of erosion in coming years. A discussion of possible mitigation options, resulting in a recommended strategy for The Pocket Beach is presented in Section 6.5 of this report.

Figure 3.26 : Future Erosion Threat to The Pocket Beach

3.8 Horseshoe Bay

The foreshore of Horseshoe Bay is shown on Figure 3.27. It is an approximately 110 metre long pocket beach contained between rocky headlands at either end. The beach faces north-east and being deeply recessed between the headlands is well protected. There is only a narrow directional window through which waves can propagate directly to the foreshore. Consequently waves arrive at the shoreline with an almost uniform alignment. Longshore transport on the beach is negligible with no discernable realignment of the beach over the years.

There is a grassed picnic area and paved car parking immediately behind the beach. The land rises steeply behind the car parking area onto a high ridge.

When considering the erosion threat to Horseshoe Bay it is necessary to consider:

- Long-term Erosion;
- Short-term Erosion; and
- Effects of Climate Change

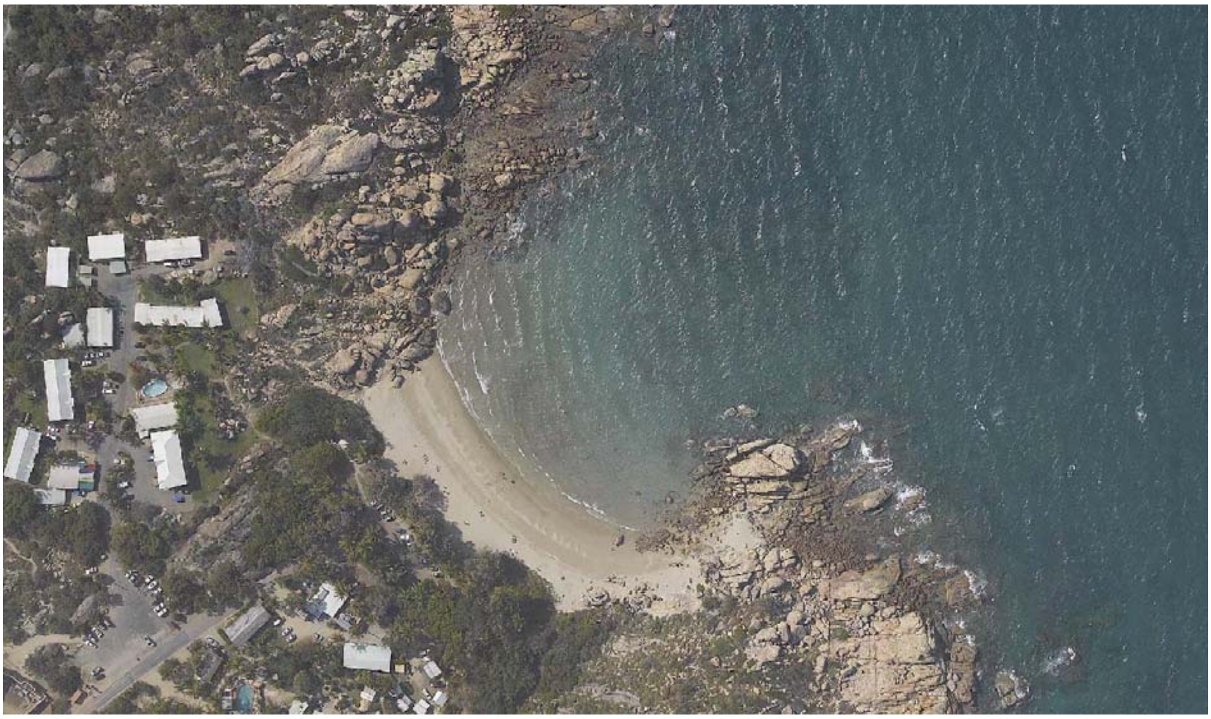

Figure 3.27 : Foreshore of Horseshoe Bay

3.8.1 Long-term Erosion

An inspection of historical aerial photographs indicates that the plan position of the foreshore at Horseshoe Bay has been stable over many years and is not evidently experiencing any on-going loss of sand that would result in long-term erosion.

3.8.2 Short-term Erosion

No foreshore surveys have been available for analysis by the Study; therefore it is not possible to undertake beach response modelling for the Horseshoe Bay foreshore.

Nevertheless site inspections indicate that despite the crest of the beach and the foreshore area immediately behind it being reasonably low, there is no evidence of any significant storm erosion having occurred at the site for quite some time. A grassy slope and mature coastal vegetation transition directly onto the sandy beach with no evidence of past erosion processes. This is due to the high degree of wave protection afforded to the pocket beach. There is invariably some onshore / offshore transport of sand occurring during storms, but there is no discernable net change to the sand volumes on the beach itself.

3.8.3 Effects of Climate Change

The stable nature of the Horseshoe Bay foreshore is expected to continue into the future.

Given the low level of the foreshore area, the biggest impact of future climate change on this foreshore will be the anticipated increase in sea level.

The rate of sea level rise as a consequence of climate change will be very gradual, and the timescales associated with the coastal processes shaping the nearshore and foreshore regions will keep pace with the slow sea level rise. Consequently the basic form of the beach profile along the Horseshoe Bay shoreline will be maintained in relation to the gradually rising sea level in front of it.

Nevertheless there will be a gradual recession of the beach, which will effectively reduce sand buffers in front of existing foreshore infrastructure. On the basis of a sea level rise of 0.4 metres over a 50 year planning period the future recession of the sandy foreshore is expected to be approximately 4 metres.

Short-term erosion (by storms/cyclones) is not expected to be appreciable greater than at present, but there will be increased occurrences of overwash.

3.8.4 Overall Threat

When investigating potential foreshore erosion at Horseshoe Bay it is necessary to consider the threat that currently exists and that which will emerge in the future (as a consequence of the likely effects of future climate change). A planning period of 50 years has been adopted for the Study when considering future erosion risk.

3.8.4.1 Present-day climate scenario

The beach has been stable over many years. Nevertheless storms have caused short-term erosion events, and will continue to do so. Erosion events will be followed by accretionary periods of beach re-building - this is an intrinsic part of natural coastal processes.

During severe storms/cyclones overwash is expected to occur. Whilst damaging non-essential infrastructure behind the beach (such as parkland vegetation, paths and car-parking facilities) such events will not cause appreciable recession of the shoreline position.

3.8.4.2 Future climate change scenario

Future climate change will result in increasing occurrences of storms that cause overwash of this shoreline - increasing the risk of storm tide inundation and the damage caused to foreshore infrastructure by associated wave action.

However since overwash does not cause significant recession of the foreshore, this increased occurrence does not on its own necessarily result in greater short-term erosion. Short-term erosion by storms/cyclones will not appreciable greater than at present.

As a consequence of sea level rise, the beach is expected to recede approximately 4 metres inland from its present alignment.

4 SHORELINE EROSION MANAGEMENT OPTIONS

4.1 Guiding Principles

There are a number of generic solutions and strategies which can be considered for erosion mitigation of shorelines. The *State Coastal Management Plan* provides a logically sound and robust approach to the problem by requiring all planning for Queensland's coastal areas to address potential impacts through the following hierarchy of approaches[9]:

- avoid — focus on locating new development in areas that are not vulnerable to the impacts of coastal processes and future climate change;
- planned retreat — focus on systematic abandonment of land, ecosystems and structures in vulnerable areas;
- accommodate — focus on continued occupation of near-coastal areas but with adjustments such as altered building design; and
- protect — focus on the defence of vulnerable areas, population centres, economic activities and coastal resources.

Application of this philosophy requires the determination of a Coastal Defence Line to effectively define whether or not the threat of erosion at a particular location is acceptable or not.

4.2 Coastal Defence Line

When considering foreshore protection measures, it is necessary to define a Coastal Defence Line which represents the landward limit of acceptable erosion. In other words, it forms the landward boundary of any erosion buffers to protect the shoreline at any particular site, or alternatively the alignment of any protection structure such as a seawall. Property and infrastructure landward of the Coastal Defence Line remains protected throughout the planning period, whereas foreshore areas seaward of the line lie within the active beach system (ie. within the erosion buffers).

Defining the position of the Coastal Defence Line at each site therefore entails consideration by Council as to what assets are to be defended. For example, at Kings Beach at Rose Bay, options could include a Coastal Defence Line on an alignment along the seaward edge of Bluewater Parade; or alternatively along the toe of the existing dune

[9] Required under the current State Coastal Planning Policy 2.2.1 (Adaptation to climate change).

4.3 Generic Erosion Mitigation Options

In essence, erosion mitigation options can be considered as "soft" non-structural solutions, or "hard" structural solutions.

Soft (or non-structural) solutions would typically include:

- Do nothing - allowing coastal processes to take their natural course while accepting the resulting losses;
- Avoiding development - by implementing regulatory controls with regard to building in undeveloped areas;
- Planned retreat - removing the erosion threat by relocating existing development away from the vulnerable area;
- Beach nourishment - rehabilitate eroding foreshores by direct placement of sand onto the beach, thereby providing an adequate erosion buffer;
- Beach scrapping - by using earthmoving plant and equipment to mechanically relocate sand from the inter-tidal zone or nearshore sandbanks into the upper beach or dune, thereby improving erosion buffers on the beach;
- Channel relocation - relocate dynamic river or creek entrances that may be contributing to shoreline erosion so that they have a lesser impact.

Hard (or structural) solutions that can be utilised to mitigate the threat of erosion include:

- Seawalls - which act as physical barriers to prevent shoreline recession;
- Seawalls with beach nourishment - where the seawall defines the inland extent of erosion, whilst sand is intermittently placed in front of the wall for improved beach amenity;
- Groynes / offshore breakwaters - used to inhibit the natural longshore movement of sand, thereby retaining sand on the eroding foreshore for longer periods;
- Groynes / offshore breakwaters with beach nourishment - where the structure assists in maintaining sand on the beach, and beach nourishment reduces the downdrift erosion caused by the groyne's interruption to longshore sand supply.

The optimum management strategy at any particular site may include "soft" or "hard" solutions, or a combination of both.

An appraisal of each generic erosion management option and potential application to the five project sites is set out below.

4.3.1 Non-structural Management Options

4.3.1.1 Do nothing

A "do nothing" strategy of coastal management can be appropriate where foreshore land is undeveloped, or assets and property are of only limited value. It is well suited to situations where available erosion buffers are sufficient to accommodate long-term and short-term erosion over the nominated planning period.

However on foreshores where existing development and infrastructure is threatened by erosion, the significant financial costs and social trauma associated with their loss are generally unacceptable.

4.3.1.2 Avoid development

Along sections of the foreshore that remain substantially undeveloped, erosion problems can be avoided by simply allowing the natural beach processes of erosion and accretion to occur unimpeded. This strategy also preserves the natural ecosystem, amenity and character of the beach.

The implementation of such a strategy would require appropriate planning controls to prevent future development and infrastructure occurring in these areas.

However such instruments are already in place, through the current designation of local Bowen foreshores as being within designated Erosion Prone Areas (refer discussions in Section 3.1). Presently any foreshore protection works or re-zoning applications within designated Erosion Prone Areas trigger an approval requirement from the Department of Environment and Resource Management.

4.3.1.3 Planned retreat

The intent of a planned retreat strategy is to relocate existing development outside of the area considered vulnerable to erosion, allowing this previously developed land to function as a future erosion buffer. This approach accommodates natural beach processes without attempting to influence them.

Where there are only small scale and non-essential Council assets being threatened by erosion, planned relocation can be the most viable and cost effective option. For example relocating paths, picnic and barbeque furniture, public toilets and other such low cost infrastructure within foreshore reserves is often much cheaper than implementing foreshore works to protect them.

However the social and financial costs involved in relocations and resumption of privately owned foreshore assets would be considerable - particularly given current property values in the coastal communities around Bowen. Strong adverse community response to this strategy is very likely. This, along with the very high cost of resumptions, is a considerable disadvantage of this option.

4.3.1.4 Beach nourishment

A strategy of beach nourishment entails the placement of sand directly onto the beach - either by using conventional earthmoving techniques or by pumping - so as to restore an adequate buffer width on the foreshore. The advantages of beach nourishment as an erosion mitigation strategy are that it has no adverse impacts on adjacent foreshores, and it maintains the beach amenity.

It is generally regarded as being the most desirable solution to erosion problems on foreshores where a suitable and economic source of sand is available.

A frequent community criticism of beach nourishment projects is that it does not provide a permanent solution to persistent long-term erosion problems - since it requires an on-going commitment to further renourishment. Nevertheless most other forms of direct intervention - even those of a “hard” structural nature - also require maintenance and a commitment to future costs (eg. the sand-filled geotextile bags forming the seawall at The Pocket Beach). When all impacts and costs are taken into account, the requirement for future nourishment campaigns typically does not detract from the cost/benefit advantage of a beach nourishment strategy.

However the ability to immediately replace sand lost in a storm so as to provide continual protection by an adequate buffer is often a challenging issue under this strategy. This is particularly the case given that there can be several storms or cyclones in any one season; and means that sand may need to be placed on the beach more than once in any cyclone season so as to be completely effective.

Sand used for nourishment is typically sourced from outside of the active beach system to offset any possibility that the benefit to the nourished foreshore is achieved at the expense of beach erosion elsewhere. This places a constraint on prompt restoration of buffers depleted by storm/cyclone events if such sources are not readily to hand.

The requirements for an effective beach nourishment strategy are determined by the local sediment transport regime. The objectives of such a strategy are to establish and maintain adequate erosion buffers. Local cross-shore sand transport processes dictate the overall volume of sand required in the buffer so as to accommodate a particular cyclone ARI. On the other hand, longshore transport processes determine the average rate at which sand needs to be added periodically to the buffers so that they are maintained in the long-term.

The buffer characteristics of sand volume and width are basically the volumes and widths that would be removed by short-term erosion processes. These characteristics were presented earlier in Section 3 for each of the five project sites under present-day climate conditions.

An appropriate beach nourishment strategy would be to initially create the buffers required for present-day conditions and to then continually monitor foreshore performance - increasing buffer volumes/widths as actual climate change conditions manifest themselves.

As discussed in Section 0, it is necessary to define a Coastal Defence Line which under a Beach Nourishment strategy represents the landward limit of acceptable beach fluctuations. In other words, it forms the landward boundary of the sand buffer which is to protect the shoreline. Property and infrastructure landward of the Coastal Defence Line will remain protected throughout the planning period, whereas foreshore areas seawards of the line fall within the dynamic erosion buffer.

Clearly such determinations will affect the volume of sand that needs to be initially imported to create the required buffer widths. For example, if the line was to lie immediately alongside Bluewater Parade at Rose Bay, then much of the existing foreshore between the road and the beach can be considered as being part of the required buffer. This would need much less sand to be placed than an option that had the line along the toe of the existing dune, which would then require importing a greater volume of sand to effectively create a completely new buffer area.

4.3.1.5 Beach scrapping

The concept of beach scrapping entails moving sand from lower levels of the cross-shore beach profile (typically from tidal flats immediately in front of a beach) up onto the beach slope or into the dune system. In essence it is simply redistributing sand that is already within the active beach profile and as such does not provide a net long-term benefit.

Beach scrapping can be beneficial in reinstating or reshaping the dune following a storm event, thereby assisting and accelerating natural processes that would otherwise rebuild the eroded dune system over much longer timeframes. However since scrapping lowers the seabed in front of the beach, it allows slightly greater wave energy to reach shore, offsetting to some degree the benefits achieved by reinforcing the beach face and/or dune.

Intensive scrapping activities would need to be undertaken on the nearshore intertidal flats of Bowen beaches on a regular basis - to ensure adequate sand was placed to create and maintain the necessary erosion buffers.

However the large volumes of sand that need to be initially placed by scrapping to form the buffers are unlikely to be economically viable or physically achievable within reasonable timeframes. Adverse impacts on intertidal flora and fauna communities are likely to be considerable under such works.

4.3.1.6 Channel relocation

In some cases foreshore erosion can be attributed in varying degrees to the dynamic nature of river or creek entrances. The sandbanks and shoals at the mouth of these natural waterways can affect tidal currents and wave patterns which can have an adverse effect on nearby shorelines. In some of those instances the problem can be alleviated somewhat by the planned relocation of the entrance or main channel flow.

4.3.2 Structural Management Options

4.3.2.1 Seawalls

Seawalls are commonly used to provide a physical barrier to continuing shoreline recession. Properly designed and constructed seawalls can be very effective in protecting foreshore assets by stopping any further recession. Consequently if such a strategy was to be implemented at any of the study sites, it would be constructed along the alignment of a nominated Coastal Defence Line.

However seawalls significantly interfere with natural beach processes by separating the active beach from sand reserves stored in beach ridges and dunes. In other words, seawalls can protect property behind the wall, but they do not prevent in any way the erosion processes continuing on the beach in front of them. In fact they very often exacerbate and accelerate the erosion.

Typically the effect of seawall construction on actively eroding shores is for the level of the beach in front of it to steadily lower - until the beach reaches a new equilibrium profile.

This lowering is primarily caused by wave action washing against the wall causing a high degree of turbulence in front of the structure - which scours the beach material. Wave energy reflected from the seawall also contributes to these scour and beach lowering processes. In many cases this lowering continues until the level of the beach is below prevailing tide levels, in which case the ocean simply washes against the face of the seawall and there is no beach for part (or possibly for all) of the tide cycle. The amenity of the beach and foreshore is therefore significantly degraded in order for the seawall to protect the area behind it.

This lowering of the sand level in front of seawalls can also present problems for the overall stability of the structure. Unless appropriate foundation and toe arrangements are constructed, the seawall can fail by undermining. Even if only damaged, it is extremely difficult and very expensive to repair existing seawalls that have been damaged by undermining. Indeed frequently the most cost effective solution is to demolish the structure and rebuild it with deeper and more robust foundations.

Another typically adverse impact of seawalls is that the original erosion problem that they were meant to solve is simply relocated further along the shore. Natural beach processes can no longer access the sand reserves in the upper part of the active beach that are behind the seawall. Consequently this sand cannot be moved downdrift by longshore sand transport processes to replenish the sand that these same processes are moving along the shoreline beyond the end of the seawall.

The deficit in sand supply to these downdrift sections initiates greater erosion, ultimately requiring extension of the seawall along the entire downdrift shoreline in order to protect it.

Seawalls have an effect on the visual amenity of a shoreline, and this can be quite adverse if the wall is high - or if it becomes so as a consequence of natural beach lowering in front of it. Such walls also inhibit easy public access across the foreshore onto the beach. Typically access stairways or ramps need to be provided on seawalls to ensure the safety of beach access by pedestrians.

Along urban foreshores, seawalls can offer sheltered habitats for vermin such as feral cats and rodents. This can adversely affect natural coastal flora and fauna values.

Appropriately designed and constructed seawalls are relatively expensive and they do not always compare favourably with the cost of other alternatives. However many seawalls constructed in Queensland have been built of rock during or immediately following severe sea conditions and significant cyclone erosion events. Under such circumstances appropriate design and construction of these walls may not have been implemented. Consequently most of the rock walls constructed in this manner require significant maintenance to prevent structural failure and the re-establishment of the original erosion problem.

Despite their disadvantages, rock seawalls are probably the most commonly used method in Queensland for protecting foreshore assets against the threat of erosion. This can probably be attributed to their versatility. They are relatively easy to construct using conventional earthmoving plant and equipment; and this is often accomplished by simply dumping rock on a prepared slope rather than applying more appropriate construction practises to create a robust structure.

Such adhoc methods can be used to not only protect long sections of foreshore, but also individual private properties. The substantial and solid appearance of rock walls can provide owners of foreshore assets with a sense of security - which unfortunately is frequently misguided given the often inadequate design and construction of these structures. Their subsequent failure or damage can not only lead to the re-establishment of the original erosion problem, but the scattering of removed rocks can adversely affect foreshore use and visual amenity.

The rock placed on the foreshore at the eastern end of Queens Beach (along the frontage of Case Park and Hanson Park) is an example of an ineffectual adhoc seawall.

As with any maritime structure, seawalls (whether they are of rock, sand-filled geotextile bags, concrete units, or indeed of any form) require rigorous engineering design and careful adherence to construction standards in order to be effective.

4.3.2.2 Seawalls with beach nourishment

To mitigate some of the disadvantages of seawalls, beach nourishment can also be undertaken to create a beach amenity in front of the structure. This sand placement also provides a reservoir of sand to feed the downdrift foreshore which would otherwise be starved of sand by the wall.

The seawall structure still serves as the primary defence against erosion so must be designed and constructed accordingly. The amount of sand initially placed as beach nourishment will depend on both where the Coastal Defence Line is located within the active beach profile and the extent of the amenity to be provided.

For example, if the Coastal Defence Line was located some distance inland then the existing foreshore between the seawall and the beach could be considered as the beach nourishment. Nevertheless, regular sand placement would be required to maintain the beach amenity, as well as prevent migration of the initial erosion problem northward along the shore. This intermittent renourishment would need to at least match the average net longshore sand transport rate.

4.3.2.3 Groynes

The longshore transport of sand on an eroding shoreline can be impeded by constructing groynes across the active beach. A groyne functions as a physical barrier by intercepting sand moving along the shore. Sand is gradually trapped against the updrift side of the structure, resulting in a wider beach on this “supply-side” of the structure. However the downdrift beach is deprived of the sand trapped by the groyne and therefore it erodes.

This process of updrift entrapment and downdrift erosion continues until such time as sand has accumulated on the updrift side of the groyne to the extent that it starts to feed around its seaward end. Sand supply is then reinstated to the downdrift foreshore; however this then simply maintains the shoreline on its eroded alignment.

Groynes cannot prevent the significant cross-shore erosion that typically occurs during cyclones. Nevertheless they have an indirect effect in that by having trapped sand on their updrift side, they have created a wider beach and an enhanced erosion buffer on that section of foreshore. However on the depleted downdrift side, the foreshore is more susceptible to cyclone erosion due to the depleted beach/buffer width.

Consequently the construction of a groyne does not in itself resolve the erosion problem, but merely transfers it further along the beach.

The same effect of impeding the longshore transport of sand by a groyne can also be achieved by a structure built offshore of the beach, but not connected to it. Such structures a called *offshore breakwaters* and function by casting a “wave shadow” onto the shoreline in its lee.

The reduced wave energy landward of the offshore breakwater means that the ability of the waves to keep moving sand along the shoreline is reduced. Consequently the supply of sand from the updrift shoreline is greater than that at which it can be moved out of the wave shadow. Sand therefore accumulates in the lee of the offshore structure. However, as is the case with a conventional groyne, the shoreline downdrift of the wave shadow is deprived of sand and therefore erodes.

4.3.2.4 Groynes with beach nourishment

The downdrift erosion caused by groynes can be compensated to a large extent by incorporating beach nourishment into the strategy. This is achieved by placing sand against the updrift side of the groyne immediately after it is constructed so that it is “filled”. Any additional sand moved against this side of the structure by natural processes can therefore be carried around the end of the groyne to supply the downdrift shoreline.

The length of updrift shoreline that benefits from such groyne and beach nourishment is somewhat limited. Therefore if long sections of shoreline require protection then a number of groynes can be built at intervals along the shoreline. This is typically called a *groyne field*.

The length and spacing of such groynes depend to a large degree on the local longshore sand transport regime; and in particular the naturally preferred stable orientation of the beach. Their length and spacing are also somewhat dependent upon each other. Under any given longshore transport regime, it is possible to achieve a similar degree of protection by using short closely spaced groynes, or longer more widely spaced structures. Such issues can only be resolved by further detailed study and design.

Nevertheless such intervention can have an adverse impact on the visual amenity of foreshores. Structures such as groynes that cross the shore can also have an adverse impact on beach use since walking along the beach will entail crossing over the groynes. This experience is also potentially marred by the different beach levels on the updrift and downdrift sides.

5 Assessment of Erosion Mitigation Options

5.1 Assessment Methodology

The preceding Section 4 provided a general overview of erosion mitigation options that can be applied to foreshores. An assessment of potential mitigation strategies for the five coastal precinct considered by this Study is presented below.

When determining a suitable erosion mitigation strategy for each of the nominated sites, the following fundamental approach has been adopted:

- firstly to identify the physical extent of the current erosion threat (as has been discussed in Section 3);
- then determine whether this existing threat is to essential or non-essential coastal assets, where such assets might include social and environmental values, private and community infrastructure; etc;
- where the threat is currently unacceptable, an erosion mitigation strategy is determined that will reduce and maintain the threat at an acceptable level - both now and into the future;
- where the nature of the coastal assets are such that the existing threat can be accommodated, then an erosion mitigation strategy is determined that will ensure the threat is not increased as climate change effects manifest themselves.

In order to rate the various options, a score is intuitively assigned to each option using a numerical scale ranging from 1 (exceptionally poor) to 10 (excellent). Therefore the higher the score, the more appropriate or desirable is the option's outcome.

It is acknowledged that there is a degree of subjectivity in such an approach, and that even amongst experienced coastal management practitioners there is likely to be differing opinions as to overall and relative scores. As will be seen, preferred strategies nevertheless strongly emerge from this process.

Whilst the strategy of Avoid Development is offered as a generic solution, it really does not have a viable application on its own. It cannot solve erosion problems on sections of foreshore that are already developed or that have infrastructure located in areas prone to erosion. However it can be used to supplement other management options that can be applied to undeveloped foreshores. For example, under Do Nothing or Planned Retreat scenarios the future integrity of these solutions can be secured by a supplementary strategy of Avoid Development within the erosion buffers that such strategies provide.

This is relatively easy to implement given that the width of the various project foreshores that are at risk of erosion over a 50 year planning period is already nominated under the State Coastal Plan as being within a designated Erosion Prone Area. Future rezoning or development of the foreshore covered by Do Nothing and Planned Retreat options can be controlled by application of appropriate coastal management principles that are already in place under the State Plan.

5.2 Kings Beach at Rose Bay

The ocean frontage of Kings Beach at Rose Bay can be considered as being a "developed foreshore" since the erosion threat affects Bluewater Parade itself, power and telecommunications infrastructure and a number of private properties - particularly at its southern end. Consequently the existing erosion threat needs to be reduced through the application of an appropriate mitigation strategy.

Strategy options have been subjectively assessed in Table 5.1, from which it is evident that a Beach Nourishment strategy is the most effective where existing and future erosion threaten essential infrastructure along the southern end of this foreshore.

Whilst a Do Nothing strategy might have negligible direct cost, the indirect financial cost and social trauma associated with the loss of private and community assets are considerable. Likewise the cost of a Planned Retreat strategy that requires property resumptions, along with the relocation of road and other infrastructure, would be very considerable indeed.

Structural management options (such as a seawall or groynes - with/without supplementary beach nourishment) rate poorly. This is due to their adverse impacts on prevailing coastal processes and environmental values, along with their high financial costs.

A Beach Nourishment strategy for Kings Beach at Rose Bay can reduce the existing erosion threat and ensure that it does not increase as climate change effects manifest themselves. Specific details of the Beach Nourishment strategy are presented in Section 6.

	Generic Management Options								
Assessment Criteria	Do Nothing	Avoid Development	Planned Retreat	Beach Nourishment	Beach Scrapping	Seawalls	Seawalls & Nourishment	Groynes	Groynes & Nourishment
Compliance with State Coastal Policy	5	*NOT APLICABLE*	9	**9**	3	2	4	2	4
Maintaining coastal processes	8		9	**9**	5	3	5	4	6
Maintenance of Local Marine Environment	8		8	**8**	2	4	6	3	5
Maintenance of Local Terrestrial Environment	4		6	**8**	8	4	5	6	6
Maintenance of Social Values	1		1	**8**	3	3	6	4	6
Visual amenity	3		6	**8**	4	2	5	2	3
Beach access and amenity	3		6	**8**	5	3	6	4	5
Initial financial cost (direct & indirect)	2		1	**7**	7	2	1	3	3
Ongoing financial cost (direct & indirect)	5		6	**5**	7	4	2	4	3
TOTAL SCORE	**39**		**52**	**70**	**44**	**27**	**40**	**32**	**41**

Table 5.1 : Option Assessment - Kings Beach at Rose Bay

5.3 Port Dennison West Beach

The ocean frontage of Port Dennison West Beach can be considered as a "developed foreshore" since it consists of intensely managed and well utilised public parkland, private property with established residences, a sailing clubhouse and power/telecommunication infrastructure. The pavement areas alongside the sailing club and the Catalina Interpretative Centre are also included in the area prone to erosion and therefore require protection.

The shoreline nominated for inclusion in the Study incorporates a number of different foreshore types, namely:

- rock armoured seawall (along the frontage to the Catalina Interpretative Centre);
- rubble seawall (on each side of the concrete ramp); and
- sandy foreshores (adjacent to the Jetty; between the sailing club and Doughtys Creek).

5.3.1 Rock armoured seawall

Visual inspections of this structure indicate that it is of poor structural integrity in places. Appropriate structural rectification works are likely in the future when it is subjected to a significant storm/cyclone event. Such rehabilitation is likely to be facilitated most economically by reconstruction - as opposed to simply repairing the existing structure. However that would best be determined by a structural audit of the seawall.

Consequently it is evident that a Do Nothing strategy is appropriate for the time being. However this should be confirmed by a structural audit of the seawall, supplemented with periodic monitoring of its condition and integrity.

5.3.2 Rubble seawall either side of the concrete ramp

Apart from being unsightly, this adhoc armouring of the foreshore has very limited functionality and cannot mitigate future expansion of the foreshore area already damaged. The structure needs to be replaced through the application of an appropriate erosion mitigation strategy.

Management options have been subjectively assessed in Table 5.2, from which it is evident that Beach Nourishment is the most effective.

Another option that scores highly is Planned Retreat. This would entail simply removing the building debris that constitutes the seawall, and also removing the concrete hardstand areas that have been damaged- creating natural foreshores on either side of the ramp instead. However such a strategy could lead to structural damage and possible failure of the concrete ramp. Such a scenario is likely to be unacceptable because the ramp is a well utilised and valued community asset, and can therefore be considered as essential infrastructure. It also has some heritage value given its association with the World War II Catalina Base near the site. It is for these reasons that the score for a Planned Retreat strategy is penalised.

A Beach Nourishment strategy achieves the same outcome as Planned Retreat - namely a natural sandy foreshore - whilst still maintaining the concrete ramp in place.

Assessment Criteria	Do Nothing	Avoid Development	Planned Retreat	Beach Nourishment	Beach Scrapping	Seawalls	Seawalls & Nourishment	Groynes	Groynes & Nourishment
	Generic Management Options								
Compliance with State Coastal Policy	5	*NOT APLICABLE*	9	**9**	3	2	4	2	4
Maintaining coastal processes	2		9	**9**	5	3	5	3	5
Maintenance of Local Marine Environment	3		8	**8**	2	4	6	3	5
Maintenance of Local Terrestrial Environment	3		6	**8**	6	3	5	5	6
Maintenance of Social Values	3		6	**8**	3	3	7	4	5
Visual amenity	1		6	**8**	4	3	6	2	4
Beach access and amenity	1		6	**8**	5	3	6	3	5
Initial financial cost (direct & indirect)	5		6	**7**	7	5	4	4	3
Ongoing financial cost (direct & indirect)	5		7	**7**	7	6	6	5	3
TOTAL SCORE	**28**		**63**	**72**	**42**	**32**	**49**	**31**	**40**

Table 5.2 : Option Assessment - Port Dennison West Beach (at concrete ramp)

5.3.3 Sandy foreshores

As discussed previously, severe storms/cyclones will not instigate particularly severe foreshore recession of the sandy shores along Port Dennison West Beach. This is because the foreshore is so low that overwash will occur. This in itself represents a significant threat to nearby infrastructure, nevertheless erosion mitigation measures to better secure the foreshore position will not necessarily mitigate damage by inundation/overwash.

Management options have been subjectively assessed in Table 5.3, from which it is evident that Beach Nourishment is again the most effective strategy.

Again the option of Planned Retreat rates well. This would entail relocating pathways, foreshore trees and other such community assets then allowing the foreshore to exist in its natural state. However this would increase the risk to the private properties (west of the sailing club and alongside the un-named creek entrance) as climate change effects manifest themselves.

A Beach Nourishment strategy for existing sandy foreshores along Port Dennison West Beach can reduce the existing erosion threat and ensure that it does not increase as climate change effects manifest themselves.

Generic Management Options

Assessment Criteria	Do Nothing	Avoid Development	Planned Retreat	Beach Nourishment	Beach Scrapping	Seawalls	Seawalls & Nourishment	Groynes	Groynes & Nourishment
Compliance with State Coastal Policy	8	*NOT APLICABLE*	9	**9**	3	2	4	2	4
Maintaining coastal processes	8		9	**9**	5	3	5	3	5
Maintenance of Local Marine Environment	8		8	**8**	2	4	6	3	5
Maintenance of Local Terrestrial Environment	7		6	**8**	6	3	5	5	6
Maintenance of Social Values	5		7	**8**	3	3	7	4	5
Visual amenity	7		7	**8**	4	3	6	2	4
Beach access and amenity	6		8	**8**	5	3	6	3	5
Initial financial cost (direct & indirect)	5		6	**7**	7	5	4	4	3
Ongoing financial cost (direct & indirect)	5		6	**7**	7	6	6	5	3
TOTAL SCORE	**59**		**66**	**72**	**42**	**32**	**49**	**31**	**40**

Table 5.3 : Option Assessment - Port Dennison West Beach (sandy foreshores)

5.4 Queens Beach

The Queens Beach shoreline is primarily a sandy beach; however there is a mixture of differently armoured seawalls on an approximately 420m long foreshore at the end of Soldiers Road. These various seawalls form the ocean frontage of two caravan parks and a number of private properties. They are of varying structural form and range considerably in their condition. An analysis of the structural integrity and performance of these various seawalls under cyclone loadings is beyond the scope of this erosion study.

As discussed in Section 4.1, a fundamental consideration in the determination of an appropriate erosion mitigation strategy on any foreshore is to determine whether the threat of erosion is to essential or non-essential coastal assets.

The Queens Beach shoreline under threat of cyclone-induced erosion mostly consists of foreshore parkland and the golf course - all of which could be considered as non-essential infrastructure. When evaluating and selecting appropriate shoreline management strategies for these particular coastal reaches of Queens Beach, the requirement to protect such foreshore use is a fundamental consideration.

By way of example, the open space along the northern-most section of the shoreline has been set aside as the Queens Beach Foreshore Reserve. Its purpose is to act as a natural coastal buffer to accommodate the physical processes of erosion and accretion, as well as to provide a reserve for coastal flora and fauna. It is a highly valued community asset. Nevertheless this strategy acknowledges and accepts that the local foreshore will fluctuate in position; and that this is to be accommodated rather than prevented. Whether or not a similar strategy is appropriate at the eastern end of Queens Beach is a matter for Council to determine in association with other stakeholders.

As well as parkland and golf fairways, private properties and residences at the eastern end of Queens Beach are also currently threatened by cyclone-induced erosion. These risks to privately owned assets clearly present their own challenges in terms of mitigating the possibility of erosion damage.

The evaluation of erosion mitigation options relies fundamentally on whether the coastal assets to be protected are essential or non-essential. The term “coastal assets” not only encompasses physical infrastructure, but also the environmental values of the local terrestrial and marine environments; visual amenity; public use and access.

For example, if foreshore parkland and the golf course fairways are considered to be non-essential infrastructure, then a strategy of Planned Retreat would be appropriate. This would allow the natural coastal processes that are shaping these foreshores to continue unimpeded. At the golf course this Planned Retreat strategy would require acceptance that fairway widths along the shoreline would become narrower and that some greens might need to be relocated further away from the foreshore.

Elsewhere non-essential infrastructure such as paths, barbeques and picnic shelters would be relocated beyond the area of future erosion threat under a Planned Retreat strategy - either gradually as a part of a systematic program of planned relocation when they require upgrading; or alternatively re-built further away from the shoreline if they become damaged.

On the other hand, if foreshore park infrastructure and the golf fairways along Queens Beach are considered essential infrastructure, then a strategy is required that will ensure that these assets are protected - or at least will be at no greater threat of erosion than they are at present.

Consequently when recommending appropriate erosion mitigation measures for Queens Beach, two approaches are offered for consideration, namely:

- Planned Retreat which allows the shoreline to respond naturally without direct intervention; or
- ensuring that the existing erosion threat is not increased in the future - particularly as climate change influences manifest themselves. Option assessments are undertaken to determine the most appropriate strategy to achieve this outcome.

When evaluating erosion mitigation options, Queens Beach can be considered as three precincts, namely:

- Queens Beach South - in the vicinity of Case and Hansen Parks;
- Queens Beach Central - along the ocean frontage of the golf course;
- Queens Beach North - fronting the Queens Beach Foreshore Reserve.

5.4.1 Queens Beach South

The selection of an appropriate strategy as an alternative to Planned Retreat for Queens Beach South is based on the fundamental philosophy that the existing erosion threat should not increase in the future as climate change influences occur. This basically requires that the predicted shoreline recession of 12 metres due to sea level rise be mitigated by each of the possible options.

Options have been subjectively assessed in Table 5.4, from which it is evident that a Beach Nourishment strategy is the most effective. More specific details as to the application of the Planned Retreat and Beach Nourishment alternatives at Queens Beach South are discussed in Section 6.4.1.

Assessment Criteria	Do Nothing	Avoid Development	Planned Retreat	Beach Nourishment	Beach Scrapping	Seawalls	Seawalls & Nourishment	Groynes	Groynes & Nourishment
				Generic Management Options					
Compliance with State Coastal Policy	*NOT APLICABLE*	*NOT APLICABLE*	*RECOMMENDED ALTERNATIVE*	9	3	2	4	2	4
Maintaining coastal processes				9	5	3	5	3	5
Maintenance of Local Marine Environment				8	2	4	6	3	5
Maintenance of Local Terrestrial Environment				8	6	3	5	5	6
Maintenance of Social Values				8	3	3	7	4	5
Visual amenity				8	4	3	6	2	4
Beach access and amenity				8	5	3	6	3	5
Initial financial cost (direct & indirect)				7	7	5	4	4	3
Ongoing financial cost (direct & indirect)				7	7	6	6	5	3
TOTAL SCORE				**72**	**42**	**32**	**49**	**31**	**40**

Table 5.4 : Option Assessment - Queens Beach South

5.4.2 Queens Beach Central

Almost the entire ocean frontage of this reach incorporates the open fairways and greens of the golf course. The exception to this is at its northern-most end, where the surf lifesaving club house is located only some 25 metres from the beach.

The options analysis below has been conducted on the golf course frontage and excludes the foreshore in the general vicinity of the surf club, since this area requires special consideration. A strategy for protecting the clubhouse is offered in the later Section 6 of this report (where recommended strategies are presented in more detail).

The selection of an appropriate alternative strategy for Queens Beach Central is based on the fundamental philosophy that the existing erosion threat should not increase in the future as climate change influences occur. This basically requires that the predicted shoreline recession of 7 metres due to sea level rise be mitigated by each of the possible options.

Management options have been subjectively assessed in Table 5.5, from which it is evident that Beach Nourishment would be the most effective as an alternative strategy to Planned Retreat. Hard structural options such as a seawall are not appropriate due to the very high cost and the significant adverse effects that such works would have on the beach and adjacent foreshores.

More specific details as to the application of the Planned Retreat and Beach Nourishment alternatives at Queens Beach Central are discussed in Section 6.4.2.

	Generic Management Options								
Assessment Criteria	Do Nothing	Avoid Development	Planned Retreat	Beach Nourishment	Beach Scrapping	Seawalls	Seawalls & Nourishment	Groynes	Groynes & Nourishment
Compliance with State Coastal Policy	*NOT APLICABLE*	*NOT APLICABLE*	*RECOMMENDED ALTERNATIVE*	9	3	2	4	3	4
Maintaining coastal processes				9	4	2	6	2	6
Maintenance of Local Marine Environment				8	2	3	6	3	5
Maintenance of Local Terrestrial Environment				8	6	3	5	4	5
Maintenance of Social Values				8	4	3	5	4	5
Visual amenity				8	4	3	6	3	4
Beach access and amenity				8	5	3	6	3	5
Initial financial cost (direct & indirect)				6	7	2	4	3	3
Ongoing financial cost (direct & indirect)				5	7	5	4	5	4
TOTAL SCORE				**69**	**42**	**26**	**46**	**30**	**41**

Table 5.5 : Option Assessment - Queens Beach Central[10]

5.4.3 Queens Beach North

The foreshore of Queens Beach North is undeveloped and the alignment of Queens Beach Esplanade is set back from erosion influences that are expected to manifest themselves over a 50 year planning period.

Consequently whilst there will be some short-term erosion and subsequent recovery along this section of foreshore in the next 50 years as a consequence of normal beach processes, there is no essential infrastructure at risk.

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[10] Option assessment excludes the foreshore immediately in front of the Surf Lifesaving Club - this area requires special consideration, refer to 6.4.2.

The preferred strategy is therefore Do Nothing. Nevertheless, to ensure the future integrity of this solution, a supplementary strategy of Avoid Development is also warranted. As discussed, there are already means in place to implement this supplementary strategy under the State Coastal Plan and Council's Queens Beach Foreshore Management Plan.

5.5 The Pocket Beach

The existing seawall constructed of sand-filled geotextile bags has proven to be effective in mitigating shoreline recession at The Pocket Beach to date. However as discussed in Section 3.7, the structure will not prevent erosion of the foreshore during particularly severe storms/cyclones.

Such events will cause the seawall to fail and the shoreline to recede, potentially destroying a significant length of Horseshoe Bay Road and damaging its intersection with Murrays Bay Road. Non-essential infrastructure (parkland, paths, etc.) would also be lost.

Any seawall along The Pocket Beach would need to be constructed to a much higher crest level than at present and require significant crest armouring to mitigate potential failure by overtopping. Such seawall works are estimated to cost in excess of $0.5 million and would significantly reduce the amenity of the existing beach and foreshore park.

Given that the primary objective of the erosion mitigation strategy is to secure trafficable access to the coastal communities at Horseshoe Bay and Murrays Bay, the most appropriate strategy would be to undertake works that would provide for such access in the event that this cyclone-induced erosion was to occur. This can be achieved through a strategy of Planned Retreat. It entails the relocation of the threatened length of Horseshoe Bay Road to an alignment further landward; and the relocation of its intersection with Murrays Bay Road. Specific details on this particular strategy variation are offered in Section 6 of this report.

It is recommended that this strategy be supplemented by the structural upgrading of the existing seawall that is constructed of sand-filled geotextile bags. An upgraded seawall at this location will assist in minimising erosion due to moderate storm events, as well as mitigate the 8 metre predicted recession that would otherwise occur as a consequence of future sea level rise.

Assessment Criteria	Do Nothing	Avoid Development	Planned Retreat	Beach Nourishment	Beach Scrapping	Seawalls	Seawalls & Nourishment	Groynes	Groynes & Nourishment
	Generic Management Options								
Compliance with State Coastal Policy	8	***NOT APLICABLE***	**10**	8	3	2	4	2	4
Maintaining coastal processes	8		**9**	9	5	3	5	3	5
Maintenance of Local Marine Environment	8		**8**	7	2	4	7	3	3
Maintenance of Local Terrestrial Environment	7		**6**	7	6	3	6	4	5
Maintenance of Social Values	1		**7**	7	3	5	6	4	6
Visual amenity	5		**7**	8	4	3	5	2	4
Beach access and amenity	5		**8**	8	5	3	6	3	5
Initial financial cost (direct & indirect)	5		**2**	1	7	1	1	3	2
Ongoing financial cost (direct & indirect)	1		**7**	2	7	5	2	3	3
TOTAL SCORE	**48**		**64**	**57**	**42**	**29**	**42**	**27**	**37**

Table 5.6 : Option Assessment - The Pocket Beach

5.6 Horseshoe Bay

The exiting foreshore of Horseshoe Bay is quite stable. Whilst there will be some short-term erosion and subsequent recovery along this beach in the next 50 years, there is no essential infrastructure at risk. The threat is limited to parkland and the car parking area only.

Shoreline recession of approximately 4 metres as a consequence of future climate change over a 50 year planning period means that this threat will gradually increase in coming years. In the event of such damage, Council should implement a strategy of retreat - rather than simply reinstating the car park area damaged by short-term erosion events. The additional width this creates between the car park and the beach should be reformed and revegetated into a small coastal dune system to act as a buffer and allow coastal processes to continue unaffected.

The preferred strategy for Horseshoe Bay is therefore Planned Retreat of the non-essential infrastructure.

6 RECOMMENDED EROSION MITIGATION STRATEGIES

6.1 Recommended Management Strategies

As discussed in Section 5, the recommended future management of the coastal precincts nominated for investigation by the Study incorporate a number of strategies, namely:

- Planned Retreat
- Beach Nourishment
- Do Nothing

6.1.1 Applied Strategies

The application of these strategies can be broadly summarised as follows:

- Kings Beach at Rose Bay - Beach Nourishment.
- Port Dennison West Beach - Beach Nourishment (and Do Nothing at the existing seawall).
- Queens Beach - combination of Beach Nourishment, Planned Retreat and Do Nothing along this variable coastal reach.
- The Pocket Beach - Planned Retreat.
- Horseshoe Bay - Planned Retreat.

Where a Beach Nourishment strategy is recommended it basically consists of:

- Initial Nourishment - through the placement of a sufficient volume of sand to establish the sand buffers that are necessary to accommodate erosion caused by a nominated Design Event.
- Ongoing Renourishment - given that the nourished foreshores can experience long-term erosion processes and/or foreshore recession induced by future climate change, it will be necessary to recharge these erosion buffers by periodic placement of additional sand.

6.1.2 Sources of Sand for Beach Nourishment

The physical characteristics of sand used for beach nourishment purposes is an important consideration when designing and implementing such projects.

Because they have been worked by the action of waves and currents, naturally occurring beach sands are typically “uniformly graded” - that is, the individual sand grains tend to be all very similar in size. When a beach is formed from sands that have a wide range of particle sizes (such as terrestrial sands extracted from quarries), a large proportion of particles smaller than those suited to the prevailing wave conditions will be winnowed from the beach slope and moved offshore. This natural sorting of widely graded beach sediments will therefore lead to a recession of the shoreface; flattening of the beach and subsequent loss of the fine fractions as they are removed from the beach and are spread over offshore areas.

It is for this reason that sands from marine sources are favoured to those that are quarried from terrestrial sources.

Further to this requirement to utilise uniformly graded sand for beach nourishment purposes, another important consideration is the physical size of the sand. Sand size is typically characterised by the average grain size, signified as D_{50}. Ideally any imported sand should match the D_{50} of the naturally occurring sand already on local foreshores; however that is frequently very difficult to achieve.

Sand of a different size to the native sand on a foreshore (ie. coarser of finer) can nevertheless be used for beach nourishment. Using coarser sand means that a lesser volume is required to provide the required erosion buffer since it is not moved to the same extent as finer sand.

The detailed engineering design of any beach nourishment works therefore needs to consider the following physical properties of available sand sources:

- grading of the sand - ideally uniformly graded;
- size of the sand - ideally the same size as that already on local beaches, however sand that is somewhat finer or coarser than this can be used, but the volumes to be placed need to account for this variation.

An analysis of the grading and the D_{50} size of sand that is commercially available from various extraction points in the Don River has been undertaken for this Study. It is evident that these Don River sources are suitable for beach nourishment purposes throughout the Bowen region - however specific specifications as to grading and size need to be made during the detailed design phase of project implementation.

6.1.3 Project Design and Approvals

Prior to implementing the recommended strategies, Whitsunday Regional Council (in consultation with other stakeholders) needs to select the Design Event for which the erosion mitigation strategies recommended by the Study are to accommodate.

This requires consideration and acceptance of the risk that such an event will occur (or be exceeded) within a 50 year planning period. Guidance on risk is offered in Section 3.3. Nominating the Design Event simply requires selecting the Average Recurrence Interval (ARI) cyclone for which immunity is required.

For example this would be either the 50 year ARI event, the 100 year ARI event, or some other event severity that might be appropriate to the risk / likelihood of its occurrence in the 50 year planning period.

Whitsunday Regional Council (in consultation with other stakeholders) also needs to select the alignment of an appropriate Coastal Defence Line along each project shoreline. Throughout the 50 year planning period, property and infrastructure landward of the selected Coastal Defence Line remain protected from long-term erosion effects; short-term erosion caused by the Design Event; and recession as a consequence of future climate change. Foreshore areas seaward of the Coastal Defence Line would lie within the active beach system (ie. within the erosion buffers).

Once these various design considerations have been determined it will then be possible to undertake engineering designs for works associated with the various proposed strategies. Appropriate approval applications based on designs and detailed drawings for the proposed works can then be prepared and submitted.

6.1.4 Management of Sandy Foreshores

Existing sandy foreshores and foreshores enhanced by a beach nourishment strategy need to be effectively managed in a manner consistent with natural processes. Appropriate management will assist in maintaining their natural ecosystem and ensure their structural integrity as erosion buffers.

Dune vegetation traps wind-blown sand on foreshore dunes which might otherwise be blown inland. Therefore rather than being permanently lost from erosion buffers (and potentially creating a nuisance to road and stormwater drainage systems), such trapped sand remains within the natural beach system.

Appropriate dune management will include the planting and protection of native dune vegetation, the clearing of weeds and other noxious species from the area, and the provision of controlled access onto the beach.

The Department of Environment and Resource Management offers valuable information and recommendations regarding the stabilisation of coastal dunes which should be applied to local foreshores enhanced by beach nourishment.

Likewise such management practices should be implemented on other reaches where the Do Nothing and Planned Retreat strategies are proposed. Where foredunes are naturally created by sand transport processes, stabilisation of these important features with primary vegetation species and controlled access is recommended.

6.1.5 Monitoring Surveys

In coming decades local foreshores are likely to experience the effects of climate change - which may see gradual increases in sea level, greater volumes of sand being transported by natural processes and increasing loads placed on seawalls. There remains considerable uncertainty about the scale and effect of such processes.

The monitoring of future shoreline response by a regular program of foreshore surveys serves an important role in assessing the effectiveness of the recommended erosion mitigation strategies in coming years; and will guide future action.

It is recommended that beach transect lines be established and regularly monitored at each of the five sites investigated by this Study. Specific requirements are included in the following discussion of the strategies to be applied at the sites.

Nevertheless all surveys must extend seaward from a position well behind the existing beach, and extend down across the beach slope and out to at least the level of low tide. Permanent marks locating each transect line are to be established by certified surveyors. Standard vertical and horizontal datums are to be used throughout all monitoring surveys (eg. Australia Height Datum and GDA94 or similar).

Surveys should be conducted at least twice annually - at the same time each year. Ideally this would be in late-October or early-November (immediately prior to the cyclone season), then again in late-March or early-April (immediately following the cyclone season). Additional surveys should be undertaken as soon as possible after significant erosion events.

The monitoring surveys should commence prior to implementation of any activities recommended by the Study, thereby providing a pre-project foreshore condition as a baseline reference.

6.2 Kings Beach at Rose Bay

The recommended erosion mitigation strategy along Kings Beach at Rose Bay is Beach Nourishment.

This consists of initial nourishment works to establish an appropriate buffer, followed by periodic renourishment campaigns to maintain the sand reserves in the newly established buffer. Comment is also offered in relation to the damaged beach access ramp at the northern end of this coastal reach.

6.2.1 Initial Nourishment

The implementation of a Beach Nourishment strategy requires the placement of sufficient sand on the foreshore to establish an adequate buffer to accommodate storm events. As discussed in Section 3.4.2, approximately 33 m^3/metre of sand would be removed from the upper beach area of Rose Bay by a 50 year ARI cyclone event; and 38 m^3/metre by a 100 year ARI cyclone. This will threaten essential infrastructure along Bluewater Parade

These potential erosion volumes therefore represent the initial nourishment volumes that need to be placed in the upper beach region to accommodate the 50 year and 100 year ARI storms - thereby maintaining a Coastal Defence Line seaward of Bluewater Parade.

As climate change influences manifest themselves, additional volumes will be required. The recommended strategy for initial beach nourishment is to establish the necessary buffers for present-day conditions; and to gradually increase these widths as actual climate change effects become apparent. Such effects would be identified by regular survey and monitoring of buffer performance.

Sand should be placed against the seaward face of the existing dune above approximately RL +1.5m AHD. Given that the dune crest is at approximately RL+4.5m AHD, a placement width of 11 metres would be required to provide the 33 m^3/metre buffer to accommodate the erosion of a 50 year ARI event; or 13 metres for the 38 m^3/metre that is required for a 100 year ARI event.

These equate to overall sand placement volumes of approximately 7,000 m^3 and 8,000 m^3 for the 50 year and 100 year ARI storm buffers respectively.

There is currently a stormwater drainage outlet on the beach near the informal beach access track approximately midway along Bluewater Parade ocean frontage. Modifications to this outlet would be required to accommodate the proposed beach nourishment works.

6.2.2 Ongoing Renourishment

As discussed previously in Section 3.4.1, the long-term erosion on the southern shores of this coastal reach appears to be around 3.5m^3/metre. This means that the erosion buffers created by the initial sand nourishment will gradually be depleted - thereby diminishing the protection that they afford.

Ongoing renourishment will therefore be required to recharge the buffers with sand. This should not be construed as a "failure" of beach nourishment, as it is typically an integral component of successful beach nourishment strategies worldwide.

Renourishment rates should at least match the net long-term erosion rates along the foreshore. Historical surveys and aerial photographs indicate that currently this renourishment rate should average around 750 m^3/year.

Given the requirement to ensure that erosion buffers are fully recharged prior to the likelihood of any cyclone erosion, it is recommended that the beach renourishment be completed prior to the onset of each cyclone season.

6.2.3 Monitoring Surveys

Whitsunday Regional Council has already established three transect lines on the foreshore opposite Bluewater Parade. However it is recommended that these transects be formally surveyed to accurately establish their vertical and horizontal datums. This will then enable them to be better utilised for accurately monitoring future foreshore fluctuations.

6.2.4 Beach Access Ramp at the Northern End

There is currently a formal beach access at the northern end of this coastal precinct (refer Figure 6.1). In recent years the ramp at its entry point onto the beach has been damaged as a consequence of storm erosion. This damage has heightened the concerns of local residents with respect to beach erosion.

However it is quite evident that the access ramp onto the sandy beach has been inappropriately located and constructed.

Sand beaches are dynamic. They change in response to the continuously varying environmental conditions that shape them. These changes can be over timescales of just days, seasons, years or even decades. Fixed structures such as the northern access ramp are not flexible, and cannot accommodate these natural beach fluctuations.

The existing section of the timber pathway that is currently reinforced with sand-filled geotextile containers will inevitably be further damaged in future and require on-going and increasing maintenance as the beach undergoes its normal fluctuations.

Figure 6.1 : Beach Access at Northern End of Rose Bay Beach

Typically beach access points such as these are constructed using *board and chain walkways*. These are flexible structures and can readily accommodate natural beach movements. A standard design that has proven effective throughout Queensland is available from the Department of Environment and Resource Management[11].

It is recommended that the damaged sand bag protected ramp currently being used for beach access be removed and replaced with a standard board and chain walkway - similar in concept to those shown in Figure 6.2.

Figure 6.2 : Typical board and chain walkway for beach access

[11] "*Board and chain walkways, steps advisory signs*". Leaflet No. V-02.2 of the series titled *Coastal sand dunes - their vegetation and management. Management guidelines for dune use*. Originally published by the Beach Protection Authority. ISSN 0312-7796. Available for download http://www.derm.qld.gov.au/register/p00298aa.pdf

6.2.5 Summary of Erosion Mitigation Strategy

In summary then the recommended erosion mitigation strategy at Kings Beach at Rose Bay is:

1. Place sand as initial beach nourishment on the foreshore south of the informal beach track (approximately opposite No.15 Bluewater Parade). The sand should be placed against the foredune above approximately RL+1.5m AHD. The required volumes being:
    a. 7,000 m^3 to provide protection against the 50 year ARI storm event; or
    b. 8,000 m^3 to provide protection against the 100 year ARI storm event.
2. Implement appropriate dune management practices on the newly nourished foreshore. As a minimum, this entails the planting and protection of native dune vegetation, the on-going clearing of noxious weed species and ensuring adequate controlled access is maintained through new dune areas.
3. Undertake ongoing beach renourishment along Bluewater Parade ocean frontage through the annual placement of 750m^3 of sand. This is to recharge the erosion buffer established by the initial beach nourishment exercise. Annual volumes and placement locations may need to be amended in response to the results of ongoing monitoring of beach performance.
4. Replace the damaged beach access ramp at the northern end of the beach with a board and chain walkway.
5. Existing shoreline transect lines to be formally surveyed to accurately establish their vertical and horizontal datums. Surveys of these three transects should occur at least twice a year (at the same times each year); as well as immediately after significant erosion events.

Figure 6.3 : Summary of Recommended Strategy for Kings Beach at Rose Bay

6.2.6 Estimated Costs of the Strategy

The costs associated with the recommended erosion mitigation strategy relate primarily to the initial nourishment campaign to create the necessary erosion buffers and the ongoing renourishment to recharge these buffers. Estimates of the costs associated with the strategy are as follows:

Activity	Cost	Annual Cost
Project Design and Approvals		
Design of initial beach nourishment	$12,500	
Obtain appropriate approvals	$2,500	
Project Monitoring		
Establish & undertake initial pre-project surveys	$2,500	
Twice annual survey of 3No. beach transects		$4,000
Allow additional survey after erosion event, say		$2,000
Beach Nourishment		
Establish / reinstate beach access for initial sand placement	$25,000	
Modify stormwater drainage system, say	$17,500	
Implementation of initial beach nourishment :		
for 50 year ARI immunity (place 7,000 m^3)	*$105,000*	
for 100 year ARI immunity (place 8,000 m^3)	*$120,000*	
Implementation / maintenance of dune management program	$15,000	$2,000
On-going renourishment (average of 750 m^3 annually)		$12,000
Totals (for various initial beach nourishment options)		
for 50 year ARI immunity	**$180,000**	**$20,000**
for 100 year ARI immunity	**$195,000**	**$20,000**

Table 6.1 : Estimated Costs of Erosion Mitigation - Kings Beach at Rose Bay

6.3 Port Dennison West Beach

Given the variable nature of the existing foreshore and erosion threat along this section of Bowen's Front Beach, different strategies are recommended for different lengths of foreshore.

6.3.1 Sandy Foreshore Alongside the Jetty

The recommended erosion mitigation strategy along this section of Port Dennison West Beach is Beach Nourishment.

Given that this section of foreshore is relatively stable, the placement of sand to supplement the beach is primarily to mitigate the anticipated 4 metre recession of the foreshore as a consequence of anticipated sea level rise. Council has the option of undertaking this at any stage during the 50 year planning period. However to mitigate the increasing threat and damage to assets behind the beach in coming years, there is merit in undertaking this work sooner rather than later.

This consists of initial nourishment works to establish an appropriate buffer, followed by monitoring of the beach through regular surveys.

It is estimated that approximately 850m^3 of sand needs to be placed on this 115 metre long section of beach to provide the necessary buffer. Given the long-term stable nature of the existing beach, there is no requirement for on-going beach nourishment envisaged; however this needs to be monitored by the surveys.

The outlet of a stormwater drain at the western end of this beach will require some modification to accommodate the proposed beach nourishment.

6.3.2 Existing Rock Seawall

This is the section of rock armoured seawall that fronts onto Port Dennison opposite the Catalina Interpretative Centre.

As discussed previously in Section 3.5.4, historical aerial photographs suggest that a seawall has been in place along this section of Port Dennison West Beach for over 30 years. Nevertheless, its current structural form and condition is poor in places. Standard design principles such as appropriate rock grading and size, minimum of two layers of interlocking rocks, toe and crest protection and a filter arrangement between the rock and underlying soil are not evident in its construction.

Consequently it cannot be considered a robust foreshore protection structure in its current condition. It is difficult to predict its structural performance under the loadings that would be applied by a severe storm/cyclone. It is likely to be overtopped by waves and to fail in places; but it could nevertheless provide satisfactory protection to the Catalina Interpretative Centre during one such event.

However once it is exposed to severe wave action, the wall will then very likely require substantial rehabilitation. It is recommended that a structural audit be carried out on the seawall to determine its current structural integrity and likely future service life. If necessary, appropriate structural rectification works should be identified by the audit however previous experience of seawall maintenance suggests that such rehabilitation is likely to be facilitated most economically by reconstruction - as opposed to simply repairing the existing structure.

In summary, the recommended strategy is Do Nothing - for now. However it is strongly recommended that the integrity and future performance of the seawall be checked by a structural audit to ensure that it can provide appropriate protection to the local foreshore during severe storms / cyclones.

6.3.3 Rubble Seawall Alongside the Concrete Ramp

The recommended erosion mitigation strategy along this section of Port Dennison West Beach is Beach Nourishment.

To facilitate the placement of sand along this foreshore it will be necessary to removed all of the building debris that constitutes the 60 metre long rubble wall on the eastern side of the ramp. Likewise the damaged area of the vertical cut-off wall and collapsed concrete hardstand on the western side will need to be removed along approximately 65 metres. Both areas then need to be trimmed prior to placement of sand for beach nourishment. The extent of preparation works are indicated conceptually on Figure 6.4; however this would need to be confirmed during the detailed design of the works.

Figure 6.4 : Preparation Works Prior to Beach Nourishment Alongside Concrete Ramp

The level of the placed sand forming the renourished foreshore should be no lower than the area immediately behind the newly created beach slope. In fact a slightly elevated dune would best be created. Typically the dune crest should be 0.3m to 0.5m higher than the foreshore behind - thereby creating a swale that can intercept and disperse any shoreward flow of runoff during severe rainfall events. A typical nourishment profile is shown conceptually on Figure 6.5.

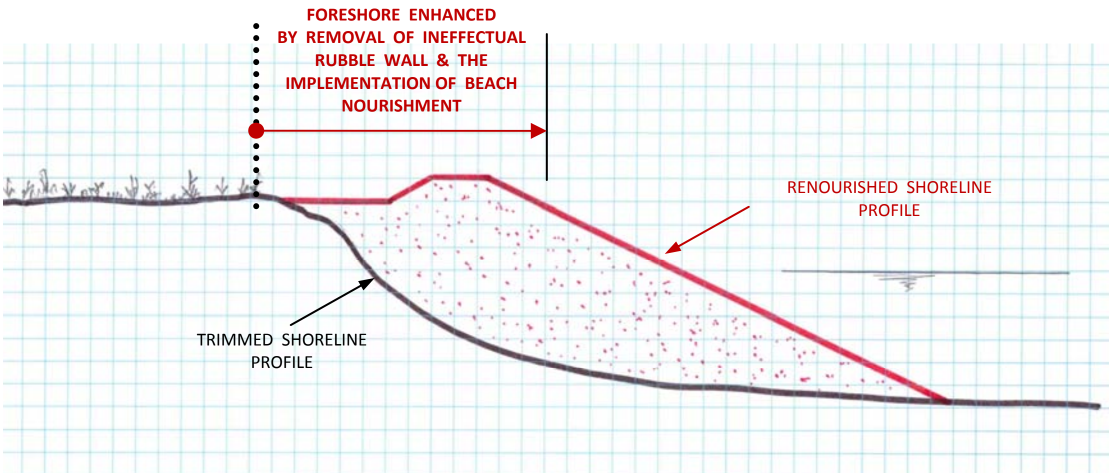

Figure 6.5 : Typical Initial Nourishment Profile

It is estimated that approximately 1,200m^3 of sand will need to be placed as beach nourishment on this section of the foreshore. Some modifications to stormwater outlets will be required to accommodate the sand placement.

It is likely that some sand-filled geotextile bags (or a similar wall system) will be required along each edge of the ramp in its upper sections to prevent the new beach profile encroaching onto the ramp itself. Such details would be addressed during the detailed design phase of implementation.

To prevent the windblown loss of sand from the new beach nourishment work (and to mitigate the nuisance of windblown and onto the concrete hardstand area) appropriate plantings of dune vegetation needs to be implemented on the beach crest/dune. Until such time as the vegetation becomes well established, it will be necessary to install temporary wind fences. These could also serve to prevent damage to new plantings by pedestrian traffic.

6.3.4 Sandy Foreshore West of the Sailing Club

The recommended erosion mitigation strategy along this section of Port Dennison West Beach is Beach Nourishment.

As discussed in Section 3.5.4, the section between the sailing club and the un-named creek some 150 metres further west has been relatively stable. The placement of sand to supplement the existing beach is to mitigate the anticipated 4 metre recession of the foreshore as a consequence of anticipated sea level rise. Council has the option of undertaking this at any stage during the 50 year planning period. However to mitigate the increasing threat and damage to assets behind the beach in coming years, there is merit in undertaking this work as soon as possible.

This consists of initial nourishment works to establish an appropriate buffer to a profile similar to that shown in Figure 6.5, followed by monitoring of the beach through regular surveys.

It is estimated that approximately 1,200m^3 of sand needs to be placed on this 150 metre long section of beach to provide the necessary buffer. Given the long-term stable nature of the existing beach, there is no requirement for on-going beach nourishment envisaged; however this needs to be monitored by the surveys.

Further west between the un-named creek and Doughtys Creek the foreshore is experiencing a slow rate of long-term erosion. This means that erosion buffers created by an initial sand nourishment campaign will gradually be depleted - thereby diminishing the protection that they afford. Ongoing renourishment will therefore be required to recharge the buffers with sand. This should not be construed as a “failure” of beach nourishment, as it is typically an integral component of successful beach nourishment strategies worldwide.

Section 3.5.4 provides discussion that identifies a recession of around 0.24m/year; which is likely to gradually increase to around 0.28m/year over a 50 year planning period as a result of climate change. This would be in addition to the anticipated 4 metre shoreline recession caused by sea level rise.

It is estimated that approximately 2,600m^3 of sand needs to be placed on this 300 metre long section of beach to provide the initial buffer. Renourishment rates should at least match the net long-term erosion rate of 0.24m/year to 0.28m/year along the foreshore. This equates to an average annual placement requirement of approximately 200 m^3.

Given the requirement to ensure that erosion buffers are fully recharged prior to the likelihood of any cyclone erosion, it is recommended that the beach renourishment should be completed prior to the onset of each cyclone season.

Following placement of sand for the initial beach nourishment on the entire foreshore west of the sailing club, appropriate dune management needs to be implemented.

6.3.5 Summary of Erosion Mitigation Strategy

In summary then the recommended erosion mitigation strategy along the various foreshore types of Port Dennison West Beach is:

Beach alongside the Jetty

- Place approximately 850 m^3 of sand as initial beach nourishment on this foreshore.

Existing rock seawall

- It is strongly recommended that the integrity and future performance of the existing seawall be checked by a structural audit to ensure that it can provide appropriate protection to the local foreshore during severe storms / cyclones.
- Implement appropriate structural rectification / upgrading if the structural audit identifies that its function might be compromised.

Adhoc rubble seawall alongside concrete ramp

- Remove all building debris / rubble from the eastern side of the ramp and all of the damaged concrete wall and pavement on the western side.
- Place approximately 1,200m^3 of sand on the foreshore as initial beach nourishment.

Sandy foreshore west of the sailing club

- Place approximately 1,200m^3 of sand as initial beach nourishment on the section of foreshore between the sailing club and the un-named creek some 150 metres further west.
- Place approximately 2,600m^3 of sand as initial beach nourishment on the 300 metre long section of foreshore between the un-named creek and Doughtys Creek.
- Undertake ongoing beach renourishment along the shoreline between the un-named creek and Doughtys Creek through the annual placement of 200m^3 of sand. This is to recharge the erosion buffer established by the initial beach nourishment exercise. Annual volumes may need to be amended in response to the results of ongoing monitoring of beach performance.

Monitoring surveys

- Shoreline transect lines are to be formally established along the Port Dennison West Beach foreshore. Nine transect lines are envisaged.
- Surveys of these transects should occur at least twice yearly (at the same times each year); as well as immediately after significant erosion events.

Dune Management

- Implement appropriate dune management practices on existing and newly nourished foreshores. As a minimum, this entails the planting and protection of native dune vegetation, the on-going clearing of noxious weed species and ensuring adequate controlled access is maintained through beach crest / dune areas.

Figure 6.6 : Summary of Recommended Strategy for Port Dennison West Beach

6.3.6 Estimated Costs of the Strategy

The costs associated with the recommended erosion mitigation strategy are as follows:

Activity	Cost	Annual Cost
Project Design and Approvals		
Design of proposed works	$22,500	
Obtain appropriate approvals	$5,000	
Project Monitoring		
Establish & undertake initial pre-project transect surveys	$11,500	
Twice annual survey of 9 No. beach transects		$13,500
Allow additional survey after erosion events, say		$5,000
Foreshore Works for Mitigation Strategy		
Undertake structural audit of existing rock seawall	$17,500	
Place 850 m^3 of sand on beach alongside Jetty	$12,000	
Remove rubble & trim foreshore alongside ramp	$17,500	
Place 1,200 m^3 of sand alongside concrete ramp	$17,500	
Place 1,200 m^3 of sand between sailing club & creek	$17,500	
Place 2,600 m^3 of sand between creek & Doughtys Creek	$36,000	
On-going renourishment between creek & Doughtys Creek		$3,500
Modify various stormwater drainage outlets, allow say	$8,000	
Implementation / maintenance of dune management program	$30,000	$4,000
Totals	$195,000	$26,000

Table 6.2 : Estimated Costs of Erosion Mitigation - Port Dennison West Beach

6.4 Queens Beach

Given the variable nature of the existing foreshore and erosion threat along Queens Beach, different strategies are recommended for different lengths of shoreline. A structural audit of the armoured seawalls at the end of Soldiers Road to determine their existing structural integrity and future performance is beyond the scope of this erosion study.

As discussed previously two alternative erosion mitigation strategies are offered for most of Queens Beach, namely Planned Retreat and Beach Nourishment. The most appropriate strategy needs to be determined by Whitsunday Regional Council in conjunction with other stakeholders - since the selection will depend upon important community considerations of what constitutes non-essential and essential infrastructure.

The best way to approach these considerations is through the application of a Coastal Defence Line (refer discussions in Section 4.2). Defining the position of a Coastal

Defence Line along Queens Beach requires stakeholders to determine what assets are to be defended. The Line forms the landward boundary of erosion buffers to protect the shoreline at any particular site. Property and infrastructure landward of the Coastal Defence Line remains protected throughout the planning period, whereas foreshore areas seaward of the line lie within the active beach system (ie. within the erosion buffers).

6.4.1 Queens Beach South

6.4.1.1 Planned Retreat

Under a Planned Retreat strategy, all park infrastructure and amenities such as paths, barbeques and picnic shelters, would be relocated beyond the threat of future erosion by a nominated ARI storm. For example the relocations would be to positions landward of Threat Lines defined previously for either 50 year ARI or 100 year ARI events.

However there are a number of private landholdings along Queens Beach South. These are in two locales - one near the intersection of Horseshoe Bay Road and Rose Bay Road; and the other between Case and Hansen Parks.

Near the intersection of Horseshoe Bay Road and Rose Bay Road the private properties are set back from the foreshore. Public parkland is located between their seaward boundary and the beach. These properties are all located beyond the Threat Lines defined by both the 50 year and 100 year ARI events - except for the western-most Lots which will become threatened by 100 year ARI events in 50 years time. A Planned Retreat strategy has no direct bearing on the properties near the intersection of Horseshoe Bay Road and Rose Bay Road until that time.

The properties between Case and Hansen Parks currently have their seaward boundary on the beach itself. Whilst a Planned Retreat strategy could be implemented for Case and Hansen Parks, this approach is very unlikely to be adopted by landowners between these two parks - as it would require their acceptance of property losses to erosion and in some instances the relocation of houses.

Under Queensland coastal legislation, the protection of these privately owned assets is a matter for the asset owners themselves if undertaken within their property boundaries. Foreshore protection works would inevitably (and understandably) be implemented by these landowners to secure their property from erosion. Such works would likely entail seawalls.

The predicted 12 metre recession of the shoreline along Case and Hansen Parks as a consequence of future sea level rise would transpire under a Planned Retreat strategy, placing the flanks of the properties immediately adjoining these parks under threat. Foreshore protection works would therefore need to be extended along these flanks.

Even if properly designed and constructed, such private works would have an adverse effect on coastal processes along the receding beach - and could in fact increase recession distances on the adjacent Case and Hansen Parks.

Whilst a Planned Retreat strategy could be implemented along Queens Beach South, it will have adverse implications to privately owned property between Case and Hansen Parks. This detracts from its merits as a preferred strategy.

6.4.1.2 Beach Nourishment

Under a Beach Nourishment strategy, imported sand would be placed along the Queens Beach South foreshore to create an erosion buffer to accommodate future shoreline recession. Private landholders will also benefit from this strategy.

The proposed Beach Nourishment will not entirely mitigate the current threat of cyclone-induced erosion but will ensure that the threat does not increase in coming years.

Its implementation consists of initial nourishment works to establish an appropriate buffer, followed by periodic renourishment campaigns to maintain the sand reserves in the newly established buffer.

Initial nourishment

As discussed previously (in Section 3.6.3), it is estimated that the Queens Beach South foreshore will recede by 12 metres through the removal of around 19.8 m^3/ metre of sand over the nominated planning period. It is therefore estimated that approximately 22,000m^3 of sand needs to be placed in the upper beach/dune region along this 1115 metre section of beach to so as to provide the necessary buffer.

There is merit in extending this sand placement along the additional 240 metres of foreshore that constitutes The Pocket Beach.

On-going Nourishment

Longshore sand transport mechanisms will remove sand from the initially created buffer. Unless there is natural recharging by sand supplied to the foreshore by these same processes, the initially created buffer will diminish in time. Periodic recharging by additional nourishment would therefore be necessary under such a scenario.

Assessments of long-term stability along the Queens Beach foreshore undertaken for this erosion study have proven inconclusive with regard to any background deficit in longshore sand supply. Such information could be determined either by detailed coastal processes modelling during the design phase of implementation; by monitoring the initial sand placement by foreshore surveys; or ideally by both means.

For the purposes of this assessment, it is assumed that sand would needed to be placed at an average of 3,000m^3/year to keep the buffer along Queens Beach South recharged.

Monitoring of Beach Nourishment

To monitor the effectiveness of Beach Nourishment, it is recommended that beach transect lines be established along Queens Beach South at approximately 200 metre spacing and that these be surveyed at least twice annually at the same time of year. Additional surveys should be undertaken on these transects immediately following significant erosion events. It is envisaged that there would be seven transects established on this section of foreshore.

6.4.2 Queens Beach Central

This is the section of Queens Beach that stretches from the un-named creek to the general vicinity of the Surf Lifesaving Club. It therefore includes the ocean frontages of the golf course and the Surf Club.

6.4.2.1 Planned Retreat

Planned Retreat effectively means relocating some putting greens and accepting narrower fairways as a consequence of the increasing risk associated with future foreshore recession.

The predicted 7 metre recession of the shoreline as a consequence of future sea level rise places the Surf Club under increased threat. The function of this important and valued community asset relies on its proximity to the beach. Furthermore the relocation of the Surf Lifesaving Clubhouse through an overall Planned Retreat strategy is likely to be beyond the financial means of the Surf Club.

Under such circumstances there is provision in the State Coastal Plan for “hard structural” erosion mitigation works such as seawalls to be approved and implemented. It is recommended that such protection measures be implemented in front of the Queens Beach Surf Club.

However to mitigate the adverse effect that a seawall would have on local coastal processes and beach amenity, it is strongly recommended as follows:

- The seawall structure should not be along the current alignment of the beach, but be buried within the existing buffer between the clubhouse infrastructure and the beach - so as to act as a “last line of defence”; and
- That the wall be designed by an appropriately qualified and experienced coastal engineer, irrespective of whether it is of rock or geotextile sand bag construction. The design must address the implications of undermining, overtopping and out-flanking as well as directly accommodating cyclone wave loadings in the event of its exposure.

6.4.2.2 Beach Nourishment

The proposed Beach Nourishment strategy on Queens Beach Central will not entirely mitigate the current threat of cyclone-induced erosion but will ensure that the existing threat of erosion to the golf course fairways/greens and the Surf Club does not increase in coming years.

It consists of initial nourishment works to establish an appropriate buffer, followed by periodic renourishment campaigns to maintain the sand reserves in the newly established buffer.

Initial nourishment

As discussed previously, it is estimated that the foreshore of Queens Beach Central will recede by around 7 metres through the removal of around 12.6 m^3/ metre of sand over the nominated planning period. It is therefore estimated that approximately 14,000m^3 of sand needs to be placed in the upper beach/dune region along this 1,100 metre long section of beach so as to provide the necessary buffer.

On-going Nourishment

Longshore sand transport mechanisms will remove sand from the initially created buffer. Unless there is natural recharging by sand supplied to the Queens Beach Central foreshore by these same processes, the buffer will diminish in time. Periodic recharging by additional nourishment would therefore be necessary.

As noted elsewhere, assessments of long-term stability along the Queens Beach foreshore undertaken for this erosion study have proven inconclusive with regard to any background deficit in longshore sand supply.

For the purposes of this assessment, it is assumed that sand would needed to be placed at an average of 3,000m^3/year to keep the buffer along Queens Beach South recharged.

Monitoring of Beach Nourishment

As recommended elsewhere for this strategy, the effectiveness of Beach Nourishment needs to be monitored. it is recommended that beach transect lines be established along Queens Beach Central at approximately 200 metre spacing and that these be surveyed at least twice annually at the same time of year. Additional surveys should be undertaken on these transects immediately following significant erosion events. It is envisaged that there would be seven transects established on Queens Beach Central.

6.4.3 Queens Beach North

The recommended erosion mitigation strategy along this section of Queens Beach is Do Nothing. Whitsunday Regional Council’s recently completed Queens Beach Foreshore Management Plan advocates maintaining this section of foreshore essentially in its natural state. Natural beach fluctuations that occur as a result of storms and cyclones will not threaten any essential infrastructure over a 50 year planning period.

It is recommended that seven beach transect lines be established at approximately 200 metres along this coastal reach so that future beach performance can be monitored. This would require the establishment of eight transect lines on Queens Beach North.

6.4.4 Summary of Erosion Mitigation Strategy

In summary then the recommended erosion mitigation strategy along the various foreshore lengths of Queens Beach is as follows:

Queens Beach South

- Either Planned Retreat or Beach Nourishment - the most appropriate to be determined by Whitsunday Regional Council in conjunction with other stakeholders - since the selection will depend upon important community considerations of what constitutes non-essential and essential infrastructure.
- Under a Planned Retreat strategy, all park infrastructure and amenities such as paths, barbeques and picnic shelters, would be relocated beyond the threat of future erosion that a nominated ARI storm poses. This would allow the natural coastal processes that are shaping the foreshore to continue unimpeded. However it would likely result in an adverse impact on adjoining private properties that would result in a requirement for these landowners to instigate their own foreshore protection measures.
- Under a Beach Nourishment strategy:
    - Place 22,000 m^3 of sand as initial beach nourishment. The sand should be placed against the foredune, typically above RL+0.5m AHD.
    - Implement appropriate dune management practices on newly nourished foreshores. As a minimum, this entails the planting and protection of native dune vegetation, the on-going clearing of noxious weed species and ensuring adequate controlled access is maintained through new dune areas.
    - Undertake ongoing beach renourishment through the annual placement of 3,000m^3 of sand. This is to recharge the erosion buffer established by the initial beach nourishment exercise. Annual volumes may need to be amended in response to the results of ongoing monitoring of beach performance.
- Seven beach transect lines be established at approximately 200 metre spacing. These transects to be surveyed at least twice annually at the same time of year. Additional surveys should be undertaken on these transects immediately following significant erosion events.

Queens Beach Central

- Either Planned Retreat or Beach Nourishment - the most appropriate to be determined by Whitsunday Regional Council in conjunction with other stakeholders.
- A Planned Retreat strategy would allow the natural coastal processes that are shaping the foreshore to continue unimpeded. It effectively means:
    - Relocating some putting greens and accepting narrower fairways on the golf course as a consequence of the increasing risk associated with future foreshore recession.
    - At the Queens Beach Surf Lifesaving Club, relocation of the clubhouse and associated facilities under a Planned Retreat strategy would significantly hinder the function of this facility. A buried seawall is recommended on the condition that:

- The seawall structure is not constructed along the current alignment of the beach, but is further inland, buried within the existing buffer between the clubhouse infrastructure and the beach so as to act as a "last line of defence"; and
- That the wall be designed by an appropriately qualified and experienced coastal engineer, irrespective of whether it is of rock or geotextile sand bag construction. The design must address the implications of undermining, overtopping and out-flanking as well as directly accommodating cyclone wave loadings in the event of its exposure

- Under a Beach Nourishment strategy:
  - Place 14,000 m^3 of sand as initial beach nourishment. The sand should be placed against the foredune, typically above RL+1.0m AHD.
  - Implement appropriate dune management practices on newly nourished foreshores. As a minimum, this entails the planting and protection of native dune vegetation, the on-going clearing of noxious weed species and ensuring adequate controlled access is maintained through new dune areas.
  - Undertake ongoing beach renourishment through the annual placement of 3,000m^3 of sand. This is to recharge the erosion buffer established by the initial beach nourishment exercise. Annual volumes may need to be amended in response to the results of ongoing monitoring of beach performance.
- Seven beach transect lines be established at approximately 200 metre spacing. These transects to be surveyed at least twice annually at the same time of year. Additional surveys should be undertaken on these transects immediately following significant erosion events.

Queens Beach North

- Given the adequate width of natural erosion buffers, in conjunction with the provisions of the Queens Beach Foreshore Management Plan, a strategy of Do Nothing is recommended.
- Nevertheless, eight beach transect lines be established at approximately 200 metre spacing. These transects to be surveyed at least twice annually at the same time of year. Additional surveys should be undertaken on these transects immediately following significant erosion events.

6.4.5 Estimated Costs of the Strategy

The costs associated with the recommended alternatives for an erosion mitigation strategy for Queens Beach are as follows:

Activity	Cost	Annual Cost
Queens Beach South - Planned Retreat		
Project Monitoring		
Establish & undertake initial pre-project transect surveys	$10,500	
Twice annual survey of 7 No. beach transects		$10,500
Allow additional survey after erosion events, say		$5,500
Foreshore Works for Mitigation Strategy		
Relocate existing park infrastructure, allow say	$200,000	
Modify various stormwater drainage outlets, allow say	$75,000	
Sub-totals	$285,500	$16,000
Queens Beach South - Beach Nourishment		
Project Design and Approvals		
Design of proposed works	$22,500	
Obtain appropriate approvals	$3,500	
Project Monitoring		
Establish & undertake initial pre-project transect surveys	$10,500	
Twice annual survey of 7 No. beach transects		$10,500
Allow additional survey after erosion events, say		$5,500
Foreshore Works for Mitigation Strategy		
Establish / reinstate beach access for initial sand placement	$3,500	
Place 22,000m^3 of sand as initial nourishment for buffer	$330,000	
On-going renourishment of approximately 3,000m^3		$45,000
Modify various stormwater drainage outlets, allow say	$10,000	
Implementation / maintenance of dune management program	$50,000	$4,000
Sub-totals	$430,000	$65,000

Table 6.3 : Estimated Costs of Erosion Mitigation Options at Queens Beach South

Activity	Cost	Annual Cost
Queens Beach Central - Planned Retreat		
Project Design and Approvals (Surf Club seawall)		
Design of proposed works	$17,500	
Obtain appropriate approvals	$5,000	
Project Monitoring		
Establish & undertake initial pre-project transect surveys	$10,500	
Twice annual survey of 7 No. beach transects		$10,500
Allow additional survey after erosion events, say		$5,500
Foreshore Works for Mitigation Strategy		
Modify various stormwater drainage outlets, allow say	$50,000	
Buried seawall at Surf Club	$75,000	
Note : excludes costs of any relocation of golf greens		
Sub-totals	**$158,000**	**$16,000**
Queens Beach Central - Beach Nourishment		
Project Design and Approvals		
Design of proposed works	$22,500	
Obtain appropriate approvals	$3,500	
Project Monitoring		
Establish & undertake initial pre-project transect surveys	$10,500	
Twice annual survey of 7 No. beach transects		$10,500
Allow additional survey after erosion events, say		$5,500
Foreshore Works for Mitigation Strategy		
Establish / reinstate beach access for initial sand placement	$10,000	
Place 14,000m^3 of sand as initial nourishment for buffer	$210,000	
On-going renourishment of approximately 3,000m^3		$45,000
Modify stormwater drainage, allow say	$6,000	
Implementation / maintenance of dune management program	$27,500	$4,000
Sub-totals	**$290,000**	**$65,000**

Table 6.4 : Estimated Costs of Erosion Mitigation Options at Queens Beach Central

Activity	Cost	Annual Cost
Queens Beach North - "Do Nothing"		
Project Monitoring		
Establish & undertake initial pre-project transect surveys	$10,500	
Twice annual survey of 8 No. beach transects		$8,000
Allow additional survey after erosion events, say		$4,000
Sub-totals	**$10,500**	**$12,000**

Table 6.5 : Estimated Costs of Erosion Mitigation Options at Queens Beach North

6.5 The Pocket Beach

The recommended erosion mitigation strategy at The Pocket Beach is Planned Retreat.

This entails the relocation of the threatened 120 metre length of Horseshoe Bay Road to an alignment further landward, beyond the threat of cyclone erosion. It would also entail modifications to the intersection with Murrays Bay Road.

It is recommended that this strategy of road relocation be supplemented by the structural upgrading of the geotextile bag seawall. An upgraded seawall at this location will assist in minimising foreshore erosion by moderate storm events, as well as mitigate the predicted 8 metre recession that would otherwise occur as a consequence of future sea level rise.

The effectiveness of this strategy of Planned Retreat needs to be considered in the context of providing a trafficable route to Horseshoe Bay in the event of severe cyclone erosion of local foreshores.

Some 340 metres further north along Horseshoe Bay Road, the road passes over a causeway immediately alongside the sandy foreshore of Greys Bay. In the event of a severe storm / cyclone it is likely that overtopping waves at the causeway will cause damage to the road pavement sufficient to prohibit passage by vehicles. This could conceivably occur prior to Horseshoe Bay Road being rendered impassable by erosion at The Pocket Beach.

Consequently the design and implementation of any relocation works associated with Horseshoe Bay Road at The Pocket Beach should be accompanied by works at the Greys Bay causeway.

6.5.1 Summary of Erosion Mitigation Strategy

In summary then the recommended erosion mitigation strategy at The Pocket Beach is:

- Design and implement road works to relocate an approximately 120 metre long section of Horseshoe Bay Road and modifications to its intersection with Murrays Bay Road.

- This road relocation work to be supplemented by the structural upgrading of the geotextile bag seawall.
- The effectiveness of this Planned Retreat needs to be considered more widely in the context of providing a trafficable route to Horseshoe Bay in the event of severe cyclone erosion of local foreshores. The causeway crossing the rear of the beach at Greys Bay could be damaged and made impassable by waves/erosion.
- Evaluate, design and implement road works if necessary to structurally upgrade the road pavement and associated causeway at Greys Bay.
- Should damage to Horseshoe Bay Road occur at The Pocket Beach as a consequence of cyclone erosion prior to implementation of the strategy, it is recommended that reinstatement works should consider an alternative more landward alignment of the road.

6.5.2 Estimated Costs of the Strategy

It is estimated that the road relocation works at The Pocket Beach would cost around $500,000. The extent and nature of associated upgrading of the causeway crossing at Greys Bay is unknown at this point.

6.6 Horseshoe Bay

The existing foreshore of Horseshoe Bay is stable. The only erosion threat is to non-essential infrastructure as a consequence of an estimated 4 metre gradual recession over a 50 year planning period, the recommended erosion mitigation strategy is Planned Retreat.

In the event of damage occurring as the shoreline gradually recedes, Council should implement a strategy of retreat rather than simply reinstating any damage to the foreshore park and associated car parking area. The additional width this creates between the car park and the beach should be reformed and revegetated into a small coastal dune system to act as a buffer and allow coastal processes to continue unaffected.

It is estimated that the relocation works associated with the seaward edge of car park would cost $75,000. However such works would only be undertaken as actual climate change influences manifested themselves.

6.7 Summary of Recommended Strategies

A tabulated summary of the recommended strategies for the five coastal precincts addressed by this study is presented in Table 6.6 overleaf.

LOCATION	EXISTING 50 year ARI cyclone erosion threat	EXISTING 100 year ARI cyclone erosion	recession due to long-term erosion processes over 50 years	predicted shoreline recession over 50 years due to climate change	FUTURE overall erosion threat (50 year ARI cyclone)	FUTURE overall erosion threat (100 year ARI cyclone)	RECOMMENDED MITIGATION STRATEGY	initial sand nourishment volume	annual sand re-nourishment volume	initial capital cost for implementation (including survey setup)	annual cost to maintain strategy (including surveys)
Kings Beach at Rose Bay	30m	36m	32m	11m	76m	80m	**Beach Nourishment**	*see Note 1*	$750m^3$	*see Note 2*	$20,000
Port Denison West Beach											
beach alongside jetty	N/A	N/A	0	4m	N/A	N/A	**Beach Nourishment**	$850m^3$	$0m^3$		
existing rock seawall	N/A	N/A	0	0	N/A	N/A	*see Note 3*			$195,000	$26,000
at concrete ramp	N/A	N/A	0	0	N/A	N/A	**Beach Nourishment**	$1,200m^3$	$0m^3$		
west of sailing club	N/A	N/A	12m	4m	N/A	N/A	**Beach Nourishment**	$3,800m^3$	$200m^3$		
Queens Beach											
South	33m	33m	0	12m	46m	46m	**Planned Retreat OR Beach Nourishment**	$22,000m^3$	$3,000m^3$	*see Note 4*	*see Note 4*
Central	26m	43m	0	7m	38m	51m	**Planned Retreat OR Beach Nourishment**	$14,000m^3$	$3,000m^3$	*see Note 5*	*see Note 5*
North	33m	48m	0	9m	49m	57m	**Do Nothing**			$10,500	$12,000
The Pocket Beach	24m	24m	0	8m	33m	35m	**Planned Retreat**			$500,000	
Horseshoe Bay	N/A	N/A	0	4m			**Planned Retreat**			$75,000	

N/A denotes insufficient data to determine.

NOTES:

1. For 50 year ARI cyclone immunity require 7,000 m^3 of sand.
   For 100 year ARI cyclone immunity require 8,000 m^3 of sand.
2. For 50 year ARI cyclone immunity, implentation cost is $180,000.
   For 100 year ARI cyclone immunity, implementation cost is $195,000.
3. Undertake a structural audit & upgrade the seawall if necessary.
4. Planned Retreat strategy : Implementation cost $285,500. Annual cost to maintain the strategy $16,000.
   Beach Nourishment strategy : Implementation cost $430,000. Annual cost to maintain the strategy $65,000.
5. Planned Retreat strategy : Implementation cost $158,000. Annual cost to maintain the strategy $16,000.
   Beach Nourishment strategy : Implementation cost $290,000. Annual cost to maintain the strategy $65,000.

Table 6.6 : Summary of Recommendations

7 IMPLEMENTATION OF THE STRATEGY

7.1 Approvals Process

The planning and legislative framework associated with coastal protection on Queensland's shorelines is discussed in Appendix A of this report. The specific approvals that are likely to be required under the recommended strategies of are shown below.

LEGISLATIVE / PLANNING INSTRUMENT	LIKELY	POSSIBLE	UNLIKELY
State Coastal Management Plan	✓		
Great Barrier Reef Marine Park Act 1975	✓		
Queensland Marine Parks Act 2004	✓		
Queensland Environmental Protection Act 1994	✓		
Sustainable Planning Act 1997	✓		
Aboriginal Cultural Heritage Act 2003		✓	
Nature Conservation Act 1992	✓		
Fisheries Act 1994	✓		
Vegetation Management Act 1999		✓	
Local Government Act 1993		✓	
Environmental Protection and Biodiversity Conservation Act 1999	✓		
Land Act 1994	✓		

7.2 Implementation of the Strategies

The recommended erosion mitigation strategies for a number of the project sites considered by the Study incorporate Beach Nourishment.

The implementation of a Beach Nourishment strategy can be tailored to suit available funding. Ideally the initial nourishment to provide the erosion buffers necessary to provide immunity for a Design Event would be undertaken in a single campaign as soon as possible.

However a staged approach whereby the buffers are created over a number of (possibly annual) nourishment campaigns might offer a more financially viable implementation.

The proposed strategy of Planned Retreat at The Pocket Beach requires the relocation of a section of Horseshoe Bay Road. Whilst costly, this strategy is comparable or cheaper in cost to other options - but nevertheless delivers a better outcome with regards to mitigating the threat of erosion and maintaining natural coastal processes. Should damage to Horseshoe Bay Road occur at The Pocket Beach as a consequence of cyclone erosion prior to implementation of the strategy, it is recommended that reinstatement works should consider an alternative more landward alignment of the road.

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APPENDIX A

- **PLANNING & LEGISLATIVE FRAMEWORK**

A. PLANNING AND LEGISLATIVE FRAMEWORK

To ensure that the proposed erosion mitigation options are consistent with planning and legislative requirements of Commonwealth, State and Local governments it is necessary to have appropriate regard for the full range of legislation that controls activities in the coastal zone.

This appendix outlines the relevant planning and legislative framework that will influence the development, assessment and implementation of appropriate erosion mitigation measures on the nominated coastal sites.

A.1 Queensland Coastal Legislation and Planning Instruments

The Queensland Government has developed a coastal management framework which includes specific legislation, policies and support tools to direct sustainable planning, development and management decisions. The *Coastal Protection and Management Act 1995 (Qld)* (hereafter referred to as, the Coastal Act) provides a comprehensive framework for the coordinated management of a diverse range of coastal resources and values in the coastal zone.

Fundamental tools to implement the Coastal Act are the State Coastal Management Plan and regional coastal management plans. The *Coastal Protection and Management Act 1995 (Qld)* provides for the appropriate management of Queensland's coastal zone. The Act recognises the diverse range of resources and values of:

"*coastal waters and all foreshore areas in which there are physical features, ecological or natural processes or human activities that affect, or potentially affect, the coast or coastal resources.*"[12]

In 2001 the State Coastal Management Plan was developed in accordance with the requirements of the Coastal Act and serves as a statutory instrument under that Act.

A.1.1 State Coastal Management Plan

The *State Coastal Management Plan* was reviewed in 2009 and at the time of preparing this report, that review has been completed and a *Draft State Coastal Management Plan* is currently in the public domain for review and comment. Until such time as the public review and subsequent drafting of a new Queensland Coastal Plan is completed, the existing State Coastal Management Plan remains in force. Once the new Queensland Coastal Plan has been finalised and approved, the current State Coastal Management Plan will be repealed.

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[12] s3 Coastal Protection and Management Act 1995 (Qld)

An objective of the Study is to provide strategic direction for the sustainable management of the five nominated coastal sites, and ensure erosion mitigation actions are consistent with the State Coastal Management Plan. A 50 year planning horizon is applied to such considerations.

Queensland's State Coastal Management Plan (SCMP) aims to protect and manage the state's coastal resources and values by providing an overarching framework for coastal management. It is founded on the following ten management topics:

- coastal use and development
- physical coastal processes
- public access to the coast
- water quality
- indigenous traditional owner cultural resources
- cultural heritage
- coastal landscapes
- conserving nature
- coordinated management
- research and information

Specific principles and policies have been developed within each of these issues so as to achieve defined coastal management outcomes. These topics are considered by the Study when assessing appropriate erosion mitigation strategies at the nominated sites.

The State Coastal Management Plan provides five policies under the topic *"Physical Coastal Processes"* that relate to the management of coastal erosion. These being:

Policy 2.2.1 Adaptation to climate change;
Policy 2.2.2 Erosion prone areas;
Policy 2.2.3 Shoreline erosion management;
Policy 2.2.4 Coastal hazards; and
Policy 2.2.5 Beach protection structures.

Comment on these policies and their relevance to the preparation of strategies under the Study are offered below.

A.1.1.1 Policy 2.2.1 Adaptation to climate change

Consideration must be given to the local implications of possible future climate change, including sea level rise and increased climatic variability. When developing erosion mitigation strategies a hierarchical approach must be applied as follows:

- *Avoid* - to focus on locating new development in areas not vulnerable to the impacts of climate change;
- *Planned retreat* - to focus on systematic abandonment of land, structures and ecosystems in vulnerable areas;
- *Accommodate* - to focus on continued occupation of coastal areas but with adjustments such as altered building design;

- *Protect* - to focus on the defence of vulnerable areas, population centres, economic activities and coastal resources.

When assessing potential mitigation options for the five project foreshores, this ranking of preferred approaches to future climate change is applied.

A.1.1.2 Policy 2.2.2 Erosion prone areas

Under this policy the State Coastal Management Plan recognises the important role of erosion prone areas as natural coastal buffers. Wherever practical, erosion prone areas are to remain undeveloped - except for temporary or relocatable structures.

In areas that have already been developed and are now in designated erosion prone areas, future use should not be at a scale or intensity greater than the existing development. Nor should such future development extend further seaward than the current alignment of buildings or services.

Retreat from the erosion prone area is the preferred strategy, but it is acknowledged that coastal protection works may be necessary to defend existing land uses and infrastructure. In such circumstances intervention by way of physical barriers (such as seawalls) should only be considered as a last resort where the threat to public safety or property is immediate and the infrastructure is not expendable. Coastal defence works are not to adversely affect coastal processes and environmental values.

Where erosion mitigation measures are required, the State Coastal Management Plan specifies the following hierarchy of actions (in order of decreasing preference):

- Remove, relocate or resume development from the threatened location; or
- Undertake beach nourishment to increase the width of the erosion buffer; or
- Push sand up from the intertidal zone onto the beach so as to provide short-term protection from erosion influences, provided such work will have only minor and temporary impacts on intertidal ecology; or
- Construct groynes or offshore breakwaters to impede longshore sand transport and increase the accumulation of sand on the eroding coast - subject to acceptable impacts on downdrift shoreline; or
- Construct a revetment / seawall as a physical barrier to permanently stop erosion and protect development; provided that such works are located as far landward as possible so as not to isolate important sand reserves from the active beach system - again subject to acceptable impacts on downdrift shoreline.

When assessing potential mitigation options for the five project foreshores, this ranking of preferred measures is applied.

A.1.1.3 Policy 2.2.3 Shoreline erosion management

Areas that are to be considered as priorities for erosion management must be taken into account when considering:

- applications for renewal or conversion of leases for leasehold land on the coast;
- issuing approvals for coastal protection works; and
- assessing proposals for funding proposals for coastal management programs.

A.1.1.4 Policy 2.2.4 Coastal hazards

Coastal hazards on the five project foreshores not only include the threat of erosion but also damage and inundation by storm tides. Under the State Coastal Management Plan wherever possible areas identified as being at risk of coastal hazards should remain undeveloped. In developed areas that are vulnerable to coastal hazards, further development must address vulnerability to storm tide inundation - including protection of evacuation routes.

Areas within each of the five coastal precincts considered by the Study that are vulnerable to storm tide effects have been identified in the *Bowen Shire Storm Tide Study* (Connell Wagner, 2004). Appropriate erosion mitigation options in these inundation prone areas have been considered when preparing erosion mitigation strategies.

A.1.1.5 Policy 2.2.5 Beach protection structures

The State Coastal Management Plan states under this policy that the construction of beach protection structures (such as seawalls) will only be approved where:

- there is a demonstrated need in the public interest; and
- comprehensive investigation has been carried out and it can be demonstrated that:
    - there would not be any significant adverse impact on longshore transport of sediments; and
    - there would be no increase in coastal hazards for neighbouring foreshores.

A.1.2 Regional Coastal Management Plan

A requirement under Section 2.2.3 of the State Coastal Management Plan is that *Regional Coastal Management Plans* (RCMP) identify any priority areas for erosion management. Regional plans are required to be consistent with and/or set more detailed requirements compared with the State Coastal Management Plan (SCMP). RCMP's implement the SCMP at the regional level and also identify key coastal sites at the regional level that require specific management interventions.

However work on the preparation of a RCMP for this area has halted whilst the review of the SCMP has been underway. However it is now understood that the regional plan will no longer be prepared (Queensland Department for Premier and Cabinet, 2009; Webbe & Weller, 2009).

A.2 Great Barrier Reef Marine Park Act

The Great Barrier Reef Marine Park Act 1975 is the primary Act in respect of the Great Barrier Reef Marine Park. It includes provisions which:

- Establish the Great Barrier Reef Marine Park itself;
- Establish the Great Barrier Reef Marine Park Authority (GBRMPA), a Commonwealth authority responsible for the management of the Marine Park;
- Provide a framework for planning and management of the Marine Park, including through zoning plans, plans of management and a system of permissions ;

- Prohibit mining operations (which includes prospecting or exploration for, as well as recovery of, minerals) in the Great Barrier Reef Region (unless authorised to carry out the operations by a permission granted under the Regulations, for the purpose of research or investigations relevant to the conservation of the Marine Park);
- Require compulsory pilotage for certain ships in prescribed areas of the Great Barrier Reef Region;
- Provide for regulations, collection of Environmental Management Charge, enforcement etc.

As a consequence of the findings of a review of the Act in 2006, amendments to the Act were made by the Australian Government in 2008, which came into force in two stages in 2008 and 2009. The purpose of the amendments was to update the Act, and better integrate it with other legislation in order to provide an effective framework for the protection and management of the Marine Park.

Within the study area, the Park's landward boundary is along the low water mark.

Zoning plans prepared in accordance with the *Great Barrier Reef Marine Park Act* define activities that may be undertaken within specific zones. In the vicinity of the nominated project sites, the adjoining area of the Park is predominantly General Use (Light Blue) Zone.

When assessing erosion mitigation strategies, the permissible activities within this zone must be taken into account. Consideration of other zones in the Park may be required if sand sourcing or other activities associated with erosion mitigation are undertaken within those zones.

A permit for certain activities within the Park is required under the Act and its regulations; *Great Barrier Reef Marine Park Regulations 1983* and the *Great Barrier Reef Marine Park Zoning Plan 2003*.

A.3 Queensland Marine Parks Act

In Queensland, the State's main legislation and regulation pertaining to marine parks are the *Marine Parks Act 2004 (Act)* and the *Marine Parks Regulation 2006 (Regulation)*. These are designed to complement the Commonwealth's *Great Barrier Reef Marine Park Act 1975*, indeed the zoning plan for the State Marine Park is the same as the zoning plan for the Great Barrier Reef Marine Park.

The *Marine Parks (Great Barrier Reef Coast) Zoning Plan 2004 (Zoning Plan)* defines the zoning arrangements, including the objectives for each zone, the allowable and prohibited activities, and those that require a marine park permit.

Whereas the landward boundary of the Great Barrier Reef Marine Park is low water mark, the landward boundary of the State Marine Park is the high water mark. The Department of Environment and Resource Management defines high water as:

"...high water means the mean height of the highest high water at spring tide." [13]

When considering erosion mitigation strategies, it is likely that any works or activities below the high water line (and therefore within the State Marine Park) will require approval under the State *Marine Parks Act 2004*.

A.4 Queensland Environmental Protection Act

The primary objective of the *Environmental Protection Act 1994* is to safeguard Queensland's natural environment whilst allowing for development in an ecologically sustainable manner. It is administered by the Department of Environment and Resource Management.

The Act establishes a general environmental duty that requires any erosion mitigation works on foreshores to be undertaken such that all reasonable and practical steps are taken to prevent or minimise environmental harm.

Environmentally relevant activities (ERAs) are authorised by an administering authority. Schedule 2 of the *Environmental Protection Regulation 2008* lists all ERAs. Included in that schedule are "Extractive and screening activities" of which ERA 16 (relating to extracting material from the bed of any State waters) may be relevant to sourcing sand for beach nourishment strategies.

Specific environmental protection policies (EPPs) currently exist and others may be prepared under the Act to protect or enhance the environment. The EPP most relevant to considerations of erosion mitigation measures is the *Environmental Protection (Water) Policy 2009*.

The intent of this policy is to achieve ecologically sustainable development with regard to Queensland waters - including those of coastal ecosystems. It provides a framework for appropriate management of environmental impacts by identifying environmental values and presents guidelines to protect and maintain the State's water environment.

A.5 Sustainable Planning Act

New planning and development laws recently came into effect in Queensland with *the Sustainable Planning Act 2009* replacing the *Integrated Planning Act 1997*. This new legislation seeks to achieve sustainable planning outcomes through:

- managing the process by which development takes place;
- managing the effects of development on the environment;
- continuing the coordination and integration of local, regional and state planning.

Development approval of foreshore protection works may be required under the Integrated Development Assessment System (IDAS).

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[13] Marine Parks (Great Barrier Reef Coast) Zoning Plan 2004 "*Schedule 11 Dictionary*" p 132.

Specifically the instruments may include but not be limited to:

- *Coastal Protection and Management Act*
- *Fisheries Act*
- State Planning Policy 2/02 (SPP 2/02) - *Planning and Managing Development Involving Acid Sulfate Soils*.
- *Vegetation Management Act 1999*.

A.6 Land Act

The Land Act applies to all land in Queensland - including that below high-water mark. Its administration requires that land to which this Act applies must be managed for the benefit of the people of Queensland by having regard to the following principles:

- Sustainability - Requires sustainable resource use and development so as to ensure that existing needs are met, and the State's resources are conserved for the benefit of future generations.
- Evaluation - Requires that land evaluation is based on the appraisal of land capability and the consideration and balancing of the different economic, environmental, cultural and social opportunities and values of the land.
- Development - Requires allocation of land for development in the context of the State's planning framework, and applying contemporary best practice in design and land management. When land is made available for development, it is allocated to persons who will facilitate its most appropriate use; and that use supports the economic, social and physical wellbeing of the people of Queensland.
- Community purpose - If land is needed for community purposes, the retention of such land is to be in a way that protects and facilitates the community purpose.
- Protection - Requires the protection of environmentally and culturally valuable and sensitive areas and features.
- Consultation - Requires consultation with community groups, industry associations and authorities as an important part of any decision making process.
- Administration - Requires that administration of the Act is consistent, impartial, efficient, open and accountable. A market approach is applied in land dealings, adjusted when appropriate for any community benefits arising from the dealing.

Erosion mitigation measures proposed by the Study on Unallocated State Land and other State Land will require a resource entitlement permit where there are direct implications (such as sand extraction activities) or indirect implications (e.g. impact on access). These provisions are also covered through the IDAS process.

A.7 Indigenous Cultural Heritage Act

Legislation exists under a number of Commonwealth and State Acts to protect Aboriginal and Torres Strait Islander cultural heritage. To ensure compliance with the *Aboriginal Cultural Heritage Act 2003*, when implementing erosion mitigation works Council must take all reasonable and practical measures to ensure that such works do not harm Aboriginal cultural heritage.

This may include:

- following the statutory "duty of care" guidelines, which may require consultation with the relevant Aboriginal party; or
- development and approval of a Cultural Heritage Management Plan.
- The State's *Native Title (Queensland) Act 1993* and the Commonwealth's *Native Title Act 1993* should both be considered when planning foreshore protection works.

A.8 Nature Conservation Act

The *Nature Conservation Act 1992* maintains biological diversity and ecologically sustainable development within areas established and managed under the Act. The Regulations under the Act that are likely to be of relevance to the Study are as follows:

- *Nature Conservation (Protected Areas) Regulation 1994* : which nominates declared protected areas such as National Parks and conservation parks;
- *Nature Conservation (Wildlife) Regulation 2006* : which identifies management intent and principles associated with certain significant species. It is read in conjunction with:
- Nature Conservation (Administration) Regulation 2006.

Any disturbance of areas so as to provide access for implementing erosion mitigation works will require assessment as to whether the area is an "essential habitat" for fauna species listed under the Act. For example, such species may include nesting habitats for listed sea turtle species if these are found to be in the area.

A.9 Fisheries Act

The *Fisheries Act 1994* provides for the management, use, development and protection of fisheries resources and fish habitats throughout Queensland. Approvals are required for marine plant disturbance, works in a declared fish habitat area or constructing or raising a waterway barrier.

Mangroves & Marine Plants

Tidal inundation of a coastal area generally indicates the presence of marine plants on a site protected under Section 8 of the *Fisheries Act 1994*. The definition of the term Marine Plant includes the following:

- A plant (a tidal plant) that usually grows on, or adjacent to, tidal land, whether it is living, dead, standing, or fallen. Material of a tidal plant, or other plant material on tidal land.

- A plant, or material of a plant, prescribed under a regulation or management plan to be a marine plant.

Areas within and adjoining the five coastal precincts covered by the Study may contain vegetation that are protected in accordance with Section 123 of the *Fisheries Act*; and as such any disturbance (trimming or removal) to these areas would require approval from the Department of Employment, Economic Development and Innovation (DEEDI).

Limited removal or trimming works on mangroves and associated marine plants may be undertaken for maintenance works on existing lawful structures or works on farm drains as per Marine Plant Code 02 and 03. However, any removal or trimming required for new construction works directly related to a development will require a development approval.

Any activities associated with the implementation of the various erosion mitigation strategies that may require the removal or harm to marine plants will require an approval from the DEEDI.

A.10 Local Government Act

The high water mark is the seaward extent of Whitsunday Regional Council's jurisdiction under the *Local Government Act 2009*. Nevertheless the Act enables local government authorities to obtain specific jurisdiction from the State with regard to the beach between the high and low water lines for special purposes - typically for beach nourishment.

Local government authorities control land use and activities under the local planning scheme (via the *Sustainable Planning Act 2009*) and Local Laws (via the *Local Government Act 2009*).

With regard to coastal management, local government has responsibilities relating to:

- land use control;
- recreational planning;
- management of local reserves;
- environmental protection and rehabilitation;
- monitoring.

A.11 Vegetation Management Act

The purpose of the *Vegetation Management Act* 1999 (VMA) is to regulate clearing of remnant vegetation on freehold and leasehold land by:

- Preserving remnant endangered, of concern and not of concern Regional Ecosystems and vegetation in areas of high nature conservation value; and
- Considering the preservation of vegetation in areas vulnerable to land degradation.

The definition of the term *Vegetation* under the Act includes the following:

- Native tree; or
- Native plant, other than a grass or mangrove.

A.12 Environment Protection and Biodiversity Conservation Act

The Commonwealth Department of the Environment, Water, Heritage and Arts administers the *Environment Protection and Biodiversity Conservation Act 1999.* Referral to the Department is required for actions that have (or are likely to have) a significant impact on a matter of national environmental significance.

These include;

- World Heritage properties
- National Heritage places
- Wetlands of international importance
- Migratory species
- Nationally threatened species and ecological communities
- The Commonwealth marine area
- Nuclear matters.

The issues potentially relevant to activities associated with the recommended erosion mitigation strategies include the world and national heritage values of the Great Barrier Reef World Heritage Area; migratory species such as bird species listed under international agreements (JAMBA and CAMBA); and nationally threatened species and ecological communities.

If erosion mitigation works recommended by the Study are declared a "*controlled action*", approval will be required under the Act before works can commence. The Commonwealth and Queensland governments have a bilateral agreement under the Act that controlled actions requiring environmental impact assessment (EIA) may be assessed in accordance to the EIA processes under Queensland law.