COASTAL ENGINEERING SOLUTIONS

in association with

NQ DRY TROPICS

CUNGULLA SHORELINE EROSION MANAGEMENT PLAN

prepared for

TOWNSVILLE CITY COUNCIL

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EXECUTIVE SUMMARY

Cungulla is a coastal community located approximately 35kms east-south-east of Townsville's CBD. The approximately 2km long crescent-shaped foreshore has been experiencing variable rates of erosion in recent decades, threatening private and public assets.

The complex interaction of waves, tidal currents, winds and creek flows are continually shaping and reshaping the shoreline fronting the Cungulla community. In recognition of the need to preserve this foreshore as a natural resource and to accommodate an expected increasing erosion threat to foreshore areas, this *Shoreline Erosion Management Plan* has been prepared. Its overall purpose is to provide a framework for the sustainable use, development and management of the Cungulla foreshore.

OBJECTIVES

The objectives of the Shoreline Erosion Management Plan are:

- to proactively plan for erosion management in a way that is consistent with all relevant legislation (Commonwealth, State and Local) as well as all relevant coastal and environmental policies;
- to investigate and address the underlying causes of shoreline erosion and its likely future progression at the local scale;
- to determine cost effective and sustainable erosion management strategies that maintain natural coastal processes and resources; and
- to consider community needs in both the short- and long-term.

RECOMMENDED SHORELINE EROSION MANAGEMENT STRATEGY

Following a review of the prevailing coastal processes, risks and values of the Cungulla foreshore the following activities are recommended by this Shoreline Erosion Management Plan:

Extent of Works

- The only section of the Cungulla coastal reach requiring direct intervention to mitigate shoreline erosion is along an approximately 585 metre foreshore extending from the northern-most end of Empress Close southwards to a location approximately 100 metres beyond Vivienne Lyons Park. This will protect private properties on Empress Close that are most vulnerable to erosion and damage by severe storms/cyclones.

Project Design and Approvals

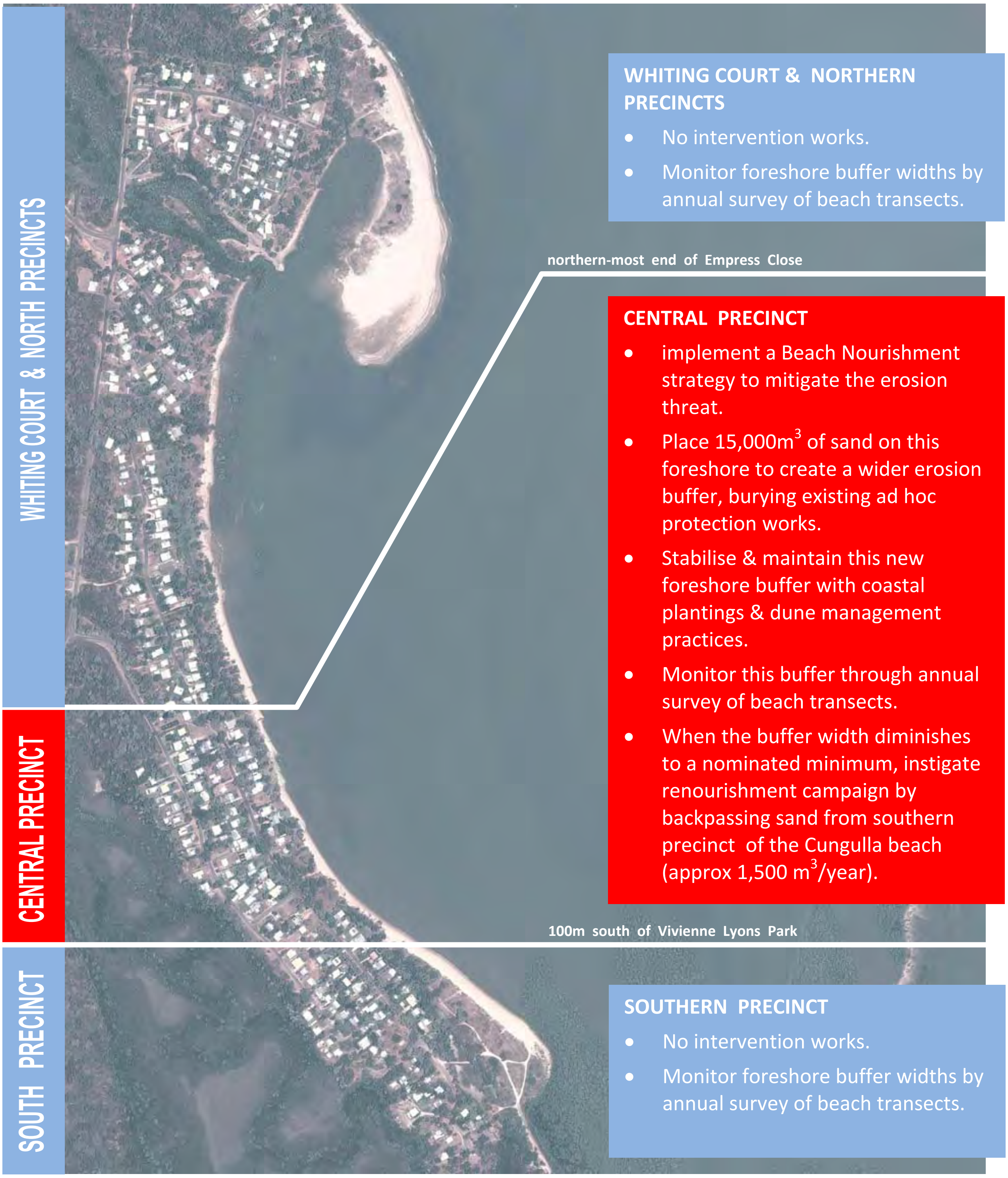
- Project stakeholders need to confirm that a 100 year ARI Design Event is appropriate to adopt for the erosion mitigation strategy recommended by this Shoreline Erosion Management Plan. This requires consideration and acceptance of the risk that such an event will occur (or be exceeded) within a particular planning horizon. Guidance on risk is offered in this Shoreline Erosion Management Plan.
- Should an event occur that is more severe than the selected Design Event, then the engineering works implemented in accordance with this Shoreline Erosion Management Plan may be compromised and coastal infrastructure could be damaged as a consequence. The selection of an appropriate Design Event is therefore an important consideration.
- Project stakeholders need to select the alignment of an appropriate Coastal Defence Line along the Cungulla shoreline. Throughout the planning horizon, 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 erosion buffers).
- Undertake detailed engineering designs, including the production of drawings and technical specifications for the necessary erosion mitigation works. This will likely require a more detailed land survey in the area where such works are to be implemented.
- Prepare and submit appropriate approval applications based on the detailed engineering designs for the proposed works. Guidance on relevant legislation and approval requirements are offered in this Shoreline Erosion Management Plan.

Project Monitoring

- Undertake a pre-project monitoring survey of the beach transect lines that have already been established as part of an earlier on-going monitoring program - as well as on two new transect lines established across the southern end of Big Beach (opposite properties in George Ansell Drive).
- Undertake beach transect surveys annually on ten of these established transect lines (namely CUN-01b and CUIN-02 to CUN-10) as well as the two new lines.
- All transect surveys are to extend offshore for a minimum distance of 500m from the toe of the sandy beach.

Beach Nourishment Strategy

- The extent of the recommended beach nourishment works is shown conceptually in the figure on the following page.
- Place sand as initial nourishment on the approximately 585 metre long at-risk section of shoreline opposite the northern section of Empress Close. This will create an erosion buffer that can accommodate the expected shoreline recession caused by a 100 year ARI cyclone event.



RECOMMENDED BEACH NOURISHMENT STRATEGY

- Most of the existing ad hoc seawalls along this section of the foreshore can be left in place; and simply be buried at the rear of the newly created sand buffer - although minor mechanical re-profiling of some of the higher walls may be required. So long as they remain buried at the back of the beach, they will not interfere with natural coastal processes.
- The actual sand quantity required to be placed in this initial nourishment exercise will depend upon the location of a Coastal Defence Line nominated by stakeholders; and the degree of protection required (ie. the selected Design Event). However as a guide, this Shoreline Erosion Management Plan has adopted a 100 year ARI Design Event; and a Coastal Defence Line along the top of the sandy beach and/or at the crest of the ad hoc protection works undertaken by local residents. This will require 15,000m^3 of sand to create an appropriate erosion buffer.
- The sand for this initial nourishment can be sourced from existing commercial sand extraction operations in the region without adverse environmental impacts.
- 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. Appropriate dune management strategies are offered in this Shoreline Erosion Management Plan.
- Whenever annual beach surveys indicate that the volume of sand in the buffer has naturally depleted below a specified limit, then a backpassing exercise would be instigated to renourish the buffer. The criteria that initiates such action would be determined as part of the detailed engineering design of the overall beach nourishment works.
- This back-passing would be achieved by using conventional earthmoving equipment, such as excavators and/or front-end loaders to collect sand from the southern foreshore; load it into trucks; which would then deliver it to the buffer area. The sand would then be spread on the foreshore by loader and/or grader to reinstate the buffer volume.
- It is likely that sand back-passing campaigns will need to be undertaken to redistribute on average 1,500m^3 /year of sand from the southern end of the Cungulla coastal reach to the at-risk foreshore along the northern section of Empress Close. This amount represents a long-term average requirement, since there will be some years of mild wave conditions which will not require the buffer to be renourished, whereas other years of more energetic wave conditions will necessitate more intensive backpassing.
- The estimated overall costs associated with the implementation of the recommended strategy under this Shoreline Erosion Management Plan are summarised on the following page. The estimates are at rates applicable in April 2013 and include GST.

SEMP component	Cost	Annual Cost
Project Design and Approvals		
Land survey in the area of proposed foreshore works	$10,000	
Engineering design of beach nourishment & sand extraction	$25,000	
Obtain appropriate approvals	$7,500	
Project Monitoring		
Establish 2 new transects & undertake initial pre-project surveys	$17,500	
Annual survey of all beach transects		$15,000
Beach Nourishment		
Initial nourishment to create erosion buffer	$475,000	
On-going renourishment by backpassing operations		$20,000
Implementation / maintenance of dune management program	$50,000	$5,000
Totals	$585,000	$40,000

- At this stage these estimates must be considered as indicative only since no detailed design has been undertaken. They have been based on an approximation of sand volumes for initial beach nourishment to provide a buffer to a Coastal Defence Line along the top of the sandy beach and/or the crest of ad hoc protection works.

1 INTRODUCTION

1.1 Background

Cungulla is a coastal community located approximately 35kms east-south-east of Townsville's CBD. The approximately 2km long crescent-shaped foreshore has been experiencing variable rates of erosion in recent decades, threatening private and public assets.

In response to this threat, many residents along the immediate foreshore have instigated ad hoc measures in an attempt to prevent further shoreline recession. To date most of these works have been unapproved and are largely ineffectual. Indeed many have actually aggravated erosion processes on nearby allotments - leading to an on-going and ever expanding need by local landholders to instigate their own erosion mitigation works. Given their ad hoc nature and inappropriate structural design and construction, such works invariably have failed or been damaged during storms - degrading foreshore use and visual amenity.

A number of campaigns have been undertaken in recent years by Townsville City Council and the Department of Environment and Heritage Protection to disseminate information relating to appropriate coastal management practices and legislative requirements for works on Cungulla's foreshore. Nevertheless there still remains a misguided resolve by many foreshore landholders to implement what are invariably unlawful and ineffectual measures to attempt erosion mitigation. There is also an understandable reluctance by landowners who have implemented such works to remove or modify them without there being an immediate implementation of appropriate protection measures.

The complex interaction of waves, tidal currents, winds and creek flows are continually shaping and reshaping the shoreline fronting the Cungulla community. In recognition of the need to preserve this foreshore as a natural resource and to accommodate an expected increasing erosion threat to foreshore areas, this *Shoreline Erosion Management Plan* has been prepared. Its purpose is to provide a framework for the sustainable use, development and management of the Cungulla foreshore.

1.2 Objectives of this Shoreline Erosion Management Plan

The objectives of the Shoreline Erosion Management Plan are:

- to proactively plan for erosion management in a way that is consistent with all relevant legislation (Commonwealth, State and Local) as well as all relevant coastal and environmental policies;
- to investigate and address the underlying causes of shoreline erosion and its likely future progression at the local scale;
- to determine cost effective and sustainable erosion management strategies that maintain natural coastal processes and resources; and
- to consider community needs in both the short- and long-term.

Shoreline Erosion Management Plans (SEMP's) are the Department of Environment and Heritage Protection's preferred method to address shoreline erosion issues at the local government level.

1.3 Structure of this Shoreline Erosion Management Plan

The Shoreline Erosion Management Plan has been structured as follows:

- This Section 1, which consists of an introduction and provides some background regarding the Cungulla coastal reach.
- In Section 2 the natural physical processes that have in the past, are currently, and will in the future, shape the project shoreline are discussed.
- A number of generic strategies that can be applied to mitigate erosion risks on sandy foreshores are presented in Section 3.
- Section 4 then provides an assessment of the most viable of these generic mitigation measures for the Cungulla foreshore.
- Section 5 provides details as to the recommended erosion mitigation option, including its costs.
- Section 6 then provides insight into local environmental values and provides advice on management actions to maintain and enhance these values within the recommended erosion mitigation strategy.
- Section 7 offers an outline of the commonwealth, state and local government legislative framework affecting the implementation of the recommended Plan.
- Section 8 then provides an overall summary of the Shoreline Erosion Management Plan, with all activities and cost estimates required to implement the Plan provided.
- Section 9 provides a list of technical references used to develop and support the findings of this Shoreline Erosion Management Plan.
- Appendices to support the technical content of the Plan are then included.

1.4 Regional and Local Setting

As illustrated in Figure 1.1, Cungulla is located on the south-western shores of Bowling Green Bay - which is an approximately 42km wide embayment between Cape Cleveland and Cape Bowling Green.

The Bay is a relatively shallow embayment facing north-north-east onto the broad open waters between the mainland and the Great Barrier Reef. At its offshore limit some 18kms from shore, Bowling Green Bay is only around 11 metres deep (below the level of the Lowest Astronomical Tide).

Figure 1.1 : Location of the Study Area in the Regional Context

The gradient of the seabed approaches onto the local foreshores of the Bay are therefore very flat. Also there are substantial intertidal flats immediately offshore of these foreshores. This, in conjunction with the flat shallow approach slopes and the surrounding land features of Cape Cleveland and Cape Bowling Green, provide natural protection and wave energy attenuation for the foreshore precinct of Cungulla.

Nevertheless, the fetches to the north-east of Bowling Green Bay are quite long, with the main Great Barrier Reef system being some 70kms offshore. It is from across these open north-east fetches that the largest waves can propagate into Bowling Green Bay and then onto the Cungulla foreshore.

There are substantial coastal wetlands adjacent to Bowling Green Bay that are drained by many natural waterways, the most significant of these being the Haughton River which flows into the Bay just to the south of Cungulla.

Figure 1.2 shows the setting of the Cungulla foreshore within a more local context.

Figure 1.2 : Cungulla Coastal Reach

There are a number of topographic and geomorphological features evident in this figure which are referred to in later chapters of this report. The most relevant of these being:

- the tidal channel that meanders across the intertidal flats immediately offshore of Cungulla;
- the sand spit at the northern-most end of the Cungulla coastal reach;
- the accumulation of sand at its southern end; and
- the waterways of Haughton River, Recovery Creek and Doughboy Creek.

Cungulla is located immediately alongside the Haughton River's confluence with Bowling Green Bay. As will be discussed in later sections, this proximity to the dynamic entrance area of such a large river has had a significant influence on the erosion problems experienced at Cungulla in recent years.

There have been intermittent beach transect surveys undertaken along the Cungulla coastal reach since December 1996; and the results of these various surveys have been utilised when preparing this SEMP.

An inspection of the survey results indicates that the foreshore level is lowest along the shoreline immediately south of Recovery Creek for a distance of around 400 metres. The crest at the rear of the beach is typically around RL+3.0m AHD on this low section, whereas elsewhere it is above RL+4.0m AHD and up to RL+4.5m AHD in places. It is typically highest along southern foreshores closer to the Haughton River entrance.

The nature of land tenure along the foreshore of Cungulla is an important consideration when assessing appropriate erosion mitigation options. As shown in Figure 1.3, most of the foreshore consists of Unallocated State Land (USL), except for an approximately 700 metre long section that is designated as a Council Esplanade. This Esplanade runs parallel to Empress Close and is located on the seaward side of properties fronting Empress Close.

As will be discussed in later sections of this report, the threat of erosion along the Cungulla coastal reach has resulted in ad hoc attempts by local residents to armour the foreshore with rocks, tyres, tree trunks, green waste, bricks and building debris. The standard of construction of the works is variable and the attempted armouring works are largely ineffectual as structural barriers during significant storm events. As well as being inappropriate structural solutions, the works are unlawful since almost all of them are built without the necessary development approval.

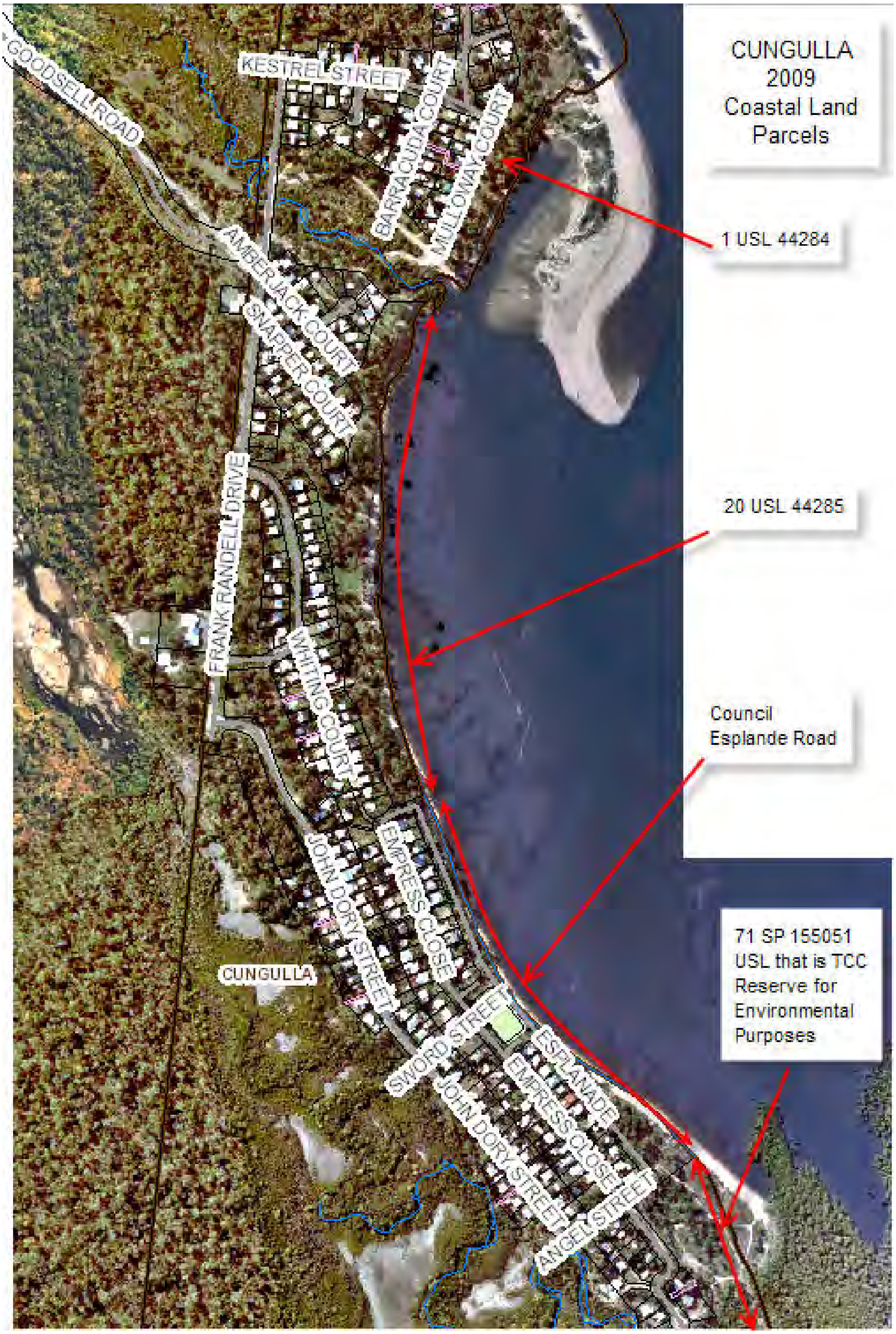


Figure 1.3 : Foreshore Land Parcels
(superimposed on a 2009 aerial photograph)

2 PHYSICAL PROCESSES ANALYSIS

The coastal environment responds continually to the ever-changing influences of waves, tides, ocean currents, winds and the supply of littoral sediments. Collectively these complex and dynamic coastal processes shape the physical environment of the Cungulla shoreline.

This section of the Shoreline Erosion Management Plan discusses the natural processes that are contributing to the existing and future erosion threats on this foreshore.

2.1 Overview

The coastal processes shaping the foreshores of Cungulla are highly complex. The erosion problem is a result of the dynamic interaction of influences from the Haughton River Entrance as well as the effects of the local littoral transport regime.

It is important to have a sound understanding of these changing local processes. Otherwise there is the very real risk that any future strategies to mitigate local erosion will be ineffectual, costly and potentially compromise the environmental and social values of the area.

Beach sands in the Cungulla area are composed predominantly of quartz, and have been derived from the weathering of the acidic igneous rocks of the region - which have then been delivered to the coastal environment through local creek and river systems. The sediment distribution in Bowling Green Bay shows quite distinctively that sand-sized sediments are confined primarily to the upper intertidal zone on local foreshores.

The boundary between the active beach face and the intertidal flats immediately in front is marked by a very abrupt change in slope and sediment type. Testing of sand samples undertaken for this SEMP shows that the beach face consists primarily of sand having an average grain size of around 0.25mm, but on the sand spit at the northern end of Cungulla this sand has a high shell content.

The surface sediments of the intertidal flats and deeper areas offshore of the beach slope are comprised predominantly of much finer unconsolidated silts and clays with little sand content.

Therefore the transport of sand in the vicinity of Cungulla occurs predominantly along the dynamic beach face of the local shoreline rather than across the wide intertidal flats immediately offshore.

Whilst tidal currents can potentially initiate and sustain movement of the finer offshore sediments during large tides, they are not of sufficient strength to move the coarser sand material that exists along the land/sea boundary that constitutes the Cungulla foreshore. It is wave action that moves this sand along the beach.

Nearshore channels have been created within the shallow intertidal flats by tidal flows and floods from the Haughton River (and to a lesser extent, from Recovery Creek and Doughboy Creek).

These channels have been continually changing their alignment and at times have been quite close to the beach at the northern end of the Cungulla coastal reach. Historically whenever a channel alignment has migrated into the zone of active beach processes, then the channel (and the tidal flows within it) have had considerable influence on these processes and have therefore altered the beach itself. Further discussion on this issue is offered in later sections of this report.

Tides also play an indirect role in local beach processes - in that the variable ocean levels allow waves to access various parts of the beach slope. Furthermore, since the amount of wave energy that reaches the beach is determined by the depth of water over the shallow intertidal approach slopes (by causing larger waves in the sea state to break before reaching the beach) tides play an additional indirect role by influencing the rate at which waves can move sand on the beach.

Nevertheless it is primarily wave energy that shapes the local sandy foreshore. Waves are generated by winds blowing on the surface of the ocean. Consequently the south-easterly waves generated by persistent south-easterly trade winds that occur during the North Queensland dry season move sand along the western shores of Bowling Green Bay towards the north and north-west. Sea breezes and wet season winds from more northerly directions result in sand being moved to the south and south-east on these shores.

However due to the significantly greater length and depth of the open water fetches to the north and north-east, greater wave energy arrives on the Cungulla foreshore from this particular sector.

In other words, whilst sand moves along the western shores of Bowling Green Bay in both directions, the net movement in the vicinity of Cungulla is towards the south and south-east; driven by the larger waves that arrive on local foreshores from the north-to-east sector.

2.2 Recent Shoreline Changes

Valuable insight can be obtained regarding the erosion processes from an assessment of changes to local foreshores that are captured in historical aerial photographs and beach transect surveys.

2.2.1 Historical aerial photographs

Aerial photographs of the Cungulla foreshore taken in 1961, 1995, 1999 and 2010 are presented for comparison in Appendix A. An interpretation of these and other historical photographs, along with a review of an earlier report on beach erosion issues (Hopley and Rasmussen, 1996) as well as site inspections, leads to the following conclusions:

- The prevailing coastal processes in Bowling Green Bay result in a net north-to-south transport of sand along the foreshore of Cungulla.
- In recent times the tidal channel that meanders across the intertidal flats immediately offshore of Cungulla has played an important role in sand transport processes on the foreshore. However this impact is gradually diminishing.

Discussion regarding these two important influences is offered later in this report.

2.2.2 Historical beach transect surveys

Surveys have been undertaken intermittently since December 1996 to identify on-going changes to the cross sectional profile of the foreshore and nearshore regions of the Cungulla coastal reach. The locations of the monitored beach transect lines are shown on Figure 2.1 and the results are summarised in Appendix B.

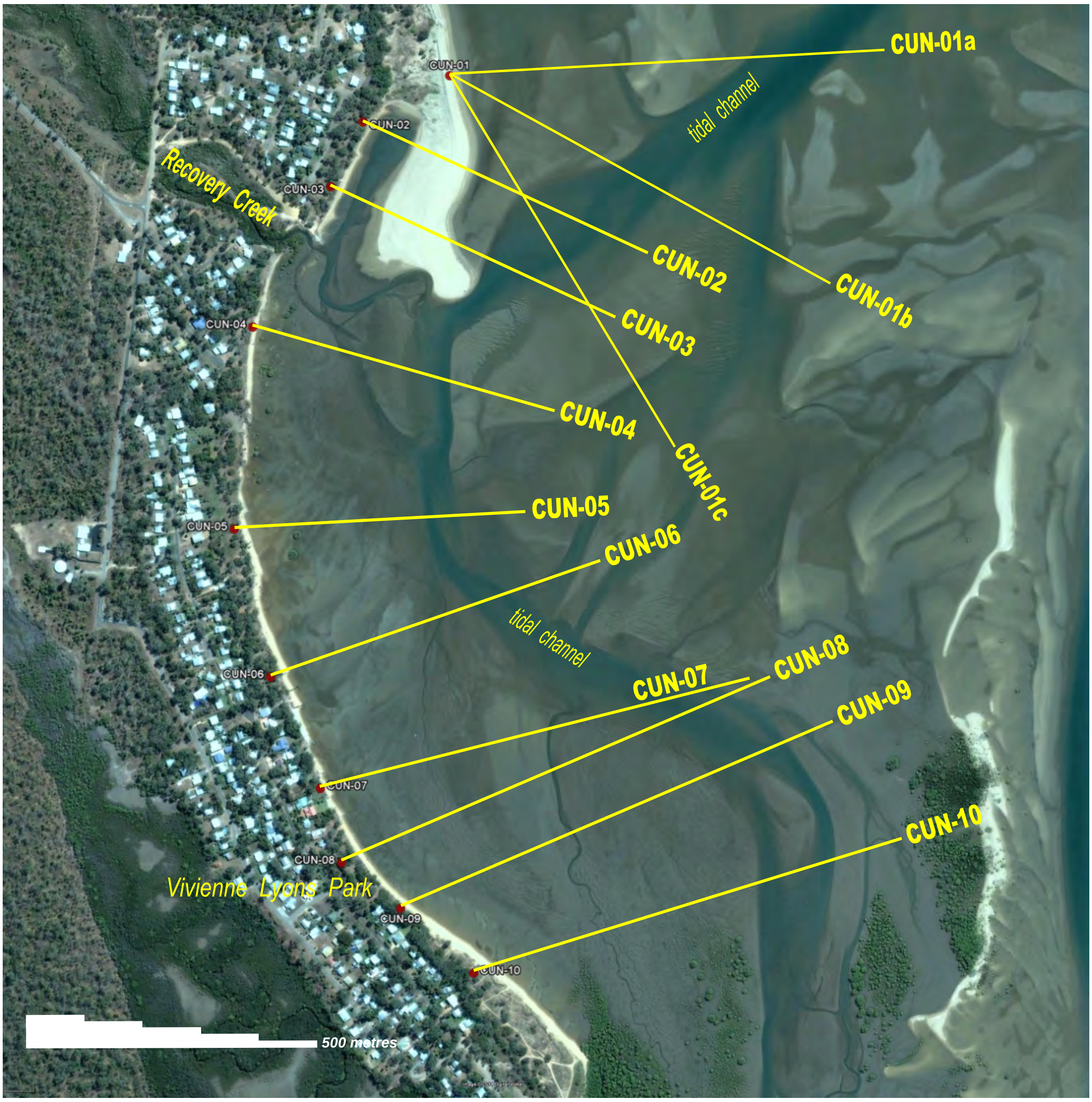


Figure 2.1 : Location of Beach Transect Survey Lines

To further assist in the interpretation of historical changes to the Cungulla foreshore, the changing position of particular contour levels were plotted for each beach transect line. Such contour positions can be identified as a distance seaward of the benchmark physically established on site at each transect location. Plots showing historical changes to these various contour levels are also included in Appendix B.

North of Recovery Creek

Transects CUN-01a, CUN-01b and CUN-01c radiate out from the sandy foreshore of Big Beach to the north of the Cungulla coastal reach. The survey results show that there has been substantial recession of this beach. The shoreline has receded by more than 70 metres since the first survey in December 1996. Sand has been transported southwards off Big Beach by longshore transport processes onto the sand spit at the northern end of the Cungulla coastal reach.

Transects CUN-02 and CUN-03 are located north of Recovery Creek and cross the northern sand spit. It is evident that the upper beach slope along this foreshore was experiencing significant erosion up until late 1997. Since that time the foreshore has remained relatively stable. This has occurred as a consequence of two interrelated phenomena, namely:

- the sand spit immediately offshore has gradually become longer, wider and higher - thereby offering increasing wave protection to this foreshore in its lee; and
- the natural migration of the deep tidal channel away from the toe of the sandy beach.

South of Recovery Creek

Transects CUN-04, CUN-05 and CUN-06 are located south of Recovery Creek along the section of foreshore that fronts properties in Snapper Court and Whiting Court. The historical surveys show that the slope of the sandy beach has varied notably in recent years, particularly along the northern part of this shoreline. The upper beach region has been slowly receding - being some 5m to 10m further landward in the 2012 survey than it was in the first survey of December 1996.

The ebb-flow tidal channel that flows approximately alongshore has gradually migrated further offshore, becoming shallower as it does so.

Ocean frontage to the northern part of Empress Close

Transects CUN-07 and CUN-08 along the section of foreshore that fronts properties in Empress Close. The surveys show that (apart from some short-term cycles of storm erosion and recovery) the shoreline position was reasonably stable until around late-2005 or early-2006. Since then there has been gradual recession of the upper beach region, particularly recently in the vicinity of CUN-07.

However transect line CUN-07 is located directly off a vacant block of land which has a natural shoreline, whereas adjacent properties have implemented ad hoc armouring measures.

It is likely that the adjacent armouring of the foreshore is contributing to the measured recession at CUN-07, and that this is a very local erosion response.

In general however it appears that the average position of the sandy shoreline has been slowly receding along the Empress Close ocean frontage.

South of Vivienne Lyons Park

Transects CUN-09 and CUN-010 are south of Vivienne Lyons Park opposite private properties on the southern end of Empress Close. The surveys indicate that the shoreline in this area has been reasonably stable - apart from some short-term erosion and recovery due to storms. However the most recent survey of July 2012 has identified notable recession since the preceding survey in February 2010.

It is possible that this is a result of TC Yasi (February 2011). The beach and dune system in this region is higher than elsewhere along the Cungulla foreshore; and unlike most of the foreshore further north, would not have been overtopped during the extreme storm tide levels of TC Yasi. Consequently the higher dune and beach slope would have experienced greater erosion.

Southern-most end of the Cungulla coastal reach

The shoreline beyond the southern-most beach transect is located in the lee of intertidal mangroves. This stand of mangroves is increasing in physical extent and increasing in its density of coverage. This section of foreshore has therefore been experiencing increasing protection from storm waves and has been accreting sand as a result. There are no established beach transect surveys in this accreting area of shoreline.

2.3 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 the Cungulla shoreline. 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 largely 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).

2.3.1 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 are available (Maritime Safety Queensland, 2012) for nearby Cape Ferguson - some 14kms north. These are presented in Table 2.1.

Tidal Plane	to AHD	to Chart Datum
Highest Astronomical Tide (HAT)	2.15 metres	3.84 metres
Mean High Water Springs (MHWS)	1.20 metres	2.89 metres
Mean High Water Neaps (MHWN)	0.40 metres	2.09 metres
Mean Sea Level (MSL)	0.07 metres	1.76 metres
Mean Low Water Neaps (MLWN)	-0.20 metres	1.49 metres
Mean Low Water Springs (MLWS)	-1.02 metres	0.67 metres
Lowest Astronomical Tide (LAT)	-1.69 metres	0.00 metres

Table 2.1 : Tidal Planes on the Cungulla Coastal Reach

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 Cungulla is 3.84 metres, with an average range during spring tides of 2.22 metres and 0.60 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 May - July). 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 around Christmas or early in the New Year. However, equally high tides occur in the winter months, but these are typically at night and therefore are not as apparent as those during the summer holiday period - which generally occur during daylight hours.

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 Cungulla to varying degrees. The deviations from predicted astronomical tidal heights 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 also significantly influence ocean water levels.

2.3.2 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 2.2 illustrates the primary water level components of a storm tide event. A brief discussion of each of these various components is offered.

- *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.

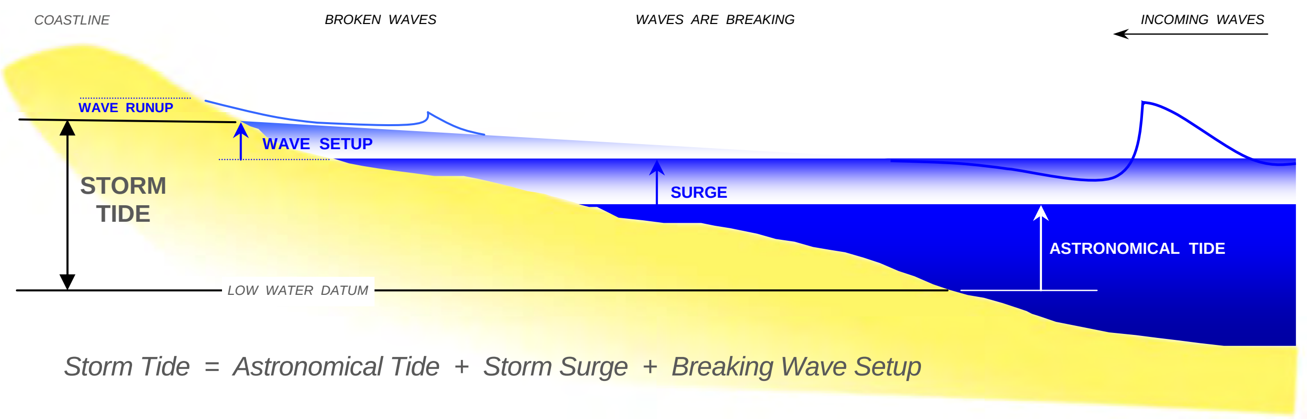


Figure 2.2 : Components of a Storm Tide Event

- *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 the storm tide vulnerability of the Cungulla foreshore.

2.3.3 Storm Tide Events at Cungulla

Storm surge can generally be estimated for a cyclone of any given intensity and size, however the storm tide level depends upon when the peak surge generated by the cyclone occurs in relation to the astronomical tide. For example, a severe cyclone which produces high waves and a large storm surge will not produce a high storm tide if it occurs around the time of low tide. The big surge and severe waves occurring at low tide might result in only a moderate storm tide level (with less wave energy reaching the foreshore due to the waves breaking in the shallower seabed approaches) than a lesser surge and moderate wave conditions occurring at high tide.

A number of studies have previously been undertaken with regard to storm tides that may occur in the Townsville region. The most recently published being the *Townsville - Thuringowa Storm Tide Study* (GHD Pty Ltd, 2007). That study also addressed the effect of future climate change on sea level rise and tropical cyclone occurrences.

The storm tides reported for the Cungulla coastal reach by that regional study have been used in the preparation of this Shoreline Erosion Management Plan and are summarised in Table 2.2 for the present-day climate scenario. These levels include the effects of breaking wave setup.

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 an even shorter timeframe as cyclone influences pass.

Average Recurrence Interval[1]	RL to AHD inc. Breaking Wave Setup
50 years[2]	2.65 metres
100 years	2.94 metres
200 years	3.20 metres
500 years	3.51 metres
1,000 years	3.56 metres

Table 2.2 : Storm Tide Levels at Cungulla

2.4 Wave Climate

Given that sand is primarily transported by wave action on this coastline, the wave characteristics on the Cungulla foreshore are critical considerations to the understanding of local coastal processes.

Waves move sand in two fundamental ways; by longshore transport and by cross-shore transport. Both processes can occur simultaneously, but both vary significantly in their intensity and direction in response to prevailing wave conditions.

Some comment regarding these important sand transport processes is warranted.

Longshore transport

This is the movement of sand along the beach. 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. Consequently an understanding of wave-driven longshore sand transport is essential for the determination of successful erosion management practices.

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.

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[1] 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.

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

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. Certainly this is the case for the Cungulla shoreline where the net transport rate is towards the south despite there being sand movement in both longshore directions throughout a typical year.

Cross-shore transport

This is the movement of sand perpendicular to the beach – in other words, it is the onshore/offshore movement of sand that is induced by wave action.

Whilst this washing of sand up and down the sloping sandy beach 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 the beach as sand is removed from the dune system and upper regions of the profile. The eroded sand is moved offshore during the storm to create a temporary sandbank near the seaward edge of the surf zone. Subsequent milder wave conditions can return this sand back onto the beach, where waves and onshore winds then re-work it 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.

Such severe wave and ocean level conditions can result in significant damage to foreshore protection works - unless they are appropriately designed and constructed. Unfortunately the standard of many of the ad hoc works implemented by Cungulla residents will not withstand repeated storm loadings.

In summary

The importance of cross-shore and longshore sand transport by waves 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.
- 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.

2.5 Longshore Sediment Transport

A comparison of historical aerial photographs indicates that waves are causing a net transport of sand from north to south along the Cungulla coastal reach. This is evident (refer to Appendix A) from:

- the growth of the sand spit at the northern end of the Cungulla coastal reach;
- the accumulation of sand at the southern end (south of the foreshore reserve of Vivienne Lyons Park); and
- the temporary accumulation of sand against man-made obstructions across the active beach system.

2.5.1 Big Beach

The beach transect surveys undertaken at Cungulla in recent years have not included Big Beach, so it is not possible to estimate volumetric changes to the foreshore north of the sand spit. Nevertheless an examination of historical aerial photographs suggests that the foredunes which previously existed in front of the high primary dunes in this area have been substantially eroded in recent decades.

It is likely that this erosion has been primarily due to episodic storm/cyclone erosion - with the eroded sand being distributed offshore across the wide sandy seabed approaches immediately offshore of the southern end of Big Beach. Such periodic offshore sand deposits have then been available to feed naturally onto the northern sand spit during subsequent milder wave conditions.

2.5.2 Northern sand spit

The northern end of the Cungulla coastal reach and the sand spit are shown on Figure 2.3. In the years between the surveys of December 1996 and July 2012, approximately 140,000m^3 of sand has been supplied to the spit from the foreshores of Big Beach further to the north. This indicates that the spit is growing at a rate of around 9,000m^3 each year.

Figure 2.3 : Locale of the northern sand spit

There is no northern sand spit evident in aerial photographs taken prior to 1961. However in those times, the offshore tidal channel was located very close to the beach along the northern end of Cungulla - particularly north of Recovery Creek where the channel was virtually along the toe of the beach slope (refer to 1961 photograph in Appendix A). It is likely that the spit was prevented from forming by the ebb tide flow in this nearshore channel.

The combined effect of the high wave exposure and the proximity of the channel to the beach at that time resulted in any sand being moved by cross-shore transport processes being swept into the tidal channel. From there it was carried offshore by channel currents; and was therefore permanently lost from the shore. Significant erosion of this area north of Recovery Creek occurred as a consequence - with 120 metre recession of this particular foreshore reported between 1942 and 1961 (Hopley and Rasmussen, 1996).

At that time there were two competing processes acting at this northern end of the Cungulla coastal reach. The southward longshore transport of sand from Big Beach towards Cungulla was acting to close off the tidal channel; whereas the flow of tidal water in the channel itself was acting to keep the channel open - by scouring any sand that was deposited into it by the competing longshore transport.

At some time prior to the aerial photograph being taken in 1995 there was either a very significant storm/cyclone season - or a number of successive years of strong cyclone activity - that saw considerable southerly longshore transport rates that overwhelmed the tidal flows in the channel. For example, the years 1993, 1994 and 1995 experienced northerly wind conditions that were more persistent than normal (Hopley and Rasmussen, 1996).

Since the channel flow then became somewhat impeded, it necessitated a natural realignment of the channel at this northern end of Cungulla Beach.

This would have resulted in a more circuitous channel alignment, leading to a reduced channel flow velocity, leading further to an increasing dominance of the longshore transport on the channel. It is likely that this eventually lead to the gradual but significant migration of the tidal channel away from the shoreline.

This steady offshore migration of the channel has enabled the sand spit to grow at an estimated average rate of 9,000 m^3/year since 1996. Its southern tip has moved southward some 470 metres since then, ie. advancing approximately 30 m/year. This growth and southern migration of the spit is expected to continue into the future. However due to the variability of future annual / seasonal conditions and prevailing wave climate, actual rates in any one year could differ markedly from this average which has been determined over approximately 15½ years.

Nevertheless the prograding sand spit will provide increasing protection to the previously at-risk foreshore north of Recovery Creek. Indeed as the spit grows southward, the foreshore immediately south of Recovery Creek will also start to benefit from the offshore protection afforded by the spit.

It is difficult to predict what might happen too far into the future as the spit continues to prograde southward in front of the northern part of the Cungulla foreshore. This uncertainty is due primarily to the problem of predicting the effect that flows from Recovery Creek will have on the sand spit.

Flows discharging out of Recovery Creek have created a meandering channel across the intertidal flats; and this channel passes to the south of the migrating sand spit. The Recovery Creek intertidal channel is interacting with longshore sand transport processes on the spit in much the same way as the somewhat larger offshore tidal channel did previously. That is, it is competing with the advancing spit in order to maintain its current alignment.

Inevitably the more dominant longshore sand transport will result in the spit continually advancing southward and the alignment of the Recovery Creek intertidal channel being pushed southwards in front of the advancing southern tip of the sand spit. Nevertheless it is unlikely that the advancing spit will connect completely with the Cungulla shoreline to create an enclosed coastal lagoon. Wet season flows in Recovery Creek are very substantial and these flows will maintain an opening to the ocean to facilitate their discharge by scouring the sand spit. Although just how this complex interaction of spit growth and channel migration will evolve in future is uncertain.

It is important to appreciate that this discussion of the Recovery Creek intertidal channel relates to the channel naturally cut across the tidal flats - not to the alignment of the creek mouth or the alignment of the creek upstream of where it discharges across the shoreline near the boat ramp.

2.5.3 Central part of the Cungulla coastal reach

Whilst the local foreshore immediately south of Recovery Creek is expected to experience increased protection in coming years (and consequently reducing erosion threat), the foreshore in the central part of the Cungulla coastal reach forming the ocean frontage to Whiting Court and Empress Close (refer to Figure 2.4 overleaf) is expected to continue to experience erosion influences.

Indeed it is possible that the erosion problem opposite Whiting Court will be greater than has been experienced to date.

This is because whilst there is a net transport from north to south along the Cungulla coastal reach, this in fact means that on average there is more sand moving southward than there is moving northward in any year. However for a site opposite to (and just to the south of) the tip of the offshore spit, any sand that moves northward along the beach into the lee of the spit may then not be transported back southward when sea and weather conditions change. Sand will nevertheless still be taken from this area by such subsequent conditions, but there will be no sand coming from the north to resupply the amount that was removed. The longshore wave processes that normally would result in this replenishment from the Cungulla foreshore further to the north of Whiting Court are diminished because the advancing sand spit blocks these waves.

Further south along the ocean frontage to Empress Close, private dwellings are quite close to the shoreline and it is along this section of foreshore that there has been considerable effort applied by landowners to protect their assets by ad hoc foreshore protection measures.

Figure 2.4 : Locale of the central section of Cungulla

In coming years there will continue to be strong erosion processes. These will significantly threaten the structural integrity of the ad hoc protection works along these various properties. As is the case elsewhere along the Cungulla foreshore, some of the individual protection works exacerbate the erosion problems of neighbouring properties due to their inappropriate design and construction. Future years will see increasing need of significant repair and/or replacement of these ad hoc works, along with increasingly adverse impacts on adjacent properties.

Without applying detailed coastal processes modelling it is difficult to estimate the net longshore sand transport rate along this central section of the Cungulla foreshore. Whilst just to the north the average long-term rate is approximately 9,000m^3/year (feeding onto the growing offshore sand spit), the orientation of the shoreline in this central region means that the rate is less.

The rate of sand accumulation south of Vivien Lyons Park would give an indication of this longshore rate, however available surveys do not adequately cover this southern accumulation area.

Consideration of the different shoreline orientations of the northern sand spit (where the longshore transport rate is 9,000m^3/year) and that along the central section of Cungulla - along with their differing seabed approaches - suggests that the longshore transport rate near the end of Snapper Court is approximately 2,500m^3/year. This rate diminishes further southward towards Vivien Lyons Park - being almost zero in the lee of the substantial stand of mangroves off the southern end of the Cungulla foreshore.

Given this variability in the average longshore sediment transport rate (from a maximum of 2,500m^3/year at its northern end, to almost zero at its southern end), for the purposes of assessing strategies for this Shoreline Erosion Management Plan an average rate of around 1,500m^3/year is adopted for the central section of the Cungulla foreshore.

It is important to appreciate that this is in fact what is known as the *longshore sand transport potential* - since it is the rate at which sand would be moved if it was freely available on the beach. If seawalls and other such protection works are in place, then clearly the prevailing wave processes are unable to move foreshore sand at this full potential.

2.5.4 Southern part of the Cungulla coastal reach

Figure 2.5 shows the foreshore south of Vivienne Lyons Park that has been accumulating sand. This accretion is supplied by net southerly longshore transport processes acting on the northern and central sections of Cungulla.

The extensive offshore sand shoals of the nearby Haughton River Entrance result in a reduced wave climate along this section of foreshore. The expanding areas of offshore mangroves also act to reduce the wave energy (and hence sand transport capability) along this local shoreline.

Figure 2.5 : Locale of the southern section of Cungulla

It is expected that this area will continue to accrete, although the rate at which it will do so will depend upon the amount of sand on the foreshore of central Cungulla that becomes freely available to be moved by waves. Armouring of the central area - either by continuing ad hoc protection works (which will require increasing repair/replacement efforts by landowners) or by a more appropriately designed and constructed seawall structure - will result in lower accretion rates

2.6 Cross-shore Sediment Transport

In addition to transporting sand along the Cungulla shoreline, waves move sand in a cross-shore direction. It is during storms and cyclones that this type of sand transport becomes critical.

Severe wave conditions in conjunction with elevated ocean water levels enable large waves to access higher levels of the beach profile - resulting in significant erosion of the beach and any dunes. Sand is removed from this upper region of the profile and is deposited offshore - resulting in recession of the shoreline and the creation of broad low sandbanks immediately offshore.

If the storm or cyclone is particularly severe, the erosion may threaten or damage foreshore infrastructure.

Technical work undertaken for this Shoreline Erosion Management Plan included application of the SBEACH proprietary mathematical model to predict the response of the beach to a severe cyclone scenario.

When considering the vulnerability of the Cungulla foreshore to storm/cyclone events, the 100 year ARI storm conditions have been investigated. The response of the beach to such an event was modelled using SBEACH at each of the surveyed transect lines located south of the prograding sand spit (refer to previous Figure 2.1 for locations).

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

- utilise cyclone wave information for the deep waters offshore of Bowling Green 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 Townsville region (DNRM, 2004) and (GHD Pty Ltd, 2007); then
- apply the local wave / storm tide conditions and the most recent beach transect surveys as input to the SBEACH model to determine the eroded profile at each location.

Figure 2.6 illustrates a typical outcome of the SBEACH numerical modelling, namely the pre-storm profile and post-storm profiles for a location at transect CUN-07 (opposite Empress Close) for a 100 year ARI cyclone scenario.

A 100 year ARI event will result in around 10 metres recession of the shoreline. As can be seen, sand is typically eroded from the upper beach area, generally from above RL+1.5m AHD. This sand is then deposited offshore of the toe of the beach, thereby flattening the beach slope. This typical cross-shore erosion process occurs along the entire Cungulla shoreline during severe storms/cyclones.

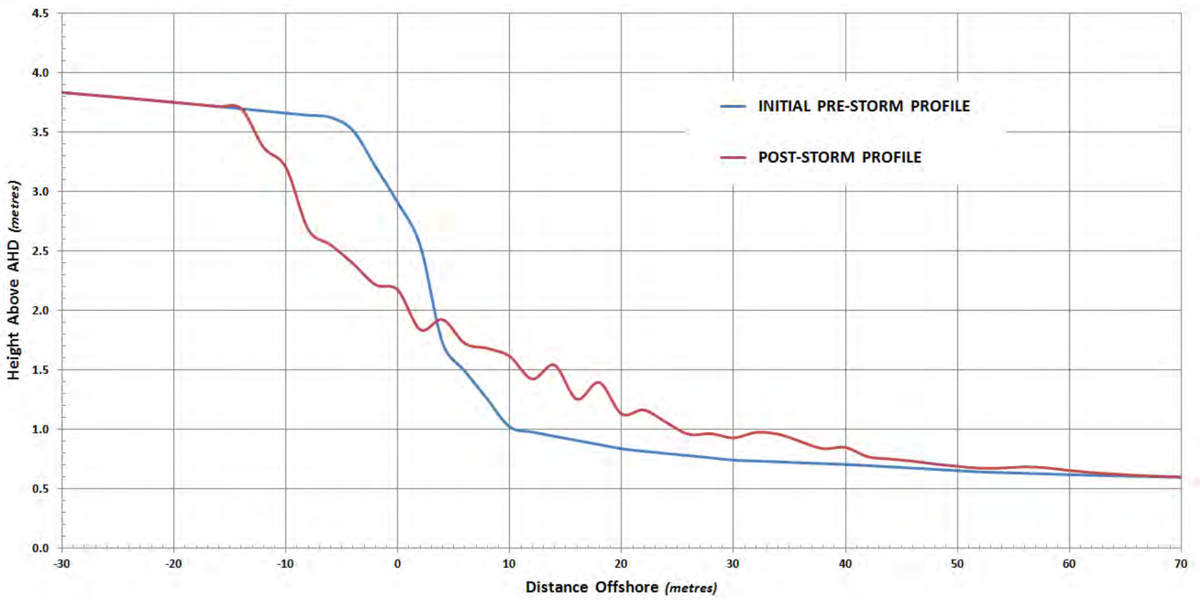

Figure 2.6 : Predicted Beach Response (at CUN-07) for 100 year ARI Event

During events greater than around 200 year ARI, there is considerable overwash of the Cungulla foreshore. This phenomenon occurs when the storm tide builds during the cyclone to be so great that waves no longer dissipate their energy directly on the beach slope or on any dunes - ocean water levels are such that the waves wash over the beach slope since it is substantially submerged.

Once overwash commences, further recession of the foreshore still occurs. However instead of being carried offshore, sand in the upper beach is swept up over the slope and carried inshore. TC Yasi in February 2011 was an example of this overwash phenomena.

The consequences of overwash can be devastating to foreshore areas since the foreshore is not only inundated by storm surge, but destructive cyclonic waves can wash over the beach and penetrate inland.

2.7 Migrating Tidal Channel

The general location of the various tidal channels associated with the Haughton River's confluence with Bowling Green Bay is illustrated in the satellite image of Figure 2.7. Whilst the main Haughton River entrance channel lies a considerable distance offshore, the minor tidal channel that meanders across the intertidal flats immediately offshore of the Cungulla shoreline has altered its alignment significantly in recent decades.

This nearshore channel acts mainly as an ebb (outgoing) tidal channel. Changes to the alignment of the ebb tide channel are evident in the series of historical aerial photographs presented in Appendix A to this report.

Figure 2.7 : Satellite image showing local tidal channels

An investigation of beach erosion processes reported by Hopley & Rasmussen in 1996 identified the significant effect that this channel has had on beach processes of the Cungulla coastal reach.

At that time the ebb tide channel was very close to the northern end of the beach and contributed significantly to erosion problems. Any sand on the beach that was moved even slightly offshore by waves would have entered the nearshore channel, to then be swept away by tidal flows and lost from the active beach system.

However since around 1996 the channel has migrated away from the shoreline. As discussed earlier, this is likely to have been a result of the net southerly longshore sand transport processes on the sand spit overwhelming the ebb tidal flows - causing a natural realignment of the channel. This offshore migration of the channel and the growth of the northern sand spit have resulted in a diminishing effect of the channel on local beach processes.

This is likely to continue into the future, with the prograding sand spit causing the ebb tide channel to remain at this more offshore location, or possibly even migrate further offshore.

2.8 Implications to Erosion Buffers

The sandy shores of the Cungulla coastal reach act as erosion buffers, protecting foreshore infrastructure and property from the natural fluctuations in the beach itself. Preceding sections of this Shoreline Erosion Management Plan provided discussion on the naturally occurring longshore and cross-shore sand transport mechanisms that affect these sand reserves.

It is evident that the cross-shore sand transport processes during severe storm events can cause rapid depletion of erosion buffers. It is evident from the beach response modelling of cross-shore sand transport that to ensure adequate protection is afforded to foreshore infrastructure and property during a 100 year ARI event, there needs to be at least a 10 metre wide buffer.

Maintaining this buffer width ensures that such infrastructure is located a sufficient distance inland so as not to be damaged by storm erosion.

Longshore sand transport also plays an important role, since it is the means by which the erosion buffers are kept naturally recharged with sand. Provided the supply of sand from updrift foreshores matches the rate at which sand is moved to downdrift foreshores, then local erosion buffers are not adversely affected by longshore transport processes.

However, as discussed earlier in Section 2.5.3 this is not the case for the central section of the Cungulla foreshore in the vicinity of Whiting Court and Empress Close. The prograding northern spit is adversely affecting longshore transport processes in this area, consequently these local erosion buffers are diminishing.

It will be necessary to supply and place an additional 1,500m^3 of sand approximately each year to recharge these buffers so that their ability to accommodate severe storm/cyclone events is not compromised.

2.9 Future Climate Change

The preceding discussions of sand transport rates and shoreline recession are based on a present-day climate scenario. Climate change as a consequence of enhanced Greenhouse gas emissions will cause environmental changes to ocean temperatures, rainfall, sea levels, wind speeds and storm systems. If climate changes develop as predicted, the Cungulla foreshore 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) 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. This suggests the possibility of a sea level rise up to 0.8 metres by the year 2100.

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.

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 along the Cungulla shoreline will likely 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 through Bowling Green Bay 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.

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 impacts as they gradually evolve.

3 SHORELINE EROSION MANAGEMENT OPTIONS

3.1 Guiding Principles

When preparing a Shoreline Erosion Management Plan there are a number of generic solutions and strategies which can be considered for erosion mitigation of shorelines. The *Queensland Coastal 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[3] of approaches:

- 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.

3.2 Coastal Defence Line

When considering foreshore protection measures on any shoreline, 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 Cungulla shoreline, or alternatively the alignment of any protection structure such as a seawall. Property and infrastructure landward of the Coastal Defence Line is protected, 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 therefore entails consideration by stakeholders as to what assets are to be defended. Options for a Coastal Defence Line along the Cungulla foreshore include:

- an alignment along the landward boundary of the USL and Council Esplanade (ie. on the seaward boundaries of private properties); or
- an alignment along the seaward boundary of the USL and Council Esplanade (ie. along the alignment of existing eroded/armoured foreshore); or
- along an alignment notionally seaward of the existing foreshore.

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[3] Required under the current *Draft Coastal Protection State Planning Regulatory Provision*, issued on 08th October 2012 by the Queensland Department of State Development, Infrastructure and Planning.

All options require consideration of the contribution any existing ad hoc foreshore armouring can provide to the preferred erosion mitigation option. As stated previously, these works are of varying standards but are typically inadequate in providing long-term erosion mitigation.

3.3 Selecting the Design Event

The Queensland Coastal Plan (Department of Environment and Resource Management, 2012) until recently required assessment of the vulnerability of any coastal area to a "Defined storm-tide event" (or DSTE) when managing development with that area. The DSTE is defined in terms of its likelihood of reoccurrence. Under *State Planning Policy 3/11: Coastal Protection* (SPP3/11), the Plan nominated a one per cent annual exceedance probability storm event as the default DSTE, which is equivalent to the 1 in 100-year ARI. This designation was in accordance with the long-established approach of using the 100 year ARI event to assess cyclone erosion and storm tide inundation on Queensland's coastline.

However at the time of finalising this Shoreline Erosion Management Plan, the State Government announced that a full review of the Queensland Coastal Plan including SPP3/11 is to be undertaken. Whilst that review is underway, the operation of SPP3/11 has been suspended. A *State Planning Regulatory Provision* (SPRP) is to apply for 12 months while the full review of the Queensland Coastal Plan is undertaken. Unlike the suspended SSP3/11, the SPRP does not nominate any particular ARI event for assessing development applications. Nevertheless the SPRP states that it is based on coastal management plan policies that were in place before the introduction of SPP3/11.

The various stakeholders associated with the implementation of this Shoreline Erosion Management Plan will need to select the Design Event for which the recommended erosion mitigation strategies are to accommodate. This requires consideration and acceptance of the risk that such an event will occur (or be exceeded) within a particular planning horizon. Nominating the Design Event requires selecting the Average Recurrence Interval (ARI) cyclone for which immunity is required.

Stakeholders may simply choose to adopt a 100 year ARI cyclone as the Design Event, since historically this has been the minimum required for ensuring appropriate coastal protection in Queensland.

However it is important to appreciate that should an event occur that is more severe than the selected Design Event, then the strategies and engineering works implemented in accordance with this Shoreline Erosion Management Plan 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, and there is merit in considering adopting a Design Event which is more severe than the minimum 100 year ARI.

The probability of events having various Average Recurrence Intervals occurring or being exceeded within a particular planning horizon can be predicted using established mathematical techniques, thereby quantifying the risk associated with each such event.

To assist in determining an acceptable level of risk when selecting a Design Event, Table 3.1 presents various probabilities of occurrence for cyclones of varying intensities (ie. for various ARI) within a 50 year planning horizon.

ARI of the event	probability of being equalled or exceeded	probability of 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 within a 50 year timeframe

3.4 Generic Erosion Management 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 scraping - 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 could be either "soft" or "hard" solutions, or a combination of both.

Prior to undertaking an appraisal of each generic erosion management option and its potential application to the Cungulla shoreline, a general discussion of each option is provided in the following pages.

3.4.1 Non-structural Management Options

3.4.1.1 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 a nominated planning period. However on foreshores where existing development and infrastructure is threatened by erosion, the high social and financial costs associated with their loss are generally unacceptable.

Indeed it is the threat of such loss along the central shores of the Cungulla coastal reach that has necessitated intervention in recent years - by way of local landowner's ad hoc attempts at foreshore stabilisation works.

A Do Nothing strategy on this eroding shoreline would potentially lead to the loss of Unallocated State Land (USL), the road esplanade and private property in Empress Close. This scenario would therefore lead to considerable economic loss and social trauma.

However in the vicinity of Recovery Creek where local foreshores are now protected in the lee of the advancing northern sand spit, the available buffer zone remains sufficient to accommodate erosion and climate change influences in coming years. Consequently a Do Nothing strategy has potential application on these northern shores.

3.4.1.2 Avoid development

Along sections of the foreshore that remain substantially undeveloped, a key objective would be to prevent an erosion problem from occurring by allowing the natural beach processes of erosion and accretion to occur unimpeded. This would also preserve the natural ecosystem, amenity and character of the beach.

There is scope to implement this option along the foreshore north of Empress Close since the foreshore prone to future erosion influences constitutes Unallocated State Land.

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 the Cungulla foreshore as being within a 60m wide Erosion Prone Area[4].

3.4.1.3 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.

This strategy requires the relocation of essential and non-essential infrastructure and/or the resumption of private land and dwellings. Where there are isolated and small scale public assets threatened by erosion, planned relocation can be a viable and cost effective option.

However the social and financial costs involved in such relocations and associated resumption of land can be considerable along significantly developed foreshores. For example a planned retreat strategy along those lengths of the Cungulla foreshore most threatened by erosion would require the resumption of private residences and landholdings along a significant length of Empress Close.

The social and financial costs involved would be considerable given current property values. Strong adverse community response to this strategy is very likely. This, along with the very high cost, is a considerable disadvantage of this option.

3.4.1.4 Beach nourishment

In recent years Townsville City Council has undertaken a number of successful beach nourishment campaigns on local shorelines - the most notable being the redevelopment of The Strand in the late-1990s.

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[4] As defined by "*Erosion Prone Area Linear Distances and their Locations for Townsville City Local Government Area*" TOC1A, Erosion prone area segment number ToC001. Date of Erosion Prone Area Declaration: 26 January 2012 CTS18073/11.

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 management strategy are that it has no adverse impacts on adjacent foreshores, and it maintains the beach amenity.

It is generally regarded worldwide 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 such as seawalls) also require maintenance and a commitment to future costs. 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.

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 erosion 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.

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 during future renourishment campaigns as actual climate change conditions manifest themselves.

As discussed in Section 3.2, 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 Cungulla shoreline. Property and infrastructure landward of the Coastal Defence Line will remain protected throughout a nominated planning period, whereas foreshore areas seaward 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 Coastal Defence Line was to lie along the seaward boundary of private properties, then much of the existing foreshore reserve between these properties and the beach can be considered as being part of the required buffer. This would need less sand to be placed than an option that had the line along the seaward boundary of foreshore reserves (such as the designated road esplanade and/or USL), which would require importing a greater volume of sand to effectively create a completely new buffer area.

Reference to discussions in Section 0 indicates that the average net longshore sand transport rates along the at-risk sections of foreshore are typically around 1,500 m^3/year towards the south. Since there is negligible supply of sand from the north to meet this demand, renourishment of the shoreline at these annual rates would be required to maintain the necessary erosion buffers.

3.4.1.5 Beach scraping

The concept of beach scraping 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 - particularly on foreshores that are experiencing long-term recession.

Beach scraping 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 scraping 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.

However the large volume of sand that needs to be initially placed by scraping to form the buffer at Cungulla is most 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.

Given that the intertidal seabed approaches to the beach at Cungulla consist of very fine grained sediments, it is most unlikely that appropriate material is available to create or supplement the naturally sandy foreshore by beach scraping.

3.4.1.6 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.

The Haughton River, Doughboy Creek and Recovery Creek are the main waterways discharging into the nearshore waters of the Cungulla coastal reach. These entrances have an influence on local coastal processes. However the scale of engineering works to alter the various flow channels and entrances so as to mitigate any impacts on local foreshores are enormous. Consequently there is no merit in considering any relocation of these flow channels.

3.4.2 Structural Management Options

3.4.2.1 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 along Cungulla foreshore, 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 during high tide. 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 ad hoc 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. Such walls can maintain a degree of structural integrity during day-to-day sea and weather conditions, but their subsequent failure or damage during severe storms 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.

Most of the armouring placed on the foreshore by Cungulla residents are examples of ineffectual ad hoc seawalls.

As an alternative to rock armouring, sand filled geotextile containers can be used to construct seawalls. Special bags can be acquired as proprietary items - indeed there is such an installation on the foreshore frontage of a Cungulla property in Empress Close. They are particularly suited to applications where the structure is buried as a last line of defence against erosion. However where sandbag seawalls are permanently exposed to the elements, there are often issues associated with their long-term robustness. Frequent repairs and/or replacement are required to ensure a long-lasting solution using these sandbags in a permanent seawall.

3.4.2.2 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 (say, along the seaward boundary of private property)) then the existing foreshore between the seawall and the beach could be considered as the beach nourishment component. 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 longshore sand transport rate of around 1,500 m^3 /year along the at-risk foreshore

3.4.2.3 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 structure. However, as is the case with a conventional groyne, the shoreline downdrift of the wave shadow is deprived of sand and therefore erodes.

3.4.2.4 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 detailed study and engineering design.

Nevertheless such intervention will have a significant impact on the visual amenity of the Cungulla foreshore. 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.

3.4.3 Advantages and Disadvantages of Generic Options

As discussed above, there are a number of generic erosion management strategies which could be implemented under this Shoreline Erosion Management Plan. Some options are better suited than others. To assist in evaluating these in the context of the Cungulla coastal reach, a summary of the advantages and disadvantages of the various strategies has been prepared in Table 3.2 (for non-structural options) and Table 3.3 (for structural options).

Erosion Management Option	Advantages	Disadvantages
Do Nothing	Maintains existing undeveloped foreshores in their natural state. Coastal processes on natural foreshores proceed unimpeded by erosion mitigation works. Could be applied to existing northern precinct in the lee of the northern sand spit.	Potential structural failure of ad hoc foreshore armouring works. Potential loss of community infrastructure, including recreational reserves. Loss of Council controlled foreshore Esplanade, including some of Vivienne Lyons Park. Significant adverse impact on visual amenity. Expected erosion of foreshore will likely encroach onto private landholdings and threaten dwellings. Will cause significant social trauma.
Avoid Development	Maintains existing undeveloped foreshores in their natural state. Coastal processes proceed unimpeded by erosion mitigation works. Planning controls to achieve outcomes are substantially in place.	Does not resolve current erosion threat along Cungulla foreshore since existing development and assets are located within foreshore areas prone to erosion.
Planned Retreat	Maintains existing undeveloped foreshores in their natural state. Coastal processes proceed unimpeded by erosion mitigation works. Improves existing beach amenity and public access. Minimal disturbance to visual amenity.	Substantial social and financial costs to implement on the foreshores under most imediate threat (ie. on the ocean frontage of properties in Empress Close). Requires relocation or accepted loss of the Esplanade for an approximate 700m length. Requires removal of illegal & ad hoc foreshore armouring works.
Beach Nourishment	Coastal processes can proceed unhindered, with no adverse impacts on adjacent foreshores. Improves existing beach amenity and public access. Improves visual amenity. Cost of initial sand placement and renourishment can be low if appropriate sand sources are close-by. A flexible solution that can be tailored to suit the currently uncertain effects of future climate change as they actually emerge.	Requires on-going commitment to annual sand re-nourishment to recharge erosion buffers. Cost of initial sand placement and renourishment can be medium/high if appropriate sand sources are a long way away.
Beach Scrapping	Improves existing beach amenity and public access. Improves visual amenity. Cost of initial sand placement and renourishment is low since sand source is close-by. A flexible solution that can be tailored to suit the currently uncertain effects of future climate change as they actually emerge.	Unlikely to achieve the volumes of sand required to create and maintain buffers without significant and intensive earthmoving activity on the intertidal flats and/or the northern sand spit. Adverse impacts likely on intertidal flora and fauna. Temporary adverse impacts on visual amenity during scrapping activities. Temporary adverse impact on beach amenity during scrapping activities.
Channel Relocation	None	Does not resolve long-term erosion problems.

Table 3.2 : Non-structural Erosion Management Options

Erosion Management Option	Advantages	Disadvantages
Seawalls	Provides robust physical barrier to halt shoreline recession.	Significant impact on visual amenity. Possibly requires removal of illegal & ad hoc foreshore armouring works. Adversely affects beach amenity by inhibiting easy access across the foreshore onto the beach. May require stairways/ramps to provide safe access onto the beach.
Seawalls and Beach Nourishment	Provides robust physical barrier to halt shoreline recession. Under most ambient conditions, coastal processes proceed unimpeded by erosion mitigation works. Improves existing beach amenity and public access. Improves existing visual amenity. A flexible solution that can be tailored to suit the currently uncertain effects of future climate change as they actually emerge.	High construction cost. Requires ongoing financial and works commitment to future sand placements in order to assure beach amenity.
Groynes	Retains sand on presently threatened foreshores for longer periods.	Does not solve the existing erosion problem, it simply transfers the problem further south. To accomodate expected erosion influences, it will be necessary to construct many groynes. Significant impact on visual amenity. Adversely affects beach amenity by inhibiting access along the shore.
Groynes and Beach Nourishment	Retains sand on presently threatened foreshores.	Requires ongoing financial and works commitment to future sand placements in order to assure beach amenity.

Table 3.3 : Structural Erosion Management Options

4 ASSESSMENT OF EROSION MANAGEMENT OPTIONS

4.1 The Cungulla Coastal Reach

When considering appropriate erosion management options along the main Cungulla foreshore it is evident that the shoreline can be considered as five coastal precincts, namely:

- Southern end of Big Beach : foreshore frontage north of Kestrel Street, including private properties in George Ansell Avenue, Cooldetta Street and Kestrel Street.
- Northern Precinct : in the lee of the northern sand spit.
- Whiting Court Precinct : south of the influence of the sand spit down to the northern end of Empress Close.
- Central Precinct : foreshore frontage of private properties in Empress Close, including the frontage to Vivienne Lyons Park.
- Southern Precinct : south of Vivienne Lyons Park.

This separation into coastal reaches does not imply that the coastal processes within each are in any way compartmentalised. They are by no means isolated or discrete sections of shoreline, since the processes affecting each have considerable influence on the others. However this partitioning lends itself to the development of viable erosion management strategies that integrate well over the entire Cungulla coastal reach.

An assessment of potential management strategies for each of these coastal precincts is presented in the following sections. When undertaking this assessment, the requirement to accommodate a 10 metre shoreline recession as a consequence of a 100 year ARI cyclone event is adopted (refer to discussions in Section 2.6).

4.2 Southern End of Big Beach

A number of private properties in George Ansell Avenue, Cooldetta Street and Kestrel Street have their seaward property boundaries fronting the southern foreshore of Big Beach. These properties are the most northerly in the Cungulla township. The general area is illustrated on Figure 4.1.

This particular foreshore has been experiencing erosion in recent years - primarily as a consequence of storms and cyclones. The shoreline has receded approximately 60 metres since 1998. The erosion has removed much of the foredunes that existed seaward of the high primary dune along this section of coast. A significant amount of erosion occurred as a consequence of TC Yasi in February 2011 - with an erosion scarp extending into the toe of the primary dune at many locations.

Figure 4.1 : Southern end of Big Beach

Nevertheless there still remains a significant buffer between the private property boundaries and the erosion scarp. The distance from the scarp to seaward property boundaries is variable, but at its narrowest is still some 42 metres to a property off George Ansell Avenue. This buffer consists of the very high primary dune system, which is typically more than 8 metres in height.

Subsequent to the dune erosion initiated by TC Yasi in 2011, the prevailing coastal processes have gradually been moving sand back onshore - thereby rebuilding the beach in front of the primary dune. This natural foreshore rehabilitation is being assisted by longshore sediment transport processes on Big Beach, which are moving sand southward into the eroded dune areas. Whilst this natural rehabilitation is expected to continue, it is unlikely that the shoreline and foredunes on the southern end of Big Beach will be reinstated to their previous location and condition.

Given the significant sand reserves in the buffer seaward of private properties at the southern end of Big Beach, no direct intervention works are recommended at this location. Instead a strategy of implementing annual monitoring surveys to capture the condition and integrity of the primary dune system is recommended.

Such surveys will provide a considerably greater understanding of the performance of the dune buffer, as well as assist in triggering the need for future intervention strategies to mitigate any emerging risk to properties.

4.3 Northern Precinct

The Northern Precinct is that section of the Cungulla foreshore which is in the lee of the northern sand spit. It encompasses the entire foreshore north of Recovery Creek (ie. opposite Mulloway Court) and extends from Kestrel Street, down to the southern-most end of all Snapper Court properties. The overall extent of the precinct is depicted in Figure 4.2.

Figure 4.2 : Northern Precinct on the Cungulla foreshore

The northern sand spit is growing due to some 9,000 m^3 of sand being supplied to it on average each year by longshore sand transport processes; with its tip moving southwards at an average rate of 30 metres each year. Consequently the Northern Precinct can be considered as gradually expanding (and therefore the Whiting Court Precinct is contracting). This needs to be appreciated when formulating appropriate erosion mitigation measures for this location.

The shoreline north of Recovery Creek consists of a natural foreshore. Whilst in the past this section of foreshore has experienced significant erosion due to the proximity (at that time) of the ebb tide channel to the beach, the on-going erosion has diminished in recent years due to the offshore migration of the ebb tide channel and the southerly prograding of the sand spit.

At present there is an approximately 45 metre wide buffer of USL to the road easement of Mulloway Court. At the very end of Mulloway Court there is approximately 26 metres buffer to a private landholding. Given the gradually increasing protection afforded to this section of the foreshore by the growing sand spit, these buffers are adequate and there is no need to implement any erosion protection along this frontage to Mulloway Court.

Between Recovery Creek and the southern end of Snapper Court the foreshore is somewhat variable. At the moment, storm waves can propagate by diffraction around the southern tip of the offshore sand spit so as to reach this particular section of the Northern Precinct. However as the spit progrades southward this section of foreshore will experience increasing protection from storm wave energy.

A reasonably robust rock and concrete block seawall has been constructed on the frontage of several Bonito Court properties immediately south of Recovery Creek. Whilst a structural audit of this seawall has not been undertaken, it appears to be of a standard that might not provide on-going long-term protection if it was exposed to the same storm wave climate as is experienced on more southerly precincts of Cungulla.

However given the increasingly benign wave climate in the lee of the growing spit, it is possible that this seawall will nevertheless serve its intended purpose of providing an erosion barrier during severe storms until such time as the spit provides considerably more protection to this section of the foreshore.

Between the southern end of the rock / concrete block seawall and the end of Snapper Court the foreshore is effectively unarmoured, with mostly a natural buffer between the beach and the adjacent vegetated area. The buffer to private properties along this section is typically around 38 metres, decreasing to around 27 metres opposite the private landholding at the very end of Snapper Court.

Again, given the gradually increasing protection afforded to this section of the foreshore by the accreting offshore sand spit, these buffers can adequately accommodate the expected recession induced by a 100 year ARI event.

In summary then, there is no need to implement any erosion protection measures along the foreshore of the Northern Precinct. However the foreshore should be monitored by surveys in coming years to confirm this assessment. The established beach transect lines CUN-02, CUN-03 and CUN-04 already provide the means to achieve this monitoring.

4.4 Whiting Court Precinct

The Whiting Court Precinct is the approximately 465 metre long section of the Cungulla foreshore which extends from the end of Snapper Court properties southwards to the northern-most end of Empress Close. It constitutes the foreshore opposite Whiting Court. The overall extent of the precinct is depicted in Figure 4.3.

Whiting Court runs approximately parallel to the shoreline in this precinct. The rear property boundaries of twenty-four private landholdings on the eastern side of Whiting Court are set back from the mostly sandy beach throughout the entire length of this Whiting Court Precinct. The foreshore between these boundaries and the beach is designated as Unallocated State Land (ie. USL).

This buffer between the shoreline and private property varies approximately in width from 34 metres to 70 metres - being narrowest at its southern end.

Given that the foreshore erosion induced by a 100 year ARI cyclone is predicted to be 10 metres, the USL between the shoreline and private properties represents an adequate erosion buffer. Properties along the eastern side of Whiting Court are therefore not presently at risk of erosion by a 100 year ARI event.

Nevertheless on-going background erosion opposite Whiting Court is expected to be greater than has been experienced to date. The reasons for this are outlined in the earlier Section 2.5.3 of this report, and are primarily a result of the prograding offshore sand spit. However because the future development of the sand spit and its effect on foreshores opposite it are uncertain, rather than implement mitigation measures that may not even be required, it is recommended that the adequacy of the natural erosion buffer offered by the foreshore USL be monitored. This would be accomplished by undertaking annual surveys of beach transect lines CUN-05 and CUN-06.

When considering the results of future monitoring surveys, it needs to be appreciated that foreshores naturally fluctuate in position in response to erosion and accretion processes. This is normal and a quite natural response to seasonal and annual fluctuations in the local wave climate. It is only when the width of natural buffers are inadequate in accommodating severe storm and cyclone events; and/or there are a long-term erosion processes that are gradually reducing the width of the erosion buffer; is there an unacceptable risk requiring intervention.

Figure 4.3 : Whiting Court Precinct on the Cungulla Shoreline

In summary, there is no need to currently implement any erosion protection along this Whiting Court Precinct of the Cungulla foreshore. Nevertheless it is recommended that the future width of the natural buffers along the Whiting Court Precinct be monitored by survey on at least an annual basis.

4.5 Central Precinct

The Central Precinct is the approximately 585 metre long section of the Cungulla foreshore which extends from the northern-most end of Empress Close southwards to a location approximately 100 metres beyond Vivienne Lyons Park. It includes private properties that are the most vulnerable to erosion and damage during severe storms/cyclones. Figure 4.4 illustrates the extent of this precinct.

The shoreline has encroached into the foreshore Esplanade along a section of this precinct, with private property boundaries within only a few metres of the shoreline.

Figure 4.4 : Central Precinct on the Cungulla Shoreline

Consequently ad hoc attempts by local residents to armour the shoreline are most numerous on this section of foreshore. The standard and location of armouring works varies significantly along the Central Precinct, with many being ineffectual as a long-term means of mitigating erosion. Also the variability in location as well as construction standard of these individual works are exacerbating erosion problems on neighbouring properties.

As well as armouring along the shoreline, a number of ad hoc structures have been privately constructed across the beach and intertidal area in a misguided attempt to create erosion mitigation by a groyne field. However all that these structures have really accomplished is the trapping of any sand being transported naturally alongshore during ambient wave conditions. This then denies the immediately down-drift foreshore of sand during such wave conditions. This places these down-drift properties at increased risk of erosion and heightens the structural threat to their ad hoc works.

During strong wave action associated with severe storms and/or cyclones, longshore sand transport processes overwhelm these improvised low groynes; so that in effect these groynes provide minimal benefit during such events.

So in summary, these improvised groynes constructed by local residents provide negligible benefit during severe storms, and adversely threaten down-drift properties at other times. Future climate change is likely to exacerbate these problems.

Technically viable erosion mitigation strategies for the Central Precinct include:

- Beach Nourishment - to establish a wide natural buffer of sand in front of the eroded foreshore. This will require an initial placement of sand to create the buffer, as well as on-going beach renourishment to maintain it.
- Seawall - a properly designed structural seawall to provide a physical barrier to shoreline recession. This will protect the infrastructure behind the seawall, but instead of solving the erosion issue, it will simply relocate it further south where there are wide natural buffers that can accommodate the erosion without threat to property or infrastructure. Also no sandy beach would remain in front of the seawall.

Each of these erosion mitigation options is technically viable and could be successfully implemented along the Central Precinct. However it will be the cost of implementation that will invariably determine the preferred option. Some further comment on technical aspects of each strategy is warranted to support the recommendations presented in the following sections of this report.

4.5.1 Beach Nourishment

This strategy basically consists of:

- Initial Nourishment - through the placement of a sufficient volume of sand to establish a sand buffer that can accommodate the erosion caused by a nominated design event (refer to Figure 4.5 for an illustration of the concept).
- On-going Renourishment - given that the nourished foreshore will experience long-term erosion processes, it will be necessary to recharge these erosion buffers by periodic placement of additional sand.

Section 2.6 reported on the outcomes of beach response modelling for a 100 year ARI cyclone event. It was established that such an event would initiate a 10 metre recession in local Cungulla foreshores. Consequently to ensure that adequate protection is afforded to foreshore infrastructure and property during a 100 year ARI event, there needs to be at least a 10 metre wide buffer in front of the Coastal Defence Line.

Assuming a Coastal Defence Line along the line of the existing foreshore erosion, then this will require the placement of around 15,000 m^3 of sand on the approximately 585 metre long Central Precinct.

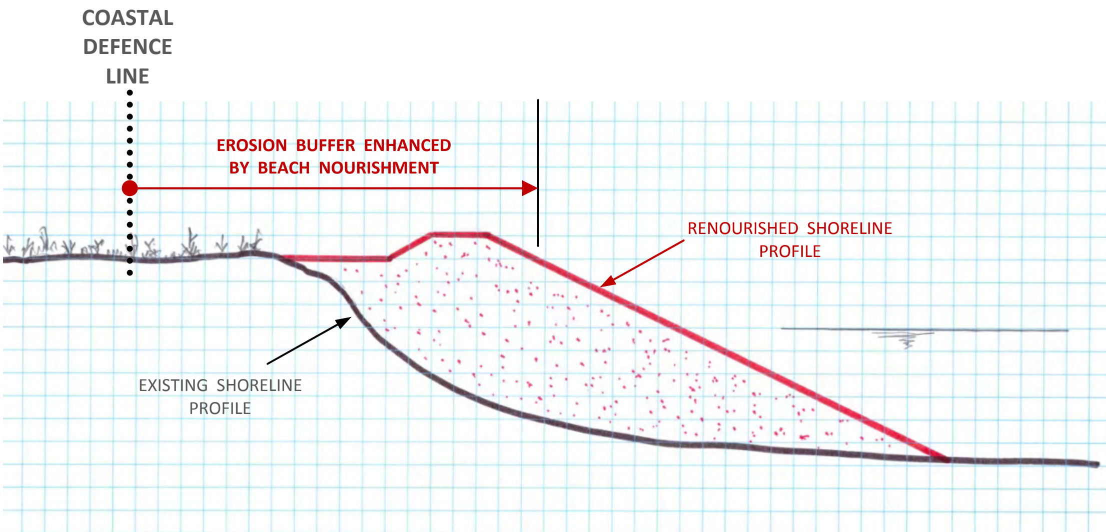

Figure 4.5 : Typical initial beach nourishment profile

Most of the existing ad hoc seawalls along this section of the foreshore can be left in place; and simply be buried at the rear of the newly created sand buffer - although minor mechanical re-profiling of some of the higher walls may be required. So long as they remain buried at the back of the beach, they will not interfere with natural coastal processes. This approach would reduce the cost of this strategy since it negates the need to remove the illegal ad hoc structures constructed by local residents.

As discussed previously, long-term erosion processes affecting the Whiting Court and Central Precincts are expected to continue into the future. This means that the erosion buffer created by the initial nourishment through sand placement of 15,000m^3 will gradually be depleted - thereby diminishing the protection that it affords.

On-going renourishment will therefore be required to recharge the erosion buffer with sand. This should not be construed in any way as a “failure” of beach nourishment, as it is typically an integral component of successful beach nourishment strategies throughout the world.

Renourishment rates should at least match the net southerly longshore transport rates along the nourished foreshore. As discussed in Section 2.5.3, this is estimated to be around 1,500m^3 per year through the Central Precinct. However this is a long-term average and actual amounts required will depend upon the prevailing longshore transport rate in any single year.

Previous experience of annual variability of wave climate in similar North Queensland coastal environments and exposures as that of Cungulla suggests for an average of 1,500m^3 per year the actual rate in any year could vary between almost none during a very mild year, up to 5,000m^3 in a particularly active year - depending upon seasonal sea and weather conditions.

Given the requirement to also ensure that the erosion buffer is fully recharged prior to the likelihood of any cyclone erosion, it is recommended that the foreshore should be monitored by surveys and that any renourishment should be completed prior to the onset of each cyclone season - that is, it should be completed prior to November.

In summary, a beach nourishment strategy for the Central Precinct of Cungulla would require the following:

- initial placement of approximately 15,000m^3 of sand to create an adequate sand buffer to accommodate the effects of a 100 year ARI cyclone event; and
- on-going placement of an average of 1,500m^3 of sand per year to keep the buffer charged with sand.

4.5.2 Seawall

A seawall appropriately designed to accommodate severe storms and cyclones can be constructed along the alignment of a nominated Coastal Defence Line. However simply dumping rocks or other such armouring material onto a foreshore does not constitute a viable seawall structure.

Engineering designs need to incorporate structural elements and details that mitigate the three fundamental modes of seawall damage/failure, these being:

- armour erosion - by ensuring the individual armour units in the wall are large/heavy enough and are placed in a manner that enables them to withstand the considerable forces applied by large breaking waves during the design event;
- undermining failure - The high levels of turbulence generated as incoming waves encounter a seawall can be sufficient to initiate scour at the toe of the seawall. If the seawall is founded at a high level, then this scouring of the seabed or beach in front of it may undermine the foundation of the seawall itself - leading to its collapse.
- overtopping failure - during severe storms, waves can run up the front face of the seawall and encroach on the surface of the fill material behind it with considerable force. This unprotected fill material immediately behind the crest of the seawall will then be scoured by the overtopping “green water”, leaving the top units in the seawall slope unsupported. These units collapse back into the scoured hole - decreasing the height of the seawall crest, causing

greater overtopping, causing increased scour behind the collapsed crest, causing greater overtopping, etc. The seawall quickly and progressively fails.

Instead of rock armour, the seawall along the Central Precinct could be constructed of sand-filled geotextile containers (such as the Elcorock proprietary system). Given previous experience of sand-filled geotextile containers in foreshore applications, it is recommended that this concept be given very careful consideration before being implemented in any seawall strategy at Cungulla.

The long-term durability of sand-filled geotextile containers and the likelihood of significant repairs and/or replacement being required in order to maintain their intended function over a planning horizon of 50 years represents a very significant challenge to this strategy.

When long-term structural durability issues and the necessary commitment to on-going maintenance efforts and costs associated with the geotextile bag concept is considered, rock armouring is very likely to be more economically viable due to its considerable robustness.

Nevertheless Figure 4.6 illustrates the minimum design standard for a seawall constructed from sand-filled geotextile containers. This structural standard ensures that the seawall is:

- constructed of appropriately sized and placed containers to withstand direct impact of breaking storm/cyclone waves;
- founded at a level that will ensure the structure will not be undermined given the nature and level of the seabed approaches at Cungulla; and
- adequately armoured at its crest to ensure that it will not fail due to the extreme overtopping expected during severe storms or cyclones.

Similar structural performance and design criteria would apply to a rock-armoured seawall.

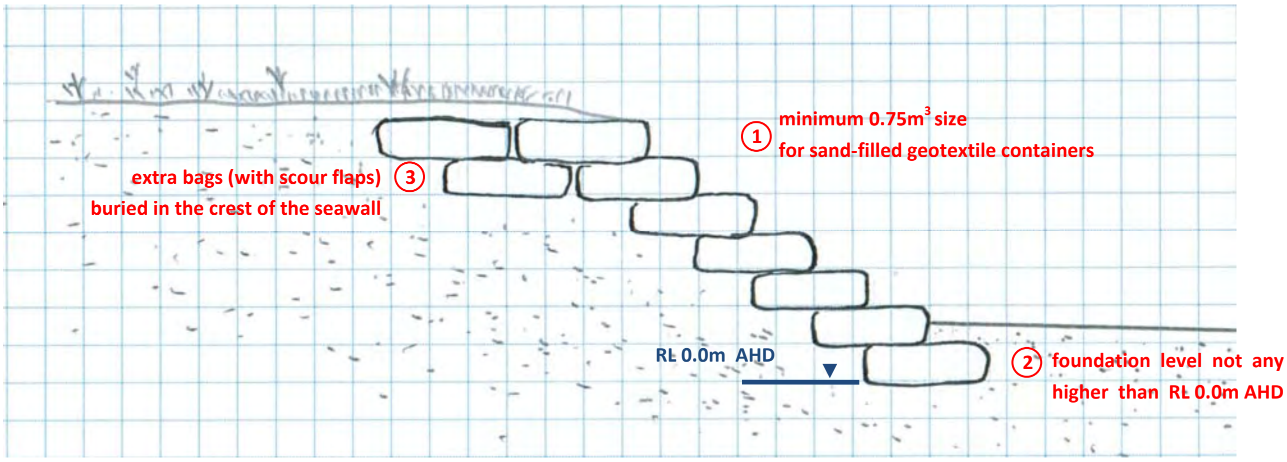

Figure 4.6 : Minimum design standard for seawall construction at Cungulla

If implementing a seawall strategy at Cungulla, it will be necessary for it to be constructed along its entire length. Simply constructing a robust seawall along isolated sections of the foreshore as part of a staged implementation will transfer greater erosion threat to those sections not appropriately armoured. For example, adjacent ad hoc seawall endeavours undertaken by local residents will experience increased erosion threat - leading to an increased requirement to repair or replace such structures.

4.6 Southern Precinct

The Southern Precinct is the approximately 330 metre long section of the Cungulla foreshore which extends from a location 100 metres south of Vivienne Lyons Park towards the large stand of mangroves at the southern-most end of the township. It includes private properties along the southern-most end of Empress Close. Figure 4.7 shows the extent of the precinct.

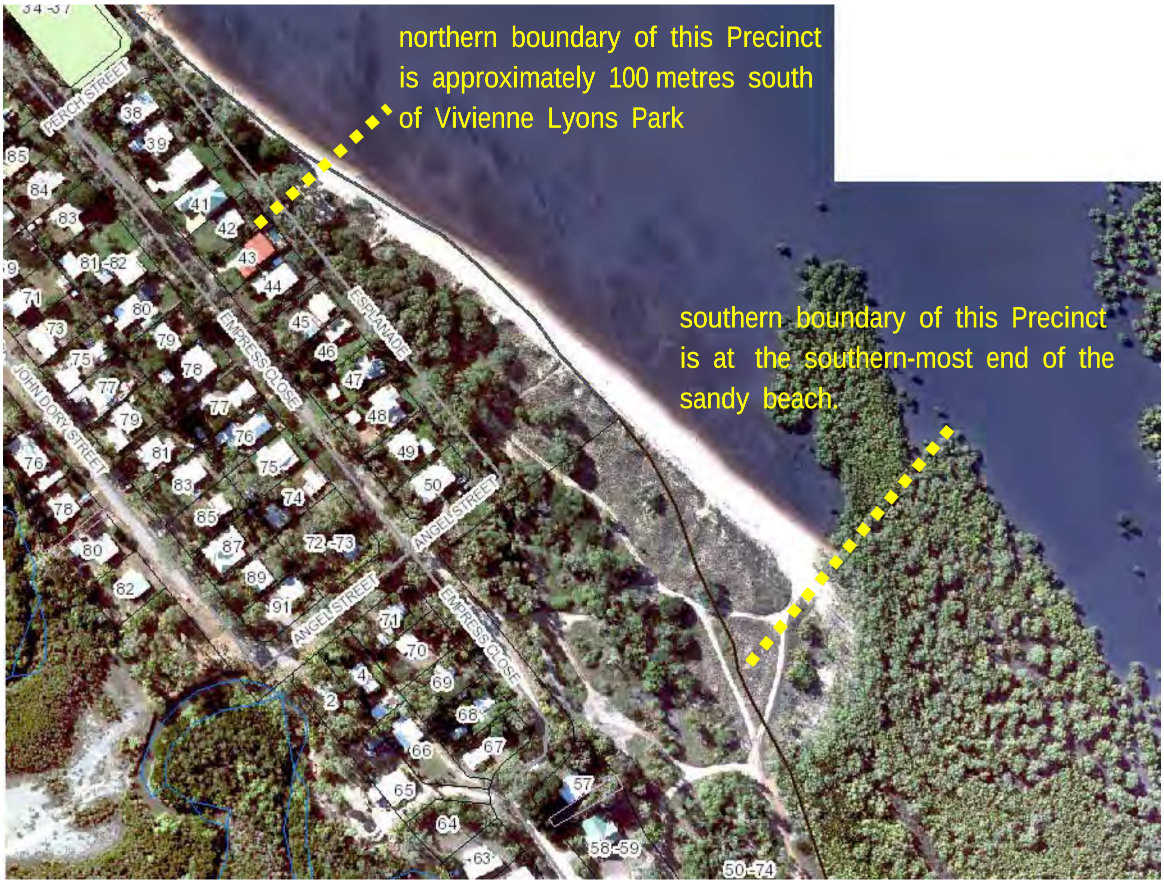

Figure 4.7 : Southern Precinct on the Cungulla Shoreline

The foreshore in the lee of the mangroves does not experience the same amount of wave energy as the foreshore further to the north - due to the attenuating effects of offshore sand shoals and the extensive mangroves immediately offshore. This attenuation of wave energy affects the ambient wave climate (ie. that which occurs on a day-to-day basis) as well as during storms. Therefore the rate at which waves move sand along this sheltered foreshore is less than that along the

Cungulla foreshore further north. Consequently this shoreline has been steadily accreting.

However since the available sand on the other more northern foreshores has diminished in recent years, the rate of accretion in the Southern Precinct has also diminished. Nevertheless there still remains a significant buffer between private properties and the shoreline. The width of this buffer varies from approximately 27 metres near Vivienne Lyons Park, to around 60 metres at the southern end of Empress Close.

If a beach nourishment strategy was adopted for the adjacent Whiting Court Precinct, then sand would be swept from that up-drift nourishment area and deposited on the shoreline of the Central Precinct - increasing the available buffer widths. This accretion would continue at much the same rate as the annual sand renourishment of the Central Precinct.

If instead a seawall strategy was implemented along the Central Precinct, any sand remaining on that foreshore would be transported alongshore and deposited on the shoreline of the Southern Precinct. Since there is very little sand remaining on the Central Precinct, soon after construction of the seawall the volumes of sand removed from the Central Precinct and supplied to the Southern Precinct would diminish almost entirely. The existing buffer widths on the Southern Precinct would nevertheless remain unaffected since the prevailing wave climate in the lee of the mangroves is considerably attenuated.

Given the existing wide buffer, and that they will not be significantly diminished by whatever strategy is implemented along the up-drift foreshores of Cungulla, there is little merit in implementing any erosion mitigation measures along the Southern Precinct.

Given that this section of the Cungulla coastal reach has been naturally accumulating due to sand supply from the north, a sustainable strategy for renourishing the eroded foreshores updrift would be to simply recycle sand back to the eroded foreshores of the Whiting Court Precinct. Recycling this sand back by mechanical plant and equipment each year constitutes a strategy of sand back-passing - which is a widely acknowledged and accepted means of foreshore management of eroding coastlines around the world.

5 RECOMMENDED EROSION MANAGEMENT

5.1 Recommended Erosion Mitigation Measures

The preceding chapter of this Shoreline Erosion Management Plan provided details as to a number of possible erosion mitigation measures, and then provided discussions regarding viable strategies which could be applied to the Cungulla coastal reach. As a consequence of those various considerations, including likely implementation costs, the following recommendations are made:

- The only section of the Cungulla coastal reach requiring direct intervention to mitigate shoreline erosion is along an approximately 585 metre foreshore extending from the northern-most end of Empress Close southwards to a location approximately 100 metres beyond Vivienne Lyons Park. This will protect all private properties on Empress Close that are most vulnerable to erosion and damage during severe storms/cyclones.
- At other locations along the Cungulla foreshore, erosion processes will primarily be associated with short-term recessions induced by cyclonic events and future climate change. However no private property, essential infrastructure or environmental values will be compromised by such recession. Consequently erosion protection measures are not recommended in these areas.
- Beach nourishment opposite threatened properties on Empress Close offers the optimum erosion mitigation strategy. It has the least impact on prevailing coastal processes and environmental values whilst offering a cost effective solution. A beach nourishment strategy is flexible and can be tailored to suit impacts of future climate change as they gradually evolve. Furthermore it enhances visual amenity and improves public access to the foreshore.

Details regarding the recommended beach nourishment strategy are offered in the following sections.

5.2 Beach Nourishment - Empress Close

A beach nourishment strategy 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.
- Sustaining the Buffer - given that the nourished foreshore experiences long-term erosion processes, it will be necessary to either recharge the erosion buffer by periodic placement of additional sand; or prevent sand being transported away.

5.2.1 Initial Nourishment

The extent of buffers required to accommodate a 100 year ARI Design Event along the shores of Cungulla have been discussed in the discussions of cross-shore sand transport processes (in Section 2.6). From which it is evident that most of the foreshore will experience storm erosion of approximately 10 metres.

As stated previously, the shoreline most at risk extends from the northern-most end of Empress Close southwards to a location approximately 100 metres beyond Vivienne Lyons Park. In order to protect this section of foreshore from storm erosion during a 100 year ARI event, it will be necessary that the initial nourishment will need to at least establish a 10 metre wide buffer in front of the selected Coastal Defence Line.

Whilst it is acknowledged that the location of a Coastal Defence Line on the Cungulla foreshore is a matter for stakeholders, for the purposes of illustrating and quantifying works under this Shoreline Erosion Management Plan a location along the top of the existing sandy beach and/or the crest of ad hoc protection works has been adopted. The general arrangement is illustrated in Figure 5.1.

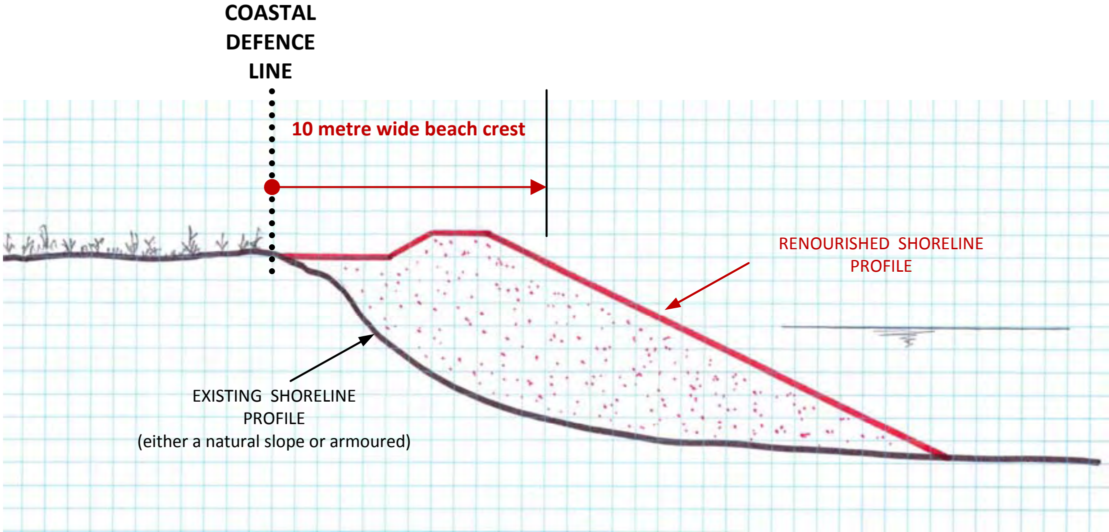

Figure 5.1 : Recommended Initial Nourishment Profile

When establishing sand buffers, the primary objective is to ensure that there is a sufficient volume of sand available to accommodate the erosion expected during the Design Event. Simply stating a buffer width does not guarantee that the required volumes are achieved. To do so requires that the crest level to which the sand buffer is placed is also defined.

The level of the buffer should be no lower than the foreshore area immediately behind the beach slope. In fact a slightly elevated dune would best be created where such a feature no longer naturally exists. Typically the dune crest should be 0.5m to 1.0m higher than the foreshore behind - thereby creating a swale that can intercept and disperse any shoreward flow of runoff during severe rainfall events.

5.2.2 Sustaining the Buffer

Since the prevailing southward longshore sand transport will be acting to deplete any newly created erosion buffer, it will be necessary to ensure that the buffer is either reinstated (by periodically collecting sand that has accumulated at the southern end of the beach and redeploying it on the eroded section); or it can be maintained by constructing groynes to impede southerly sand transport.

Having to sustain the newly created erosion buffer should not be construed as a "failure" of beach nourishment works, as it is typically an integral component of successful beach nourishment strategies throughout the world. The two measures to achieve this at Cungulla are discussed below.

5.2.2.1 Backpassing from the southern end of the foreshore

On-going renourishment will be required to recharge the buffer with sand.

Monitoring by annual surveys will enable the adequacy of the buffer to accommodate a severe storm/cyclone event to be regularly determined. When such surveys indicate that the volume of sand in the buffer has naturally depleted below a specified limit, then this would trigger a sand renourishment exercise. The criteria that initiates such action would be determined as part of the engineering design of the overall beach nourishment works.

Nevertheless sand renourishment rates will likely match the rates of net longshore transport along the nourished foreshore. This varies somewhat in the vicinity of the at-risk foreshore opposite Empress Close, but averages around 1,500 m^3/year along its entire length.

Rather than source the sand required for recharging the buffer from distant sources, it could be obtained by "backpassing" sand from the southern end of the Cungulla foreshore.

Sand backpassing operations redistribute sand within the littoral system. It involves the mechanical transport of sand from a wide stable foreshore back onto an updrift sediment-starved beach. This method is often utilised in locations where coastal processes are such that sand from an eroding foreshore moves alongshore and is deposited in a more sheltered area.

The concept is shown conceptually in Figure 5.2. It entails deploying an excavator/front-end loader on the southern end of the Cungulla beach to load sand from the beach into trucks - which then deliver it back onto the beach from where it was removed by the southerly littoral drift. This renourishment campaign would be triggered by the results of annual surveys of buffer widths.

This backpassing essentially "recycles" the sand back onto the eroding beach. The sand volumes are moderate and the haul distances are short, it therefore provides a very cost-effective scheme for sustaining the erosion buffer on the updrift beach. It is also very flexible and can be easily tailored to suit the variable nature of longshore sand transport rates, and any emerging effects of future climate change.

Figure 5.2 : Proposed back-passing of sand from southern accumulation area

5.2.2.2 Construct a groyne field

Instead of recharging the buffer regularly by backpassing, groynes could be constructed across the foreshore to impede the longshore transport of sand out of the buffer. The concept is illustrated on Figure 5.3. However the number, length and positions of groynes shown on this figure are estimates only based on desk-top study of stable beach compartments. Detailed coastal process modelling would be required as part of final engineering design to determine these issues specifically.

Figure 5.3 : Proposed groyne field to retain buffer

A significant disadvantage of this option is the high cost of constructing the groynes. Whilst they could be constructed of sand-filled geotextile containers, a more robust and long-term outcome would be rock groynes. Either structural solution entails high costs.

Another significant disadvantage is that it would be necessary to place more than 15,000m^3 of sand to initially create an appropriate buffer. This is because the naturally preferred alignment of the shoreline within each compartment between two groynes faces more northerly than the existing foreshore. A minimum 10metre erosion buffer width is required against the northern end of each beach compartment to provide protection to the Coastal Defence Line in each of these areas.

This means that there is a greater width of sand needed at the southern end of each compartment - resulting in a requirement for more sand to be placed than simply a long 10m wide buffer that was then maintained by periodic backpassing.

The significant cost of the groynes and the extra sand to provide the necessary minimum buffer widths along the entire foreshore is well in excess of that for a backpassing strategy to recharge the buffer. Consequently groynes are not recommended.

5.2.3 Management of sand dunes

The small dune system established by beach nourishment needs 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 foreshore landowners), such trapped sand remains within the natural beach system.

Appropriate dune management strategies for newly nourished foreshore areas are discussed in Section 6 of this Shoreline Erosion Management Plan. Activities 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 through the dunes onto the beach.

Likewise such management practices should be implemented on other sections of the Cungulla shoreline. Where foredunes are naturally created by sand transport processes, stabilisation of these important features with primary vegetation species and controlled access is recommended.

5.3 Potential Sources of Sand for Nourishment Works

When assessing the viability and costs of beach nourishment at Cungulla an important consideration is the source of sand for the initial placement of 15,000m^3 and a potentially annual average of 1,500m^3 for renourishment purposes. Clearly a distant source will result in high costs to transport the sand to Cungulla.

This Shoreline Erosion Management Plan has considered two fundamental philosophies for supplying 15,000m^3 of sand for the initial placement of beach nourishment, namely:

- the sand spit near the northern end of the Cungulla foreshore; and
- sand sourced from commercial sand extraction operations in the region.

Comment on each of these potential sources is offered in the following sections.

5.3.1 Sand spit at northern end of Cungulla

The prograding sand spit at the northern end of Cungulla coastal reach offers a nearby and sustainable source of appropriate sand. Testing of sand samples indicate that the physical characteristics of the sand in this spit matches that on the Cungulla foreshore. The northern sand spit is therefore recommended as a source for the 15,000m^3 initial sand placement opposite the at-risk foreshore fronting Empress Close.

An analysis of recent and historical beach transects across the sand spit indicate that since the survey of February 2010, approximately 15,000 m^3 of sand has accumulated above the level of Highest Astronomical Tide (HAT) in this area. Therefore the removal of this sand would provide the volume necessary to initially nourish the at-risk section of Cungulla foreshore. This would simply be reinstating the sand spit to its physical extend and condition as of February 2010.

The proposed sand sourcing methodology is illustrated conceptually in Figure 5.4. It entails using conventional earth-moving equipment such as excavators and front-end loaders to extract the sand from the surface of the spit and load it into trucks. These trucks would then deliver this sand to the downdrift foreshore fronting Cungulla.

Figure 5.4 : Potential sand sourcing methodology

An advantage of this sand sourcing methodology is that (being above the level of HAT) it is outside of the boundary of the Great Barrier Reef Marine. However it entails running fully laden sand trucks through the suburban streets of Cungulla - with implications to traffic management, public safety and potential damage to road surfaces.

More critically though, concurrent investigations identified that the extraction of sand from this location presented a potential risk to migratory shorebirds that frequent the northern sand spit. Subsequent consultation between NQ Dry Tropics and Townsville City Council resulted in the exclusion of this sand source as part of the SEMP/erosion mitigation strategy - on the basis that the level of potential risk to the migratory birds and to the significant wildlife habitat of the spit was not acceptable.

5.3.2 Sand sourced from commercial extraction operations

There are a number of commercial operations in the region that can supply suitable sand for the initial nourishment of the Cungulla foreshore.

Therefore a significant advantage of such a sand supply arrangement is that all environmental approvals relating to sand extraction are likely to be current through the existing lease arrangements. A potential disadvantage is that in order for the supplied sand to be suitable for beach nourishment there may need to be some screening of the material to remove unsuitable material or any over- or under-sized sand fractions. Furthermore long road haul distances from these sources not only have significant cost implications; the number of heavy trucks required for the operation have adverse implications on traffic and public safety.

Nevertheless beach nourishment campaigns using sand sourced from commercial extraction operations have been successfully and cost effectively implemented in the Townsville region in recent years. The most significant of these being the redevelopment of The Strand foreshore.

The suitability and cost of sand sourced in this way can only be determined with confidence through a process of formal tendering for the sand supply contract.

5.4 Estimated Costs of Beach Nourishment Activities

The costs associated with a beach nourishment option relate primarily to the initial beach nourishment to create the necessary erosion buffers; and the on-going renourishment to recharge these buffers. Estimates of these costs are provided below.

5.4.1 Initial beach nourishment

As discussed previously, the volume of sand required to initially create the erosion buffer could be obtained from either the prograding northern sand spit or from commercial sand supply operations.

Supplying sand from the northern sand spit would entail deploying conventional earth-moving equipment such as excavators / front end loaders to load 15,000m^3 of sand into trucks for subsequent delivery to the target foreshore opposite Empress Close. The estimated one-off cost of this sand transfer exercise is $375,000.

Supplying sand from commercial suppliers operating from an existing sand lease in the Haughton River is estimated to cost $475,000. However the actual cost of such sand will depend somewhat on the competitive environment of commercial sand supply operations prevailing at the time of the initial nourishment campaign. Under a formal tendering regime, costs could vary significantly from those quoted by suppliers when preparing cost estimates for this Shoreline Erosion Management Plan.

5.4.2 On-going renourishment

As noted in the preceding Section 5.2.2, backpassing of sand from the southern end of the Cungulla coastal reach is recommended as the means of sustaining the newly created erosion buffer opposite the northern end of Empress Close.

When annual beach surveys indicate that the volume of sand in the buffer has naturally depleted below a specified limit, then a backpassing exercise would be instigated to renourish the buffer. The criteria that initiates such action would be determined as part of the detailed engineering design of the overall beach nourishment works.

There will be some years of mild wave conditions which will result in no requirement to renourish the buffer. Other years of more energetic wave conditions may require more intensive backpassing. Nevertheless it is likely that backpassing campaigns will closely match the rates of net longshore transport along the newly created buffer. This varies somewhat in the vicinity of the at-risk foreshore opposite Empress Close, but averages around 1,500 m^3/year over the length of the buffer.

However for cost estimating purposes, it is assumed that an annual backpassing campaign to relocate 1,500 m^3 of sand from the southern end of the Cungulla coastal reach to the at-risk foreshore opposite Empress Close will be implemented. The annual cost of backpassing operations is estimated as $20,000.

5.5 Monitoring Surveys

If implemented, monitoring the performance of the Shoreline Erosion Management Plan ensures that potential threats to project outcomes can be addressed in a proactive manner.

Given that a primary objective of the Shoreline Erosion Management Plan is to manage erosion along the Cungulla shoreline, regular surveys of the foreshore should be undertaken as part of the Plan.

Beach transect lines were first established on this shoreline in December 1996. Since then other surveys have been intermittently commissioned. It is strongly recommended that an annual survey of ten of these established transect lines be instigated (namely CUN-01b and CUN-02 to CUN-10).

It is also recommended that an additional two transect lines be established across the currently eroded foreshore at the southern end of Big Beach (opposite properties in George Ansell Drive).

In coming decades the Cungulla foreshore is likely to experience the effects of climate change - which may see gradual increases in sea level and greater volumes of sand being transported by natural processes. 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 therefore serves an important role in assessing the effectiveness of recommended erosion management strategies in coming years and to guide future action.

6 MAINTAINING EXISTING ENVIRONMENTAL VALUES

The aim of this Shoreline Erosion Management Plan is to restore the natural function of the Cungulla foreshore and to increase its resilience under the increasing pressures of an urban environment. The preceding Section 5 of the Plan provided details as to the recommended erosion mitigation strategy that best integrates with the natural coastal processes shaping the Cungulla foreshores.

Nevertheless there are additional activities that can further assist in maintaining local environmental values - particularly those associated with the natural flora and fauna of this shoreline. This section of the Plan provides insight into the local terrestrial environment and provides advice on management actions to address known and foreseen threats.

6.1 Overview

As discussed previously, the Cungulla coastline has been experiencing erosion over the last few decades. Section 2 of this document details the physical processes causing this erosion. Surveys of the Cungulla foreshore have been undertaken since 1996 and a summary of their outcomes is presented in Appendix B.

The foreshore from Kestrel Street to just south of Vivienne Lyons Park is highly modified with low to no dune height, limited native foreshore vegetation, numerous weed species and has piles of rocks, tyres, tree trunks, green waste, bricks and building debris littering the foreshore. As illustrated in Figure 6.1, the Regional Ecosystem for this area is mapped as *11.2.5 Corymbia-Melaleuca woodland complex of beach ridges and swales*.

North of Kestrel Street, the foreshore has dunes up to 10m high with robust vegetation cover in most places. In locations where dune vegetation has been removed, the dune height is at its lowest. Weed species are at their most prevalent in this section of foreshore. In early 2013, weed control and revegetation was undertaken on the area containing *Barleria repens.* Since then local community members have taken on the responsibility of maintaining the newly planted trees.

The regional ecosystem for this area is mapped as *11.2.5 Corymbia-Melaleuca* (Moreton Bay Ash-Tea Tree) *woodland complex of beach ridges and swales* and 11.2.2 *Complex of Spinifex sericeus* (Spinifex)*, Ipomoea pes-caprae* (Goat's foot vine) *and Casuarina equisetifolia* (She Oak) *grassland and herbland on foredunes*. It is pertinent to note that the latter vegetation community is classed as *Of Concern*. A regional ecosystem is listed as *Of Concern* if:

> *remnant vegetation is 10-30 per cent of its pre-clearing extent across the bioregion; or more than 30 per cent of its pre-clearing extent remains and the remnant extent is less than 10,000 hectares.*

Figure 6.1 : Regional Ecosystem mapping for Cungulla Foreshore

The most species occurring on the Cungulla shoreline are listed in Table 6.1.

Common Name	Scientific Name	Foreshore	Spit	Size
Beach wattle	Acacia crassicarpa	Y		tree
River Mangrove	Aegiceras corniculatum	Y		tree
Grey Mangrove	Avicennia marina	Y		tree
Nickernut	Caesalinia bonduc	Y	Y	shrub
Beach Bean	Carnivalia rosea	Y	Y	creeper
Doder Laurel	Cassytha Filiformis	Y	Y	creeper
Casuarina	Casuarina equisitefolia	Y	Y	tree
Lollybush	Clerodendrum sp.	Y		shrub
Moreton Bay Ash	Corymbia tessellaris	Y		tree
Beach Tamarind	Cupaniopsis anacardioides	Y		tree
Cottonwood	Hibiscus tiliaceus	Y	Y	tree
Goat's Foot	Ipomea-pes-caprae	Y	Y	creeper
Swamp Tea Tree	Melaleuca dealbata	Y		tree
Tea Tree	Melaleuca viridiflora	Y		tree
Pandanus	Pandanus tectorius	Y		tree
Burdekin Plum	Pleiyogynum timorense	Y		tree
Mangrove	Rhizophora sp.	Y		tree
Sea Purslane	Sesuvium portulacastrum	Y		creeper
Spinifex	Spinifex sericeus	Y	Y	creeper
Salt Couch	Sporobolus virginicus	Y		creeper
Sea Almond	Terminalia arenicola	Y		tree
Sea Almond	Terminalia cattapa	Y		tree
Portia Tree	Thespesia populnoides	Y		tree

Table 6.1 : Vegetation on the Cungulla shoreline

6.2 Threatened Plants and Animals

According to *Wildlife Online*[5], there are no known threatened plants listed under the *Nature Conservation Act 1992* within Cungulla.

Shorebirds are known to utilise the sand spit and beaches of Cungulla - including the endangered Little Tern and the vulnerable Beach-Stone Curlew as listed under the *Nature Conservation Act 1992* (refer to Figure 6.2).

Under the *Nature Conservation Act 1992,* four near-threatened bird species also occur at Cungulla namely the square-tailed kite, the Australian swiftlet, the black-necked stork and the eastern curlew. A more comprehensive list of known birds to occur in the area is included in Appendix C.

[5] http://www.ehp.qld.gov.au/wildlife/wildlife-online/ Website managed by Queensland's Department of Environment and Heritage Protection

Figure 6.2 : Threatened shorebirds (photos by Neil Mattocks, QPWS)
Little Tern (left) and Beach-Stone Curlews (right)

6.3 Weed Management

Thirteen weed species were found on the Cungulla foreshore during a survey undertaken in November 2012. These are listed in Table 6.2 below.

Common Name	Scientific Name	South of Kestrel St	Spit	North of Kestrel St	Priority for control
Coral Creeper	*Barleria repens*			Y	High
Mother-of-Millions	*Bryophyllum spp.*			Y	High
Rubbervine	*Cryptostegia grandiflora*	Y		Y	High
Lantana	*Lantana camara*	Y		Y	High
Asparagus fern	*Asparagus spp.*			Y	Medium
Periwinkle	*Catharanthus roseus*	Y		Y	Medium
Guinea Grass	*Panicum maximum*	Y		Y	Medium
Mother in laws tongue	*Sansevieria trifasciata*	Y		Y	Medium
Mossman River Grass	*Cenchrus echinatus*	Y		Y	Low
Coconut	*Cocos nucifera*	Y		Y	Low
Streaked Rattlepod	*Crotalaria pallida*	Y	Y	Y	Low
Nut Grass	*Cyperus rotundus*	Y		Y	Low
Natal Grass	*Melinis repens*	Y		Y	Low

Table 6.2 : Weed species found on the Cungulla shoreline

6.3.1 Priority Weeds

Guidelines for removal of high and medium priority weeds are given in the following sections.

6.3.1.1 Coral Creeper

This species is a creeping or scrambling shrubby plant usually less than 70 cm tall. However when growing in the forest understorey it scrambles over nearby shrubs and can occasionally climb up to 2m in height.

Figure 6.3 shows the characteristics of this weed. It was first reported in 2006 in Brisbane and has been sighted in dense populations near urban centres on the Queensland coast. Coral creeper reproduces by seed and vegetatively via its rooting stems.

Figure 6.3 : Coral Creeper native to Africa

Individual plants and stems can be manually removed by hand pulling, taking care to ensure that as little as possible of the root system is left behind. In cases where total removal of the plant cannot be carried-out, the removal of flowers and immature fruit (preventing the opportunity for seed dispersal) will help reduce the potential of new infestations becoming established in the surrounding area.

Treatment using Starane has proven to be successful in treating a large area at this location. However other herbicides which might be successful include Glyphosate, 2,4-D or Fluroxypyr. Application methods may include cut & swab, stem scraping and leaf wiping or foliar spray. For the latter application, the use of a suitable non-ionic surfactant is recommended due to the glossy nature of the leaves.

6.3.1.2 Lantana

This species is a Class 3 declared plant under Queensland legislation and is listed as a Weed of National Significance. All colour varieties are banned from sale. This is a perennial heavily-branched shrub that can grow as compact clumps, dense thickets or as scrambling and climbing vines. It grows to three metres in height, with a spread of four metres. There are small thorns on the branches. It will colonise any soil and forms dense impenetrable thickets that smother native vegetation.

For removal, it is preferable to use chemical control on regrowth after brush cutting or cutting with a handsaw. Foliar spraying, including use of splatter guns, is effective in controlling lantana. A broad range of herbicides are approved for use on lantana.

Isolated plants can be removed by hand, however ongoing monitoring for regrowth is necessary. There are also a number of biological control agents that reduce growth rates reducing spread, however these do not kill the plant.

Figure 6.4 : Lantana flower

6.3.1.3 Mother-of-millions

Mother-of-millions (refer to Figure 6.5) is a Class 2 declared plant under Queensland legislation. This perennial plant is erect, smooth, fleshy and succulent; growing to 1 metre or more tall. It produces small plantlets along the edges of the leaves which drop readily, develop roots and establish quickly to form a new colony. Due to its reproductive potential and its adaptation to dry conditions, it can be very difficult to eradicate.

Whilst the infestation of this weed at Cungulla is still small, its control is strongly recommended.

Figure 6.5 : Mother-of-millions

Mechanical treatment of this weed is generally not recommended as it can reproduce from broken pieces of plant. However, isolated infestations or individual plants can be hand-pulled - with care taken to remove all plant material.

There are also several herbicides approved for use on this weed and foliar spraying can be very effective.

6.3.1.4 Rubber vine

Rubber vine (refer to Figure 6.6) is a Class 2 declared plant under Queensland legislation and is listed as a Weed of National Significance. This is a robust woody perennial climbing vine, growing to 2 metres unsupported or up to 30 metres in trees.

Figure 6.6 : Rubber vine Seedpod

The stems, leaves and seed pods have a milky sap when broken or cut. Rubber vine invades and smothers riparian vegetation and forms dense, sometimes impenetrable thickets. It also creates a habitat for feral animals.

Burning is highly effective at controlling this weed. However, dune vegetation is sensitive to fire, so this is not the recommended control method at Cungulla. Basal barking, cut stump, and mechanical removal are the recommended methods for the Cungulla foreshore.

6.3.1.5 Guinea Grass

Guinea grass is a perennial species and can form quite large clumps. Commonly found at around 1.5 m tall, some individual plants have been recorded 3 m high. Although Guinea Grass is not a declared weed under Queensland legislation, it can be problematic on dune systems since its large biomass increases the risk of fire - which is a major threat to dune vegetation.

The recommended control methods for Guinea Grass on the Cungulla foreshore are slashing or spraying with an approved herbicide.

6.3.1.6 Asparagus fern

This Class 3 declared plant under Queensland legislation is now a major weed on sand dunes in NSW and is one of the most difficult and labour intensive weeds to eradicate. The only sighting of this weed at Cungulla was in two potted plants at the rear of Lot 97 on EP2286. These plants must be contained or removed in order to reduce the risk of the species spreading throughout the Cungulla foreshore.

6.3.1.7 Periwinkle

This species is widely spread throughout Queensland, but is not declared under legislation and is still sold in nurseries. Patches of periwinkle occur along the foreshore with a large patch being found near the Kestrel Street car park. This species is easily hand-pulled, but follow up visits must be undertaken as the seed can remain dormant for many years.

6.3.1.8 Mother in laws tongue

This is another weed not declared under Queensland legislation. One patch of this species was found on the foreshore approximately near Lot 411 on C9203. This can be removed by digging out the clumps, ensuring to remove every piece of rhizome. Plant material needs to be bagged and destroyed to avoid reshooting.

6.3.2 Other Weeds

Although many people associate coconut trees with beaches, these trees do not provide particularly effective sand stabilisation. There are other coastal vegetation species that are better suited to this role. Cungulla residents should be encouraged to plant other more suitable coastal species on the foreshore instead of coconuts.

Other less aggressive weeds (Mossman River Grass, Nut Grass, Natal Grass and Streaked Rattlepod) are present on the Cungulla foreshore. The control of these species can be undertaken once the high- and medium-priority weeds have been treated.

6.4 Erosion Management Through Revegetation

This section of the SEMP has been designed to enhance the recommended strategy of Beach Nourishment on the Cungulla foreshore.

To assist in retaining sand on the beach following the initial nourishment of 15,000m^3 of sand (thereby enhancing the durability of the natural erosion buffers), the newly created dune should be vegetated. Recommendations for this revegetation of the renourished dune system at Cungulla are offered below.

Native coastal vegetation plays an important role in forming and stabilising dunes. Dunes naturally build in height and width since pioneer plant species such as Spinifex and goat's foot and beach debris (logs, branches, etc.) all trap windblown sand.

Tree roots help to stabilise the dune and so enables the dune itself to better accommodate erosion by wind and waves. Because the frontal dune protects the area behind from wind and waves, more complex plant communities can develop on the back dune and in the swale.

In order to achieve the best results from revegetation work, the natural vegetation structure should be replicated. Certain trees are more tolerant of the harsh foredune and dune crest environment, and have adaptations that help to stabilise the sand dune. The revegetation guidelines discussed in the following sections have been categorised in accordance with particular locations within the cross-shore dune profile shown below in Figure 6.7.

Many of the plants suggested for revegetation purposes are representative of what already exists at Cungulla. Information on other suitable native coastal plants and how to cultivate them can be found in:

- *Coastal Plants of the Burdekin Dry Tropics* booklet, available online at http://www.nqdrytropics.org.au/coastal-plants-book
- *Native Grasses for revegetation in the Townsville region*, available online at http://wiki.bdtnrm.org.au/images/9/99/Native_Grasses_v3.pdf
- *The Burdekin Delta Tree Guide*, by Dr. Greg Calvert (Available at Mary Who? Bookshop, Flinders St, Townsville or from Lower Burdekin Landcare Association)

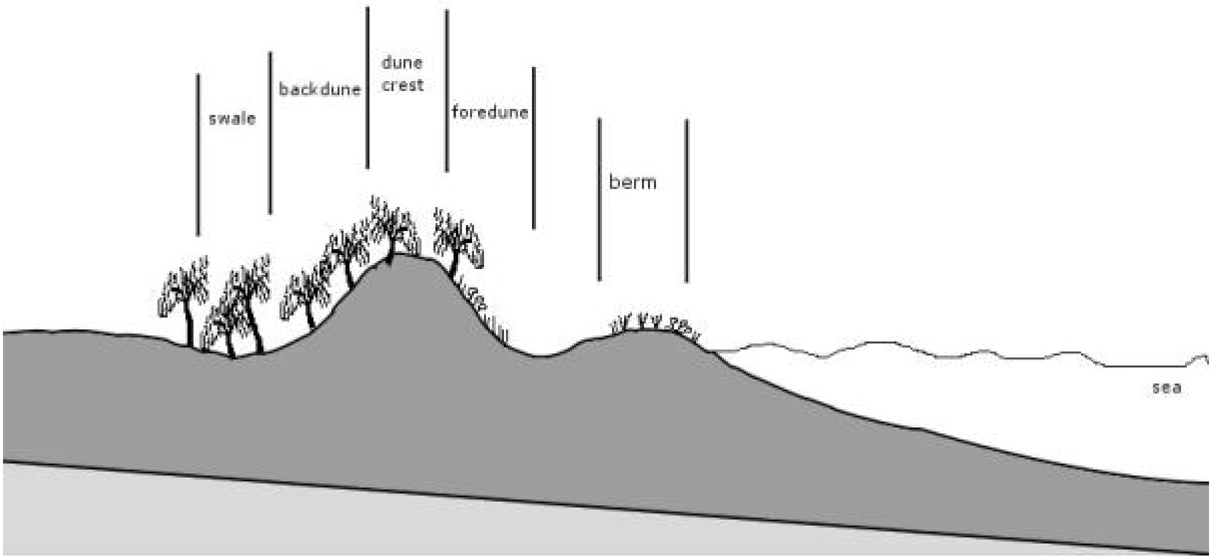

Figure 6.7 : Typical dune profile

6.4.1 Foredune

The following species are recommended for vegetation of the newly nourished foredune at Cungulla:

- Spinifex
- Goat's foot

- Beach Bean

These three species are common on the Cungulla foreshore. The vertical parts of these plants capture windblown sand, leading to the natural build up of the dune. They also perform an important role by stabilising the dunes with their sprawling runners and woody roots. Some coastal tree species may survive in the foredune area; however the survival rate of trees will not be as high as those planted on the dune crest.

6.4.2 Dune crest

The conditions on the crest of the dune are slightly less harsh than on the foredune - which means a larger variety of plants can survive at this location. These plants act as a wind break and protect the vegetation behind from salt and wind, as well as binding and stabilising the dune. Suggested species for revegetation of the dune crest include:

- She-Oak
- Wattle
- Lollybush
- Pandanus
- Sea Almond
- Nickernut
- Beach bean
- Goat's foot
- Spinifex
- Portia Tree
- Cottonwood

Although she-oaks and wattles are important for binding the sand together well; and for converting nitrogen in the sand and air, they can be sensitive to the impacts of severe storms. Consequently they should be planted amongst other dune species.

6.4.3 Backdune

The back dune are of the foreshore offers greater protection to vegetation than the dune crest, so it can even better support more species. Some suggested species for revegetation of the back dune include:

- She-Oak
- Wattle
- Lollybush
- Pandanus
- Sea Almond
- Nickernut
- Portia Tree
- Cottonwood
- Burdekin Plum
- Beach Tamarind
- Moreton Bay Ash
- Tea Tree
- Native grasses

6.4.4 Swale

Most of the species in the back dune area can also be found in swale areas. However if the area is wet for long periods of time, most plants will not survive. Tea trees are the best to plant in wet areas, as they have a high tolerance to excess water. Some native grasses may also survive in these areas.

6.5 Fire Management

The lighting of fires is not recommended on the Cungulla foreshore as dunes are environmentally sensitive areas. Removal of guinea grass and lantana will assist in reducing the fire risk to the foreshore.

6.6 Waste Management

In order for the prevailing coastal processes and ecosystem to function as naturally as possible it is important that all green waste, tyres and rubble be kept off the foreshore and dune system. Local Cungulla residents should ensure that they dispose of their waste responsibly.

As discussed elsewhere in this Shoreline Erosion Management Plan, the ad hoc attempts by local residents to armour the foreshore with rocks, tyres, tree trunks, green waste, bricks and building debris are largely ineffectual as structural barriers during significant storm events. As well as being completely inappropriate structural solutions, the works are unsightly and are unlawful since most are built without the necessary development approval.

6.7 Access Control

Once the recommended initial beach nourishment has been implemented, the potential erosion and loss of vegetation due to excessive and wide-spread pedestrian traffic needs to be appropriately managed.

Dedicated pedestrian access to the beach should be provided to limit the impacts of foot traffic on the newly created dune. Fencing off areas of the dune for revegetation and installing interpretive signage at the location of the works would be beneficial to the durability of the recommended beach nourishment strategy.

7 RELEVANT LEGISLATION

7.1 Background

To ensure that the recommended foreshore management 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 section of the Shoreline Erosion Management Plan outlines the relevant legislative framework that will influence the development, assessment and implementation of appropriate erosion mitigation measures on the Cungulla shoreline.

The following discussion of legislative requirements was compiled from advice received from each of the Government agencies administering relevant legislative provisions. It is important to note that the advice was based on earlier draft recommendations of the Shoreline Erosion Management Plan - which included sourcing of the initial sand nourishment volume of 15,000m^3 from the northern sand spit at Cungulla.

Subsequent further investigations identified that the extraction of sand from that location presented a potential risk to migratory shorebirds that frequent the sand spit. Subsequent consultation between NQ Dry Tropics and Townsville City Council resulted in the exclusion of that sand sourcing option from the Shoreline Management Plan on the basis that the level of potential risk to the migratory birds and significant wildlife habitat was not acceptable.

7.2 Environment Protection and Biodiversity Conservation Act 1999

The EPBC Act provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places - defined in the EPBC Act as matters of national environmental significance.

The eight matters of national environmental significance to which the EPBC Act applies are:

- world heritage sites
- national heritage places
- wetlands of international importance (often called *'Ramsar'* wetlands after the international treaty under which such wetlands are listed)
- nationally threatened species and ecological communities
- migratory species
- Commonwealth marine areas

- the Great Barrier Reef Marine Park
- nuclear actions

In the case of the proposed erosion mitigation works at Cungulla, consideration needs to be made to the impacts they might have on nationally threatened species and migratory shorebirds. A referral can be made to the Department of Sustainability, Environment, Water, Population and Communities. If the impacts are deemed likely to be significant, the project will be classed as a "controlled action" and will be subjected to an assessment and approval process.

While extraction from the northern spit would have likely required referral based on the potential risk to migratory birds, it is considered that referral is not required for the recommended erosion mitigation activities since sand for beach nourishment purposes will be provided from existing approved sand extraction operations.

7.3 Coastal Protection and Management Act 1995

Activities that have the potential to impact on coastal processes generally require a development approval under the *Sustainable Planning Act 2009;* and are assessed under the provisions of the *Coastal Protection and Management Act 1995*. For example, the construction of a rock seawall to prevent beach erosion is considered tidal works, the construction of recreational facilities within the dune is considered operational works involving interference with quarry material. The placement of sand on the beach as part of a beach nourishment program could be either of the above activities - requiring approval depending on the exact location of the activity with respect to the high water mark.

It is considered that the proposed beach nourishment strategy for the Cungulla foreshore would require a development approval. Firstly, the proposed beach nourishment would constitute tidal works; while the extraction of sand from accumulated deposits at the southern end of Cungulla beach for intermittent and on-going renourishment would be operational works involving the interference with quarry material.

While the *Coastal Protection and Management Act* provides specific criteria for assessing a development application for these legislative triggers, the Draft *Coastal Protection State Planning Regulatory Provision Protecting the Coastal Environment* (SPRP) provides guidance to decision makers while the State Government undertakes a full review of the State Coastal Plan. The SPRP will operate for 12 months from 8 October 2012 or until earlier repealed. Section 2.2(6) and (7) of the SPRP is most relevant to the proposed activities of beach nourishment at Cungulla:

> *(6) For developed areas, structural engineering and stabilisation works will be initiated only as a last resort where erosion presents an immediate threat to public safety or property and infrastructure that is not expendable. The siting, design and materials used for works will not cause any significant adverse impacts on the coastal resources of the location*

nor significantly impact on the natural cycles of erosion and accretion of beaches.

(7) Construction of structures for the purpose of beach protection (including artificial reefs, banks, wrecks, breakwaters and groynes) in coastal waters will only be approved where:

(a) there is a demonstrated need in the public interest

(b) comprehensive investigation has been carried out and it can be demonstrated that:

(i) there would not be any significant adverse impacts on the longshore transport of sediments

(ii) there would be no increase in coastal hazards for the neighbouring foreshore.

As well as the above provisions of the SPRP, Section 2.2(9) (iii) and (v) is also relevant to the proposed sand extraction.

(9) The following matters are to be addressed to achieve the conservation and management of Queensland's coastal biodiversity:

(a) the maintenance and re-establishment of the connectivity of ecosystems; particularly to ensure viable populations of protected native species continue to exist throughout their range, by maintaining opportunities for long-term survival, genetic diversity and the potential for continuing evolutionary adaptation. This includes the protection of significant wildlife habitats, such as:

(iii) protecting beaches providing significant wildlife habitats (including roosting, nesting and breeding habitat for turtles, birds or crocodiles) through suitable management measures including buffers for those habitats

(v) retaining the current extent and quality of migratory and resident shorebird roosting and feeding habitat. If habitat is to be lost it should be replaced, where practicable, before loss, by an equivalent artificial habitat in a location that minimises any alteration of distribution and abundance of shorebirds.

This Shoreline Erosion Management Plan provides supportive evidence to satisfy these guiding principles. For example, the exclusion of the option to remove 15,000 m^3 of sand from the northern spit minimises any disturbance to migratory birds and mitigates the loss of significant wildlife habitat.

Whilst the Department of Environment and Heritage Protection guidelines for the approval process are currently outdated in regard to the suspended State Planning Policy, they do provide guidance on other requirements to be met as part of the development application process - for example, certified engineering drawings showing specific details of the proposed activities.

At the time of compiling this Shoreline Erosion Management Plan the guidelines can be found at:

- *http://www.ehp.qld.gov.au/coastal/development/pdf/constructing-tidal-works.pdf*, and
- *http://www.ehp.qld.gov.au/coastal/development/pdf/operational-work-state-coastal-land.pdf*

7.4 Fisheries Act 1994

The *Fisheries Act 1994* provides for the management, use, development and protection of fisheries resources and fish habitats throughout Queensland. The provisions most relevant to the proposed erosion mitigation strategy at Cungulla would be those associated with approval requirements for marine plant disturbance. 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.

It is unlikely that the proposed activities will directly impact on marine plants, but if disturbance is unavoidable, a development application under the *Sustainable Planning Act* (referred to previously), will need to be referred to the Department of Agriculture, Fisheries and Forestry. Figure 7.1 shows that Cungulla is not within the Fish Habitat Area.

Figure 7.1 : Designated Fish Habitat Area in relation to Cungulla

7.5 Marine Parks Act 2004

Marine parks established over tidal lands and waters protect and conserve the values of the natural marine environment while allowing for its sustainable use. They protect habitats including mangrove wetlands, seagrass beds, mudflats, sandbanks, beaches, rocky outcrops and fringing reefs.

Park boundaries can be established over tidal lands and waters up to the highest astronomical tide (HAT). The parks include the subsoil below and airspace above their boundaries, and the plants and animals within them.

Should equipment be required to access the area seaward of the boundary, a Marine Park Delegate would need to determine whether or not a marine park permit would be required. It is unlikely that referral is required for the recommended beach nourishment strategy.

7.6 Environmental Protection Act 1997

Carrying out extraction (other than by dredging) of 5,000 tonnes or more of material in a year from an area other than a wild river area is considered as accessable development under the *Environmental Protection Regulation 2009.*

Since the proposed annual backpassing from the southern end of the beach is estimated to be approximately 1,500m^3 (ie. around 2,200 tonnes) and would be removed from an area above the level of Highest Astronomical Tide, no approval under the Environmental Protection Act will be required.

7.7 Sustainable Planning Act 2009 /Land Act 1994

As discussed previously, the proposed activities require a development approval under the Sustainable Planning Act 2009. Under the legislation, the Department of Natural Resources and Mines (DNRM) need to provide Owner's Consent - since the proposed works will occur on State Land. DNRM will also need to consider if the proposed activity is appropriate on the current tenure of the land; or if a different tenure would be required.

Beach nourishment works can be undertaken on unallocated State land (USL). However USL is not an appropriate tenure for groynes or seawalls. If the latter options were chosen over beach nourishment, an alternative tenure would need to be in place for these works to occur.

8 RECOMMENDED SHORELINE EROSION MANAGEMENT PLAN

8.1 Recommended Strategy

Following a review of the prevailing coastal processes, risks and values of the Cungulla foreshore the following activities are recommended by this Shoreline Erosion Management Plan:

Extent of Works

- The only section of the Cungulla coastal reach requiring direct intervention to mitigate shoreline erosion is along an approximately 585 metre foreshore extending from the northern-most end of Empress Close southwards to a location approximately 100 metres beyond Vivienne Lyons Park. This will protect private properties on Empress Close that are most vulnerable to erosion and damage by severe storms/cyclones.

Project Design and Approvals

- Project stakeholders need to confirm that a 100 year ARI Design Event is appropriate to adopt for the erosion mitigation strategy recommended by this Shoreline Erosion Management Plan. This requires consideration and acceptance of the risk that such an event will occur (or be exceeded) within a particular planning horizon. Guidance on risk is offered in this Shoreline Erosion Management Plan.
- Should an event occur that is more severe than the selected Design Event, then the engineering works implemented in accordance with this Shoreline Erosion Management Plan may be compromised and coastal infrastructure could be damaged as a consequence. The selection of an appropriate Design Event is therefore an important consideration.
- Project stakeholders need to select the alignment of an appropriate Coastal Defence Line along the Cungulla shoreline. Throughout the planning horizon, 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 erosion buffers).
- Undertake detailed engineering designs, including the production of drawings and technical specifications for the necessary erosion mitigation works. This will likely require a more detailed land survey in the area where such works are to be implemented.
- Prepare and submit appropriate approval applications based on the detailed engineering designs for the proposed works. Guidance on relevant legislation and approval requirements are offered in this Shoreline Erosion Management Plan.

Project Monitoring

- Undertake a pre-project monitoring survey of the beach transect lines that have already been established as part of an earlier on-going monitoring program - as well as on two new transect lines established across the southern end of Big Beach (opposite properties in George Ansell Drive).
- Undertake beach transect surveys annually on ten of these established transect lines (namely CUN-01b and CUIN-02 to CUN-10) as well as the two new lines.
- All transect surveys are to extend offshore for a minimum distance of 500m from the toe of the sandy beach.

Beach Nourishment

- The extent of the recommended works is shown conceptually on Figure 8.1.
- Place sand as initial nourishment on the approximately 585 metre long at-risk section of shoreline opposite the northern section of Empress Close. This will create an erosion buffer that can accommodate the expected shoreline recession caused by a 100 year ARI cyclone event.
- Most of the existing ad hoc seawalls along this section of the foreshore can be left in place; and simply be buried at the rear of the newly created sand buffer - although minor mechanical re-profiling of some of the higher walls may be required. So long as they remain buried at the back of the beach, they will not interfere with natural coastal processes.
- The actual sand quantity required to be placed in this initial nourishment exercise will depend upon the location of a Coastal Defence Line nominated by stakeholders; and the degree of protection required (ie. the selected Design Event). However as a guide, this Shoreline Erosion Management Plan has adopted a 100 year ARI Design Event; and a Coastal Defence Line along the top of the sandy beach and/or the crest of the ad hoc protection works undertaken by local residents. This will require 15,000m^3 of sand to create an appropriate erosion buffer.
- The sand for this initial nourishment can be sourced from existing commercial sand extraction operations in the region without adverse environmental impacts.
- 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. Appropriate dune management strategies are offered in this Shoreline Erosion Management Plan.
- Whenever annual beach surveys indicate that the volume of sand in the buffer has naturally depleted below a specified limit, then a backpassing exercise would be instigated to renourish the buffer. The criteria that initiates such action would be determined as part of the detailed engineering design of the overall beach nourishment works.

- This back-passing would be achieved by using conventional earthmoving equipment, such as excavators and/or front-end loaders to collect sand from the southern foreshore; load it into trucks; which would then deliver it to the buffer area. The sand would then be spread on the foreshore by loader and/or grader to reinstate the buffer volume.
- It is likely that sand back-passing campaigns will need to be undertaken to redistribute on average 1,500m^3 /year of sand from the southern end of the Cungulla coastal reach to the at-risk foreshore along the northern section of Empress Close. This amount represents a long-term average requirement, since there will be some years of mild wave conditions which will not require the buffer to be renourished, whereas other years of more energetic wave conditions will necessitate more intensive backpassing.

Estimated Costs of Beach Nourishment

- The estimated cost of initial beach nourishment to create the necessary erosion buffer along the at-risk foreshore along the northern end of Empress Close is $475,000. This is based on sourcing 15,000m^3 of sand from existing commercial sand extraction operations in the region; and placing it on the foreshore along the northern end of Empress Close.
- Given that the buffer will be gradually depleted by longshore sand transport processes, it will be necessary to recharge the erosion buffer by periodic placement of additional sand by backpassing. The timing of these backpassing campaigns will be determined by actual depletion rates as measured from annual surveys, however the long-term average annual cost is estimated at $20,000.

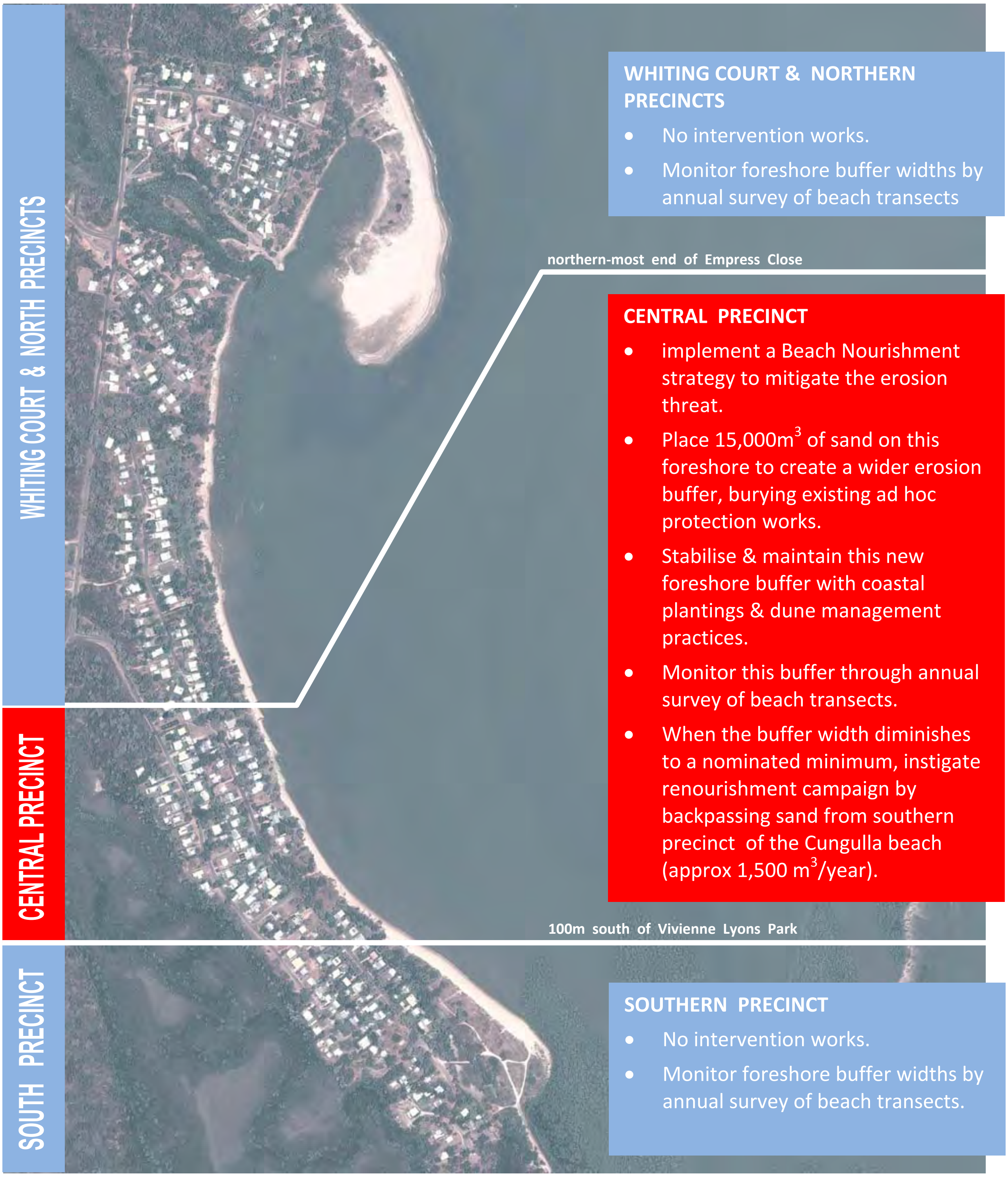

Figure 8.1 : Recommended Shoreline Erosion Management Strategy

8.2 Estimated Implementation Costs of the Plan

The estimated overall costs associated with the implementation of the recommended Shoreline Erosion Management Plan are summarised below. These costs are at rates applicable for April 2013 and include GST.

At this stage these estimates must be considered as indicative only since no detailed design has been undertaken. They have been based on an approximation of sand volumes for initial beach nourishment to provide a buffer to a Coastal Defence Line along the top of the sandy beach and/or the crest of ad hoc protection works.

SEMP component	Cost	Annual Cost
Project Design and Approvals		
Land survey in the area of proposed foreshore works	$10,000	
Engineering design of beach nourishment & sand extraction	$25,000	
Obtain appropriate approvals	$7,500	
Project Monitoring		
Establish 2 new transects & undertake initial pre-project surveys	$17,500	
Annual survey of all beach transects		$15,000
Beach Nourishment		
Initial nourishment to create erosion buffer	$475,000	
On-going renourishment by backpassing operations		$20,000
Implementation / maintenance of dune management program	$50,000	$5,000
Totals	$585,000	$40,000

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APPENDIX A

COMPARISON OF HISTORICAL FORESHORE CHANGES

1961

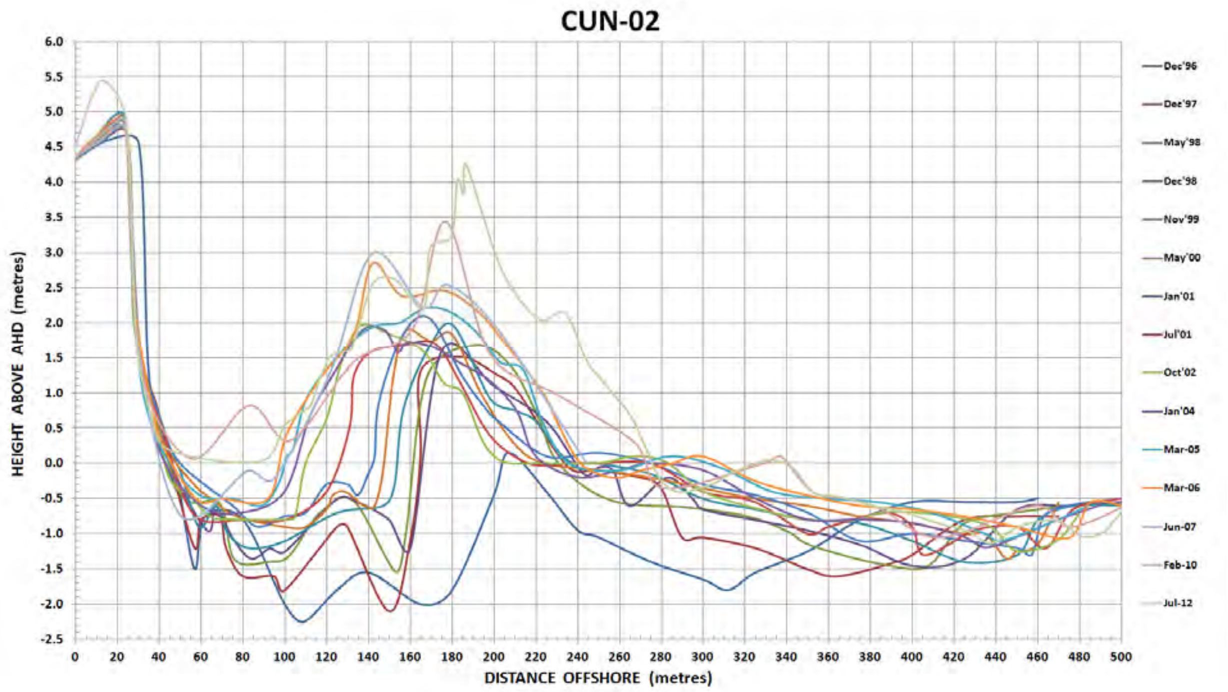
1995

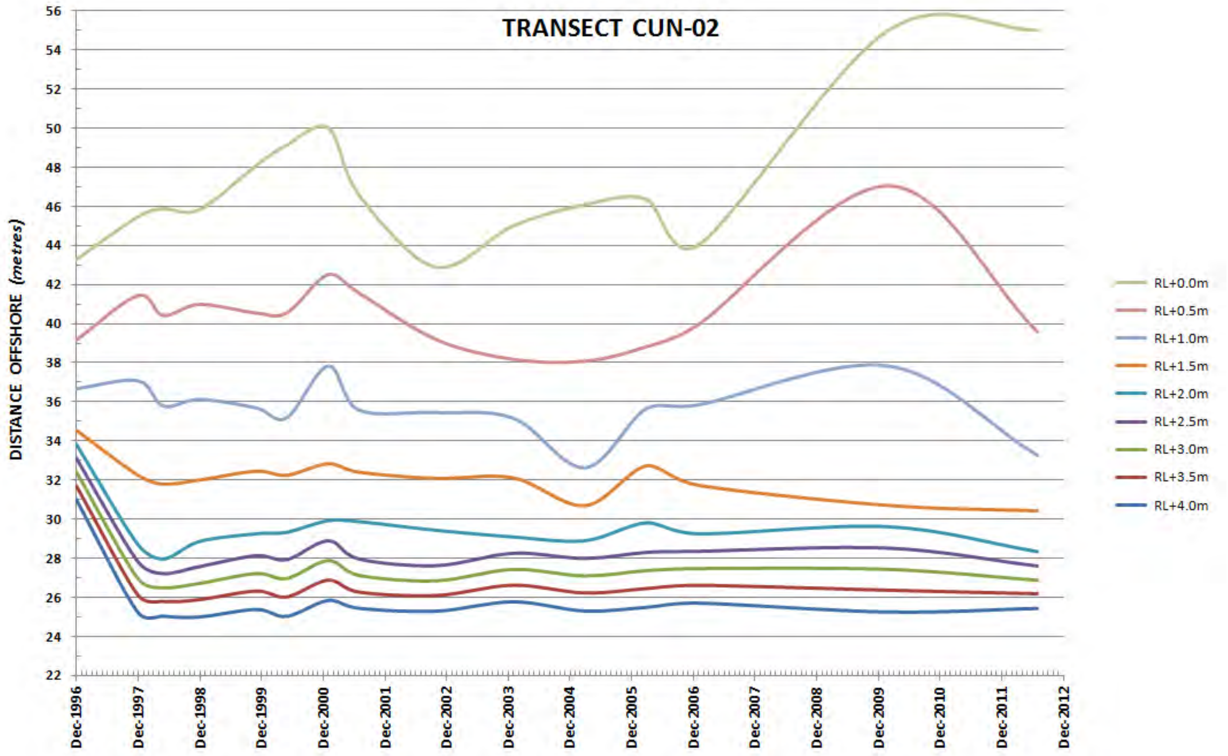
1999

2010

APPENDIX B

RESULTS OF BEACH TRANSECT SURVEYS


CUN-02
HEIGHT ABOVE AHD (metres)
DISTANCE OFFSHORE (metres)
Dec'96
Dec'97
May'98
Dec'98
Nov'99
May'00
Jan'01
Jul'01
Oct'02
Jan'04
Mar-05
Mar-06
Jun-07
Feb-10
Jul-12


TRANSECT CUN-02
DISTANCE OFFSHORE (metres)
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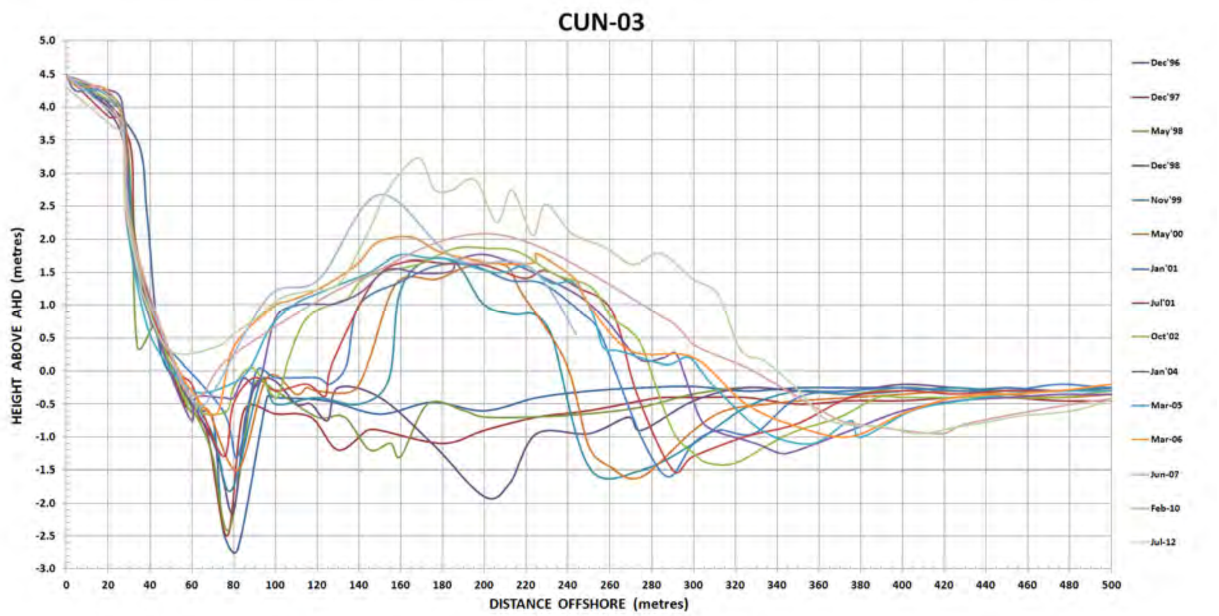
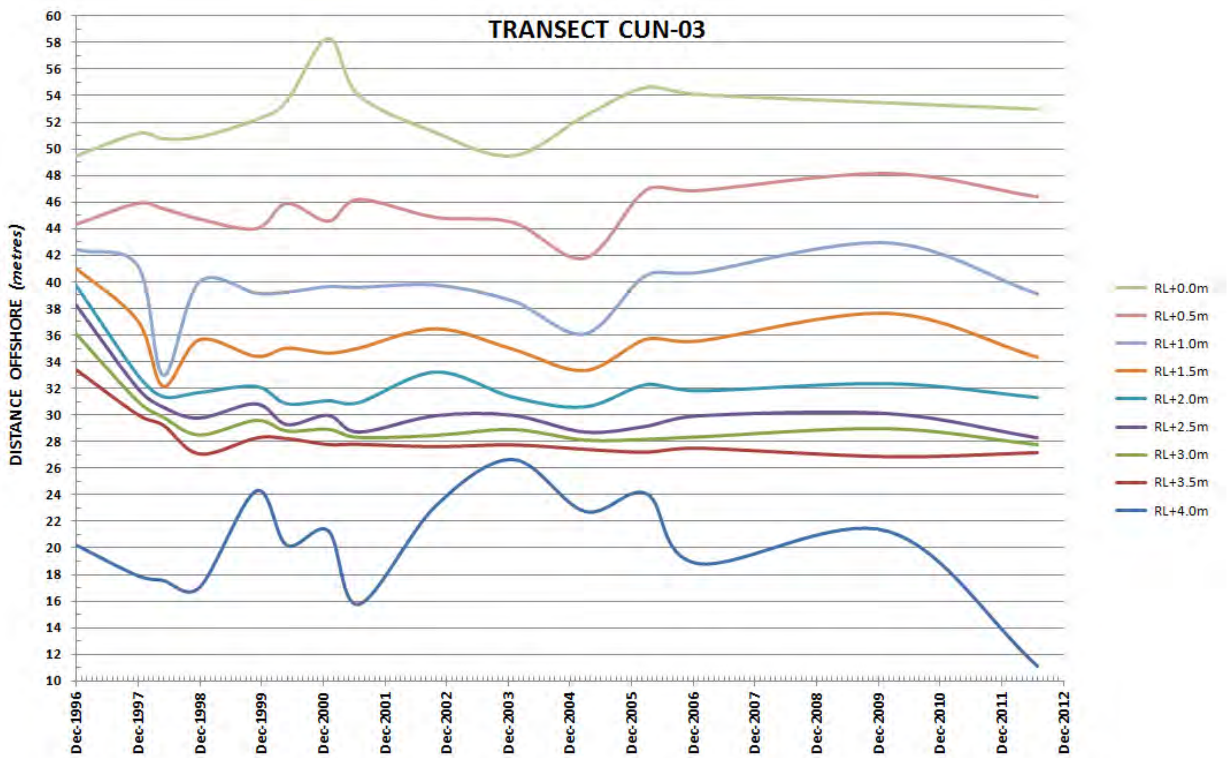
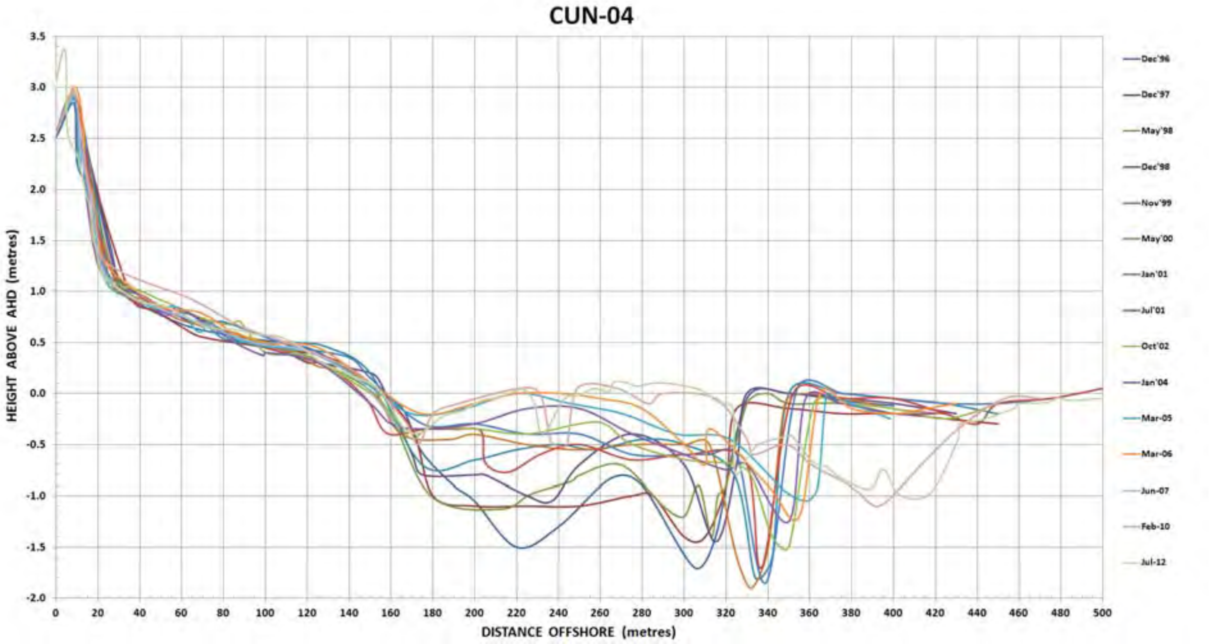
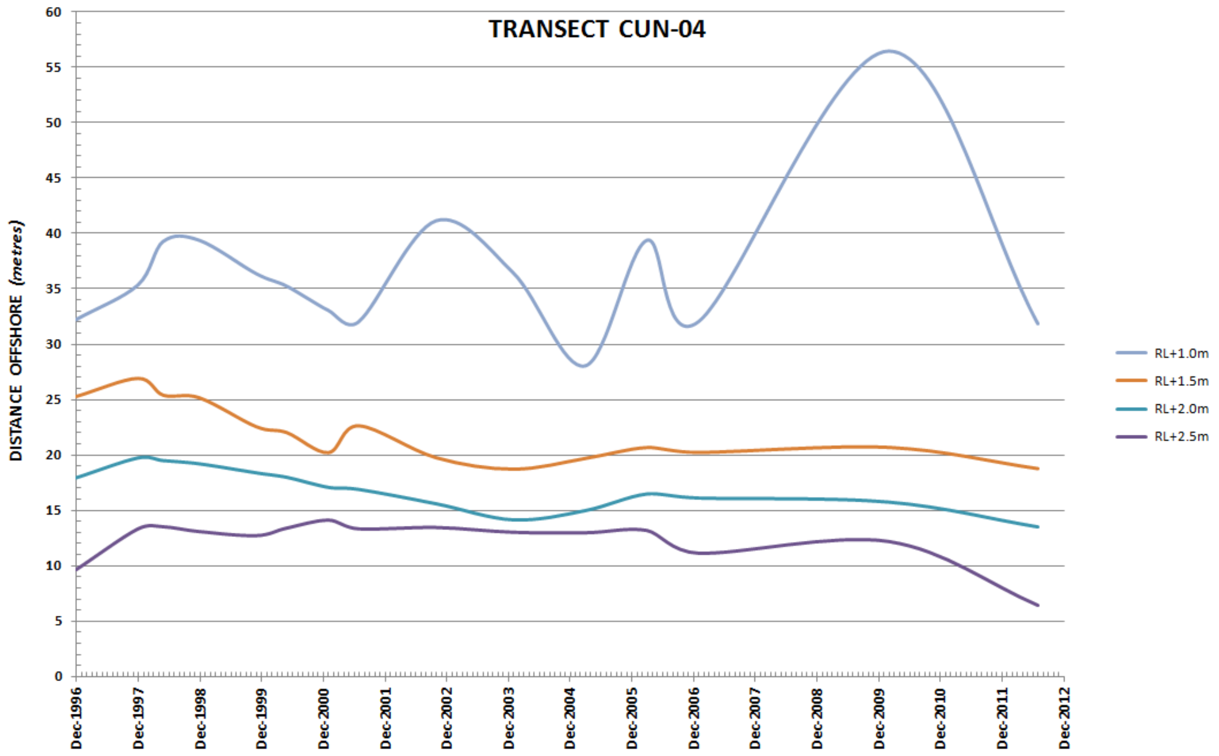
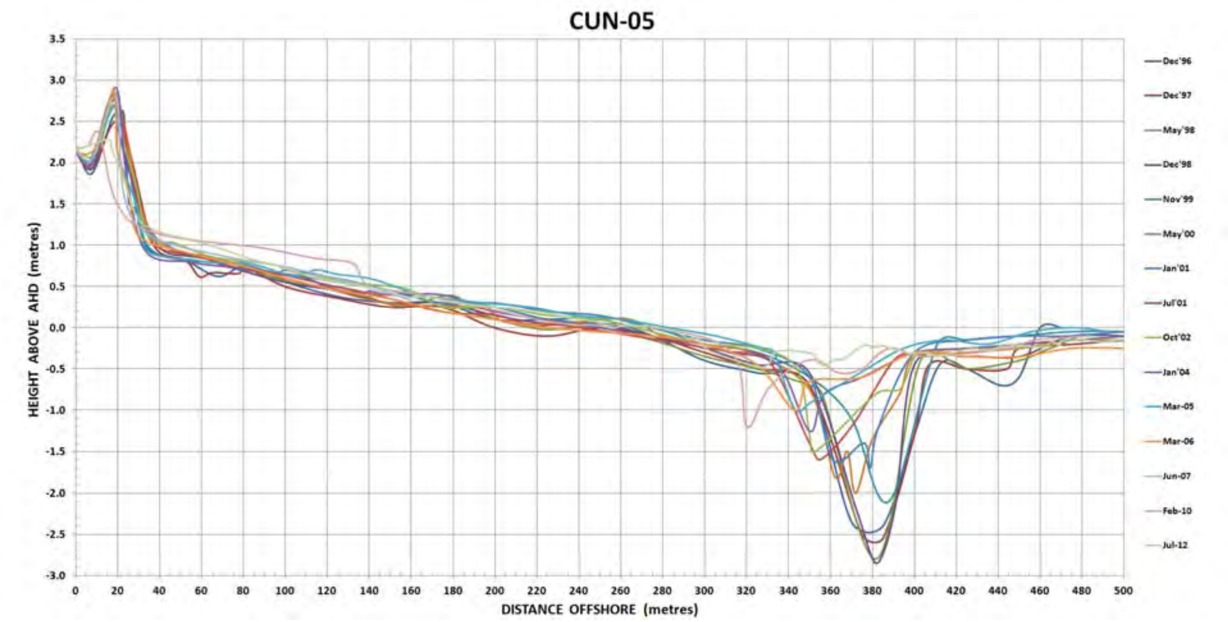
RL+0.5m
RL+1.0m
RL+1.5m
RL+2.0m
RL+2.5m
RL+3.0m
RL+3.5m
RL+4.0m


CUN-03
HEIGHT ABOVE AHD (metres)
DISTANCE OFFSHORE (metres)
Dec'96
Dec'97
May'98
Dec'98
Nov'99
May'00
Jan'01
Jul'01
Oct'02
Jan'04
Mar-05
Mar-06
Jun-07
Feb-10
Jul-12


TRANSECT CUN-03
DISTANCE OFFSHORE (metres)
RL+0.0m
RL+0.5m
RL+1.0m
RL+1.5m
RL+2.0m
RL+2.5m
RL+3.0m
RL+3.5m
RL+4.0m


CUN-04
HEIGHT ABOVE AHD (metres)
DISTANCE OFFSHORE (metres)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500
Dec'96
Dec'97
May'98
Dec'98
Nov'99
May'00
Jan'01
Jul'01
Oct'02
Jan'04
Mar-05
Mar-06
Jun-07
Feb-10
Jul-12


TRANSECT CUN-04
DISTANCE OFFSHORE (metres)
60
55
50
45
40
35
30
25
20
15
10
5
0
Dec-1996 Dec-1997 Dec-1998 Dec-1999 Dec-2000 Dec-2001 Dec-2002 Dec-2003 Dec-2004 Dec-2005 Dec-2006 Dec-2007 Dec-2008 Dec-2009 Dec-2010 Dec-2011 Dec-2012
RL+1.0m
RL+1.5m
RL+2.0m
RL+2.5m


CUN-05
HEIGHT ABOVE AHD (metres)
DISTANCE OFFSHORE (metres)
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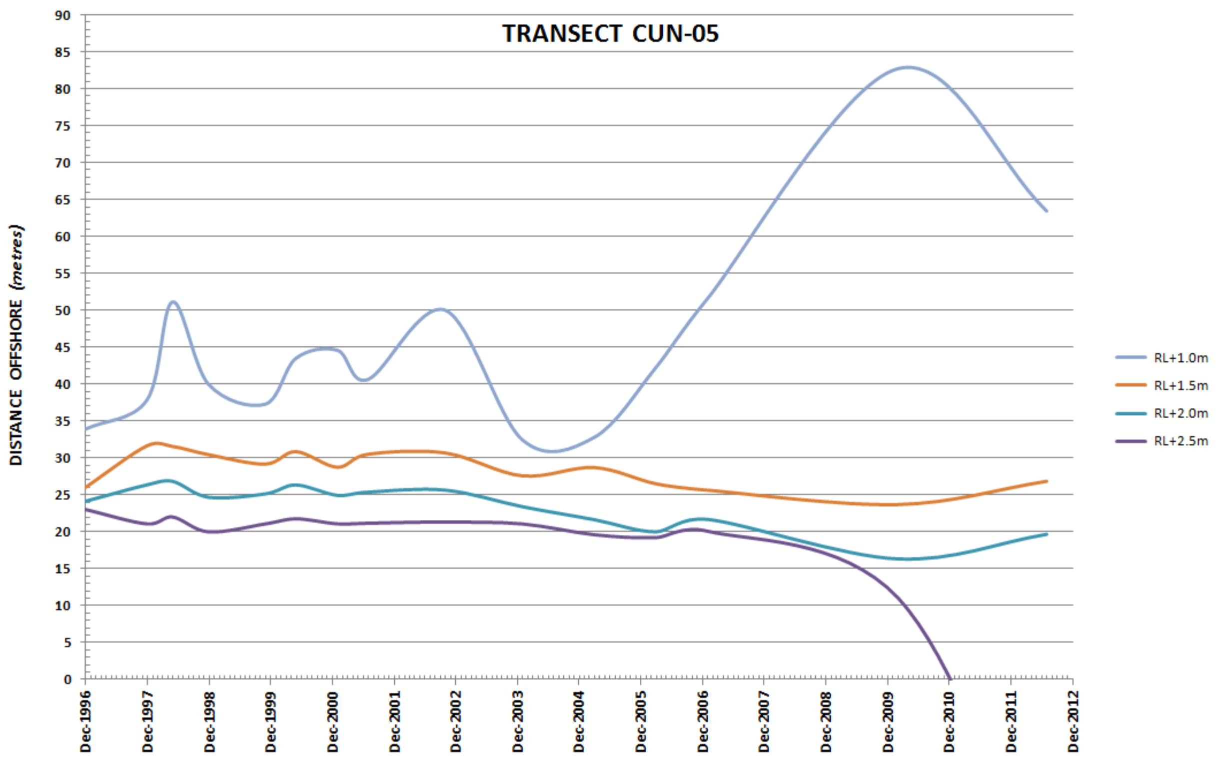
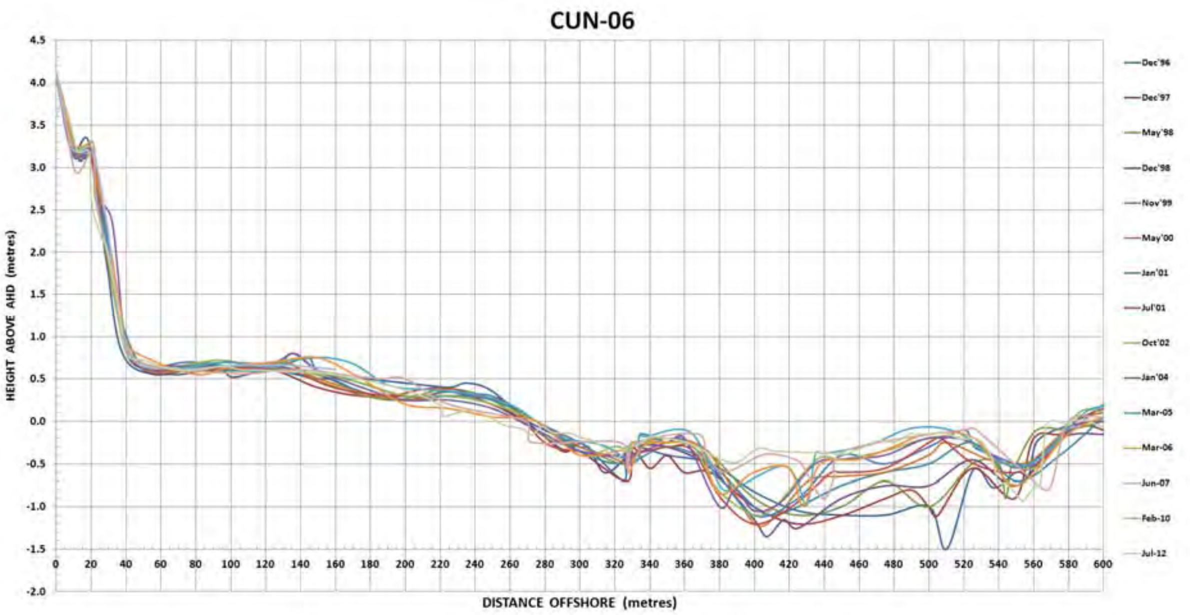
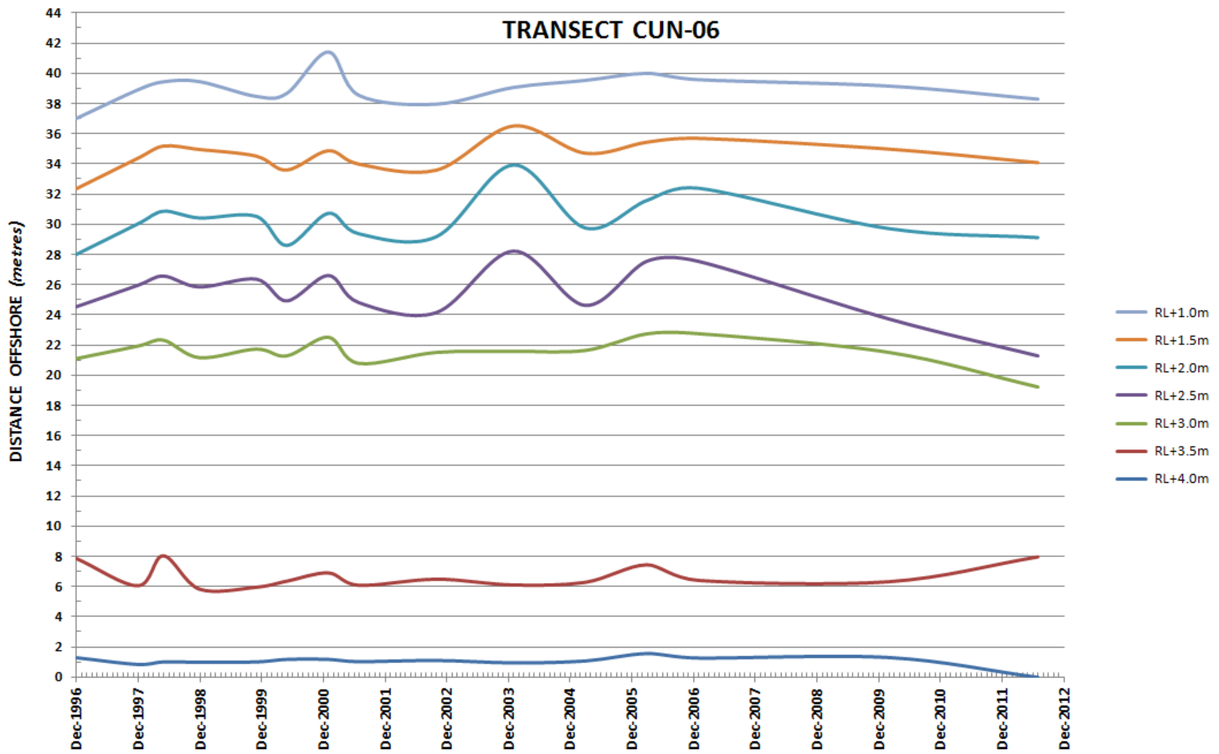
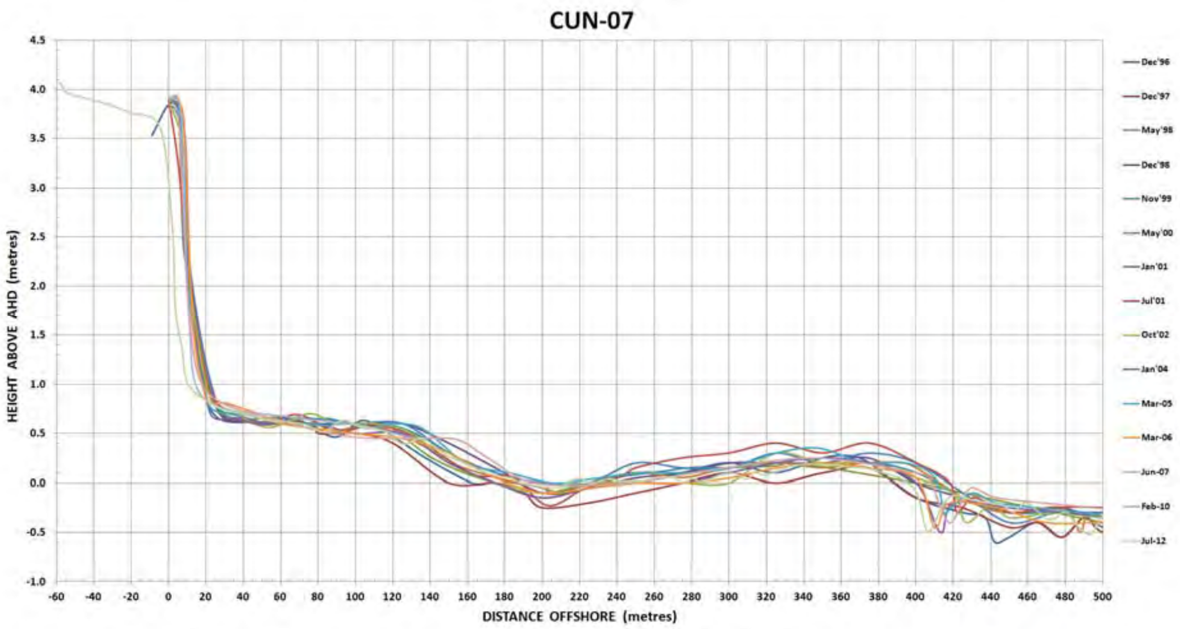
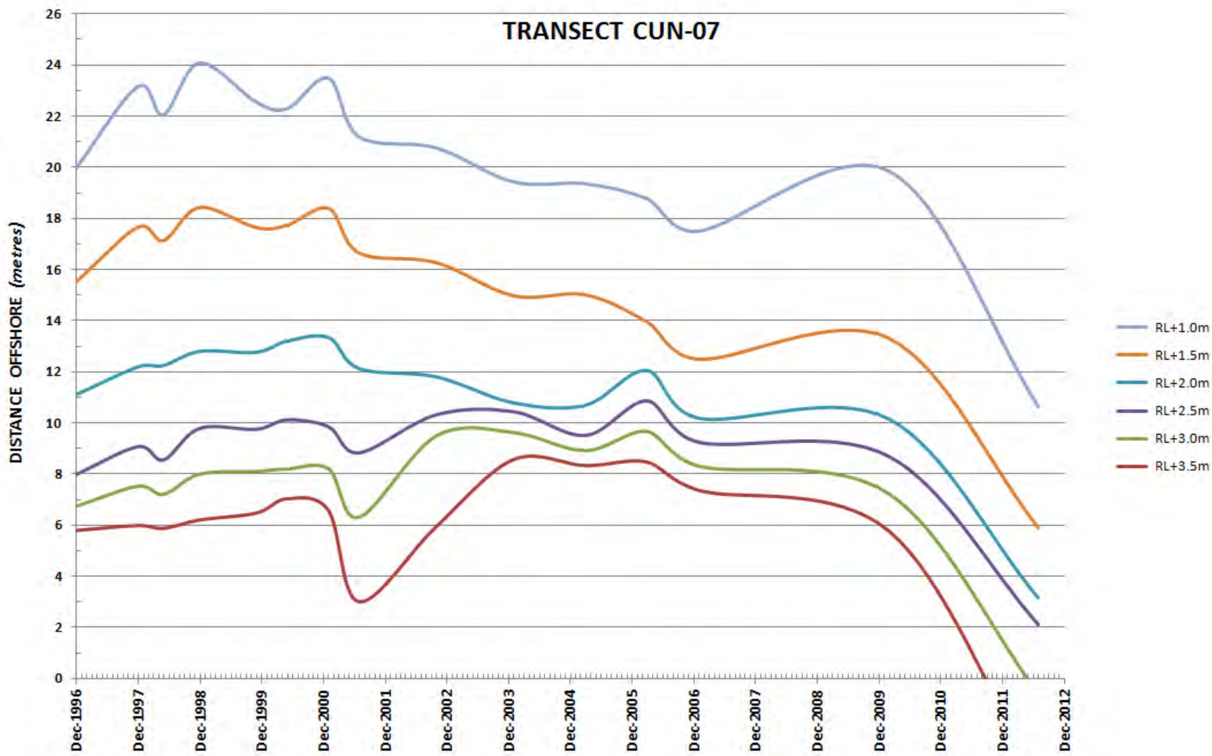
Dec'97
May'98
Dec'98
Nov'99
May'00
Jan'01
Jul'01
Oct'02
Jan'04
Mar-05
Mar-06
Jun-07
Feb-10
Jul-12

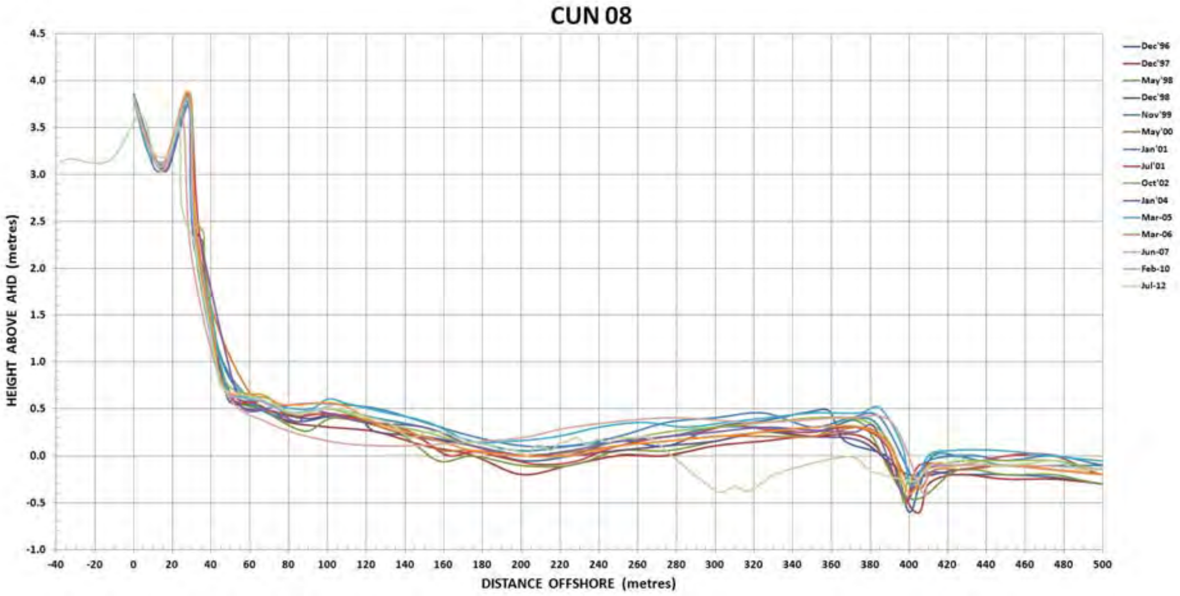

TRANSECT CUN-05
DISTANCE OFFSHORE (metres)
RL+1.0m
RL+1.5m
RL+2.0m
RL+2.5m

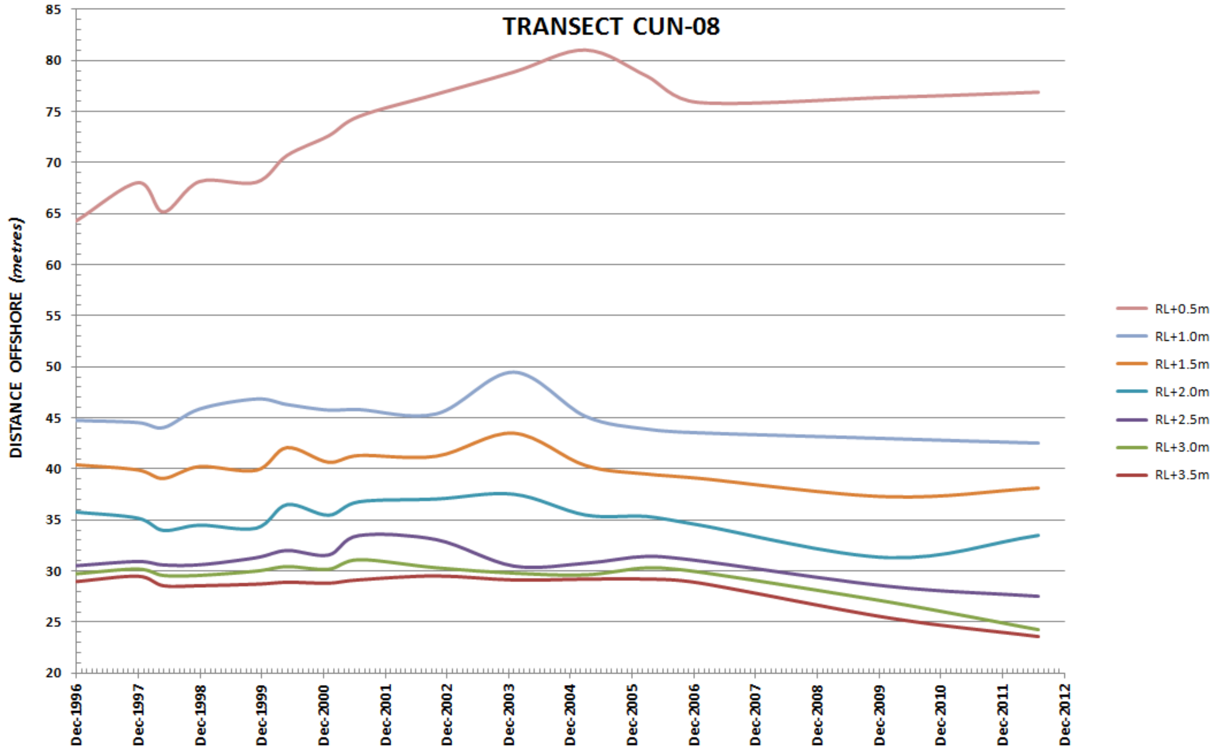

CUN-06
HEIGHT ABOVE AHD (metres)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600
DISTANCE OFFSHORE (metres)
Dec'96
Dec'97
May'98
Dec'98
Nov'99
May'00
Jan'01
Jul'01
Oct'02
Jan'04
Mar-05
Mar-06
Jun-07
Feb-10
Jul-12

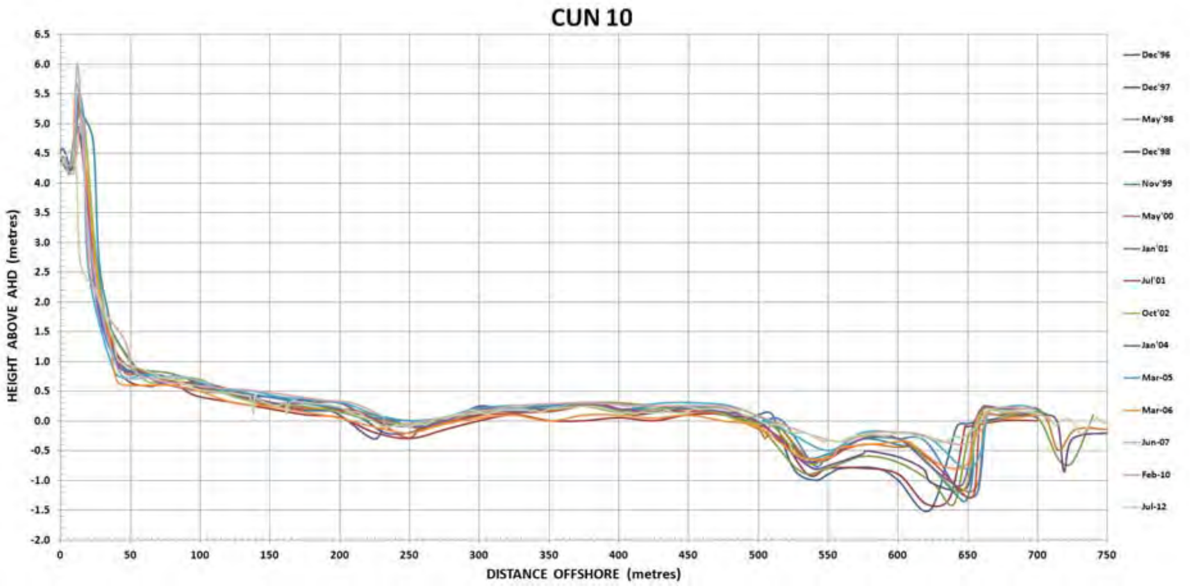

TRANSECT CUN-06
DISTANCE OFFSHORE (metres)
44 42 40 38 36 34 32 30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0
Dec-1996 Dec-1997 Dec-1998 Dec-1999 Dec-2000 Dec-2001 Dec-2002 Dec-2003 Dec-2004 Dec-2005 Dec-2006 Dec-2007 Dec-2008 Dec-2009 Dec-2010 Dec-2011 Dec-2012
RL+1.0m
RL+1.5m
RL+2.0m
RL+2.5m
RL+3.0m
RL+3.5m
RL+4.0m


CUN-07
HEIGHT ABOVE AHD (metres)
DISTANCE OFFSHORE (metres)
Dec'96
Dec'97
May'98
Dec'98
Nov'99
May'00
Jan'01
Jul'01
Oct'02
Jan'04
Mar-05
Mar-06
Jun-07
Feb-10
Jul-12

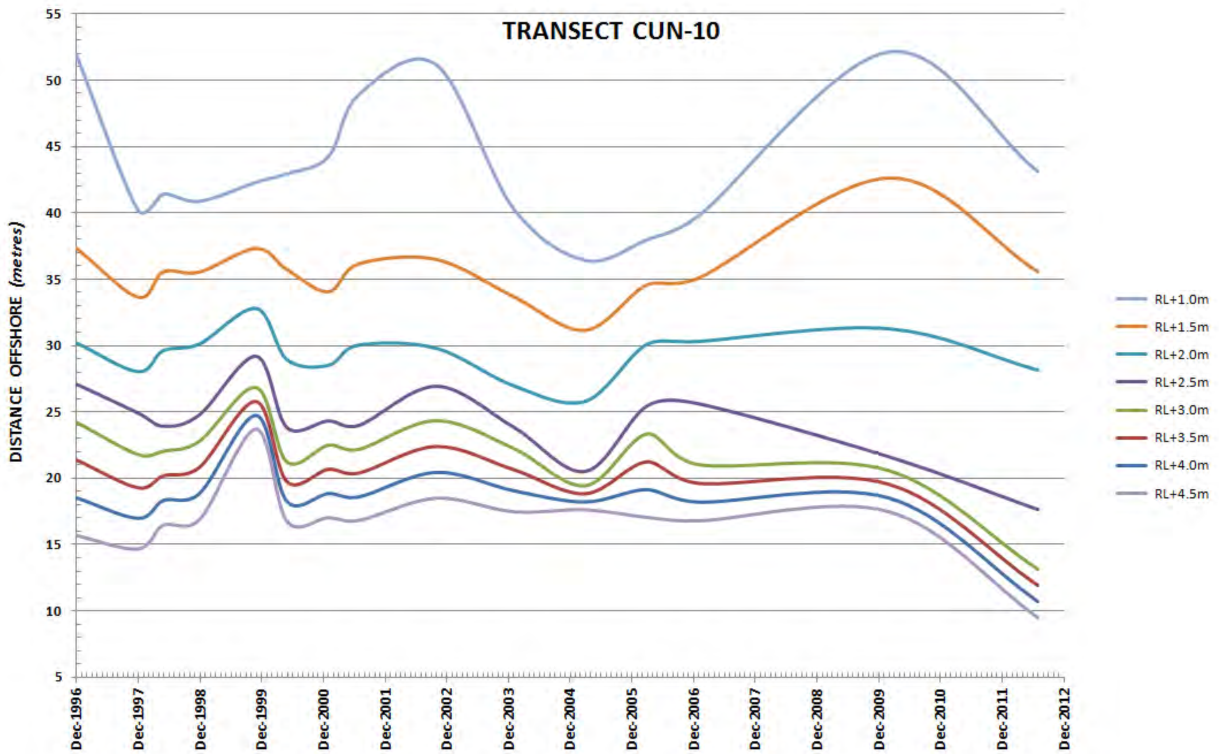

TRANSECT CUN-07
DISTANCE OFFSHORE (metres)
RL+1.0m
RL+1.5m
RL+2.0m
RL+2.5m
RL+3.0m
RL+3.5m


CUN 08
HEIGHT ABOVE AHD (metres)
DISTANCE OFFSHORE (metres)
Dec'96
Dec'97
May'98
Dec'98
Nov'99
May'00
Jan'01
Jul'01
Oct'02
Jan'04
Mar-05
Mar-06
Jun-07
Feb-10
Jul-12


TRANSECT CUN-08
DISTANCE OFFSHORE (metres)
RL+0.5m
RL+1.0m
RL+1.5m
RL+2.0m
RL+2.5m
RL+3.0m
RL+3.5m



CUN 10
HEIGHT ABOVE AHD (metres)
DISTANCE OFFSHORE (metres)
Dec'96
Dec'97
May'98
Dec'98
Nov'99
May'00
Jan'01
Jul'01
Oct'02
Jan'04
Mar-05
Mar-06
Jun-07
Feb-10
Jul-12



TRANSECT CUN-10
DISTANCE OFFSHORE (metres)
RL+1.0m
RL+1.5m
RL+2.0m
RL+2.5m
RL+3.0m
RL+3.5m
RL+4.0m
RL+4.5m

APPENDIX C

BIRDS KNOWN TO OCCUR AT CUNGULLA

Birds known to occur at Cungulla. Information taken from DEHP's Wildlife Online website. Conservation status listed under the Nature Conservation Act 1992.

Legend:

Endangered (E), Vulnerable (V), Near Threatened (NT), Least Concern (C) and Introduced Species (I)

Scientific Name	Common Name	Status
Accipiter fasciatus	brown goshawk	C
Actitis hypoleucos	common sandpiper	C
Aerodramus terraereginae	Australian swiftlet	NT
Alectura lathami	Australian brush-turkey	C
Anas gracilis	grey teal	C
Anas superciliosa	Pacific black duck	C
Anhinga novaehollandiae	Australasian darter	C
Anseranas semipalmata	magpie goose	C
Anthus novaeseelandiae	Australasian pipit	C
Aprosmictus erythropterus	red-winged parrot	C
Apus pacificus	fork-tailed swift	C
Aquila audax	wedge-tailed eagle	C
Ardea ibis	cattle egret	C
Ardea intermedia	intermediate egret	C
Ardea modesta	eastern great egret	C
Ardea pacifica	white-necked heron	C
Ardea sumatrana	great-billed heron	C
Ardenna tenuirostris	short-tailed shearwater	C
Arenaria interpres	ruddy turnstone	C
Artamus cinereus	black-faced woodswallow	C
Artamus leucorynchus	white-breasted woodswallow	C
Burhinus grallarius	bush stone-curlew	C
Butorides striata	striated heron	C
Cacatua galerita	sulphur-crested cockatoo	C
Cacomantis pallidus	pallid cuckoo	C
Cacomantis variolosus	brush cuckoo	C
Calidris acuminata	sharp-tailed sandpiper	C
Calidris canutus	red knot	C
Calidris ferruginea	curlew sandpiper	C
Calidris ruficollis	red-necked stint	C
Calidris tenuirostris	great knot	C
Calyptorhynchus banksii	red-tailed black-cockatoo	C
Caprimulgus macrurus	large-tailed nightjar	C
Centropus phasianinus	pheasant coucal	C
Ceyx azureus	azure kingfisher	C
Ceyx pusilla	little kingfisher	C
Chalcites lucidus	shining bronze-cuckoo	C
Chalcites minutillus minutillus	little bronze-cuckoo	C
Chalcites minutillus russatus	Gould's bronze-cuckoo	C
Charadrius bicinctus	double-banded plover	C
Charadrius leschenaultii	greater sand plover	C
Charadrius mongolus	lesser sand plover	C
Charadrius ruficapillus	red-capped plover	C
Chlidonias hybrida	whiskered tern	C
Chroicocephalus novaehollandiae	silver gull	C
Cincloramphus cruralis	brown songlark	C
Circus approximans	swamp harrier	C
Cisticola exilis	golden-headed cisticola	C
Colluricincla megarhyncha	little shrike-thrush	C
Columba livia	rock dove	I
Conopophila rufogularis	rufous-throated honeyeater	C
Coracina novaehollandiae	black-faced cuckoo-shrike	C

Coracina papuensis	white-bellied cuckoo-shrike	C
Corvus coronoides	Australian raven	C
Corvus orru	Torresian crow	C
Cracticus nigrogularis	pied butcherbird	C
Cracticus quoyi	black butcherbird	C
Cracticus tibicen	Australian magpie	C
Cygnus atratus	black swan	C
Dacelo leachii	blue-winged kookaburra	C
Dacelo novaeguineae	laughing kookaburra	C
Dicaeum hirundinaceum	mistletoebird	C
Dicrurus bracteatus	spangled drongo	C
Ducula bicolor	pied imperial-pigeon	C
Egretta garzetta	little egret	C
Egretta novaehollandiae	white-faced heron	C
Egretta picata	pied heron	C
Egretta sacra	eastern reef egret	C
Elanus axillaris	black-shouldered kite	C
Entomyzon cyanotis	blue-faced honeyeater	C
Ephippiorhynchus asiaticus	black-necked stork	NT
Esacus magnirostris	beach stone-curlew	V
Eurystomus orientalis	dollarbird	C
Falco berigora	brown falcon	C
Falco cenchroides	nankeen kestrel	C
Fregata ariel	lesser frigatebird	C
Gavicalis fasciogularis	mangrove honeyeater	C
Gavicalis versicolor	varied honeyeater	C
Gelochelidon nilotica	gull-billed tern	C
Geopelia humeralis	bar-shouldered dove	C
Geopelia striata	peaceful dove	C
Gerygone levigaster	mangrove gerygone	C
Gerygone magnirostris	large-billed gerygone	C
Grallina cyanoleuca	magpie-lark	C
Grus rubicunda	brolga	C
Haematopus longirostris	Australian pied oystercatcher	C
Haliaeetus leucogaster	white-bellied sea-eagle	C
Haliastur indus	brahminy kite	C
Haliastur sphenurus	whistling kite	C
Hieraaetus morphnoides	little eagle	C
Himantopus himantopus	black-winged stilt	C
Hirundapus caudacutus	white-throated needletail	C
Hirundo neoxena	welcome swallow	C
Hydroprogne caspia	Caspian tern	C
Lalage leucomela	varied triller	C
Lalage sueurii	white-winged triller	C
Lichmera indistincta	brown honeyeater	C
Limosa lapponica	bar-tailed godwit	C
Limosa limosa	black-tailed godwit	C
Lonchura castaneothorax	chestnut-breasted mannikin	C
Lonchura punctulata	nutmeg mannikin	I
Lophoictinia isura	square-tailed kite	NT
Lopholaimus antarcticus	topknot pigeon	C
Malurus melanocephalus	red-backed fairy-wren	C
Meliphaga notata	yellow-spotted honeyeater	C
Melithreptus albogularis	white-throated honeyeater	C
Melithreptus lunatus	white-naped honeyeater	C
Merops ornatus	rainbow bee-eater	C
Microcarbo melanoleucos	little pied cormorant	C
Microeca flavigaster	lemon-bellied flycatcher	C
Milvus migrans	black kite	C
Mirafra javanica	Horsfield's bushlark	C
Myiagra alecto	shining flycatcher	C
Myiagra rubecula	leaden flycatcher	C

Myzomela obscura	dusky honeyeater	C
Nectarinia jugularis	olive-backed sunbird	C
Numenius madagascariensis	eastern curlew	NT
Numenius minutus	little curlew	C
Numenius phaeopus	whimbrel	C
Nycticorax caledonicus	Nankeen night-heron	C
Nymphicus hollandicus	cockatiel	C
Ocyphaps lophotes	crested pigeon	C
Oriolus sagittatus	olive-backed oriole	C
Pachycephala melanura	mangrove golden whistler	C
Pachycephala rufiventris	rufous whistler	C
Pandion cristatus	eastern osprey	C
Passer domesticus	house sparrow	I
Pelecanus conspicillatus	Australian pelican	C
Petrochelidon ariel	fairy martin	C
Petrochelidon nigricans	tree martin	C
Phalacrocorax sulcirostris	little black cormorant	C
Phalacrocorax varius	pied cormorant	C
Philemon buceroides	helmeted friarbird	C
Philemon citreogularis	little friarbird	C
Philemon corniculatus	noisy friarbird	C
Platalea regia	royal spoonbill	C
Platycercus adscitus	pale-headed rosella	C
Plegadis falcinellus	glossy ibis	C
Pluvialis fulva	Pacific golden plover	C
Pluvialis squatarola	grey plover	C
Podargus strigoides	tawny frogmouth	C
Ptilinopus regina	rose-crowned fruit-dove	C
Ptilonorhynchus nuchalis	great bowerbird	C
Ramsayornis modestus	brown-backed honeyeater	C
Rhipidura albiscapa	grey fantail	C
Rhipidura leucophrys	willie wagtail	C
Scythrops novaehollandiae	channel-billed cuckoo	C
Sphecotheres vieilloti	Australasian figbird	C
Sternula albifrons	little tern	E
Stomiopera flavus	yellow honeyeater	C
Stomiopera unicolor	white-gaped honeyeater	C
Strepera graculina	pied currawong	C
Streptopelia chinensis	spotted dove	I
Sturnus tristis	common myna	I
Tachybaptus novaehollandiae	Australasian grebe	C
Taeniopygia bichenovii	double-barred finch	C
Taeniopygia guttata	zebra finch	C
Thalasseus bengalensis	lesser crested tern	C
Thalasseus bergii	crested tern	C
Threskiornis molucca	Australian white ibis	C
Threskiornis spinicollis	straw-necked ibis	C
Todiramphus chloris	collared kingfisher	C
Todiramphus macleayii	forest kingfisher	C
Todiramphus sanctus	sacred kingfisher	C
Trichoglossus haematodus moluccanus	rainbow lorikeet	C
Tringa brevipes	grey-tailed tattler	C
Tringa nebularia	common greenshank	C
Tringa stagnatilis	marsh sandpiper	C
Vanellus miles	masked lapwing	C
Vanellus miles miles	masked lapwing (northern subspecies)	C
Xenus cinereus	terek sandpiper	C
Zosterops luteus	yellow white-eye	C