Draft Report

Horseshoe Bay SEMP

Townsville City Council

26 June 2019

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Dear Adam

Horseshoe Bay SEMP

Attached please find our Draft Report of the Shoreline Erosion Management Plan (SEMP) for Horseshoe Bay.

We would like to take this opportunity to thank the local community, Council's project team and yourself for the invaluable assistance provided in developing the SEMP to this point.

Water Technology welcomes the opportunity to respond to a review of the Draft SEMP by all stakeholders. We look forward to working further with the project's stakeholders to progress this document to the Final Report stage.

Yours sincerely

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EXECUTIVE SUMMARY

The complex interaction of waves, tides, winds and nearby coastal creeks are continually shaping and reshaping the shoreline of Horseshoe Bay Beach. The dynamic nature of this coastal environment means that sections of the foreshore are experiencing erosion that is threatening essential infrastructure and adversely affecting social and environmental values.

In recognition of the need to preserve this foreshore as a natural resource and to accommodate the ever-increasing pressures of urban development and tourism on an eroding shoreline, Townsville City Council has commissioned this *Shoreline Erosion Management Plan.*

A Shoreline Erosion Management Plan (SEMP) is a non-statutory planning document that sets out an agreed framework and management strategy for responding to existing erosion problems and possible future erosion threats. The Horseshoe Bay SEMP will provide a framework for the sustainable use, development and management of foreshores at risk of erosion along Horseshoe Bay Beach.

A planning horizon of 20 years has been adopted for the SEMP. This is the longest of the range in planning horizons recommended by the State Government in guidelines pertaining to the preparation of a SEMP.

Objectives

The Horseshoe Bay SEMP will develop management goals that are agreed to by Council and the community. It will:

- Enable Townsville City Council and the local community to proactively plan for erosion management in a way that is consistent with community values and the policies of Queensland's State Coastal Management Plan.
- Investigate and address the underlying causes of shoreline erosion and its likely future progression.
- Determine cost effective and sustainable erosion management strategies that maintain natural coastal processes and resources.
- Consider the community's short-term and long-term needs.

The Queensland Department of Environment and Science has published guidelines to assist local governments in the preparation of shoreline erosion management plans (SEMPs). That guideline advocates that a SEMP should "be based on a planning period of up to 20 years". The approach adopted for this SEMP is to adopt the maximum 20-year recommended planning horizon when determining appropriate erosion mitigation strategies.

The Erosion Processes

This study has identified three predominant drivers of erosion along the study foreshore – and these relate to offshore sediment transport, longshore sediment transport and land use issues.

Cyclonic Storm Erosion

- The most energetic mechanism of erosion in the study area is cross shore sediment transport resulting from elevated water levels and energetic wave conditions generated by tropical cyclone activity. During tropical cyclones, energetic waves strip sand from the beach and deposit it in sandbars offshore.
- This issue is exacerbated by the fact that the beach sits within a north facing embayment that is protected from the persistent south-easterly wind waves and offshore swell waves that would typically return these sediments to the shoreline in the months following these events. This means that the natural recovery of the beach after these events is slow, and it likely takes the beach many years to recover from such cyclone related erosion events.

- Therefore, during periods (typically decadal timeframes) of higher than average tropical cyclone frequency, there is a net recession of the shoreline. Conversely, during calmer periods there is a net accretion of the shoreline. These periods are typically affected by longer term La Niña and El Niño cycles.
- This has been observed at Horseshoe Bay over the last few decades. Historical aerial photos show that the shoreline experienced recession during the 1960's and 1970's which tended more towards La Niña conditions (and more tropical cyclones). The beach then recovered during the 1980's and 1990's, which tended more towards El Niño (and fewer cyclones) before receding again from 2000's and 2010's. This later period experienced a relatively high frequency of such events, including Cyclones Jim (2006), Larry (2006), Ellie (2009), Olga (2010), Charlotte (2011), Yasi (2011), Oswald (2013), Dylan (2014), Ita (2014) and Debbie (2017).
- This multi-decadal cycle of erosion and accretion has also been affected in recent decades by a number of land use issues along the Esplanade Foreshore. These have further impeded the ability of the beach to naturally recover following storm and cyclone events. These are outlined below.

Land Use Issues along The Esplanade Park

Water Technology and Townsville City Council have identified a number of land use issues along The Esplanade Park and foreshore that contribute to (and exacerbate) localised erosion along Horseshoe Bay Beach. The Esplanade Park behind the beach comprises compacted soils, short park grasses and impermeable pavement. Furthermore, the Esplanade Park behind the beach at Horseshoe Bay is relatively flat, with a slight grade down towards the beach and no significant beach swale or ridge formations. This land form impedes beach recovery and exacerbates erosion along Horseshoe Bay beach in the following ways:

- Compacted soils and impermeable pavements along The Esplanade Park prevent rainfall infiltration into the groundwater system. As a result, periods of intense rainfall during the wet season can generate significant overland flow flooding along The Esplanade Park and Pacific Drive.
- In a more typical dune and swale beach system, such rainfall runoff would be naturally directed to flow across the ground into swales behind the dune, which would "flood" during heavy rainfalls, but quickly drain to the groundwater soon after the event. However, along the Esplanade Park, this overland flow is directed down towards the beach where it forms scour channels and strips sand off the beach.
- Therefore, it is common that a number of rainfall events across a single wet season (or across a number of wet seasons) can cumulatively generate this type of erosion before the beach has had a sufficient chance to recover naturally.
- This process is worsened by the presence of stormwater outlets positioned on the beach. Although the total flow through the outfalls can be relatively small, the instantaneous discharge rates can be high - particularly as the area is prone to intense rainfall. Stormwater discharged from these outlets onto the beach generate significant localised erosion and scour.
- At present there is unlimited and uncontrolled pedestrian access to the beach across The Esplanade Park. As a popular and heavily trafficked beach, this uncontrolled pedestrian access destabilises the dune, damages the existing vegetation along the park and also prevents the growth of appropriate coastal dune vegetation.
- The type of vegetation along The Esplanade park is sub-optimal - the park mostly comprises short grasses which do not catch sand and build dunes like natural coastal dune vines and grasses do. The existence of robust and healthy coastal dune vegetation is vital to developing resilience along the foreshore by trapping sand and assisting the natural beach recovery processes.

Local Longshore Drift

A detailed numerical wave modelling assessment has investigated the local wave climate, and the directionality and magnitude of longshore sediment transport along Horseshoe Bay Beach. The rates of longshore sediment transport at the study area are low, due to both the relatively low wave energy experienced at the site, and the fact that most waves approach from a relatively shore-normal direction. Results show that on average, around 1,200 m^3 of sand per year is transported eastwards from the Esplanade Beach into the corner of the bay. This transport predominantly occurs during the wet season, when wave energy in the eastern corner of the bay is increased (on average) by the presence of summer northerly winds and waves. Very little longshore sand drift occurs during the dry season (May to August). At this location, once the sediment has been moved east towards the corner of the bay, there is no natural mechanism by which it can return. This creates an imbalance in the sand supply at the eastern end of the embayment.

The local morphological processes are also affected by the presence of two ephemeral creeks situated at either end of the developed foreshore - Endeavour Creek in the centre of the bay and Beeran Creek at the far eastern end. These creeks oscillate in an intermittent fashion between being open to the ocean via a shallow entrance channel, and being closed off by the formation of a beach berm. This process has a seasonal impact on the in-situ volume of beach sands within the study area foreshore. During the wet season when the entrances to Beeran and Endeavour Creeks are open, they slowly fill with sediments from the nearshore zone, acting as a (temporary) sink for the local sediment transport processes and disrupting the local longshore transport regime. This temporary loss of sediments typically results in an equivalent (temporary) shoreline recession downdrift of the entrance. This process is further exacerbated by the increased rate of longshore transport that occurs during the wet season.

Options Assessment

In order to identify a preferred strategy for addressing the erosion issues at Horseshoe Bay, the potential options outlined in Section 5 were assessed using a high level, semi-quantitative multi-criteria matrix framework. The matrix provides a methodical and transparent approach to comparing different options that is readily understood by the stakeholders and community. Options were assessed considering a number of criteria, including:

- Performance and Construction Criteria:
  - Effectiveness at protecting the foreshore and related infrastructure;
  - Durability;
  - Constructability;
- Environmental Impacts:
  - Impact on local coastal processes (such as waves, currents and sediment transport);
  - Impact on local ecology (flora and fauna);
  - Compatibility with future climate change impacts (such as sea level rise);
- Social and Community Impacts:
  - Impact on local scenery and visual amenity;
  - Social and cultural impact;
  - Level of community support;
- Compliance with State and regional plans

Additionally, high level estimates of the capital cost and ongoing maintenance costs for each option were developed based on preliminary concept designs, and typical unit rates for materials, construction and transportation. These estimates were based on previous experience of similar works and discussions with local contractors. From here, a 20-year net present value life cycle cost has been estimated, that includes the capital cost and ongoing maintenance costs for each option and has been calculated using a 7% discount rate.

This incorporates the different spans of design life and frequency of maintenance for each of the various options. At this early stage these estimates must be considered as indicative only since no detailed design has been undertaken.

The results of the options assessment have identified a range of cost-effective shoreline erosion management solutions for this SEMP. The options are outlined below.

Recommended Shoreline Erosion Management Strategy

Following a review of the environmental and social values of the Horseshoe Bay foreshore, the prevailing coastal processes, the causes and extent of the erosion risk, along with an evaluation of possible erosion mitigation options, the recommended future management of the Horseshoe Bay foreshore has emerged. It incorporates a number of components, namely:

- Ongoing Sand Scraping (on an annual and as-needed basis);
- Beach Dune and Foreshore Management; and
- Stormwater Management.

Sand Scraping

Since around 2014, Sand Scraping has been undertaken by Townsville City Council as a means to protect the at-risk shoreline from erosion. This involves 'scraping' sand from the accumulation zone at the sand lobes at the Beeran Creek entrance, to the section of beach in front of the Esplanade and Pacific Drive. On its own, sand scraping does not provide an enduring solution to those sections of shoreline experiencing ongoing and long-term erosion processes. 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. Nevertheless, it has been implemented effectively at Horseshoe Bay Beach to reinstate the local beach amenity after erosion events, and for short-term recharging of sand buffers in the upper beach profile.

Despite the temporary nature of the works, they provide a relatively inexpensive and effective solution over a 20 years planning period – compared to implementation of hard structures such as seawalls, or a wide scale beach nourishment program. In recent years it has provided tangible (albeit relatively short-lived) benefits in terms of beach protection, recreational use and visual amenity.

Historically the volume of shifted sand is around 4,000-5,000m^3, placing around 10 m^3/m along the entire Esplanade or around 20 m^3/m along The Esplanade east of the boat ramp. The scraping generally provides between 5 to 10 metres of additional beach width immediately after placement. Council's current approval for beach scraping works extends for up to 5,000m^3 - and there is merit in amending the approval to permit a higher volume of sand scraping to better enable nourishment to extend further west, to include the foreshore west of the boat ramp. A permit of 8,000 to 10,000 m^3 would allow for a larger 20 m^3/m of nourishment along the full 460 m long stretch of the Esplanade – both east and west of the boat ramp. This additional volume of scraping would provide a larger storm erosion buffer for the frontal dune, and in doing so would facilitate the natural growth of local dune vegetation. It would also provide greater recreational amenity benefits.

There is also merit in applying beach scraping at Horseshoe Bay Beach as a proactive strategy of erosion management, rather than just the present approach of it being reactive. In other words, it could be better used to prepare for, and partially mitigate, expected storm erosion.

Dune and Foreshore Management

The dune system in the study area needs to be effectively managed in a manner consistent with natural processes. Appropriate dune and foreshore management will assist in maintaining the natural ecosystem and ensure the structural integrity of the frontal dune as an erosion buffer. This component of the erosion mitigation strategy would include the following elements:

- **Revegetation of The Esplanade Park:** The planting of coastal vegetation species would allow for good drainage and have a growth habit that allows for trapping of wind-blown sand and beach re-building process to accelerate beach recovery. This revegetation would create a densely vegetated green zone, that provides a dense sward of root systems able to provide optimal stabilisation, and act as a barrier to trap wind-blown sand. This would increase the resilience of the local dune system, and improve the capacity of the local beach and dune system to recover after storm events.
- **Regrade and Reshape the Esplanade Park and Frontal Dune:** Where possible/appropriate it would be beneficial to establish a gradient across the park - redirecting overland flow away from the beach and back towards the stormwater system along Pacific Drive. This would include earthworks to reshape the frontal dune to provide a traditional dune and swale formation, so that the leading edge of the frontal dune is reformed around 1 metre higher than the surrounding foredune/esplanade park. This constructed dune and swale system would reduce overland flow impacts on the beach and promote groundwater recharge (as a bio-filtration system). The dune crest would need to be vegetated with native coastal vegetation. Some low height sand fencing may also assist in developing initial dune stability after construction.
- **Redesign Esplanade Accessways:** The existing paved stone and brick walkways along The Esplanade park could be replaced with permeable paving materials that allow for infiltration of surface run-off. This would decrease surface run-off and overland flow during rainfall events and reduce the impact of these processes on local beach erosion.
- **Limit and Formalise Pedestrian Access:** In order to assist in building and maintaining a vegetated Esplanade Park, there would be benefits to limiting access across the park to a number of formalised accessways (provided in the form of permeable paving as described above). This would prevent the uncontrolled movement of pedestrians over the frontal dune, which currently contribute to dune erosion and increased surface runoff. In particular, the 240 m stretch of the Esplanade Park to the west of the boat ramp could be fenced off and beach access could be limited to a small number of beach accessways at around 50-100 m spacings. The stretch of Esplanade Park east of the boat ramp could also be fenced to some extent, with consideration given to other park uses.

Stormwater Management

A practical and effective erosion mitigation option for the Horseshoe Bay foreshore would be to formalise and/or upgrade the current stormwater system along the Esplanade and Pacific Drive. This is discussed in more detail in Section 5.6.3, but would generally comprise upgrading the stormwater system along Pacific Drive to better accommodate high intensity rainfall events, and minimise overland flow across Esplanade Park. This would include:

- **Upgrades:** Upgrading existing pipes and assets as required to prevent flooding during severe rainfall events, including potentially with permeable concrete pipes, such as HydroCon pipes, to further promote ground water infiltration;
- **Extensions:** The local stormwater network should be extended to properties which are currently without service. Furthermore, integrating a kerb along the western stretch of Pacific Drive would assist in the containment and management of overland runoff, including surface run-off diverted to Pacific Drive from the Esplanade Park.
- **Diversion:** The local stormwater system could be redirected/diverted so that it fully discharges into Beeran Creek, instead of partly discharging to the stormwater outfalls on Horseshoe Bay Beach. This would allow the stormwater outfalls along Horseshoe Bay to be decommissioned and removed, and would mitigate the current erosion issue of beach scour at those stormwater outlets.

It is anticipated that this option would require a local, site specific, stormwater management study - in order to assess the potential options in detail and inform the design of the requisite stormwater infrastructure and upgrades.

An additional option provided in this SEMP is the provision of leaky rainwater tanks to upstream properties, with a priority to unconnected properties. These tanks promote the principles of water sensitive urban design under intense rainfall conditions, and would help the local stormwater system buffer against the first flush rainfall during intense rainfall events.

Project Monitoring

Once implemented, monitoring the performance of the SEMP ensures that potential threats to project outcomes can be addressed in a proactive manner. Given that the primary objective of the SEMP is to manage the erosion threat along Horseshoe Bay Beach, regular surveys of the foreshore should be undertaken as part of the Plan. It is recommended that a regular survey campaign be undertaken as follows:

- Ten transect lines should be established at approximately 50 metre spacings, covering the full east-to-west span of Pacific Drive. Surveys of these transects should be conducted twice annually - both at the same time each year. Ideally this would be in late-October or early-November (immediately prior to the cyclone season), then again in late-March or early-April (immediately following the cyclone season). The location of these transects would be determined during detailed engineering design phase of project implementation.
- All beach transect surveys should extend offshore well beyond the toe of the beach to ensure that as much of the littoral system is captured by the survey. This will require planning to ensure that surveys are undertaken during periods of low spring tides.
- The monitoring surveys should commence prior to implementation of any physical works recommended by this SEMP, thereby providing a pre-project foreshore condition as a baseline reference.

The monitoring survey program should be reviewed every three years and modified as required to ensure seasonal and annual changes to beach profiles are being appropriately captured, and that the survey program is providing the necessary technical support to maintaining SEMP outcomes. The monitoring of future shoreline response by a regular program of foreshore surveys serves an important role in assessing the effectiveness of the recommended strategies in coming years and to guide future action

Outcomes

Whilst providing for appropriate mitigation of the erosion threat along Horseshoe Bay Beach, the recommended strategy also achieves the following important outcomes:

- Preserves the visual character of the foreshore; and improves areas where the visual amenity has been diminished;
- Maintains convenient access to the beach while managing the impacts of increasing numbers of beach users on the stability of The Esplanade Park and its associated vegetation;
- Maintains the long-term stability of the foreshore, while acknowledging that long-term, short-term and seasonal fluctuations in erosion patterns occur; and
- Preserves the environmental values of the foreshore area and restores these values when/where appropriate.

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GLOSSARY AND DEFINITIONS

Term / Abbreviation	Definition
accretion	The accumulation of beach sediment on a shoreline, having been deposited by natural processes.
AEP	Annual Exceedance Probability: The measure of the likelihood (expressed as a probability) of an event equalling or exceeding a given magnitude in any given year. A 90% AEP flood has a high probability of occurring or being exceeded each year; it would occur quite often and would be relatively small. A 1%AEP flood has a low probability of occurrence or being exceeded each year; it would be fairly rare but it would be relatively large.
AHD	Australian Height Datum (AHD) is the geodetic datum for altitude measurement in Australia. The level of 0.0 m AHD approximately corresponds to mean sea level.
ARI	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% AEP (probability of occurring in any particular year)
angle of repose	The steepest angle at which a sloping surface formed of loose unconfined material is naturally stable.
astronomical tide	Water level variations due to the combined effects of the Earth's rotation, the Moon's orbit around the Earth and the Earth's orbit around the Sun. It excludes and oceanographic or meteorological influences.
bathymetry	The term bathymetry originally referred to the ocean's depth relative to sea level, although it has come to mean "submarine topography," or the depths and shapes of underwater terrain.
calibration	The process by which the results of a computer model are brought to agreement with observed data by fine-tuning certain model parameters.
coastal inundation	Flooding of coastal land due to inundation by ocean waters.
coastal processes	The physical processes that act to shape the coast and the landforms that make up the coast.
Coriolis force	The Coriolis effect describes the pattern of deflection taken by objects not firmly connected to the ground, as they travel long distances around the Earth. This force is caused by the latitudinal gradient in the earth rotational speed.
CSIRO	The Commonwealth Scientific and Industrial Research Organisation, the federal government agency for scientific research in Australia.
dilation	The observed tendency of a compacted granular soil (such as sand) to expand in volume as it is sheared.
ebb tide	The outgoing tidal movement of water within an estuary.
ephemeral	Meaning short lived or temporary. In the context of the Horseshoe Bay creeks in means that those creeks are sometime open to the ocean, and at other times closed.
EVA	Extreme Value Analysis. A statistical tool to estimate the likelihood of the occurrence of extreme values based on observed/measured data.

Term / Abbreviation	Definition
exceedance probability	The probability of an extreme event occurring at least once during a prescribed period of assessment is given by the exceedance probability. The probability of a 1 in 100 year event (1% AEP) occurring during the first 25 years is 22%, during the first 50 years the probability is 39% and over a 100 year asset life the probability is 63%.
flood tide	The incoming tidal movement of water within an estuary.
fluvial	Fluvial processes are associated with the actions of rivers, creeks and streams - and the deposits and landforms created by them.
foreshore	The area of shore between low and high tide marks and land adjacent thereto.
geophysical survey	A geophysical survey detects and maps subsurface features.
HAT	Highest Astronomical Tide: the highest water level that can occur due to the effects of the astronomical tide in isolation from meteorological effects.
hydrographic survey	A hydrographic survey maps the features of the sea bottom.
intertidal	The area of a shoreline that is above water at low tide and under water at high tide (in other words, the area between the low and high tide levels).
king tides	King tide is a non-scientific term, but the popular concept is that it is the higher high waters which occur around Christmas, when the earth is closest to the sun.
LAT	Lowest Astronomical Tide. the lowest water level that can occur due to the effects of the astronomical tide in isolation from meteorological effects
littoral	Relating to (or situated on) the shore of the sea.
littoral drift	The natural geographical process that consists of the transportation of sediments along a coast.
longshore	In the direction along the shoreline (i.e. parallel to the coast).
MHWN	Mean High Water Neap. The long-term mean of the heights of two successive high waters when the range of tide is the least at the time of first and last quarter of the moon.
MHWS	Mean High Water Springs. The long-term mean of the heights of two successive high waters during those periods of 24 hours (approximately once a fortnight) when the range of tide is greatest, during full and new moon.
MLWN	Mean Low Water Neap. The long-term mean of the heights of two successive low waters over the same periods as defined for MHWN.
MLWS	Mean Low Water Springs. The long-term mean of the heights of two successive low waters over the same periods as defined for MHWS.
MSL	Mean Sea Level. The mean level of the sea over a long period (preferably 18.6 years) or the mean level which would exist in the absence of tides.
MSLR	Mean Sea Level Rise.
neap tides	Neap tides occur during the time of first and last quarter of the moon, 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.

Term / Abbreviation	Definition
significant wave height	Due to the random nature and size of waves, the term "significant wave height" is used by engineers and scientists to quantify wave heights in a sea state. It represents the average of all the third highest waves that occur over a particular timeframe. It is typically written as Hs. It is important to appreciate that in deep offshore waters the largest individual wave in the sea state may be around twice the significant wave height
spring tide	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 alignment). These are called "spring" tides and they occur approximately every 14 days.
storm surge	The meteorological component of the coastal water level variations associated with atmospheric pressure fluctuations and wind setup.
storm tide	Coastal water level produced by the combination of astronomical and meteorological (storm surge) ocean water level forcing.
subaerial	On the earth's surface, not underwater or underground.
subaqueous	Situated under water.
tidal planes	A series of water levels that define standard tides, eg. 'Mean High Water Spring' (MHWS) refers to the average high water level of Spring Tides.
Wave Height	The vertical difference between the elevation of a wave crest and a neighbouring trough.
Wave Frequency	The number of waves per second, measured in Hz.
Wave Length	The horizontal distance between two wave crests.
Wave Period	The time it takes for two successive wave crests to pass a given point.
Wave Run-up	The vertical distance between the maximum height that a wave runs up the beach (or a coastal structure) and the still water level, comprising tide and storm surge.
Wave Set-up	When waves break on a beach, they produce wave set-up, which is an increase in the nearshore water level above the still water elevation of the sea. Wave set-up can be considered as a piling up of water against the shoreline that is caused by breaking waves causing a transfer of kinetic to potential energy.
WRB	Wave Rider Buoy. A floating buoy design to measure wave height, period and direction.

1 INTRODUCTION

1.1 Regional and Local Setting

Horseshoe Bay is located on the north-eastern shores of Magnetic Island. It is the largest bay on Magnetic Island and contains a north facing beach that is approximately 3 km long. The bay is contained by a series of protruding rocky headlands (White Rock Point to the west and The Point to the east) and the physiographic form of the bay offers significant natural protection from the south-east trade winds and waves.

Horseshoe Bay is a somewhat shallow embayment facing north onto the broad open waters between Magnetic Island and the Great Barrier Reef. At its seaward limit the bay is only some 8 metres deep (below the level of the Lowest Astronomical Tide). These northerly fetches are quite long, with the main Great Barrier Reef system being some 70 kms offshore. It is from across these open fetches that the largest and most energetic waves can propagate into Horseshoe Bay.

The bay contains the most popular beach on the island – and it is the place most visitors to the island head for. The main settlement is situated on low-lying coastal land toward the eastern end of the bay. The main road from Picnic Bay ends at the bay and the small settlement accommodates tourists as well as providing limited shopping facilities.

Two small creeks drain across the beach - Endeavour Creek in the centre of the bay and Beeran Creek at the far eastern end. These creeks oscillate in an irregular fashion between being open to the ocean via a shallow entrance channel and being closed off via the formation of a beach berm. Their level of connectivity to the ocean and the position of the creek entrance on the beach depends on the prevailing balance of coastal and catchment processes.

The wider Townsville Region is subject to tropical cyclones, storm surges and flooding which can all cause abrupt changes to beach conditions.

FIGURE 1-1 STUDY AREA LOCATION

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1.2 The Erosion Problem

The erosion issues at the foreshore are the result of longshore and cross-shore sediment transport processes. The most energetic mechanism of erosion in the study area is cross shore sediment transport resulting from elevated water levels and energetic wave conditions brought about by tropical cyclone activity. The last 10 to 15 years has seen a relatively high frequency of such events, including Cyclones Jim (2006), Larry (2006), Ellie (2009), Olga (2010), Charlotte (2011), Yasi (2011), Oswald (2013), Dylan (2014), Ita (2014) and Debbie (2017).

These events have resulted in episodic storm erosion and the transfer of sand from the beach to farther offshore and lower down the beach profile. The day-to-day wave energy within the bay is relatively low. The bay is sheltered from swell wave energy which would otherwise return the sediments to the upper beach profile and rebuild the beach. As a result it likely takes the beach many years to recover from such cyclone related erosion events.

The Bay itself is contained within headlands that likely form a closed littoral cell. That is, the net volume of sand in the system should remain more or less constant over time with little net loss or gain in sand volumes from one year to the next. Whilst the local beach is likely very well aligned with the incident wave climate, previous studies and aerial images showing entrance condition/morphology indicate that the prevailing coastal processes result in a net west-to-east transport of sand in front of the at-risk developed foreshore. Once at this end of the beach, there are no wave or hydrodynamic processes that can move it back towards the eroding foreshore. Therefore, there is in effect a sand sink at the creek entrance, with a net loss of sand from the beach in front of the developed foreshore. It is this slow regression of the foreshore that now sees the onshore/offshore sand transport processes threatening the developed foreshore.

The Horseshoe Bay Coastal Erosion Mitigation Options report (Aurecon, 2015) also highlighted the following issues affecting erosion at the study area:

- The maintenance of the park areas and movement of sand from Pacific Drive following TC Yasi has temporarily robbed the eastern beach system of some of the sand budget, and as such when sand movements do occur this can cause exaggerated responses in other areas such as in front of Pacific Drive. Loss of overall beach length north of the community may exaggerate the seasonal movements in the beach in front of Pacific Drive.
- Redistribution of sand due to sea level rise over recent decades. Changes in ocean water level can cause cross-shore redistribution of sand, described mathematically by a process known as the Bruun Rule. The other impacts are changes in the distribution of wave energy reaching the beach due to increased depths of water over time.
- Natural fluctuations associated with longer term movements related to creek entrance locations or large scale climatic movements occurring along with the short term seasonal fluctuations can cause coastal erosion issues for infrastructure built too close to the foreshore. It is hard to assess if this is the cause; however, the significant role the creek entrance lobes play in the overall sediment budget suggest that this likely affects longer term movements of the beach.

Furthermore, Townsville City Council has identified a number of land use issues contributing to adverse erosion impacts and lack of beach recovery in the following ways:

- Unlimited, uncontrolled pedestrian access destabilises the dune and prevents coastal vegetation growth which would otherwise aid in natural beach recovery processes.
- Impervious parkland concrete and paving adds to overland flow erosion of the dune and beach.

- Park grasses do not catch sand and build dunes as effectively as coastal vines and grasses and therefore inhibit natural beach recovery.
- Compacted soils in the Esplanade prevent rainfall infiltration and cause greater overland flows which erode the dune and beach.
- Storm water drainage to the beach contributes to dune and beach erosion.
- Placement of personal water craft, (kayaks, canoes, dinghies) in the Esplanade reduces available public space for recreation and tourism operators; inhibits beach recovery such as dune revegetation works; and concentrates pedestrian use impacts into smaller areas.
- Vehicles being driven over the Esplanade east of Pacific Drive are preventing any beneficial coastal vegetation from growing in this region.

In response to this erosion threat, Townsville City Council has undertaken a number of beach renourishment campaigns in recent years, including the annual transfer of sand from the eastern corner of the bay to the area in front of the Esplanade to mitigate localised erosion impacts and promote beach recovery.

This successfully nourished the local beach between 2015 and 2017, although erosion of the upper beach profile and some scarping affecting beach amenity (and some non-essential infrastructure) continued. In 2018, successful stabilisation of the top of the beach was achieved. This included extending the upper beach profile seaward of the Esplanade by approximately 5 metres along the eastern half of the Esplanade from the boat ramp to Beeran Creek - and included the formation of a small swale and dune. Uncontrolled pedestrian movement reduced the height of the dune rapidly and significantly such that subsequent rain events saw minor overland flow erosion of the dune in early 2019. Approximately 5,000 m^3 of sand was transferred in 2018.

This strategy of ongoing beach nourishment to create and maintain adequate erosion buffers on eroding sections of the shoreline has proven to be relatively effective. Nevertheless, the strategy has been reviewed when preparing this Shoreline Erosion Management Plan.

1.3 Objectives of this Shoreline Erosion Management Plan

The proposed Horseshoe Bay Shoreline Erosion Management Plan will provide a framework for the sustainable use, development and management of this foreshore. A Shoreline Erosion Management Plan (SEMP) is a non-statutory planning document that sets out an agreed framework and management strategy for responding to existing erosion problems and possible future erosion threats.

This will be achieved by considering the physical coastal processes in conjunction with the environmental, cultural, social and economic values of these shorelines. The Horseshoe Bay SEMP will develop long term management goals that are agreed to by Council and the community. It will:

- Enable Townsville City Council and the local community to proactively plan for erosion management in these vulnerable areas in a way that is consistent with community values, relevant legislation (Commonwealth, State and Local) and all relevant coastal and environmental policies;
- Investigate and address the underlying causes of shoreline erosion and its likely future progression;
- Determine cost effective and sustainable erosion management strategies that maintain natural coastal processes and resources; and
- Consider community needs in both the short- and long-term.

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

1.4 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 to the need and development of the Plan.
- Section 2 provides an assessment of the environmental and social "values" of the Horseshoe Bay coastal precinct.
- Then in Section 3 the natural physical processes that have in the past, are currently, and will in the future, shape the project shoreline are discussed.
- This is followed in Section 4 by a discussion of the risks that these various natural processes represent to local coastal values and infrastructure.
- Section 5 then offers a number of potential strategies to mitigate these risks, and then provides a ranking of each - leading to the establishment of a preferred erosion management strategy.
- Section 6 provides details as to the recommended erosion mitigation strategy, including its estimated costs.
- The process of implementing the preferred strategy is then presented in Section 7.

Appendices to support the technical content of the Plan are then included. These contain an outline of the commonwealth, state and local government planning and legislative framework affecting the implementation of the Plan; detailed assessments of the local marine and terrestrial environments; historical beach surveys; and plots showing the erosion vulnerability of local foreshores.

2 COASTAL VALUES

The Horseshoe Bay foreshore offers a diversity of seascapes and landscapes - providing extensive recreational and lifestyle opportunities to residents and visitors that are enhanced by considerable environmental, social and cultural values.

2.1 Environmental Values

Fish species in Horseshoe Bay are typical of those of inshore coral reefs. A range of groups is represented, including planktivores, territorial and roving herbivores, benthic invertebrate feeders and predators. The abundance of predators such as sharks, coral trout, snappers and emperors may be less compared to the Great Barrier Reef locations because Magnetic Island is open to fishing and is subject to baited drumlines under Queensland's Shark Control Program.

A number of migratory wading birds are also present at times, including the ruddy turnstone, sharp-tailed sandpiper and the whimbrel. The endangered little tern is also known to occur in Horseshoe Bay.

Green turtles (Chelonia mydas) are frequently observed by divers in the waters surrounding Magnetic Island and specifically in Horseshoe Bay. Typically, a small number of green turtles are observed nesting on Magnetic Island each season, while some seasons there aren't any at all. The Queensland Parks and Wildlife Service (QPWS) recorded 15 nests on the island in the 2017/18 season – with 12 of those found in Horseshoe Bay. Endangered flatback turtles have also been recorded as nesting in nearby Nelly Bay. Unfortunately, turtles nesting on the beach bring them in close contact with people and local traffic. Nevertheless, several successful hatchings have been recorded. Turtle nesting and hatching activities typically occur each year from October to March. Consequently, the implementation of any erosion mitigation strategy needs to consider such activities.

Estuarine crocodiles transit through the Cleveland Bay area on an irregular basis (QPWS, 2007) and are occasionally sighted from Townsville beaches and in the waters around Magnetic Island. However, Horseshoe Bay is not considered a regular habitat for crocodiles. They have never been recorded as using Horseshoe Bay as a haul-out site.

Clearly the rich diversity of habitats and their associated marine flora and fauna in the Horseshoe Bay area represents environmental resources and values that require protection and careful management. This is recognised through the designation of the surrounding waters as a Habitat Protection (Dark Blue) Zone of the Great Barrier Reef Marine Park.

When considering appropriate erosion management strategies in Horseshoe Bay it is necessary to consider the following specific issues relating to the local marine environment:

- the proximity of nearshore habitats to the beach;
- proximity of nearshore reef systems;
- activities of sea birds and shorebirds;
- sea turtle nesting and hatching activities.

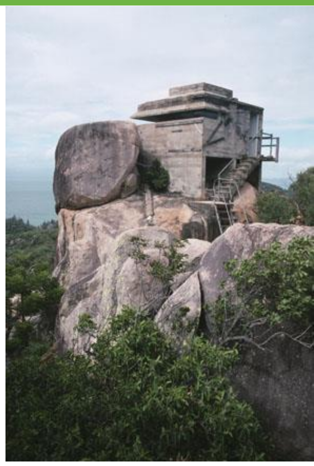
The one threatened ecological community, the twenty-four listed threatened species and the forty-three migratory species protected by the *EPBC Act* within the study area are listed in Appendix A.

2.2 Heritage Values

2.2.1 National and State Heritage

The local heritage values within Horseshoe Bay were assessed by inspecting The Australian National Heritage Database (DEE, 2019) and the Queensland Heritage Register (DES, 2019). The results are summarised in Table 2-1 below.

TABLE 2-1 SUMMARY OF HERITAGE ITEMS

Heritage Item	Place ID	Description of Significance	Class
The Forts	8976	Fort complex built into the granite boulders of the island to protect Townsville during World War Two. Consists of concrete gun emplacements, observation posts, signals stations etc. Set among granite boulders and originally finished with timber falsework and cladding to simulate boulders. The Forts are located on Radical Bay Road, between Horseshoe Bay and Arcadia - over 2km inland from the Horseshoe Bay Shoreline. They are not expected to be affected by the SEMP in any way. 	Historic
Horseshoe Bay Lagoon Environmental Park	8985	The Horseshoe Bay Lagoon Environmental Park is not in itself of National Estate significance but occurs within the significant Magnetic Island area. Horseshoe Bay Lagoon is the only substantial body of freshwater on Magnetic Island although the lagoon dries up in very dry seasons. Formation of the Lagoon probably occurred when an old beach sand ridge, inland from Horseshoe Bay, cut off surface drainage from the sea. The Environmental Park is about 3.5 ha in size, and encompasses a low lying swampy forest, the Lagoon and a Sandy Ridge. Near the Lagoon, in seasonally inundated areas, MELALEUCA leucodendron (weeping tea tree) usually forms tall stands. There is good development of Eleaocharis DULCIS (bulkuru) and other sedges associated with the lagoon while NYMPHAEA GIGANTEA (blue water lily) occurs on the Lagoon. Other vegetation in the area includes pandanus, carbean and gum forest. The area is an important habitat for birds, especially waterbirds. Of the Island birds, thirteen have been recorded only at the Lagoon and a further fourteen are largely dependent on that area. All works undertaken as part of this SEMP should consider potential impacts upon this environmental park.	Natural

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2.2.2 Indigenous Heritage

According to Queensland Parks and Wildlife Service (QPWS, 2013), there are a number of Aboriginal material culture sites on Magnetic Island, the majority of which are intact. QPWS works closely with the Wulgurukaba people to identify these sites and manage them appropriately. An inventory of material culture sites is currently being developed collaboratively and includes recommendations for management. The inventory is currently maintained by QPWS. Veth and George (2004) outline a range of material evidence for past and continuing Aboriginal use of Magnetic Island. These are summarised in Table 2-2 below.

TABLE 2-2 SUMMARY OF INDIGENOUS CULTURAL ITEMS ON MAGNETIC ISLAND (VETH & GEORGE, 2004)

Aboriginal Cultural Item	Description of Significance
Shell middens	Shell middens are located within all catchments on the island. Relatively undisturbed sites may contain features of cooking hearths, stone arrangements, artefact knapping horizons and terrestrial dietary remains. The island has a representative sample of the different kinds of middens found along the North Queensland coast and islands within the Great Barrier Reef. Some middens also contain European materials in their upper levels that date to the last half of the 19th century and represent contact sites. Some sites have been disturbed by visitors or pests.
Pigment art	Pigment art is known at a number of localities both from the coast and the interior of the island. As they are in more remote locations they have not been disturbed by visitors. Weathering, particularly rainfall, has threatened some sites and drip lines have been installed to divert water from damaging the art.
Stone artefact scatters	As well as being found in middens, a number of discrete locations contain stone artefact scatters that illustrate past habitation, food processing and implement manufacturing activities.
Quarry and knapping sites	A number of volcanic suites have been actively quarried on the northern sections of the island and contain preforms for scraper, blade and axe productions. Although some walking tracks pass near these sites their overall integrity is high.
Burials	There are a number of known historic Aboriginal burials on the island. Aboriginal skeletal remains have been exposed during earthworks (such as Nelly Bay) and as a result of natural processes such as foreshore erosion (such as Bolger Bay). Some ground penetrating radar work was undertaken in Florence Bay to assess the presence of burial sites, none have been identified to date.

2.3 The Social Environment

Social values can be described as a human use values that are based on cultural associations or recreation. At Horseshoe Bay this may include beach activities (running, sitting, relaxing on the sand etc), water recreation (swimming, snorkelling etc), watercraft activities (kayaking, paddle boarding etc), fishing and/or boating, use the Esplanade park or visiting the local shops, markets or restaurants.

The local Aboriginal people have an ancient and ongoing association with the area, including a complex cultural, spiritual and social relationship with natural waterways and coastal foreshores. The Wulgurukaba people are the Aboriginal Traditional Owners of Magnetic Island and have lived on the island and nearby mainland for thousands of years. Aboriginal people have a strong sense of identification with the island and its culturally significant sites (QPWS, 2013). The Wulgurukaba people claim to hold native title over Magnetic Island and have registered an Indigenous Land Use Agreement (ILUA) for the claim area. The ILUA requires the negotiation of a memorandum of understanding regarding the preservation of cultural resources and values in the national park, including protection of cultural resources, employment, naming of protected areas, camping and signage.

Magnetic Island offers a quiet and less crowded opportunity to enjoy the natural environment of the Great Barrier Reef World Heritage Area but is nevertheless within close proximity to Townsville's CBD. Consequently, it contributes significantly to public recreation, relaxation and enjoyment – not only for the local population of approximately 2,500 (ABS, 2016) but also to the many Townsville residents and tourists who visit the island.

When considering appropriate erosion management strategies it is necessary to consider the following specific issues relating to the social environment of Horseshoe Bay:

- ensuring no adverse implications to Aboriginal cultural, spiritual and social relationships with the foreshore;
- maintaining existing public use and access to the beaches and foreshore areas;
- maintaining the high visual amenity of the foreshore.

As part of this SEMP, a community engagement survey was undertaken to better ascertain the social values of Horseshoe Bay to the local community. The outcomes of the survey is discussed below in Section 2.4.

2.4 Community Consultation

An online Community Engagement Survey was undertaken as part of the SEMP in order to determine what the local community considers to be the most important ecological, social, cultural, aesthetic, recreational, and economic values of the study area. The survey aimed to understand how often local people visit the Horseshoe Bay waterfront (which comprises the beach, The Esplanade, shops and restaurants), and what activities they engage in whilst there. The survey also aimed to understand community perceptions of coastal change (from storm tide, sea level rise and coastal erosion), and attitudes towards potential adaptation options.

2.4.1 Survey Development

In development of the survey the population demographics of Magnetic Island were used to help curate the survey to ensure a high level of community engagement. Key information included: the median age (54 years), the percentage of permanent residence who have access to the internet at home (78%) and the portion of people who are proficient in English (98%).

The survey was developed as a central element of the community values assessment for the study and was delivered in an online format on Council's website. A number of recruitment techniques were used to maximise respondent numbers, including; emails to potential participants, social media, local newspapers and engagement with local community groups such as MIRRA (Magnetic Island Community Resident and Rate Payers Association) and MICDA (Magnetic Island Community Development Association). The survey method uses a combination of tick box and Likert scale response options to gain a detailed insight into community attitudes, knowledge and experiences.

The survey questions tried to be as specific to Horseshoe Bay as possible, whilst still maintaining some consistency with the broader survey applied for Adapting to Coastal Change in Townsville (AECOM, 2019). Some questions (7, 8 and 9) were adapted directly from that survey – as they are directly applicable to the SEMP.

As this was an online survey, the potential for individuals to submit more than one survey in order to shape or influence overall results should be acknowledged. Some capacity for monitoring this process was provided through cross referencing of IP addresses, along with date and time submission points. However, the capacity for multiple submissions could not be precisely tracked. This means that, as is always possible within an online survey addressing issues of importance for community members, the potential for one person submitting more than one survey cannot be definitively discounted – and as such is flagged as a potential data validity issue.

2.4.2 Survey Results

Question 1: Which of the following best describes you?

The purpose of this question was to gather information regarding the background and residential status of respondents. The results showed a relatively even split amongst respondents - from Horseshoe Bay, other locations on Magnetic Island, and the Townsville Mainland. Overall, most respondents were from Magnetic Island (62%).

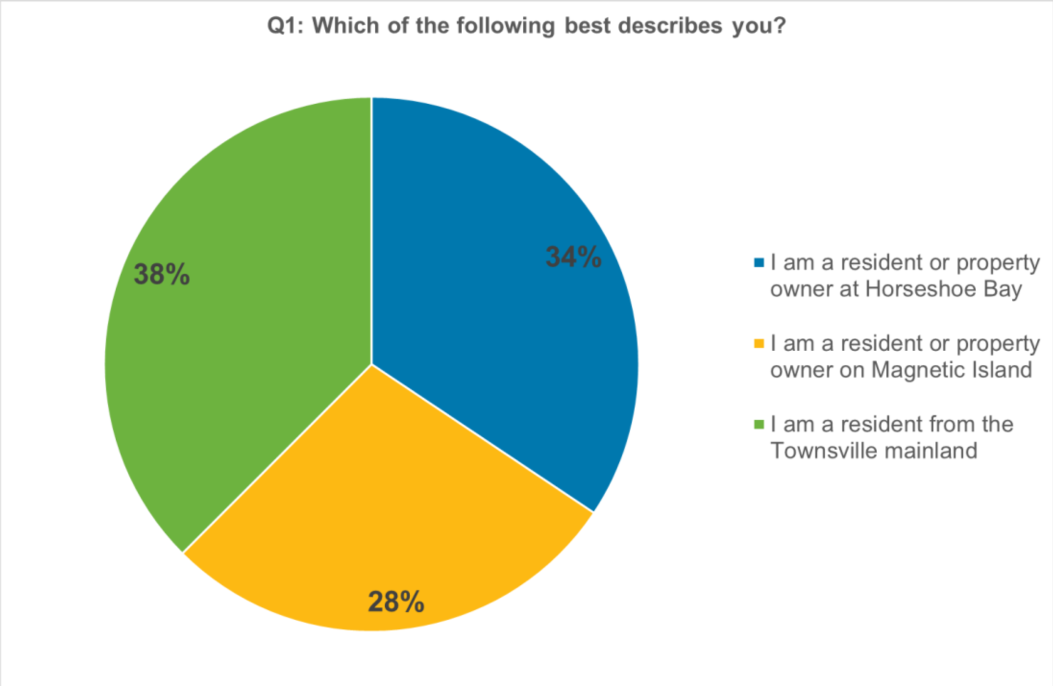

FIGURE 2-1 COMMUNITY CONSULTATION: QUESTION 1

Question 2: How often do you visit Horseshoe Bay Beach / Esplanade Park?

The purpose of this question was to determine the local usage of the beach and Esplanade Park.

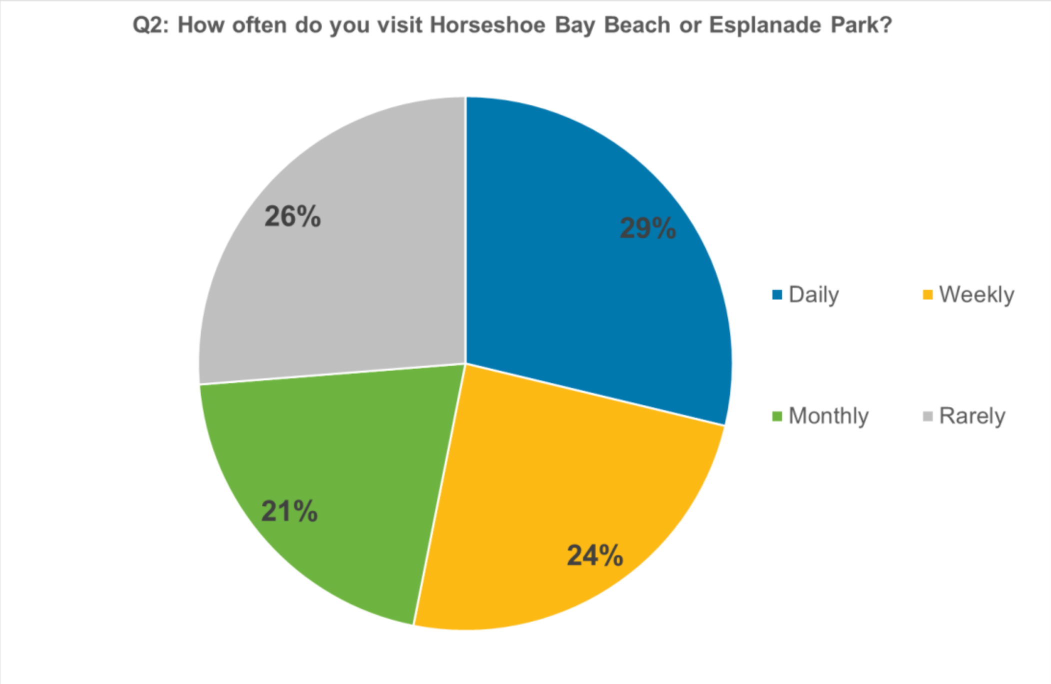

FIGURE 2-2 COMMUNITY CONSULTATION: QUESTION 2

Overall around 53% of respondents visit this area on at least a weekly basis - and this is relatively consistent with, but slightly less than, the proportion of respondents who live on Magnetic Island (around 62%). This suggests that the area is highly utilised by residents of Magnetic Island.

Question 3: How often do you visit Horseshoe Bay Restaurants and Shops?

The utilisation of the shops and restaurants along the Esplanade was slightly lower than that of the beach and the Esplanade Park. Overall, around 43% of respondents utilise the restaurants and shops on at least a weekly basis.

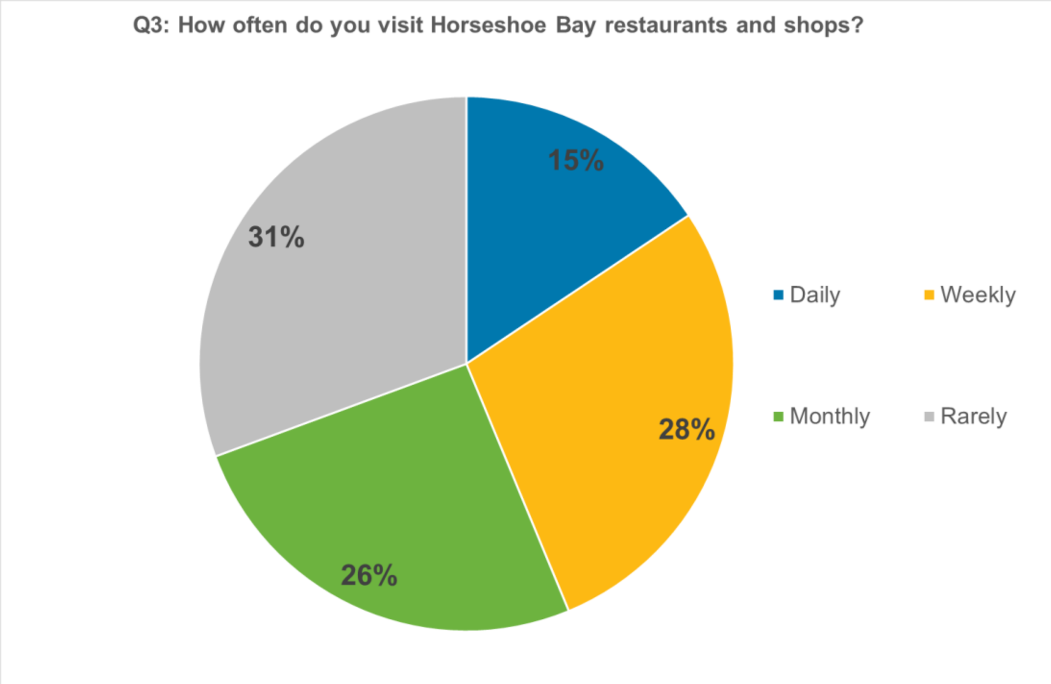

FIGURE 2-3 COMMUNITY CONSULTATION: QUESTION 3

Question 4: When you visit the Horseshoe Bay Waterfront, which of the following activities do you engage in?

The purpose of this question was to ascertain the most common usage and engagement points along the waterfront. Visiting the restaurants and shops is the most common activity, with over 85% of respondents saying that they patronise these businesses when they visit the waterfront. Similarly, nearly 60% of respondents stated that they visit the Horseshoe Bay markets, suggesting that this is also a very popular activity.

Use of the sandy beach area and the Esplanade Park are also popular and enjoyed by 82% and 63% of respondents respectively. Nature observation also scored highly, at round 65%, suggesting that the local foreshore is highly regarding and utilised, and that the natural beauty of the bay is highly valued.

Water based recreation is less highly utilised (as is typical), with fishing and watercraft activities enjoyed by around 20-25% of respondents.

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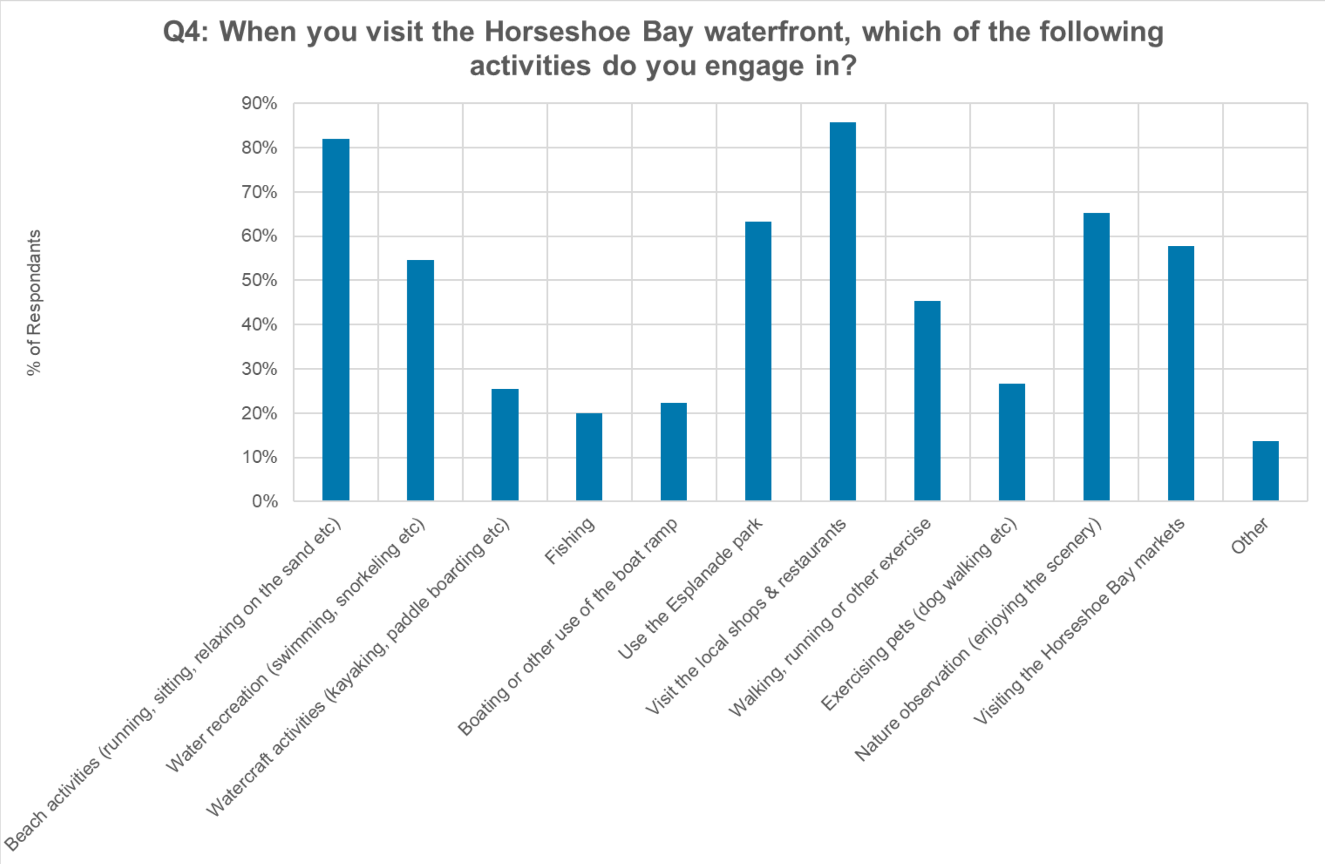

FIGURE 2-4 COMMUNITY CONSULTATION: QUESTION 4

Question 5: What are your main reasons for choosing to visit the Horseshoe Bay Waterfront?

The purpose of this question was to ascertain why locals and visitors choose Horseshoe Bay for their various activities, as opposed to other potential waterfront locations. This enabled an assessment of what makes the area special, preferable or unique in the eyes of the community.

Once again, the local shops and restaurants featured prominently, with 68% of respondents saying that these amenities are among the main reasons that they choose to visit the area. The local scenery was also highly valued by the community, according to over 64% of respondents.

The local recreational areas also featured as a prominent reason to visit the area - with the sandy beach area and foreshore park gaining responses of 63% and 47% respectively. The safe swimming conditions also featured prominently, with around 39% of respondents suggesting the calm wind and wave conditions played a role in their decision to visit Horseshoe Bay.

Local amenities such as showers, changerooms and car parking did not feature as strongly in people's considerations. Whilst these amenities may be well appreciated by the locals, they do not commonly comprise the main reasons for visiting the area.

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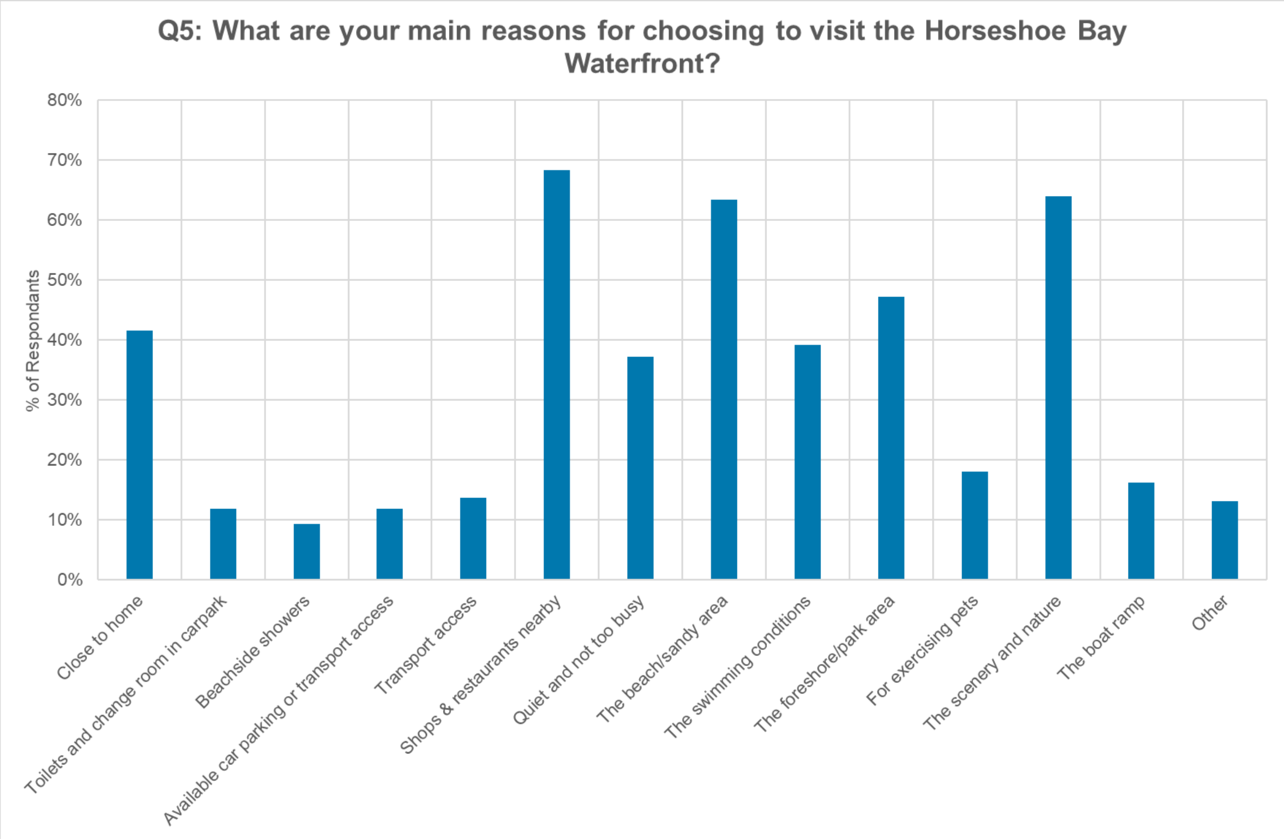

FIGURE 2-5 COMMUNITY CONSULTATION: QUESTION 5

Question 6: Please rank the following coastal spaces of the Horseshoe Bay Waterfront in order of (1) most valued to (6) least valued.

In order to determine which coastal areas are most (and least) highly valued by the community, respondents were asked to provide responses in the form of a ranking. It is important to recognise the distinction between what is popular / utilised, with what is valued – as certain areas which are not commonly used may be highly valued (or highly regarded) nonetheless due to aesthetic or environmental significance.

For this assessment, a lower number corresponds to an area that is more valued (a ranking of 1 being the highest value). All responses were collated and then an average ranking was generated for each area.

Results showed that the beach and sandy area is the most valued space along the foreshore – by a significant margin. With an average ranking of 1.8, this area was commonly ranked either first or second by most respondents and is very clearly a highly regarded space.

The foreshore park/esplanade and coastal dunes were the next highest ranked, with average scores of 2.6 and 3.2 respectively. Subsequent questions allow conclusions to be drawn regarding the recreational, aesthetic and environmental significance of these spaces.

Local infrastructure spaces ranked lower – with the boat ramp scoring the lowest with an average score of 5.1.

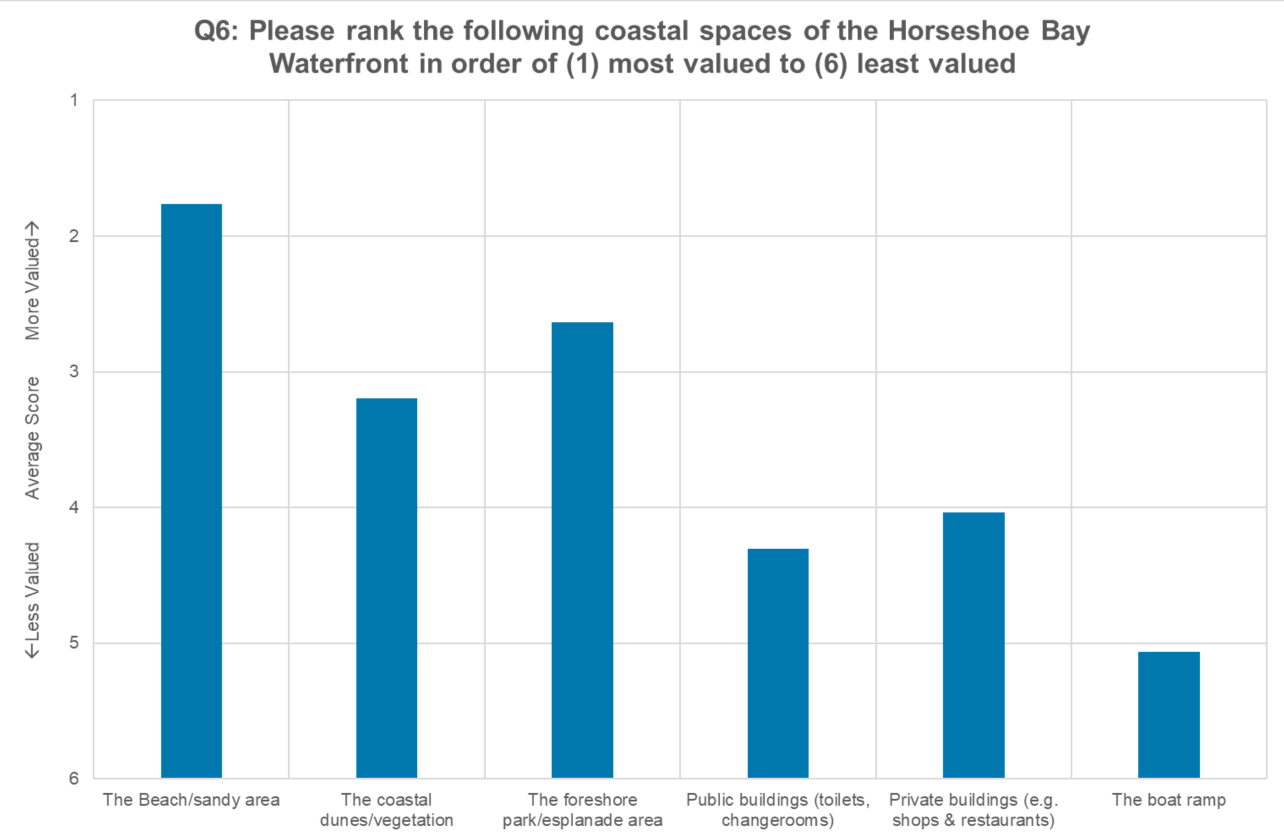

FIGURE 2-6 COMMUNITY CONSULTATION: QUESTION 6

Question 7: What do you value about the Horseshoe Bay Waterfront?

Respondents were asked to state what they valued (conceptually) about the Horseshoe Bay Waterfront. Respondents could choose as many responses as they felt applicable amongst the following:

- **Scenic values:** it is beautiful
- **Social values:** it allows me to connect with friends, family and the community
- **Economic values:** it supports local business and tourism
- **Recreational values:** the recreational uses/activities it provides me
- **Environmental values:** it allows me to connect with nature
- **Cultural values:** indigenous and spiritual importance
- **Heritage values:** its historic importance

Overall, the aesthetic beauty of the foreshore is very highly regarded – with scenery of the area valued by over 90% of respondents. This was the most highly valued aspect of the Horseshoe Bay Waterfront by a significant margin.

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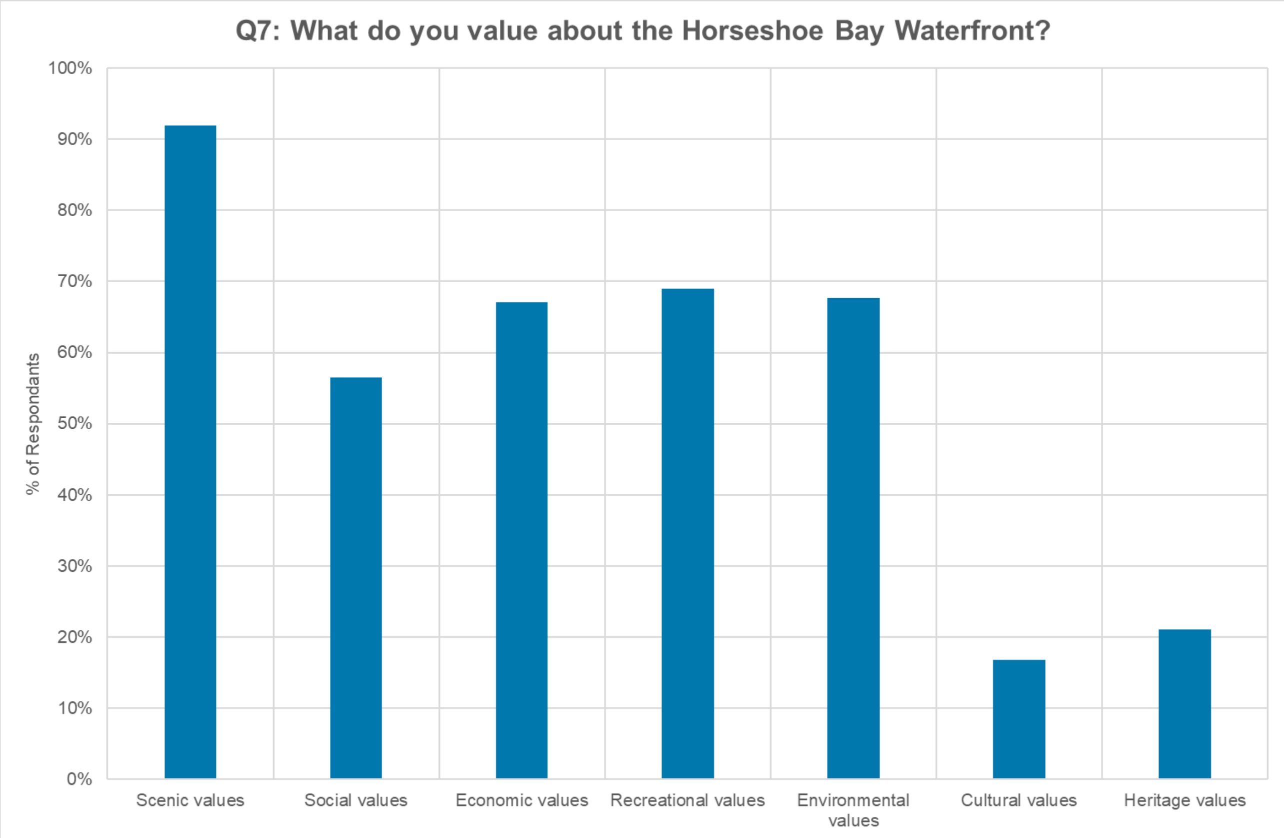

FIGURE 2-7 COMMUNITY CONSULTATION: QUESTION 7

Economic, environmental and recreational values were more or less equally valued by the community, with each chosen by around 65-70% of respondents. The high regard for the economic and recreational importance of the area is reflected in the high utilisation rates of the local shops and restaurants identified in previous questions. Additionally, the recreational importance is highly correlated with beach and watercraft activities enjoyed by locals and visitors.

Cultural and Heritage values ranked lower amongst respondents.

Question 8: How concerned are you about the effects of coastal change (from storm tide, sea level rise and coastal erosion) at Horseshoe Bay on:

For this question, respondents were asked to state how concerned they are regarding the effects of coastal change on various foreshore locations and uses. For each area/usage, respondents were asked to select from one of five options ranging from "Not Concerned" to "Extremely Concerned".

Overall, most respondents were concerned about impacts on the beach, coastal vegetation and open park spaces. These represent the most exposed locations in terms of erosion, inundation and sea level rise. Around 50% of respondents were either "Very Concerned or "Extremely Concerned" about impacts on coastal vegetation (the dunes) and the local park (the esplanade park). Over 40% were either "Very Concerned or "Extremely Concerned" about impacts on beach access and recreational use of the beach. Generally speaking, a very low proportion of respondents were "Not Concerned" at all about coastal change impacts on these areas – generally around 10%. This level of concern corresponds to the high usage of these areas, and the high scenic and environmental values placed on the waterfront by local residents and visitors.

TABLE 2-3 COMMUNITY CONSULTATION: QUESTION 8

Area / Usage	Not concerned	Slightly concerned	Moderately concerned	Very concerned	Extremely concerned
Coastal vegetation and habitats	8%	11%	30%	22%	28%
Parks and open spaces	6%	17%	30%	21%	25%
Beach access	13%	12%	30%	16%	28%
Recreational use of the beach	9%	20%	27%	20%	23%
Local business and tourism	9%	14%	33%	22%	21%
Public infrastructure (e.g. roads, toilets, carparks)	11%	16%	34%	18%	20%
Public safety	27%	18%	25%	17%	12%
Cultural sites and places	29%	17%	27%	14%	12%
Private property (including property prices & insurance)	28%	24%	26%	10%	12%

Generally speaking, there was less concern regarding impacts on cultural sites and places. There was also less concern regarding impacts on private property, however it should be noted that there are relatively few coastally adjacent properties along the foreshore compared to the survey size.

Question 9: How concerned are you about the following coastal changes in Horseshoe Bay?

For this question, respondents were asked to state how concerned they are regarding the various types of coastal change on public and private infrastructure at the Horseshoe Bay foreshore. For each area/usage, respondents were asked to select from one of five options ranging from "Not Concerned" to "Extremely Concerned".

Generally speaking, there was greater concern amongst respondents for impacts to public land/infrastructure than to private land.

Overall the issues of greatest concern was the potential impacts of cyclonic erosion. The relatively recent occurrences of tropical cyclones in the region, including TC Owen (2018), TC Debbie (2017) and TC Yasi (2011) appears to have left respondents cognisant of the potential impacts of storm erosion related to tropical cyclones. Overall, 71% of respondents were either "Very Concerned or "Extremely Concerned" about cyclonic erosion impacts to public land and infrastructure. There was less concern for the associated cyclonic storm surge and temporary ocean flooding.

The next biggest issue of concern was that of sea level rise and the gradual inundation of low lying coastal land. Generally, around 40-50% of respondents were either "Very Concerned or "Extremely Concerned" about such impacts on public and private land.

There was somewhat less concern regarding gradual coastal erosion due to shoreline recession. Nonetheless, around 30-40% showed high concern with regards to the impacts associated with this form of erosion.

TABLE 2-4 COMMUNITY CONSULTATION: QUESTION 9

Area	Not concerned	Slightly concerned	Moderately concerned	Very concerned	Extremely concerned
Some gradual coastal erosion on public land with minimal impact on buildings and infrastructure	14%	24%	25%	17%	19%
Some gradual coastal erosion on private land with minimal impact on buildings	19%	27%	25%	16%	13%
Coastal erosion from a cyclone resulting in permanent loss of public land (not to be replaced)	4%	7%	17%	27%	44%
Coastal erosion from a cyclone resulting in permanent loss of private land	8%	22%	21%	19%	29%
Temporary ocean flooding of public land and infrastructure due to storm tide	11%	16%	32%	20%	20%
Temporary ocean flooding of private land and buildings due to storm tide	13%	19%	30%	21%	16%
Gradual invasion of dry public land by water due to sea level rise	12%	14%	25%	23%	25%
Gradual invasion of dry private land by water due to sea level rise	16%	20%	24%	19%	20%

Question 10: In general, how supportive are you of the following generic adaptation options? Rank from 1 (most supportive) to 10 (least supportive)

The purpose of this question was to ascertain the notional support amongst the local community for a range of generic coastal adaptation options. In order to determine options are generally most (and least) favoured by the community, respondents were asked to provide responses in the form of a ranking. For this assessment, a lower number corresponds to a higher ranking. All responses were collated and then an average ranking was generated for each option. The options comprised:

Option 1 – Sand Scraping (yearly, or as needed after erosion events). Moving sand from other locations within the bay to in front of the Esplanade

Option 2 - A buried seawall (rock or sandbag) beneath the Esplanade as a last line of defence to protect infrastructure in a severe storm event

Option 3 - Re-vegetate and stabilise the coastal dunes and foreshore

Option 4 - Limit pedestrian access to a number of controlled access points, to assist coastal vegetation growth

Option 5 - Formalise storm water runoff along Pacific Drive and divert stormwater into Beeran Creek

Option 6 - Protect the sandy beach with hard structures (e.g. groynes, breakwaters)

Option 7 - Relocate infrastructure to less vulnerable areas when it is at risk (e.g. buildings, playgrounds, car parks)

Option 8 - Remove (and do not replace) infrastructure when it is at risk (e.g. buildings, playgrounds, car parks)

Option 9 - Prevent/limit further development in vulnerable areas

Option 10 - Do nothing

The average ranking for each option is provided below in Figure 2-8. Generally, the strongest level of support is for revegetation and stabilisation of the local dunes and foreshore, with an average rank of 2.8. Beyond this option, there are a number of options that score relatively closely, within the range of 4 to 5.5. These include, Council's current program of periodic sand scraping, formalising the stormwater runoff down the Esplanade and Pacific Drive, and a buried seawall structure beneath the Esplanade as a last line of defence against coastal erosion and shoreline recession.

Limiting future development in exposed areas also has reasonable support amongst the community. However, these is significantly less support for relocation of infrastructure to less vulnerable areas, and removal of at-risk-infrastructure.

Overall, the "Do Nothing" option was the least supported by respondents.

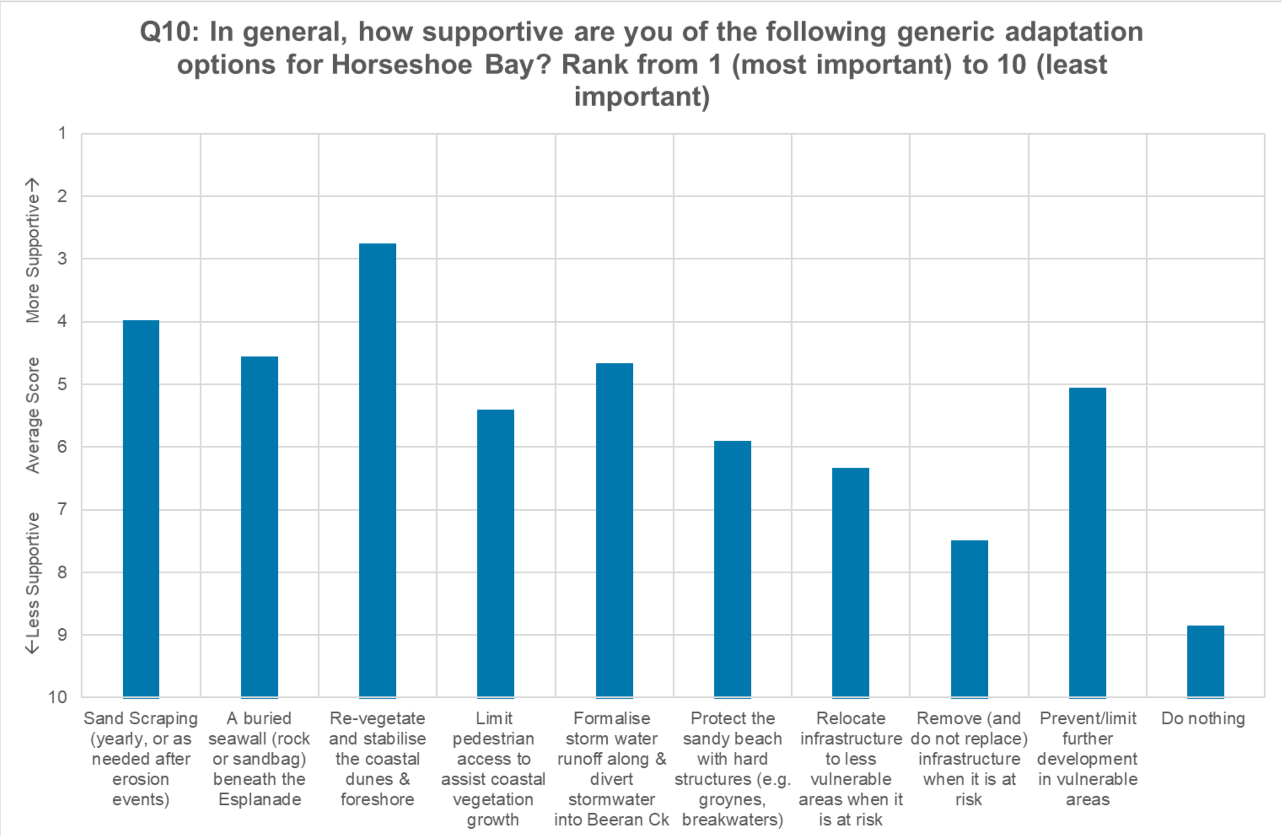

FIGURE 2-8 COMMUNITY CONSULTATION: QUESTION 10

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Question 11: Overall, which of the following do you believe are the most important factors to consider when making decisions about coastal adaptation measures? Rank these factors from (1) most important to (6) least important)

The purpose of this question was to ascertain what the local community believes to be the most important considerations when determining coastal adaptation options. For this assessment, a lower number corresponds to a higher ranking. All responses were collated and then an average ranking was generated for each option.

The results showed a high level of correlation with the results of Question 6, which asked resident why they visit the Horseshoe Bay waterfront. The highest priority was maintaining a sandy beach for amenity and recreational use, and this was closely followed by the need to maintain coastal vegetation and natural ecosystems. The desire to maintain grassed open public spaces (the esplanade park) also scored quite highly. These results were also well correlated with the high regard the survey respondents had for the scenic, recreational and environmental values of the study area (Question 7) and reflect a desire to protect and maintain these values of the waterfront as part of any future coastal adaptation measures.

Protection of private and public infrastructure was considered less important. This may also be reflected in the result of the results of Question 9, which suggested that there is generally a lower level of concern about the effects of coastal change on such infrastructure than there is for protecting the sandy beach and dunes.

Overall the financial cost of the option was considered to be the least important factor. This suggests that the community would support investment in options that protect and maintain the values of the Horseshoe Bay waterfront.

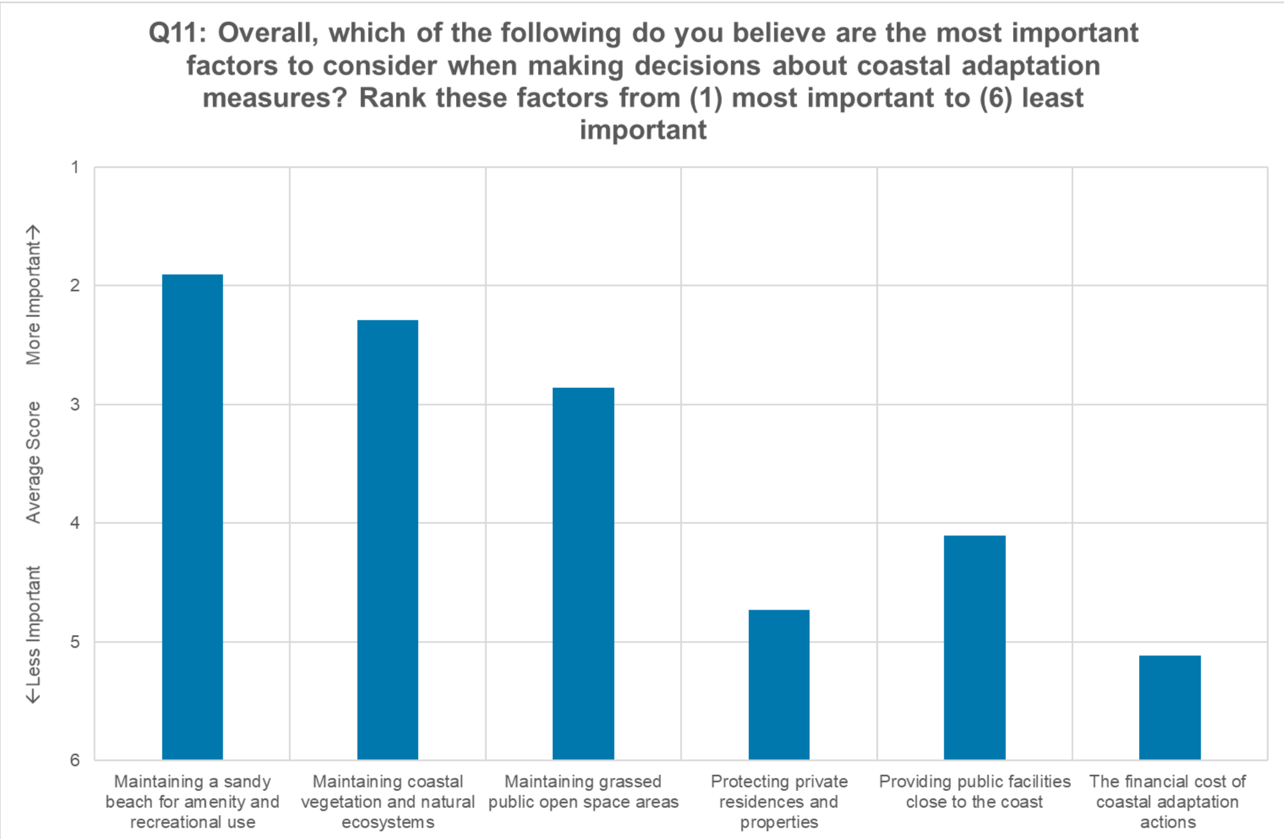

FIGURE 2-9 COMMUNITY CONSULTATION: QUESTION 11

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Question 12: Lastly, what words or phrases would you use to describe what you value about Horseshoe Bay Beach?

This question was be used to develop a "word cloud", which we have found to be a useful tool for conveying community values in similar projects. A word cloud is an image composed of words used in a particular dataset, in which the size of each word indicates how often they are used.

The resulting word cloud is provided below, and several themes can be observed within in. The first notable theme is that of the physical beauty and aesthetic amenity of the waterfront. The most common word was *beautiful* which reflects the high regard for the scenic values of the area. Additional words of this nature included *scenery*, *sunsets* and *views* which also featured prominently.

The environmental values of the area also featured prominently. The words *natural*, *undeveloped*, *untouched*, *environment*, *wildlife*, and *vegetation* also featured amongst respondents. Of a similar vein, the value people placed on the waterfront being a place was also evident, with *relaxing*, *relaxed*, *peaceful*, *serenity* and *escape* all featuring amongst the responses.

The recreational values were also evident, particularly the ability to utilise the calm and safe swimming/boating conditions and the resulting opportunity for water sport activities in the bay – as responses included the words *anchorage*, *boating*, *ramp* (as in, the boat ramp), *activities*, *swimming*, *safe* and *water sports*.

The economic values were also evident, with *tourism* being one of the most common phrases. Aside from this, *shops*, *restaurants*, *cafes*, *markets* and *businesses* all featured. Social values were also amongst the respondent's answers, including *family*, *hub*, *fun*, *friendly*, and *friends*.

FIGURE 2-10 COMMUNITY CONSULTATION WORD CLOUD

Overall, it can be seen that the Horseshoe Bay waterfront is considered by locals and visitors to be a beautiful and natural area, that possesses high environmental value and provides recreational, social and economic benefits to the community.

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3 PHYSICAL PROCESS 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 Horseshoe Bay foreshore.

This section of the Shoreline Erosion Management Plan defines and quantifies the natural processes that are contributing to the existing and future erosion threats on this shoreline. It is necessary to have a sound understanding of these processes in order to develop and appropriately assess possible erosion mitigation strategies.

3.1 Coastal Geomorphology

Beach sands on Horseshoe Bay are composed predominantly of quartz and have been derived from the weathering of the igneous rocks of Magnetic Island and from sources farther afield. Horseshoe Bay is located geologically in relatively close proximity to the Burdekin River (to the north) and Herbert River (to the south), which provide the dominant sediment supply to the central Great Barrier Reef (GBR) coast (Aurecon, 2015). Over geological timescales, sand from these major GBR catchments has built up the nearshore terrigenous zone (GHD, 2018), and as a result the Horseshoe Bay embayment has been accretive with sediment collecting in the embayment to create the coastal flats.

In the present day, the embayment can be considered to have relatively low rates of sand delivery, and can be considered to be a nearly closed littoral system in terms of the overall sediment budget (at least over management timeframes). That is, the overall volume of sand within in the embayment should remain more or less constant over time with little net loss or gain. However, within the Horseshoe Bay littoral system, the movement of sediments is dynamic and driven by both long-shore and cross-shore processes acting over seasonal and interannual timescales – and punctuated by frequent but irregular tropical cyclone activity.

Whilst tidal currents can potentially initiate and sustain movement of the fine offshore sediments in Cleveland Bay, they are not of sufficient strength to move the coarse sand that exists along the land/sea boundary that constitutes the Horseshoe Bay foreshore (refer to later discussions in Section 3.2.4). It is wave action that moves this sand.

Tides play an indirect role - in that the variable ocean levels allow waves to access various parts of the beach face. Also, since the amount of wave energy that reaches the beach is determined by the depth of water over the fringing reef flats (by causing larger waves in the sea-state to break before reaching the beach) tides play another indirect role by influencing the rate at which waves will move beach sand.

During the site visit conducted by Water Technology in March 2019, two sediment samples were taken from the beach at Horseshoe Bay, the location of these samples is presented within Figure 3-1. These samples were subsequently subjected to particle size distribution testing to provide information on their sediment characteristics. The results of the analysis are presented below within Table 3-1.

FIGURE 3-1 SEDIMENT SAMPLING LOCATIONS

The particle size distribution detailed in Table 3-1 reveals that the sediment at both locations can be classified as medium grained sand. A further breakdown of the analysis shows that sample A is comprised of 92% sand and 8% gravel and sample B is comprised of 98% sand and only 2% gravel. Both samples have an extremely low (less than 1%) concentration of fines. More detailed results are provided in Appendix B.

TABLE 3-1 PARTICE SIZE DISTRIBUTION RESULTS (ALS ENVIRONMENTAL, 2019)

Sieve Size	Passing (%) – Sample A	Passing (%) - Sample B
0.075 mm	100	100
0.15 mm	93	95
0.30 mm	77	53
0.425 mm	58	32
0.60 mm	45	18
1.18 mm	19	4
2.36 mm	2	<1
4.75 mm	<1	<1

3.2 Local Coastal Processes

3.2.1 Event Frequency

When discussing the severity and occurrence of natural events such as storms, engineers and scientists assign a measure of an event's severity by way of either an *Average Recurrence Interval* (ARI) or an *Annual Exceedance Probability* (AEP).

Where an ARI (sometimes also referred to as a *Return Period*) is assigned, it represents the average time that elapses between two events that equal or exceed a particular condition. For instance, a 100-year ARI event is one which is expected to be equalled or exceeded *on average* once every 100 years. However, since events occur randomly in any particular timeframe under consideration (rather than at precise regular or cyclical intervals), they have a probability of occurrence within that time. However as noted in the now superseded 1987 edition of *Australian Rainfall and Runoff* (Institution of Engineers Australia, 1987):

> *"Use of the terms "recurrence interval" and "return period" has been criticised as leading to confusion in the minds of some decision makers and members of the public. Although the terms are simple superficially, they are sometimes misinterpreted as implying that the associated magnitude is only exceeded at regular intervals, and that they are referring to the elapsed time to the next exceedance."*

Use of the term ARI can lead to misperceptions, such as the viewpoint that having just experienced a 100-year ARI event, there will not be another one like it for 100 years. This is not correct. It is therefore preferable to express the occurrence of a storm event in terms of Annual Exceedance Probability (i.e. AEP). This trend in technical nomenclature is reflected in recent updates of *Australian Rainfall and Runoff* (Geosciences Australia, 2019).

For example, "…… *a storm tide level of RL+2.52m above AHD at Horseshoe Bay has a 1% (i.e.0.01) probability of being equalled or exceeded in any one year…..*" can be more correctly (and more appropriately) understood than the equivalent statement of *a "….. a storm tide level of RL+2.52m above AHD at Horseshoe Bay has an average recurrence interval of 100 years….".*

Consequently, throughout reporting for this SEMP, the Annual Exceedance Probability (AEP) is used in preference to Average Recurrence Interval (ARI) or Return Period when discussing event severity and/or occurrences. With ARI expressed in years, the relationship between ARI and AEP is expressed as the following equation, as given in Laurenson et al (1987):

$$AEP = 1 - exp\left(\frac{-1}{ARI}\right) \qquad \textbf{Equation 3.1}$$

Table 3-2 below is provided to assist in appreciating the relationship between AEP and ARI. Typically ARIs of greater than 10 years are very closely approximated by the reciprocal of the AEP (for example, 20 year ARI ≈ 1/20 or 0.05 AEP). Table 3-2 also indicates the likelihood of the occurrence of an event in a typical management decision making timeframe – taken nominally as 50 years.

TABLE 3-2 RELATIONSHIP BETWEEN AVERAGE RECURRENCE INTERVAL AND ANNUAL EXCEEDANCE PROBABILITY

Average Recurrence Interval (ARI) in years	Annual Exceedance Probability (AEP)	Probability of Experiencing at Least One Event in 50 Years
1	63.2%	~100%
2	39.3%	~100%
5	18.1%	~100%

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Average Recurrence Interval (ARI) in years	Annual Exceedance Probability (AEP)	Probability of Experiencing at Least One Event in 50 Years
10	9.5%	99.3%
20	4.9%	91.8%
50	2%	63.2%
100	1%	39.3%
200	0.5%	22.1%

3.2.2 Tropical Cyclones

The most extreme waves and water levels at the study area are generated by infrequent, but severe, tropical cyclone activity. Therefore, an understanding of the tropical cyclone climatology is vital to understanding the recurrence of severe storm erosion events at Horseshoe Bay. To this end, as assessment of historical tropical cyclone activity has been undertaken by interrogating the Bureau of Meteorology's Southern Hemisphere Tropical Cyclone Data Portal (BoM, 2019a). Figure 3-2 depicts the most severe tropical cyclones (in terms of local wind speeds) affecting Magnetic Island since 1950. It is important to note that whilst the Bureau's tropical cyclone records date back to the early 1900's, data is considered to more reliable in the post world war two era – due to the development of over-the-horizon radar technology that can accurately record their location and intensity.

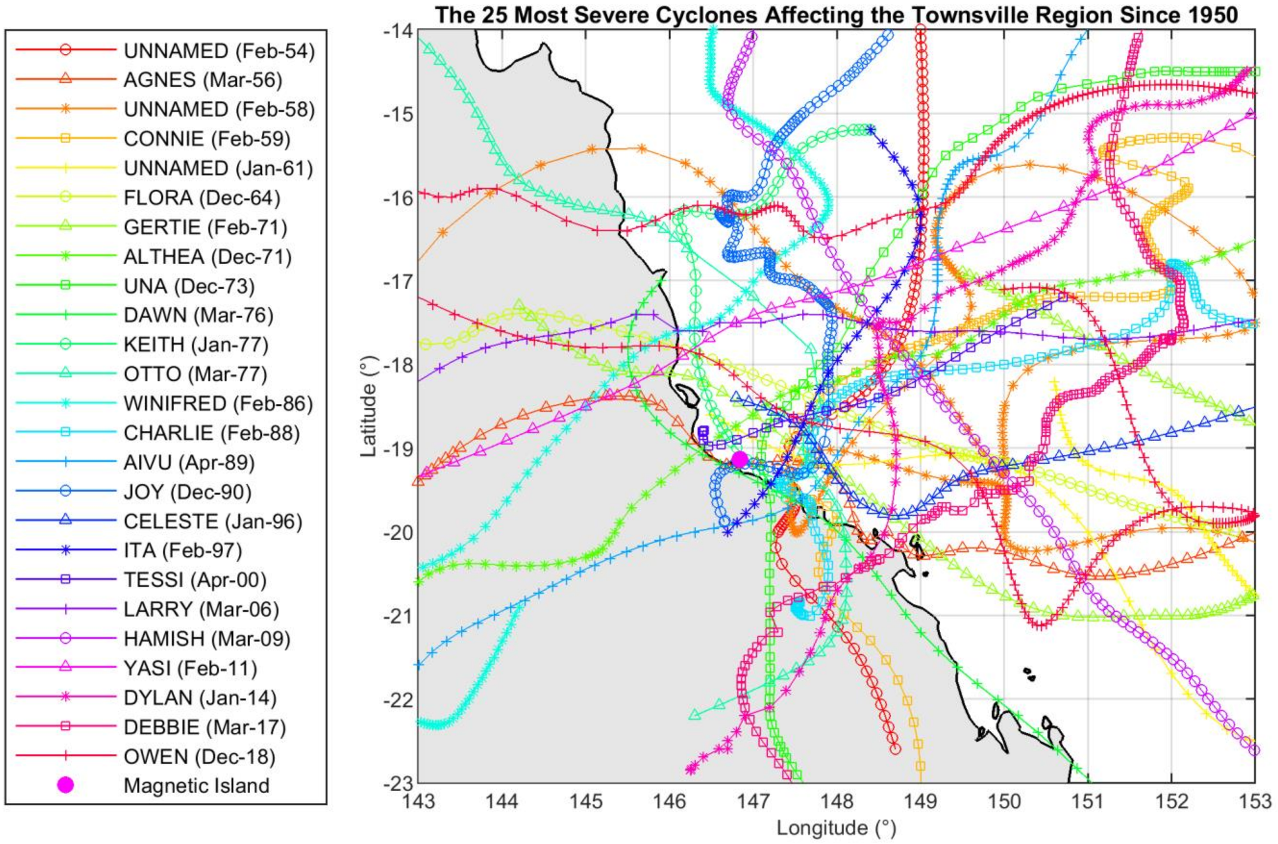

FIGURE 3-2 HISTORICALLY SIGNIFICANT CYCLONES FOR THE TOWNSVILLE REGION

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The most significant cyclones to have impacted the region include TC Althea (1971), TC Joy (1990), TC Tessi (1998), and more recently TC Yasi (2011). It should be noted that other older cyclones such as Cyclone Leonta (1903) and Cyclone Sigma (1896) also generated significant damage in the region, however records are less reliable for these storms.

An analysis has been undertaken on the seasonality and frequency of all cyclones passing within 300 km of Magnet Island since 1950. The top pane of Figure 3-3 depicts the month of cyclone formation (referred to as cyclogenesis) of each of these cyclones. In Australia, the official tropical cyclone season runs from 1 November to 30 April. Figure 3-3 shows all recorded cyclones affecting Horseshoe Bay most commonly form between January and March, with the highest rate of cyclogenesis occurring during the month of January. Cyclones forming as early as November and as late as April do occur, but they are relatively infrequent (accounting for less than 10% of all cyclone formations combined).

From January 1950 to December 2018, over 75 tropical cyclones have tracked within 300 km of Magnetic Island, which equates to a long term average of around 1.1 cyclones per season. However, there is significant interannual and interdecadal variability in the frequency of their formation. Figure 3-3 shows the frequency of their occurrence has varied over the years. In particular, the frequency of tropical cyclones was above average throughout the 1970's, at around 1.6 per season (which included severe TC Althea (1971), one of the strongest storms ever to affect the Townsville area) and to a lesser extent the 1980's (1.3 per season). The frequency of cyclone formation dropped during the 1990's and 2000's, but nonetheless contained some intense systems including TC Joy (1990), TC Tessi (1998) and TC Larry (2006) and TC Hamish (2009). The frequency of Cyclone formation increased again in the 2010's, including TC Yasi (2011) and TC Owen (2018).

The causes for this decadal variability are not fully understood, though tropical cyclone frequency is known to be related to some inter-annual phenomena such as El Niño Southern Oscillation (ENSO). According to the Bureau of Meteorology (2019b), there are fewer tropical cyclones in the Australian region during El Niño years (on average). This is particularly true around Queensland, where cyclones are half as likely to cross the coast during El Niño years compared La Niña or neutral years.

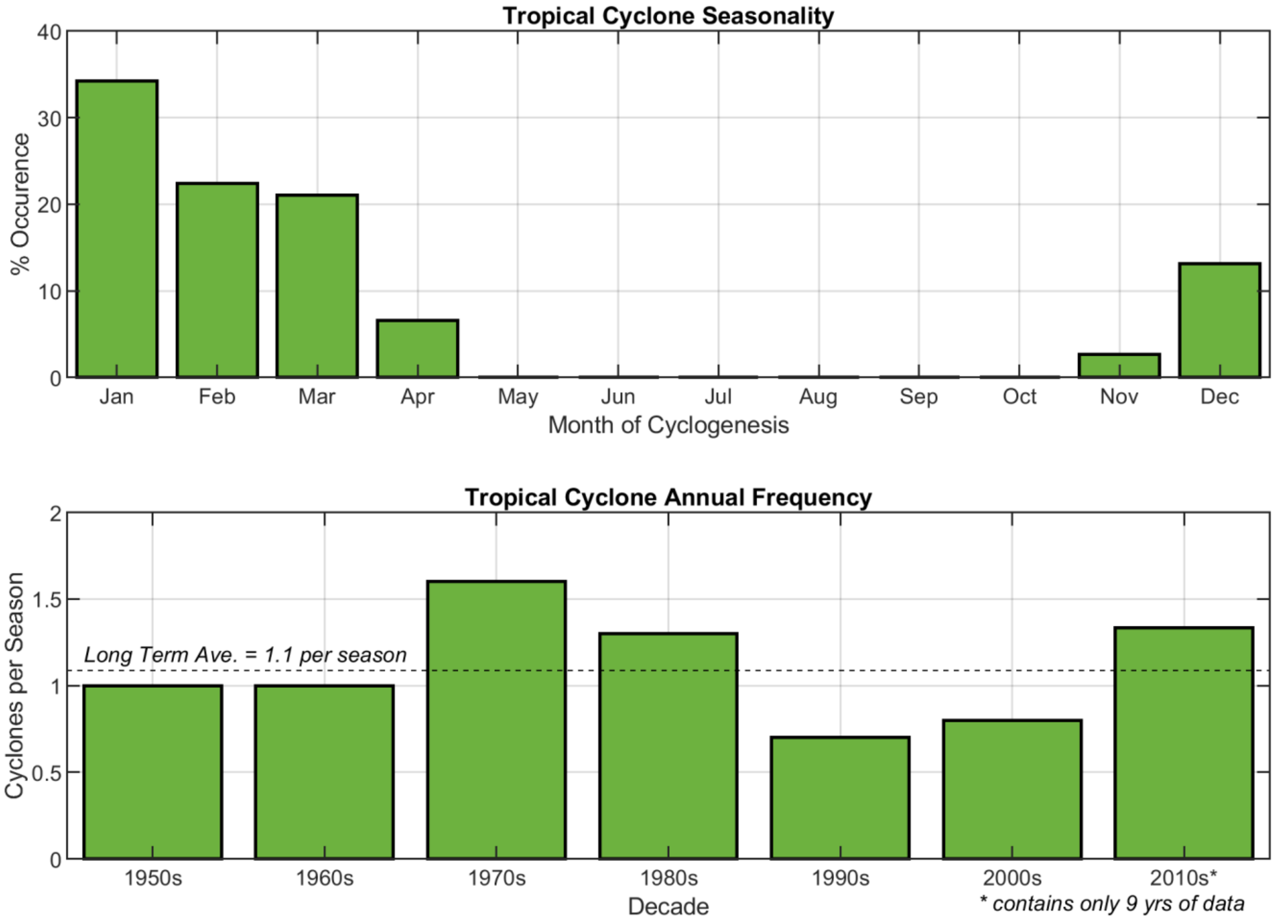

FIGURE 3-3 SEASONALITY AND HISTORICAL FREQUENCY OF TROPICAL CYCLONES AFFECTING TOWNSVILLE

3.2.3 Ocean Water Levels

When considering the processes that shape shorelines it is necessary to consider the prevailing ocean water levels. 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 levels also need to be considered.

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 Tides* - 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 Tides* - 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, atmospheric pressure fluctuations induced by severe synoptic events (such as tropical cyclones), and oceanographic influences such as coastal trapped waves.

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. While the vertical tidal fluctuations are generated as a result of these forces, the distribution of land masses, bathymetric variation and Coriolis force determine the local tidal characteristics. 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.

Coastal water levels in the study area are dominated by the astronomical tide. Tides at this location are semi-diurnal, which means Horseshoe Bay experiences two high tides and two low tides per day. Tidal planes have been published for Magnetic Island (MSQ, 2019) and these are presented in Table 3-3 below.

TABLE 3-3 TIDAL PLANES AT MAGNETIC ISLAND (MSQ, 2019).

Tidal Plane	Relative to m AHD	Relative to m CD
Highest Astronomical Tide (HAT)	2.14	3.98
Mean High Water Springs (MHWS)	1.17	3.01
Mean High Water Neaps (MHWN)	0.33	2.17
Mean Sea Level (MSL)	0.07	1.91
Australian Height Datum (AHD)	0.00	1.84
Mean Low Water Neaps (MLWN)	-0.27	1.57
Mean Low Water Springs (MLWS)	-1.09	0.75
Lowest Astronomical Tide (LAT)	-1.84	0.00

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 alignment). 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 3-3, the maximum possible astronomical tidal range at Magnetic Island is 3.98 metres, with an average range during spring tides of 2.26 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 (i.e. December - February) and also in mid-year (i.e. 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 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 based on 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 Magnetic Island 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 height of low and high water are primarily caused by wind. A strong wind blowing directly onshore will "pile up" the water and cause tides to be higher than predicted, while winds blowing off the land will have the reverse effect. Clearly the occurrence of storm surges associated with tropical cyclones can significantly influence ocean water levels.

Storm Tides

Coastal water levels in the study area are dominated by the astronomical tide. However, significant short term variations from the predicted tide level can occur – and these variations are referred to as storm surge. The total water level resulting from astronomical tides and the increase in the still water level due to storm surge is referred to as a *storm tide*. Figure 3-4Figure 3-4 illustrates the primary water level components of a storm tide event. A brief discussion of each of these various components is offered below.

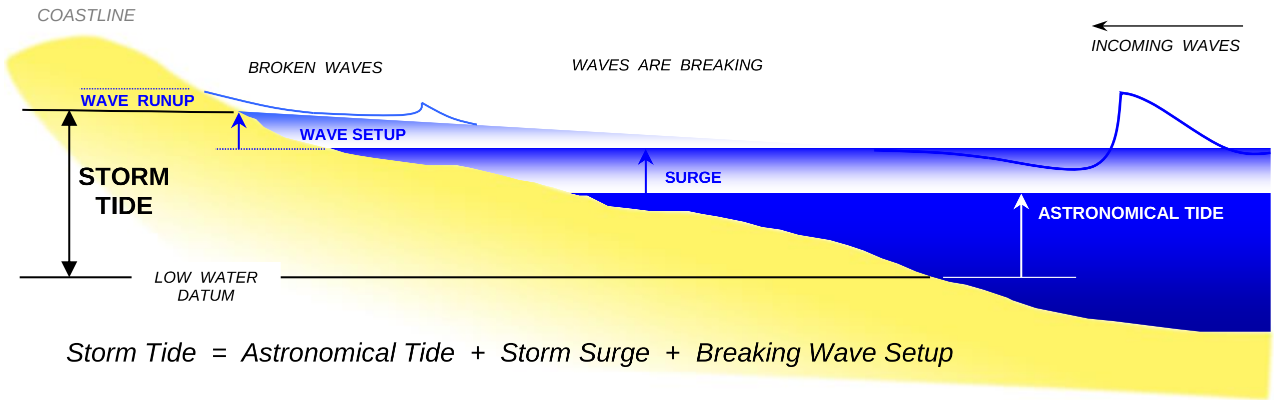

FIGURE 3-4 COMPONENTS OF A STORM TIDE EVENT

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.
Storm Surge	Non-periodic variations from the astronomical tide are typically associated with the effect of wind on sea level. 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 severe storm or tropical cyclone. The magnitude of the surge is dependent upon several factors such as the intensity of the storm, its overall physical size, the speed at which it moves, and if associated with a cyclone - the direction of its approach to the coast, as well as the specific bathymetry of the coastal regions affected. To predict the height of storm surges, these various influences and their complex interaction are typically replicated by numerical modelling techniques using computers
Wave Set-up	The strong winds associated with 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. Wave set-up can be considered as a piling up of water against the shoreline that is generated by breaking waves causing a transfer of kinetic to potential energy.

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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. 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 Run-up	Wave run-up is the vertical height above the local still 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 natural foreshore (or a structure) 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 concrete seawall. Wave run-up heights and levels therefore change on a wave by wave basis. Since 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 Horseshoe Bay foreshore.

Storm Tide Events in the Townsville Region

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 addresses the effect of enhanced Greenhouse conditions on sea level rise and tropical cyclone frequency and intensity. Data is also presented for the more regional QLD Oceans Hazard Assessment (DNRM, 2004).

The storm tides reported by that regional study have been used in the preparation of this Shoreline Erosion Management Plan and are summarised in Table 3.2 for the present day climate scenario. The GHD (2007) levels are inclusive of wave set-up, whilst the DNRM (2004) levels are not. The GHD levels are considered to be more robust, as that study was more recent and included a higher resolution assessment over the study area.

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

TABLE 3-4 DESIGN STORM TIDE LEVELS AT HORSESHOE BAY (FROM GHD, 2007)

ARI Years	AEP (%)	GHD 2007 (m AHD) [*inclusive* of wave set-up]	DNRM 2004 (m AHD) [*excluding* wave set-up]
50	2%	2.4	-
100	1%	2.5	2.3
200	0.5%	2.8	-
500	0.2%	3.0	2.5
1,000	0.1%	3.3	2.7
10,000	0.01%	4.7	-

Longer Term Sea Level Processes

Water levels in the study area will also be affected by longer term physical processes that act over timescales ranging from weeks to decades. These processes include long term mean sea level rise due to climate change (discussed in Section 3.2.11), and regional atmospheric and oceanographic processes such as the El Niño Southern Oscillation (ENSO).

The ENSO phenomenon in the southern Pacific Ocean, cause medium term variations in mean sea level, that occur over timescales of several months to several years. During El Niño years, when the Southeast trade winds weaken, sea surface temperatures are cooler and mean sea level is lower than average. Conversely, during La Niña years, the southeast trade winds strengthen, resulting in warmer than average sea surface temperatures and higher than average mean sea level. The phases of ENSO are tracked by a metric known as the Southern Oscillation Index (SOI), which measures the difference in surface air pressure between Tahiti and Darwin (BoM, 2017b). Sustained SOI values above about +8 indicate La Niña event conditions, while sustained values below about –8 indicate El Niño conditions.

As part of investigations for this SEMP, a high-level analysis has been undertaken in order to investigate the influence of ENSO on mean sea level at the study area. Long term sea level data has been obtained from the Australian Baseline Sea Level Monitoring Project (ABSLMP), which is managed by the National Tidal Centre and the Bureau of Meteorology (BoM, 2017c). Data was obtained from 1992 to the present from the ABSLMP station at Cape Ferguson, around 20 km south-east of Magnetic Island. A correlation between yearly mean sea level anomaly and yearly average SOI has been undertaken. For these analyses the yearly average has been calculated for the 12 months running from July to June, as ENSO "events" tend to peak during the summer (wet season). The results are depicted in Figure 3-5, and show that the two variables are relatively well correlated.

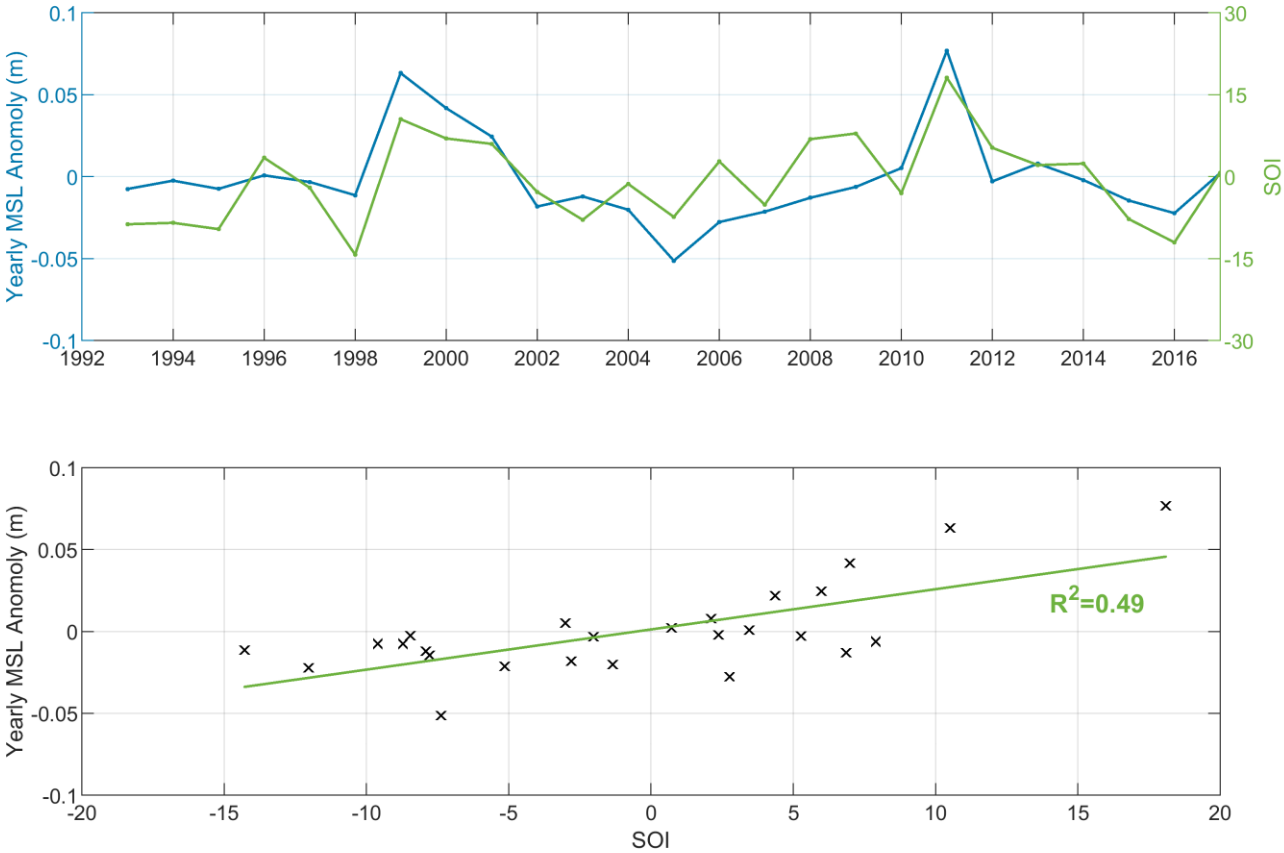

FIGURE 3-5 INFLUENCE OF SOI ON YEARLY MSL ANOMOLY AT CAPE FERGUSON

Generally, the yearly average MSL is higher during periods of higher SOI (that is, La Niña periods) and lower during periods of lower SOI (El Niño). The analysis shows that around 49% of the natural variability in yearly MSL can be explained by the ENSO phenomena. Whilst ENSO related yearly average MSL anomalies may be of the order of ± 0.1 m, during any given month the influence may be higher, of the order ± 0.2 m or higher.

The historical rate of mean sea level rise (MSLR) at the Cape Ferguson tide gauge from 1992 to 2019 as reported by the ABSLMP (2017c) is 4.5 mm/yr. However, some of this raw calculated MSLR may be affected by ENSO (for instance, a greater tendency towards El Niño at the start of the record and a tendency towards La Niña at the end of the record – or vice versa). Therefore, an adjusted rate of MSRL has been calculated by removing the ENSO influence depicted in Figure 3-5. The results, depicted in Table 3-5, show that the net rate of MSLR at Cape Ferguson during this time was approximately 4.0 mm/yr.

This calculated rate of MSLR is relatively consisted with the findings of White et al (2014), who assessed historical mean sea level change at a number of locations around Australia (also presented in Table 3-5). After removing the effects of higher frequency processes (such as ENSO and atmospheric pressure), they determined that the average rate of MSLR around Australia from 1993 to 2009 was 3.1 ± 0.6 mm/year. This numbers are also comparable to the global rates of MSLR since the early 1990's determined by the IPCC (2013).

TABLE 3-5 MEAN SEA LEVEL RISE RECORDED AT CAPE FERGUSON FROM 1992 – 2019.

Rate of MSLR – Early 1990's to Present	MSLR
Cape Ferguson - Raw MSLR: 1993-2018	4.5 mm/yr
Cape Ferguson - MSLR with ENSO influence removed: 1993-2018	4.0 mm/yr
Australian Average (White et al, 2014): 1993-2009	3.1 mm/yr
Global Average (IPCC, 2013): 1993-2010	3.2 mm/yr

3.2.4 Nearshore Currents

Ocean currents in Cleveland Bay are predominantly driven by tides and winds. Over the years there have been many studies of ocean circulation in Cleveland Bay. These have typically been numerical modelling studies augmented with some field measurements to assist in verification of the modelling predictions. Whilst these various studies have invariably been comprehensive, they define the structure and magnitude of tidal currents in the deeper waters of Cleveland Bay (or in the immediate vicinity of Townsville Port) rather than on the land/sea interface that constitutes the sandy shoreline of Horseshoe Bay. Nearshore current speeds are considerably less than those offshore because the wide shallow reef flat that exists along the shoreline, and the presence of the protruding rocky headlands that envelop Horseshoe Bay significantly inhibits tidal flows in these areas.

Consideration of the physical characteristics of the sand in Horseshoe Bay indicates that bed shear stresses of around 0.2-0.3 N/m^2 are required to initiate movement of the sand. If this was to be achieved by ocean currents alone, then depth averaged tidal currents of at least 0.3 m/s would be needed in the nearshore zone. This is further supported by Hjulström (1935), provided in Figure 3-6, that also shows the critical flow speed for sediment suspension is around 0.3 m/s for the local sediment size.

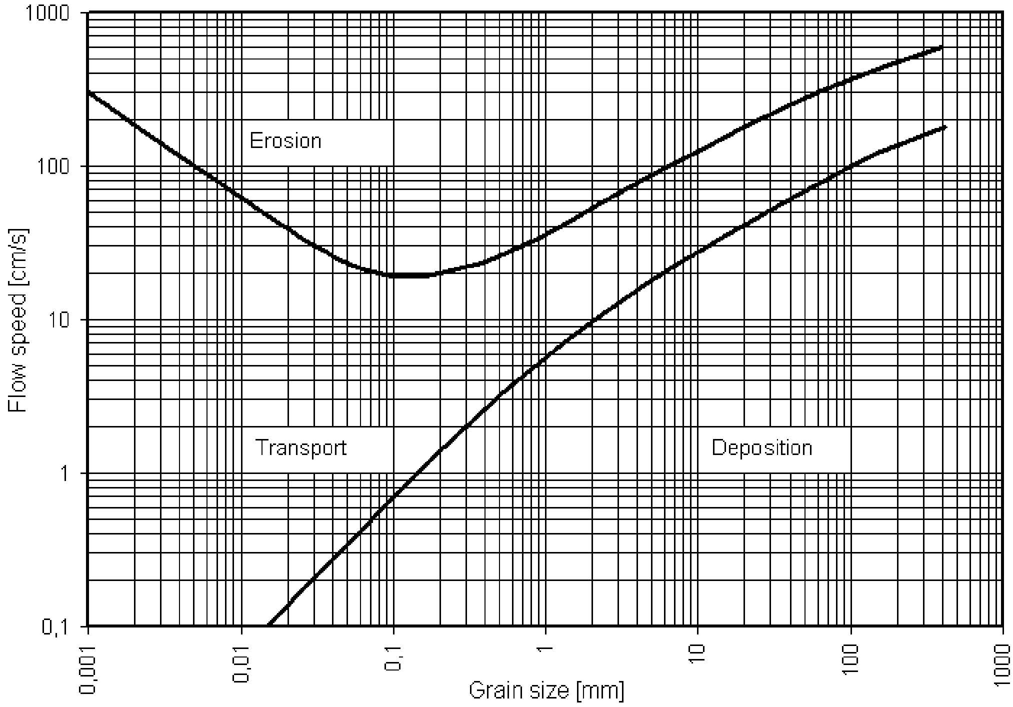

FIGURE 3-6 HJULSTRÖM CURVE (HJULSTRÖM, 1935)

Field measurements undertaken in nearshore waters during the various investigations and studies for the environmental approvals of the Nelly Bay Harbour development (on the south-eastern side of Magnetic Island) indicate that velocities on the reef flat of the nearby Nelly Bay never exceed 0.25 m/sec (McIntyre and Associates, 1986 and Parnell, et al., 1988). It is likely that tidal currents within Horseshoe Bay are even lower in magnitude due to the physiographic form of the bay and the sheltering provided by the headlands of the embayment.

As part of this study, coupled hydrodynamic and wave modelling was undertaken of the study area under both ambient and cyclonic conditions. A spatial map of the maximum modelled current speeds observed over the model simulation are presented below within Figure 3-7. These results show the relatively low current speeds within the bay, which are of the order of 5 -10 cm/s.

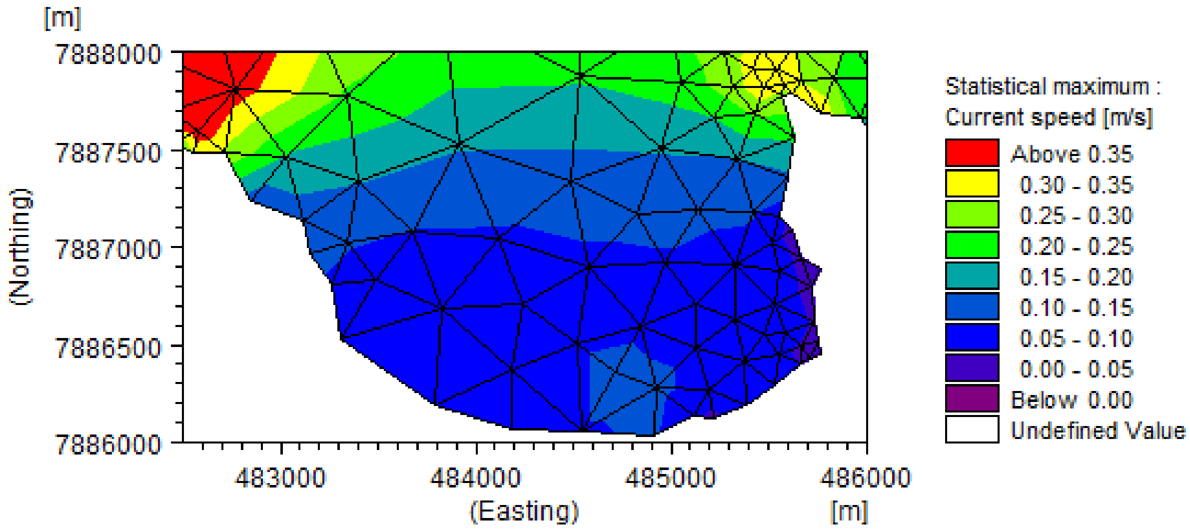

FIGURE 3-7 MAXIMUM MODELLED TIDAL CURRENT SPEEDS FOR HORSESHOE BAY (JUNE – JULY 2016)

Consideration of these factors suggests that current driven sediment transport at the study area is expected to be negligible, as the magnitude of tidal currents are not high enough to initiate or entrain suspended sediment. It is waves that play the dominant role in sand transport.

3.2.5 Wind Climate

The wind climate throughout the Townsville region is measured by the Bureau of Meteorology (BoM) at several weather stations:

- Townsville Airport {station 032040} – 17 km south-west of Horseshoe Bay;
- Cape Ferguson {station 032182} - 28 km south-east of the Horseshoe Bay;
- Lucinda Point {station 032141} – 83 km north-west of Horseshoe Bay;

A summary of the available data at each gauge is shown in Table 3-6.

TABLE 3-6 WIND DATA SUMMARY

Location	Record	Data Provider
Cape Ferguson	2009 – Present	BoM
Lucinda Point	1996 - Present	BoM
Townsville Airport	1940 - Present	BoM

The Townsville Airport and Cape Ferguson gauges, whilst close to the site, are significantly impacted by topographic features and the interaction coastal sea breeze wind conditions during the morning and evening. The Lucinda gauge is located on a structure roughly 5.7 km offshore and provides the best representation of wave-generating open water conditions.

For these reasons, data from the Lucinda anemometer was selected to use in the modelling for wind-generated waves. A data gap in the Lucinda Point wind record occurs between February 2011 and June 2013, likely associated with damage to the anemometer incurred during Tropical Cyclone Yasi.

The wind climate of Lucinda is summarised within a wind rose presented in Figure 3-8. Townsville is situated in the trade wind belt and as a result winds in the area are dominated for most of the year by the south-east trade winds. There is, however, a pronounced seasonality in the wind local climate (see Figure 3-9). During the dry season from June to August, winds tend to arrive consistently from a more southerly direction. Conversely, during the wet season months of November to February, winds are more easterly, and interspersed with afternoon northerlies (and occasionally tropical cyclone activity).

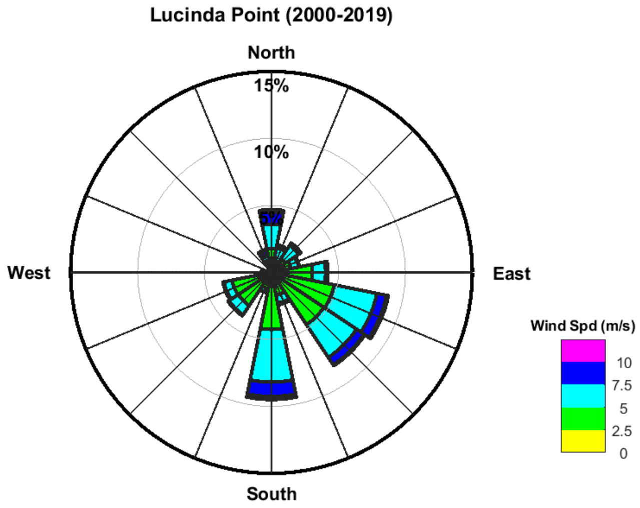

FIGURE 3-8 WIND ROSE OF LUCINDA POINT (2000-2019)

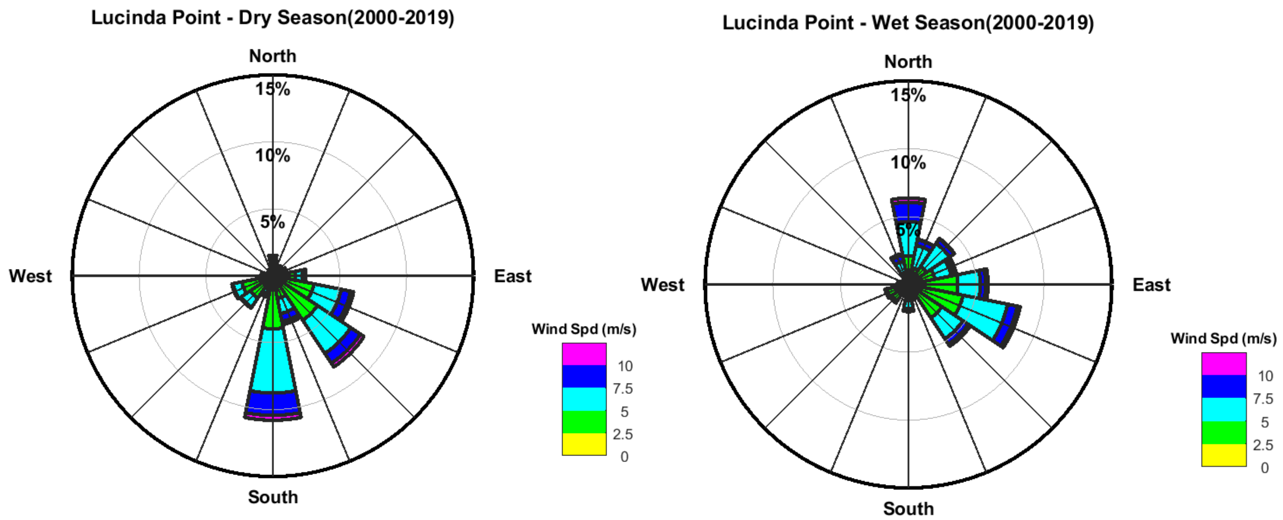

FIGURE 3-9 WIND ROSES OF LUCINDA POINT (2000-2019): DRY SEASON (LEFT), WET SEASON (RIGHT)

3.2.6 Wave Climate

3.2.6.1 Types of Waves Affecting Local Sediment Transport

Waves arrive in the nearshore waters around Horseshoe Bay as a consequence of several phenomena, namely;

- **Swell waves** - generated by weather systems in the distant waters of the Coral Sea and Pacific Ocean out beyond the Great Barrier Reef. In order to propagate into Horseshoe Bay, these waves must pass through and over the extensive reefs and shoals that constitute the Barrier Reef. There is considerable attenuation of wave energy during this propagation process, and very little swell wave energy reaches Horseshoe Bay.

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- **Distant Sea waves** - generated by winds blowing across the open water fetches between the mainland and the outer Great Barrier Reef system (some 70 kms offshore). This primarily includes the fetches north of Horseshoe Bay.
- **Local Sea waves** - generated by winds blowing across the open waters of Horseshoe Bay, between Magnetic Island and the mainland.

Waves from these various sources can occur simultaneously. Given that sand transport processes are primarily driven by waves, a significant focus of the work undertaken for this Shoreline Erosion Management Plan has been the determination of the ambient (i.e. the "day-to-day") wave climate - as well as the extreme wave climate (i.e. due to cyclones and severe storms). Because of the complex nature of the wave and sand transport processes, the work has utilised numerical modelling techniques.

Following sections of this report provide some details as to the methodology and the results of that modelling. However some comment is warranted with respect to the various types of waves that can affect sand transport on Horseshoe Bay beach.

Swell Waves

As swell waves generated by weather systems out in the Coral Sea propagate shoreward, the Great Barrier Reef significantly inhibits the passage of its energy. Nevertheless, whilst inshore swell wave heights are quite low, because of their relatively long wave periods (typically in excess of around 12 seconds) they contribute to local sediment transport processes.

Distant Seas

The significant distances between the mainland and the Great Barrier Reef means that quite sizeable waves can be generated by winds blowing across these fetches - particularly during cyclones which are a relatively common synoptic event in these waters. To the north of Horseshoe Bay there are very long open water fetches across which winds can generate significant wave energy. It is from this sector that the largest waves can approach the entrance to Horseshoe Bay. These waves generally occur during the wet season, when afternoon northerly winds and waves can be quite strong. Additionally, periodic tropical cyclone activity can also generate highly energetic northerly winds and waves that can affect Horseshoe Bay beach.

The wave climate of distant seas at the study area is dominated by the south-east trade winds and waves. As a north facing embayment situated in between protruding headland boundaries – Horseshoe Bay Beach (particularly the eastern stretch) is highly protected from the direct effects of these south-easterly waves. These waves can diffract and refract around the northern tip of the of these headlands and propagate shoreward to Horseshoe Bay beach – however by the time they do so the attenuating effects of diffraction and refraction mean that the energy of these waves is heavily diminished.

Local Seas

The same winds that blow across the open water fetches between the mainland and the Great Barrier Reef (to generate Distant Seas) also blow across the enclosed waters of Horseshoe Bay. Consequently, they generate waves within the Bay itself – these waves are called Local Seas. Since these fetches are relatively short (approximately 2 km) and shallow, the resulting wave energy is minimal and they are do not play an important role in the longshore transport of sand on this shoreline.

3.2.6.2 Available Wave Data

The regional wave climate has been investigated through analysis of data recorded at nearby Cape Cleveland waverider buoy (WRB). This WRB was first established in 1975 and is situated in approximately 17 m water depth below Lowest Astronomical Tide. It recorded non-directional waves from 1975 to 2000 but has been recording wave direction thereafter. Details of the WRB are provided in Table 3-7.

TABLE 3-7 CAPE CLEVELAND WRB HISTORY

Time Period (approx.)	Recording Frequency	Directionality
1975-1982	12 hourly	Non-directional
1982-1991	6 hourly	Non-directional
1991-2000	Hourly	Non-directional
2000-2019	Hourly	Directional

The wave climate is summarised in the wave roses of Figure 3-10 and Figure 3-11 in terms of annual and seasonal *significant wave heights*[1]. Inspection of this data shows that overall the majority of waves arrive from the east – driven by the dominance of the southeast trade winds. However, there is some seasonal variation in the regional wave climate. During the dry season (winter) months, there is a greater occurrence of waves from the south to south-east sectors. Conversely, during the wet season (summer) months there is an increased occurrence of waves from the north to north-east sectors, which are generated by the seasonal northerly winds.

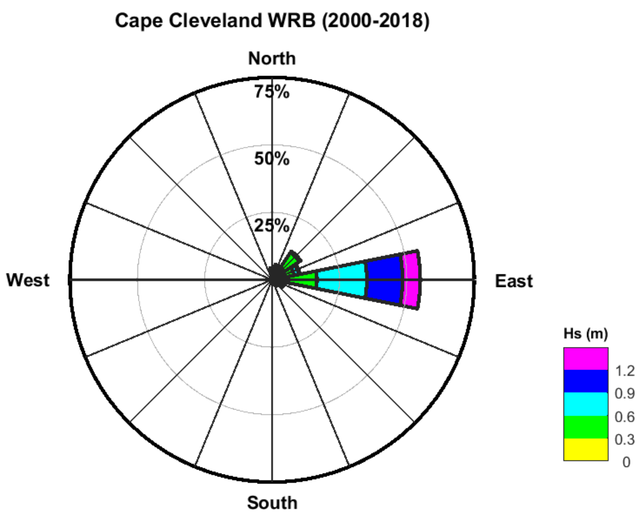

FIGURE 3-10 ANNUAL WAVE ROSE AT CAPE CLEVELAND WRB (2000-2018)

[1] Due to the random nature and size of waves, the term "*significant wave height*" is used by engineers and scientists to quantify wave heights in a sea state. It represents the average of all of the third highest waves that occur over a particular timeframe. It is typically written as Hs. It is important to appreciate that in deep offshore waters the largest individual wave in the sea state may be around twice the significant wave height.

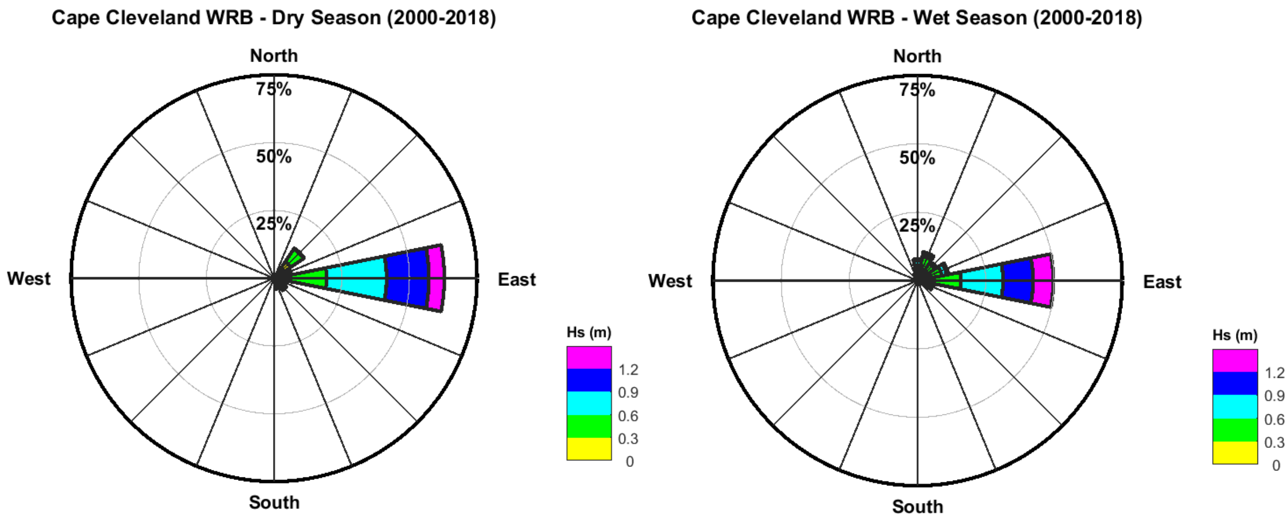

FIGURE 3-11 WAVE ROSES AT CAPE CLEVELAND (2000-2019): DRY SEASON (LEFT), WET SEASON (RIGHT)

The time series of Hs and Tp from the WRB are provided in Figure 3-12. This plot shows that under ambient wave conditions, Hs is generally less than 2 m. However, the area is sporadically affected by tropical cyclone activity which can generate Hs in excess of 5 m. The largest Hs recorded at the buoy was 5.5 m during TC Ului in January 2011. During TC Yasi in February 2011 higher waves than this occurred, but the WRB was damaged during the cyclone and stopped recording prior to its peak. The maximum individual wave height was likely to have been of the order of 10 m, with Hs value likely to be around 6 m.

Figure 3-13 also depicts the joint occurrence of Hs and Tp. It shows that the majority of waves at the sites are local sea and distant local sea waves with peak wave periods between 2 - 9 secs. It also shows that some longer period swell (Tp > 10s) also reaches the study area but is generally associated with smaller wave heights of Hs < 0.5 m.

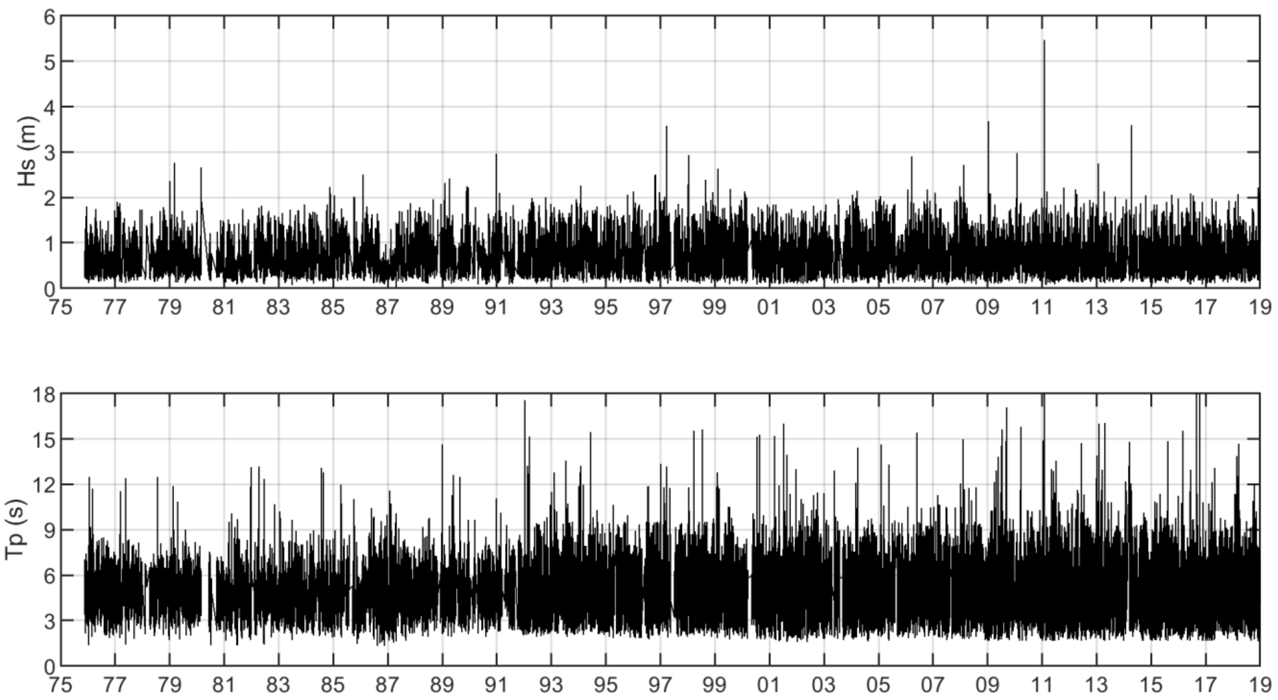

FIGURE 3-12 TIME SERIES OF RECORDED WAVE DATA AT CAPE CLEVELAND WRB: 1975-2019

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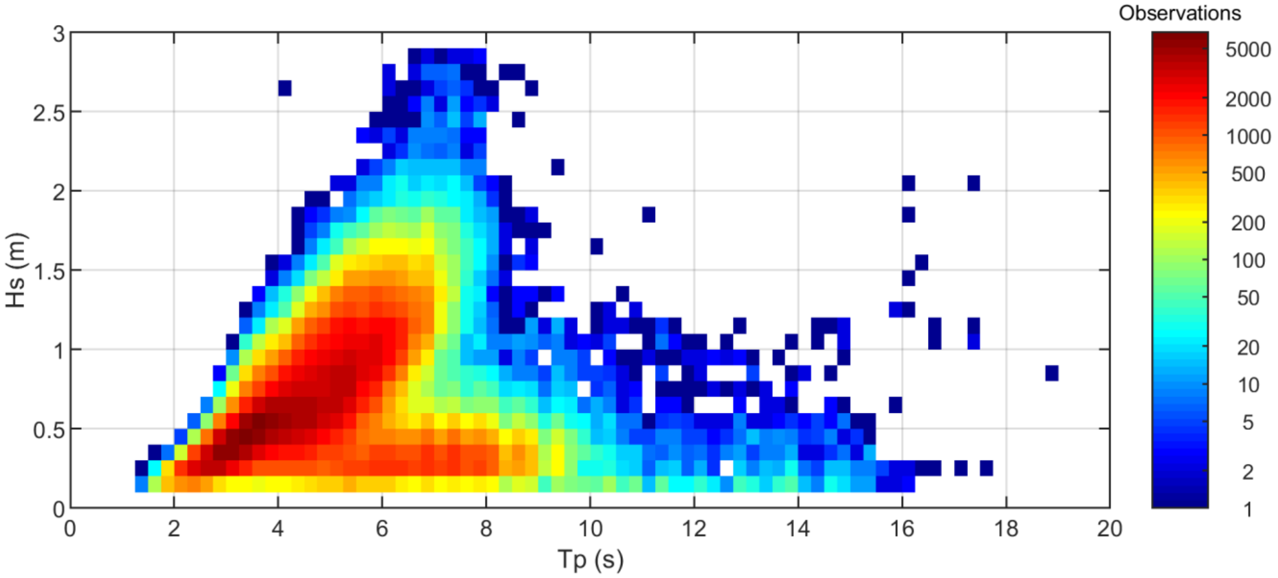

FIGURE 3-13 JOINT OCCURNCE OF HS V TP AT CAPE CLEVELAND WRB: 1975-2019

3.2.6.3 Numerical Wave Modelling

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

This approach has been adopted when preparing this Shoreline Erosion Management Plan - so as to obtain an understanding of waves and potential wave-induced sand transport when determining appropriate foreshore management strategies.

The MIKE 21 Spectral Wave (SW) proprietary model package was used to determine the wave climate at Horseshoe Bay. The model is based on an unstructured flexible mesh with an extent shown in Figure 3-14. In order to maintain the computational efficiency of the model, mesh resolution is of the order of 4000 m farther afield from the site. However, the mesh resolution in and around Horseshoe Bay was of the order of 60m, which allowed for an accurate replication of the local bathymetry and a detailed description of local wave processes.

In order to have confidence in the wave model results, a robust model calibration was undertaken whereby the model results were compared with measurements from the Queensland Government's Waverider buoy (WRB) located offshore of Cape Cleveland. Model Calibration consisted of fine-tuning SW module parameters so that a good match was produced between the simulated and the measured waves at this location. An example of the comparison of modelled and measured waves are presented in Figure 3-15 for a nominal period in the recorded wave history that contains both ambient and storm-related (more energetic) wave conditions. Results are presented in terms of both maximum wave height (Hmax) and significant wave height (Hs). The results demonstrate that the model shows good agreement with the recorded wave data.

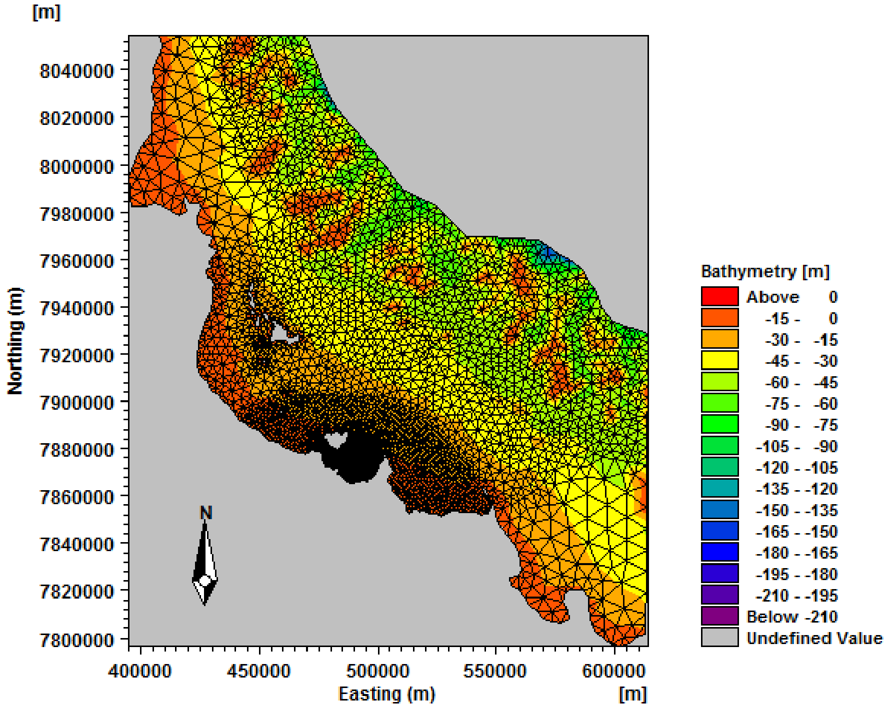

FIGURE 3-14 MIKE21 SPECTRAL WAVE MODEL DOMAIN

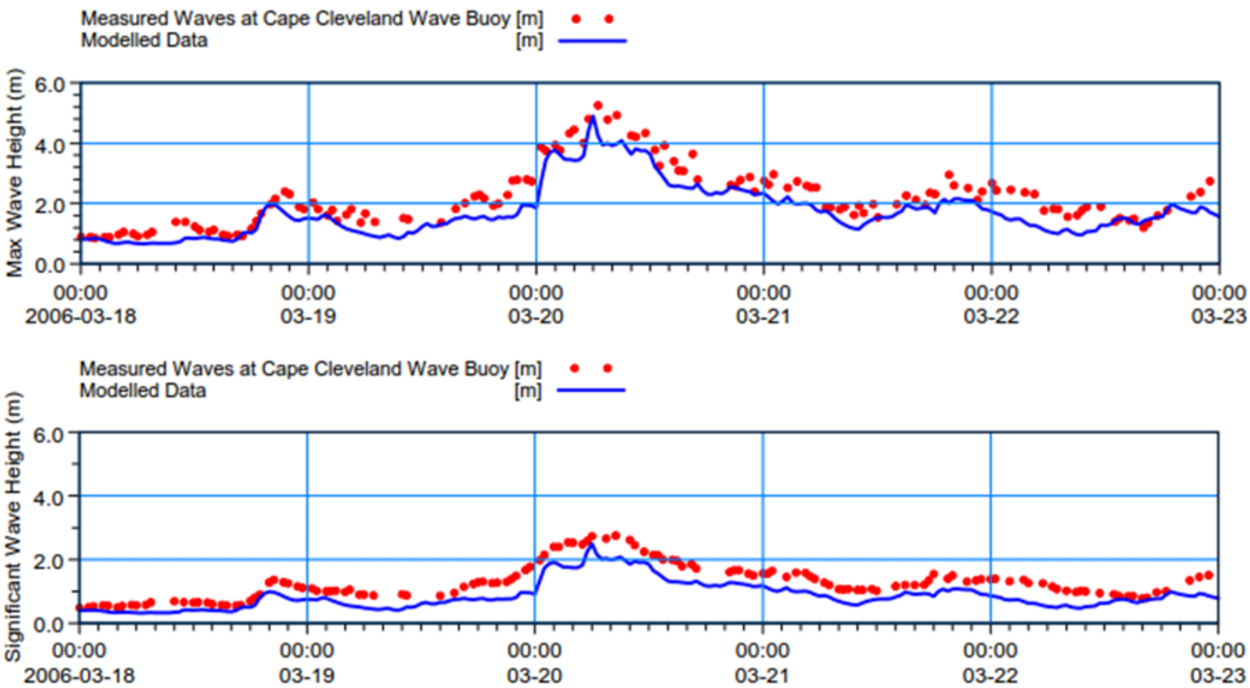

FIGURE 3-15 COMPARISON OF MEASURED AND MODELLED WAVES AT CAPE CLEVELAND

Once the model calibration was completed, wave hindcast modelling was undertaken at the study area – in order to convert the 20 years of (directional) historical wind records over the study area into an equivalent set of modelled nearshore wave conditions. The outcomes of the wave hindcast provides a time series of wave height, period and direction at hourly intervals for the 20 years hindcast period.

The design wave conditions for multiple annual exceedance probabilities (AEP's) within Horseshoe Bay were calculated using the 21 year wave hindcast results. The data was extracted offshore within a central location inside the bay at the -5m LAT depth contour. A number of probability distributions were tested against the offshore significant wave height data. The probability distributions that were investigated are as follows: General extreme value (GEV), Gumbel, Log Normal, Log Pearson III, Weibull and Generalised Pareto. The Weibull distribution showed the greatest data fit and was adopted for the analysis. Analysis of the wave period was also completed to determine the period which is associated with the largest observed significant wave heights. From the analysis described above, the characteristic offshore wave heights and periods were determined. These can be seen below in Table 3-8.

TABLE 3-8 WAVE CLIMATE STATISTICS IN HORSESHOE BAY

Wave Condition	Hs (m)	Associated Tp (s)
50th Percentile (Median)	0.4	Variable (local & distant seas)
90th Percentile	0.6	
99th Percentile	1.2	5.4
63% AEP (1 year ARI)	2.0	6.6
9.5% AEP (10 years ARI)	3.1	8.4
5% AEP (20 years ARI)	3.5	8.9
2% AEP (50 years ARI)	4.0	9.6
1% AEP (100 years ARI)	4.3	10.0
0.5% AEP (200 years ARI)	4.7	10.5

3.2.7 Longshore Sediment Transport

This is the movement of sand along the beach and occurs predominantly within the surf zone. It determines in large part whether shorelines erode, accrete or remain stable. Consequently an understanding of longshore sand transport is essential to sound coastal management practice.

Waves arriving with their crests at an angle to the plan alignment of the shoreline create an alongshore current which initiates and maintains sand transport along the beach. The angle at which the incoming waves act on the beach face may only be very small (as may be the waves themselves), nevertheless their continual and relentless action is sufficient to account for notable volumes of sand to be moved annually on local shorelines.

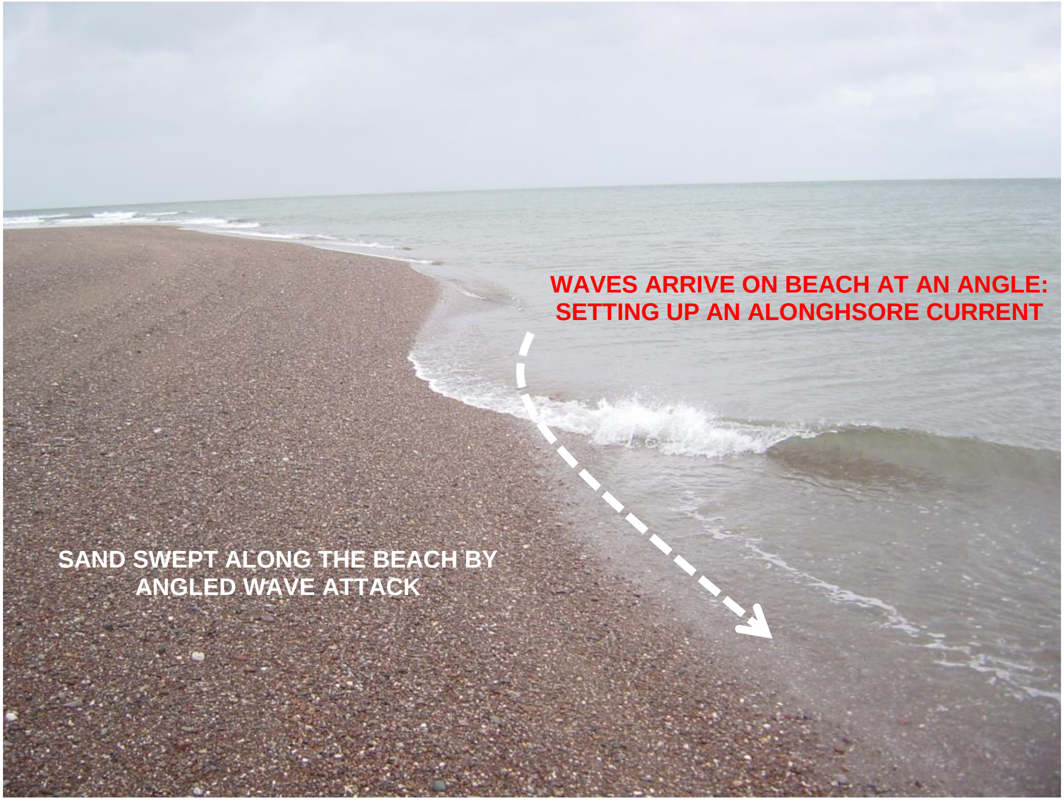

FIGURE 3-16 LONGSHORE SEDIMENT TRANSPORT (SOURCE: CES, 2010)

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

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

As previously discussed in this report, Horseshoe Bay is contained within protruding rocky headlands that likely form a closed littoral cell. The net volume of sand in the system should remain more or less constant over time, with the embayment as a whole considered relatively stable in the timeframes associated with this SEMP. However, localised erosion and accretion have been observed at certain locations within the embayment, and this means that there is currently an imbalance in the sand supply at the eastern end of the embayment.

The longshore sediment transport regime at Horseshoe Bay Beach has been assessed by investigating the energy of the local wave climate and the direction of wave approach relative to the beach. Quantification of annual longshore transport rates have been undertaken using several longshore sediment transport models and formulae used by coastal engineers and scientists. The directional wave climate along Horseshoe Bay is established by the comprehensive spectral wave modelling (as discussed in Section 3.2.6.3).This has been used to investigate the longshore sediment transport regime over the 20-year period from 1999 to 2019.

The energy weighted mean wave direction (EWMWD) within Horseshoe Bay is shown summarised below in Figure 3-17. The wave breaking processes is captured within the plot showcased by the reduction in vectors length (wave energy) as they move towards the shoreline. In conjunction with losing energy whilst entering the bay, the waves also interact with the sea floor and refract (move towards shallower water). This is observed significantly within the south eastern corner of the bay, where the wave energy refracts towards the east (i.e. more perpendicular to shore). Since the vectors align with the shoreline at a relatively perpendicular angle, it can be inferred that there is only a small amount of longshore transport occurring within the bay.

It is pertinent to note that sediment transport rates in any one year may differ from the average rate as a consequence of seasonal, annual and decadal variations of prevailing climatic conditions.

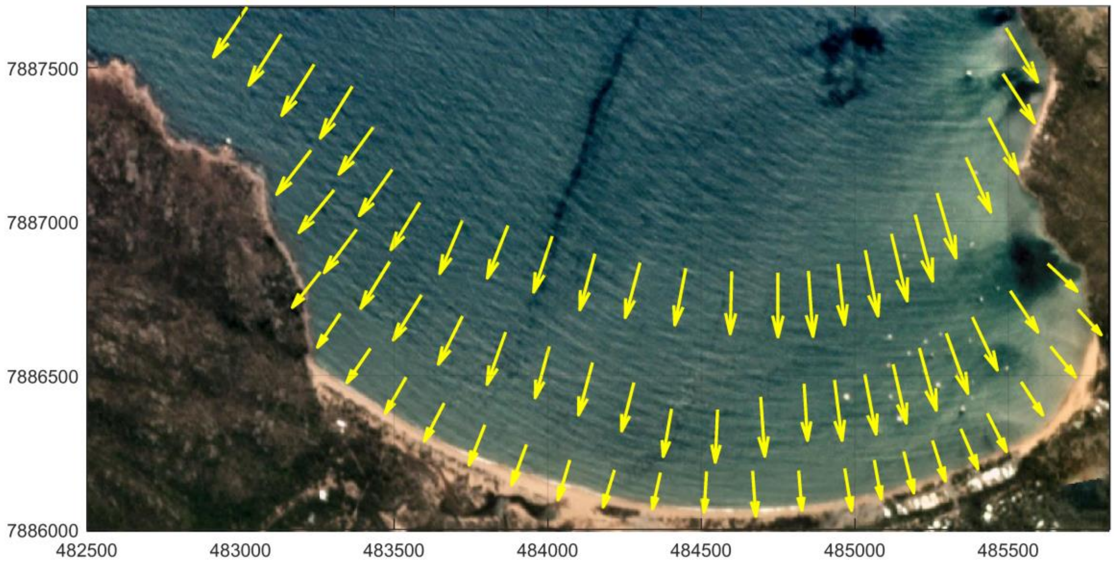

FIGURE 3-17 AVERGAGE WAVE ENERGY VECTORS (1996-2018)

The impact of seasonality on the wave climate and sediment transport mechanisms have also been investigated by filtering the data to isolate the months of the dry season (May-August) and wet season (December to March). To identify the differences between these two seasons, the EWMWD have again been plotted within Figure 3-18. The plot shows that the overall shoreline wave energy within eastern corner of the bay is low, with some minor seasonal variability. The eastern end of the bay is essentially sheltered from the easterly sector waves all year round, and so the slight seasonal changes in the prevalence of the northerly and westerly winds and waves are likely to have the biggest impact on wave directions (and sediment transport direction) at this end of the beach.

Figure 3-18 shows that during the dry season, wave energy arrives from a direction that is slightly more west of north. This seasonal variability is likely due to the slightly more pronounced effect of westerly, offshore land/sea breeze that occurs during the dry season - see Figure 3-9. During the wet season, the dominance of northerly winds and waves bring the EWMWD back to a direction closer to north.

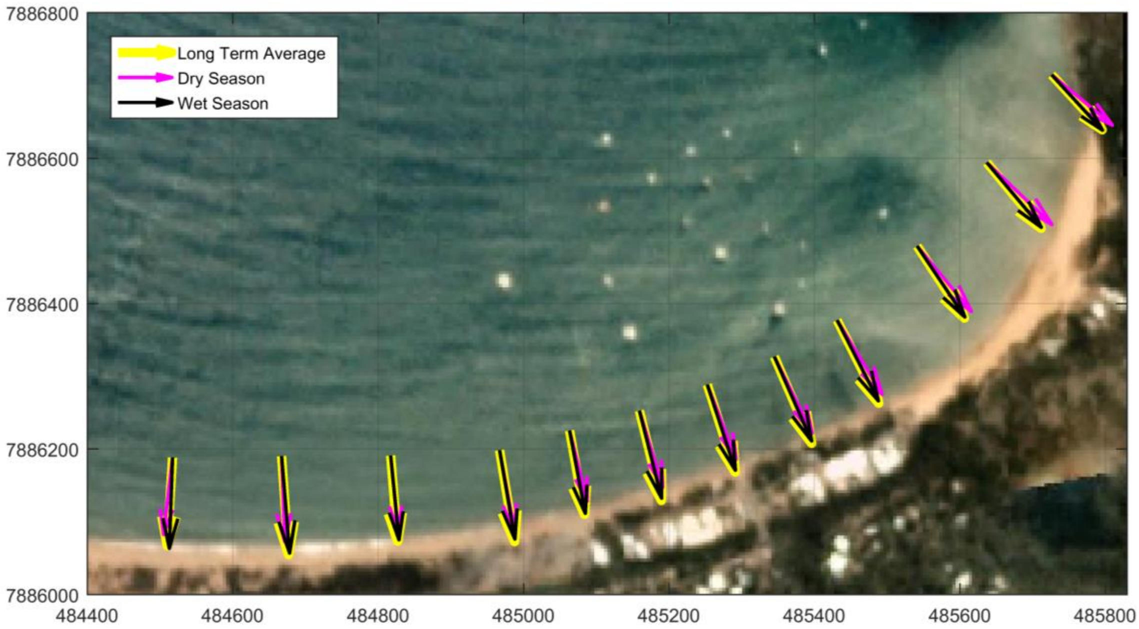

FIGURE 3-18 AVERGAGE WAVE ENERGY – WET SEASON, DRY SEASON AND OVERALL

As well as seasonal changes in the wave climate, larger scale climate patterns may also impact the wave climate at the site, including the ENSO cycle within the Pacific Ocean. The impact of the El Nino and La Nina weather patterns have been investigated by filtering the complete data set using the Southern Oscillation Index (SOI), into the following categories:

- El Nino Periods – Where SOI less than -8.
- La Nina Periods – Where SOI is greater than +8.
- Neutral Periods – Where SOI is between +4 and -4.

The associated mean wave direction for El Nino, La Nina and Neutral periods are presented below within the vector plot in Figure 3-19. This plot shows, that during the ENSO cycle has only a very limited effect on La Niña Periods, waves may approach the beach from a slightly more westerly direction, and this can be attributed to the higher prevalence for storminess and tropical cyclones during La Niña, which cause more frequent deviations wind and wave direction from the background south-east trades. During El Niño periods, waves may approach the beach from a direction that is more northerly, or slightly east of north.

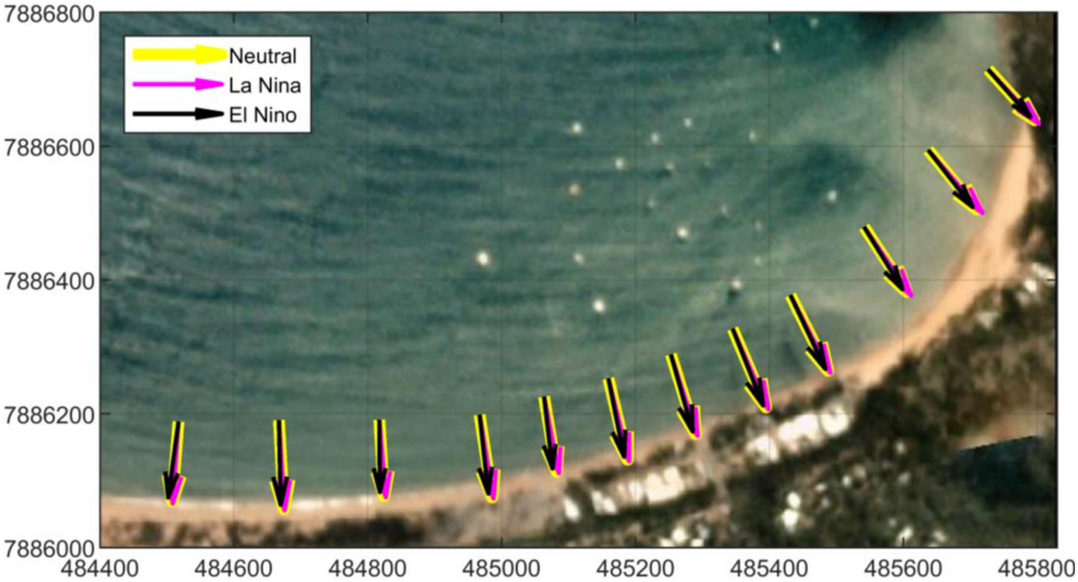

FIGURE 3-19 AVERGAGE WAVE ENERGY VECTORS – EL NINO, LA NINA AND NEUTRAL

These variabilities in wave energy and direction affects the longshore sediment transport that is observed within Horseshoe Bay. As detailed earlier, when waves approach the shoreline at any angle that is not perpendicular to shore, longshore sediment transport can be initiated. The more oblique the wave angle is to the shoreline the greater is the rate of longshore transport. In order to determine the longshore transport within Horseshoe Bay, the Kamphuis (1991) longshore sediment transport model has been utilised and is presented below:

$$Q_k = 6.4 \times 10^4 \, H_s^4 \, T_p^{1.5} \, m_b^{0.75} \, D^{-0.25} \, sin^{0.6}(2\alpha_b) \qquad (m^3/year)$$

H_s = Significant Wave Height

T_p = Peak Wave Period

m_b = Bed slope

D = Sediment Grain Size

α_b = The angle of wave approach relative to the shoreline

This expression was used to estimate the longshore sediment transport on a timestep-by-timestep basis – based on the numerical wave modelling results. This has been used to investigate the longshore sediment transport regime over the 20-year period from 1999 to 2019. These results are intended to provide an indicative assessment, and are likely to be somewhat conservative in nature.

It should be noted that longshore sediment transport modelling using more sophisticated proprietary computer programs such as LITPACK and the MIKE21 ST model packages were considered. However, given the overall low magnitude of alongshore transport at the study area, an approach adopting the empirical equations above is considered appropriate for the purposes of an order of magnitude assessment.

On all exposed coastlines, there will be periods where sea conditions result in longshore sand transport in one direction, and then at other times there can be a reversal and sand transport will be in the other direction. Normally, if the overall transport in one direction is (more-or-less) cancelled out by the other then the beach is considered to be in equilibrium. However, this is not the case at the eastern end of Horseshoe Bay. At this location, once the sediment has been moved east towards the corner of the bay, there is no natural mechanism by which it can return. This creates an imbalance in the sand supply at the eastern end of the embayment.

The resultant longshore sediment transport rates modelled at the beach in front of The Esplanade are presented below within Table 3-9. These longshore transport rates are significantly lower than that of an open coastline (not-embayed) location. As expected, the rates are low due to both the relatively low wave energy experienced at the site, and the fact that most waves approach from a relatively shore-normal direction.

Results show that on average, around 1,200 m^3 of sand is transported eastwards from the Esplanade Beach into the corner of the bay. As a form of indirect validation, Council's existing management approach of sand scraping delivers around 2,000 m^3 to 4,000 m^3 of sand per year to The Esplanade beach from the eastern sand spit in order to maintain desired beach volume for amenity. However, not all of the 2,000 m^3 - 4,000 m^3 each year would be lost due to longshore transport, since other mechanisms (such as offshore transport, wind-blown transport) would also contribute. The results also show an average annual transport rate of 800 m^3 to the west. As previously discussed, this is a theoretical rate, and unlikely to be fully realised, as the sediment supply from locations farther east lack a sufficient transport mechanism.

In terms of seasonal variation, Table 3-9 shows that alongshore transport drops off considerably during the dry season months (May to August), since offshore wave energy generally decreases. Furthermore, offshore waves generally approach from the south to south-east sectors during this time – which is a wave direction from which Horseshoe Bay is sheltered. During the Wet Season, the longshore transport rates increase with the increased wave energy and high proportion of summer northerly winds and waves.

TABLE 3-9 NET LONGSHORE SEDIMENT TRANSPORT WITHIN THE VICINITY OF THE ESPLANADE

Period	Approx. Yearly *Eastwards* Transport Rate (m^3/yr)	Approx. Yearly *Westwards* Transport Rate (m^3/yr)
Long Term Average	1,200	800
Dry Season (May to Aug)	150	300
Wet Season (Dec to Mar)	2,000	1,300

3.2.8 Cross-shore Sediment Transport

This is the movement of sand perpendicular to the beach – in other words, onshore/offshore movement. Whilst this washing of sand up and down the beach profile occurs during ambient conditions (i.e. 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 since sand is removed from the dunes and upper regions of the profile. If the storm or cyclone is particularly severe, the erosion may threaten or damage foreshore infrastructure. The eroded sand is moved offshore during the storm to create a sand bank near the seaward edge of the surf zone. Subsequent milder wave conditions 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.

FIGURE 3-20 CROSS-SHORE SEDIMENT TRANSPORT (SOURCE: CES, 2010)

Technical work undertaken for this Shoreline Erosion Management Plan included application of the SBEACH proprietary mathematical model to predict the response of the beach profile to cyclonic conditions. The 1% AEP storm conditions at the Horseshoe Bay shoreline within the vicinity of the Esplanade. The fundamental approach to this beach response modelling has been to:

- utilise the 1% AEP result of the wave hindcast modelling presented in Table 3-8 as the input for the wave conditions into the SBEACH model.
- utilise 1% AEP storm tide level for extreme events which has been previously determined by modelling of storm tides in the Townsville region (GHD, 2017) as water level (time-varying tide) inputs for the SBEACH model;
- utilise a beach profile transect for Horseshoe Bay extracted from 2016 LiDAR for the land component and the model bathymetry ~~for~~ the bathymetric component.
- utilise the median grain sizes derived from the sediment sampling testing to undertake sensitivity testing of erosion width to the sediment grain size.
- run the SBEACH model to assess the 100 years ARI horizontal erosion width for the Horseshoe Bay foreshore.

Results of the SBEACH modelling are presented bellow within Table 3-10 and shows that the sediment grain size does influence the degree of erosion experienced during a design storm event. However, the results are of a similar order of magnitude for each simulation.

Generally, a 1% AEP storm event is likely to remove around 20 m^3 per metre length of beach, causing shoreline recession of approximately 20 metres. This would result in an erosion zone extending back to around Pacific Drive (with the Esplanade Park largely eroded), as depicted in Figure 3-22.

TABLE 3-10 100YR ARI SHORT TERM EROSION DISTANCE – SBEACH RESULTS

Simulation Grain Size	Erosion Volume (m^3/m)	Beach Recession (m)
0.5mm (Sample A)	16	18
0.3mm (Sample B)	20	22

This erosion does not include any overland flow or local stormwater scour due to rainfall, which would likely exacerbate the erosion values determined above (which are due to waves and storm tide only).

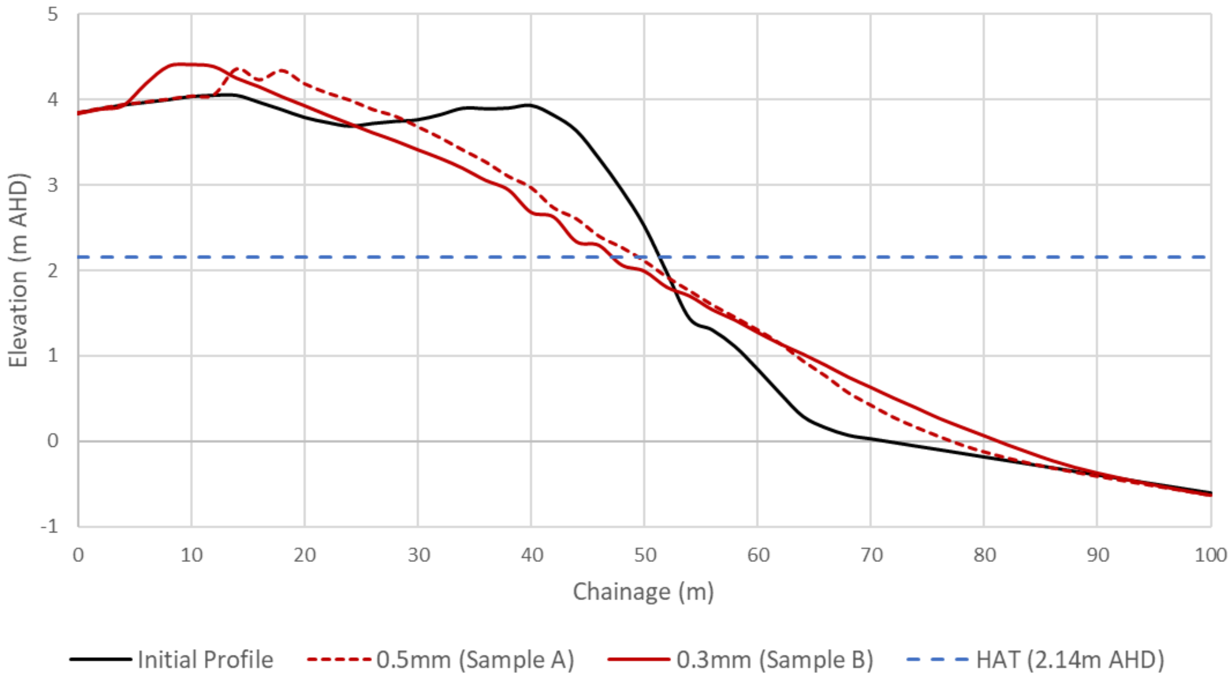

FIGURE 3-21 SBEACH MODELLED EROSION

The estimated 1% AEP erosion does not directly impact any of the buildings located on the southern side of Pacific Drive. The erosion buffer between the buildings and the estimated eroded area increases from roughly 12m at the eastern end of Pacific Drive to roughly 18m in the western section of Pacific Drive under the modelled erosion scenario.

As erosion encroaches onto the road, it is likely that the rate of erosion could reduce due to the influence of the hard surface. The SBEACH model assumes a totally sandy profile and does not take into consideration any binding effects that may be associated with the bitumen. As such the modelled erosion distances can be considered as slightly conservative.

It should be noted that during rarer or more severe storms (greater than 1% AEP), there may be considerable overwash of the Esplanade 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 the 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. There can be devastating consequences to foreshore areas during overwash since the foreshore is not only inundated by storm surge, but destructive cyclonic waves can wash over the dunes and penetrate inland.

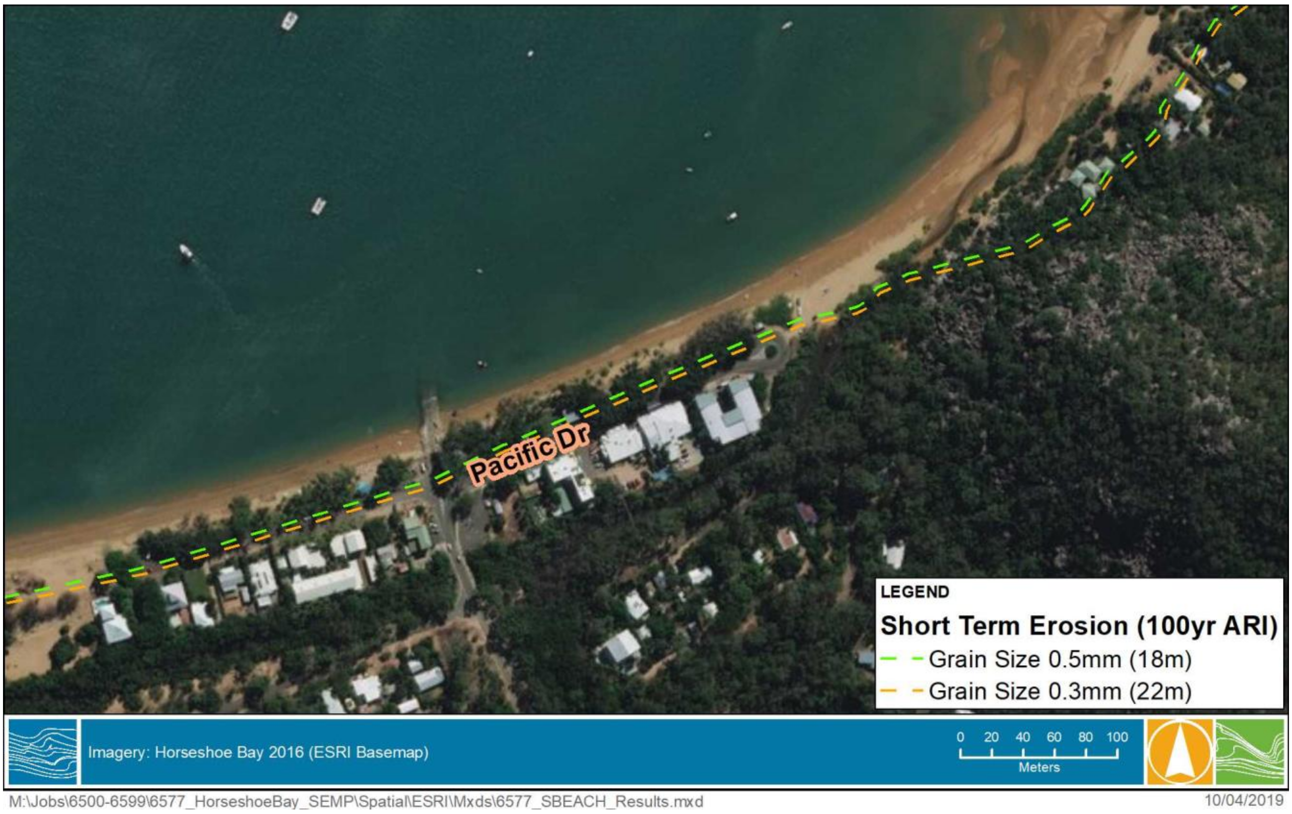

FIGURE 3-22 100 YEAR ARI STORM EROSION DISTANCES

3.2.9 Local Estuary Processes

The local morphological processes are also affected by the presence of two ephemeral creeks situated at either end of the developed foreshore - Endeavour Creek in the centre of the bay and Beeran Creek at the far eastern end. These creeks oscillate in an intermittent fashion between being open to the ocean via a shallow entrance channel, and being closed off via the formation of a beach berm.

The condition of the entrance (open or closed) is determined by the balance of catchment and coastal processes. The action of coastal processes (waves and tides) will naturally act to close the creeks entrances by depositing local beach sediments in the creek entrance (sediments that become suspended in the nearby surf zone). Conversely, during rainfall events creek outflows will act to scour out the sediments from the creek entrance and deposit them as a lobe of sand further offshore in the nearshore area. Therefore, the entrance condition of the creeks tends to vary seasonally on a wet season (entrance open) and dry season (entrance closed) basis.

This process has a seasonal impact on the in-situ volume of beach sands at the study area foreshore. During the wet season when the entrances to Beeran and Endeavour Creeks are open, they slowly fill with sediments from the nearshore zone, acting as a temporary sink for the local sediment transport processes and disrupting the local longshore transport regime. This temporary loss of sediments typically results in an equivalent temporary shoreline recession downdrift of the entrance. This process is further exacerbated by the increased rate of longshore transport that occurs during the wet season owing to the more energetic wave activity.

During the dry season sand migrates from the near shore lobes back onto the beach. With the entrances to the creeks closed, this sand is then redistributed along Horseshoe Bay Beach by wave action – leading to a temporary accretion of the beach. This migration of sand has the greatest impact on beaches near the outlets

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of Endeavour and Beeran Creeks. This process is particularly important for the main beach area in front of Pacific Drive (Aurecon, 2015).

3.2.10 Implications to Erosion Buffers

As well as offering considerable environmental and social benefits, the sandy foreshores of Horseshoe Bay serve as erosion buffers, protecting valuable foreshore infrastructure and property. Preceding sections of this Shoreline Erosion Management Plan provided discussion on the longshore and cross-shore sand transport mechanisms that affect these sand reserves.

It is evident that the cross-shore sand transport processes during severe storms and cyclones can cause rapid depletion of the erosion buffers. To ensure that adequate protection is afforded to foreshore infrastructure, the volumes of sand and the minimum buffer widths required seaward of such infrastructure are summarised in Table 3-10. Maintaining these buffers ensures that foreshore assets are 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 matches the rate at which sand is moved to downdrift foreshores, then local erosion buffers are not adversely affected by longshore transport processes. As was discussed previously, this is not the case for the Horseshoe Bay shoreline since once sand has been transport eastward by local waves, there is no natural mechanism to transport is sand westward back onto the previously depleted foreshore.

Pacific Drive is located some 20 m back from the foredune along the Esplanade. Along the southern side of the road (a further 10 m from the foreshore) sits a row of homes and small businesses. Reference to Table 3-10 indicates that these homes currently have immunity against complete loss by erosion for events up to 1% AEP. This immunity will diminish somewhat over a 20 year planning period due to sea level rise and long term shoreline recession, unless erosion mitigation works are implemented.

3.2.11 Impact of Climate Change

The preceding discussions of sediment transport rates 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 the frequency and intensity of tropical cyclones. If climate changes develop as predicted, the Horseshoe Bay foreshore will be subjected to potentially greater storm and cyclone energy, higher waves, stronger winds and increased water levels.

In its Fifth Assessment Report (AR5) released in 2013 the Intergovernmental Panel on Climate Change (IPCC, 2013) makes projections for global mean sea level rise during the 21st century. AR5. Projections are made for a number of different global greenhouse gas emissions scenarios, known as Representative Concentration Pathways (RCP's). 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. Nonetheless, according to AR5, the thermal expansion of the oceans and glacial melting have been the dominant contributors to 20th century global mean sea level rise, and this pattern is likely to continue to 2100. Because of these complexities, there is a wide range in the predictions of global sea level rise for the coming century. The AR5 projections for mean sea level rise are reproduced in Figure 3-23. It predicts MSLR within the range of 0.3 to 0.95 m by 2100 (relative to 1986-2005 MSL).

The National Climate Change Research Facility (NCCARF) makes more localised projections of MSLR around Australia, based on IPCC modelling. The MSLR projections for Townsville are provided in Figure 3-24 and Table 3-11, and show that by 2090, projected MSLR for Townsville under the very high emissions scenario is between 0.44 to 0.87 m, with a best estimate of 0.64 m.

The Queensland Department of Environment and Heritage Protection presently adopts a MSLR projection of 0.8 m above present day levels by 2100. This is consistent with the 5AR (IPCC, 2013) and NCCAF RCP8.5 emission scenario.

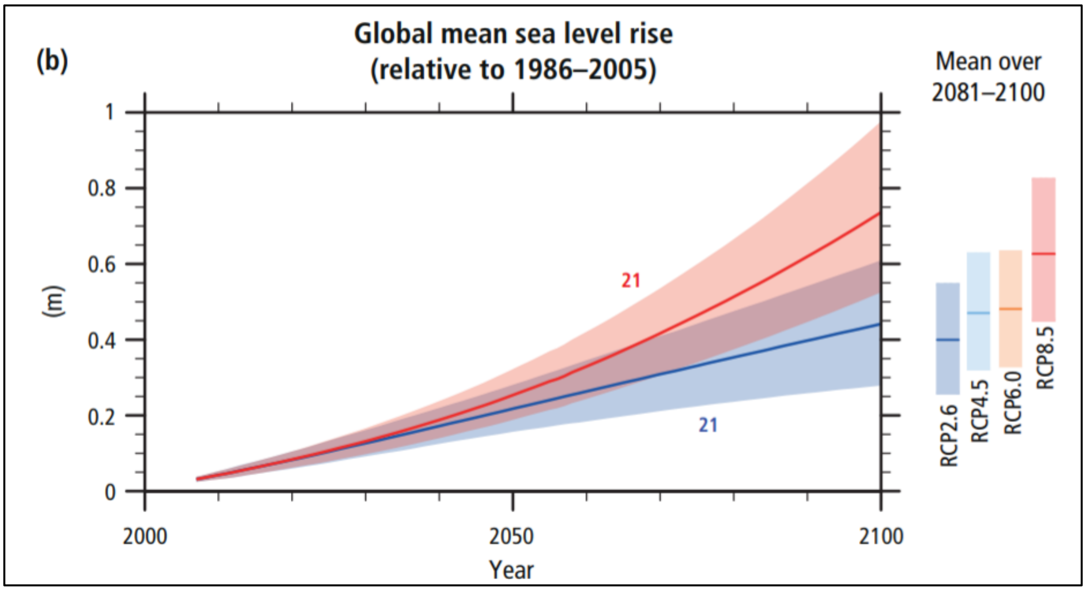

FIGURE 3-23 IPCC (2013) GLOBAL SEA LEVEL RISE PROJECTIONS

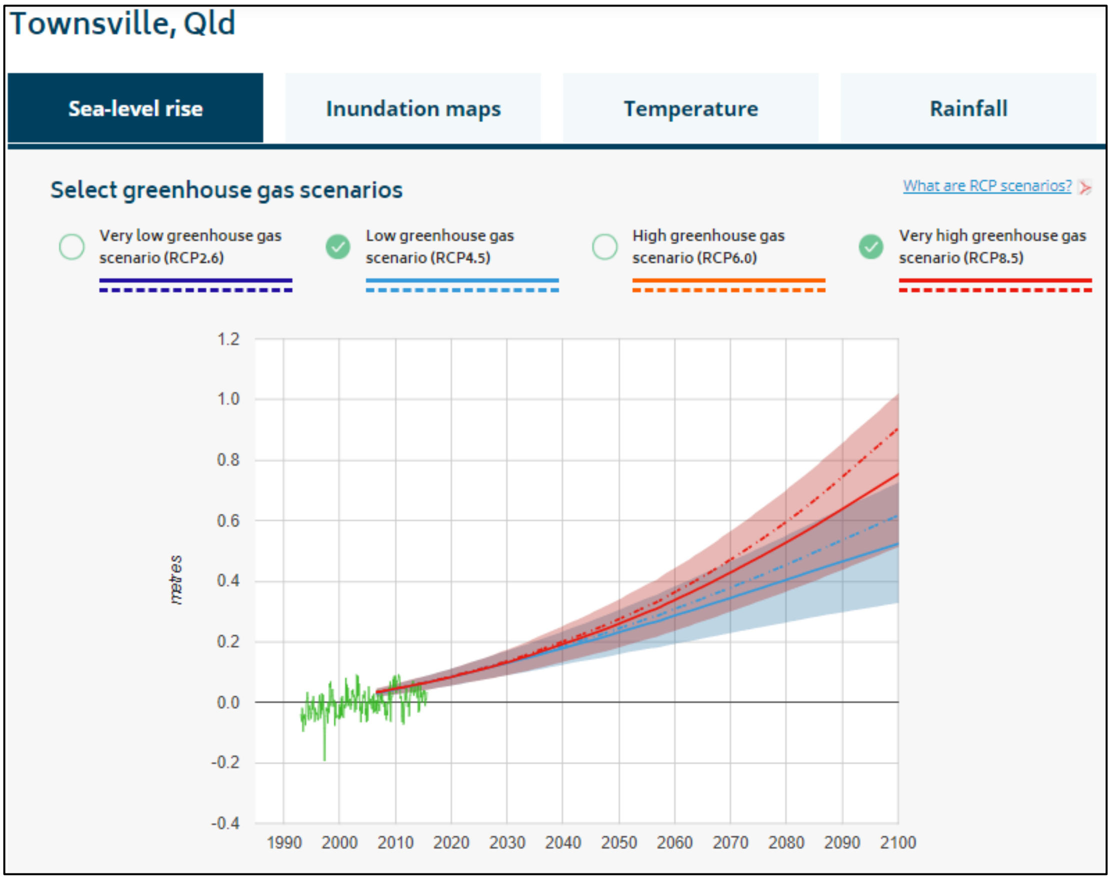

FIGURE 3-24 NCCARF (2018) TOWNSVILLE SEA LEVEL RISE PROJECTIONS

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TABLE 3-11 TOWNSVILLE MEA SEA LEVEL RISE PROJECTIONS (IN M), RELATIVE TO THE 1986:2005 AVERAGE

Date	Very Low Emissions (RCP2.6)	Low Emissions (RCP4.5)	High Emissions (RCP6.0)	Very High Emissions (RCP8.5)
2030	0.13 (0.09-0.17)	0.13 (0.09-0.17)	0.12 (0.08-0.17)	0.13 (0.09-0.18)
2050	0.22 (0.14-0.29)	0.23 (0.16-0.31)	0.22 (0.15-0.29)	0.26 (0.18-0.35)
2070	0.30 (0.19-0.42)	0.35 (0.23-0.47)	0.34 (0.23-0.45)	0.43 (0.30-0.57)
2090	0.39 (0.23-0.55)	0.47 (0.30-0.65)	0.48 (0.31-0.65)	0.64 (0.44-0.87)

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.

To accommodate any such adverse impacts on future coastal processes when compiling this Shoreline Erosion Management Plan, the effects of a 10% increase in offshore wave heights and a 5% increase in offshore wave periods have been incorporated - along with a 0.8 m sea level rise. This increase in wave characteristics equates very approximately to a 10% increase in the intensity of cyclones for any given AEP.

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

Nevertheless, there will be a gradual recession of the position of the shoreline, which will effectively reduce sand buffers in front of existing foreshore infrastructure. The seabed on the wave approaches through across the Horseshoe Bay reef flat 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 already low rates of longshore transport within Horseshoe Bay, it is unlikely that any significant changes to longshore transport will be realised.

Climate change influences can potentially increase the cross-shore transport rates associated with cyclones. To asses this, the erosion and recessions along the project foreshore resulting from predicted climate change for this section of coast has again been modelled using the SBEACH shoreline response model. This was undertaken by updating the model to incorporate sea level rise of 0.8m. The results showed that the shoreline response is again estimated to be roughly 20 m of recession and an erosion volume of around 20 m^3 for the 1% AEP storm event. It is thought that the sea level rise and present results are similar due to the limiting effect of the low height of the frontal dune. Which is overtopped under both present day and future sea level rise scenarios.

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

3.3 Overland Flow and Stormwater Processes

In the natural environment rainfall runoff directly enters the ocean via rivers, creeks, lakes and lagoons that can be intermittently open or closed. It can also indirectly find its way to the ocean as a dispersed groundwater flow through beaches and dunes (Gordon, 2011). When development takes place adjacent to the beach, these natural drainage systems can be disrupted. Therefore, a common problem facing coastal councils is that of stormwater from building development, roads, car parks and parkland immediately behind the beach causing scouring of the foreshore.

Often, this is captured in drainage systems and piped directly onto the beach. Although the total flow through such systems can be relatively small, the instantaneous discharge rates can be high, particularly in areas that are prone to intense rainfall (such as that from tropical storms and cyclones). As a result, stormwater discharged through such outlets and onto the beach can generate significant localised erosion and scour. The result is typically the generation of erosion channels through the beach berm and across the beach into the ocean. This increased erosion can have a double effect whereby the outfall erosion allows waves to penetrate to the back of the beach, further exacerbating the erosion.

Additionally, rainfall that would have previously found its way into the groundwater system by infiltration can be intercepted by non-porous hard surfaces behind the beach, and generate a sheet flow as this water flows down the dune and across the beach face out to sea. This flow may also generate localised erosion as sheet erosion gives way to erosion along small channels.

In a more typical dune and swale beach system, such rainfall runoff is naturally directed to flow across ground into shallow grassed depressions, such as the swale behind the dune (see Figure 3-25). These swales may “flood” during heavy rainfall, but quickly drain to the aquifer in the dune soon after the rainfall event.

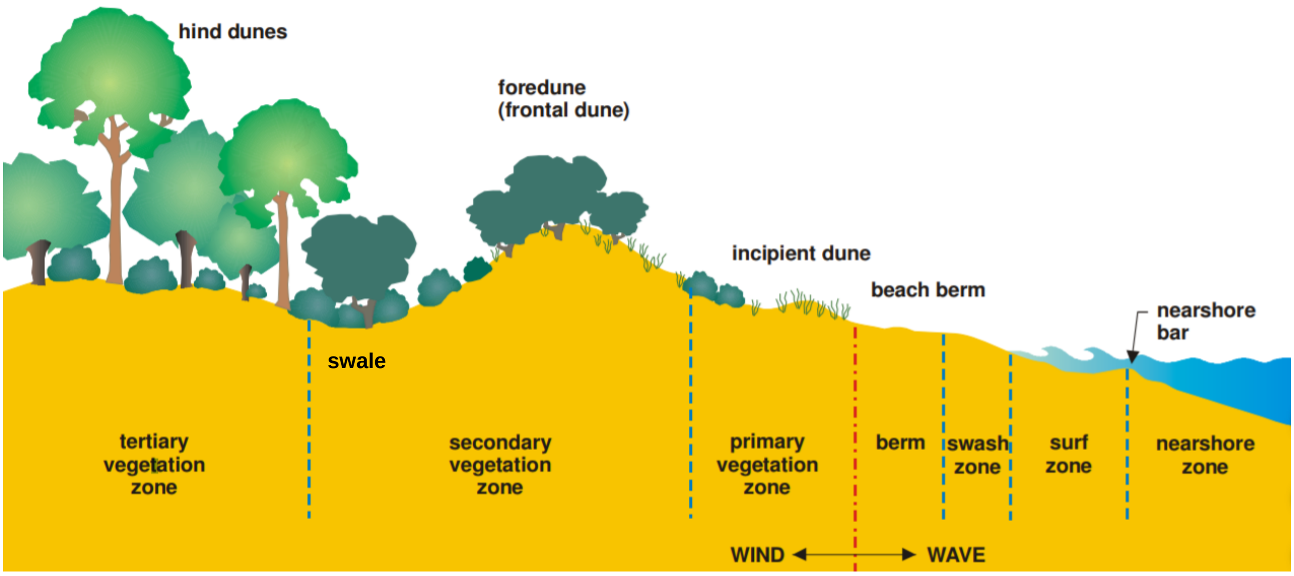

FIGURE 3-25 TYPICAL FORESHORE DUNE AND SWALE FORMATION (SOURCE DECCW, 2010)

However, the Esplanade Park behind the beach at Horseshoe Bay is relatively flat, with a slight grade down to the beach with no significant beach swale or ridge formations (see Figure 3-26). This has historically presented a problem for coastal erosion arising from overland flow and back beach stormwater discharge. This means that the beach has a reduced resilience to overland flooding. This condition, combined with the lack of sufficient coastal vegetation, and highly trafficked uncontrolled pedestrian access over the top of the beach, has contributed to overland flow and beach erosion issues at the site.

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FIGURE 3-26 ESPLANADE PARK (WITH SPARSE VEGETATION AND SLOPING DOWN TO THE BEACH)

An example of this erosion is provided in Figure 3-27, which depicts the aftermath of a February 2018 rainfall event. During this event, overland flow across the Esplanade park resulted in the formation of small channels directed across the beach that generated significant localised erosion and scour.

FIGURE 3-27 STORMWATER RUNOFF AND EROSION DURING FEBRUARY 2018

This event also generated localised erosion around the stormwater outfalls located at the western end of Pacific Drive – at the end of the Esplanade. This is depicted in Figure 3-28.

FIGURE 3-28 STORMWATER OUTFALL DISCHARGE AND EROSION DURING FEBRUARY 2018

Once eroded from the beach, this material is deposited in the nearshore zone, and then shifted by the waves and tidal action. Over time, these sediments are delivered back to the beach by wave action. However, as previously discussed, the natural rate of beach accretion at Horseshoe Bay is very slow, and recovery can take years. Therefore, it is common that a number of rainfall events in a single wet season (or across a number of wet seasons) that can consecutively and cumulatively generate this type of erosion before the beach has had sufficient chance to recover.

4 COASTAL HAZARD AND RISK ASSESSMENT

The preceding sections of this Shoreline Erosion Management Plan quantified long-term foreshore recession processes attributed to longshore sand transport processes and episodic storm-induced erosion as a consequence of cyclonic conditions.

However, it is necessary to relate these shoreline responses to the actual hazard this represents - by considering the extent and nature of “at-risk” property and infrastructure.

4.1 Erosion Threat

4.1.1 Designated Erosion Prone Areas

A major focus of coastal risk management is determining the extent of foreshore areas that are vulnerable to both short-term and long-term erosion processes over a specified planning period. In Queensland, the extent of this vulnerable area is delineated through calculation of what is termed the Erosion Prone Area Width (or EPAW). The establishment of Erosion Prone Areas along Queensland’s coastline has been an intrinsic part of the state’s coastal management policy since 1968. The concept is to set aside undeveloped buffer zones along the shoreline, thereby implementing a philosophy that biophysical coastal processes should be accommodated rather than prevented. The most basic form of accommodation is to avoid locating development and vital infrastructure within dynamic coastal areas affected by the natural processes of shoreline erosion and accretion.

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

The procedure adopted in determining the EPAW involves estimating long-term erosion rates, the extent of short-term erosion corresponding to a design storm event (in this case a tropical cyclone) and adopting a specific ‘planning period’. The planning period affects the width of the long-term erosion component, which is usually based on assessed annual erosion rates. It also influences the calculated short-term erosion width, because the selection of the extreme event used to calculate storm erosion is based on the probability of its occurrence over the specified period.

The current Horseshoe Bay EPAW, as defined by Queensland’s Department of Environment and Science (DES) and AECOM (2018), has been set for the study area, and is presented in Appendix C. The designated EPAW along the Horseshoe Bay foreshore varies but is generally around 125 m, measured landward from the seaward toe of the frontal dune. This EPAW was determined during the preparation of the Townsville Coastal Hazard Adaptation Strategy and has not been recalculated for this SEMP.

The EPAW considers the possible extent of short-term and long-term erosion processes (as well as the implications of future climate change) over the development planning period. It is calculated using the following formula, as required by DES guidelines:

$$\boldsymbol{E} = [(\boldsymbol{N} \times \boldsymbol{R}) + \boldsymbol{C} + \boldsymbol{S}] \times (\boldsymbol{1} + \boldsymbol{F}) + \boldsymbol{D} \qquad \text{Equation 4.1}$$

Where:

E = erosion prone area width (metres)

N = planning period (years)

R = rate of underlying long-term erosion (metres per year)

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C = short-term erosion from the design storm event (metres)

S = erosion due to sea level rise over the planning period (metres)

F = factor of safety (0.4 is applied)

D = dune scarp component to allow for slumping of the erosion scarp (metres).

An outline of each of these components within the Horseshoe Bay region is detailed within the following sections.

4.1.2 Planning Period

The EPAW varies directly with the duration of the planning period. There are no definitive or stipulated methods of determining the ideal duration of the planning period. However, a number of issues need to be considered.

If the planning period is too short, any underlying long-term erosion may quickly erode the buffer zone and direct action will be required to counter the erosion threat – hence negating the potential advantages of the planning concept and providing only a short-term postponement of existing problems.

If the planning period is too long, it will result in a buffer zone that is unrealistically large in terms of the public's perception of the magnitude of future erosion and can be inconsistent with the timescale of alternating erosion and accretion trends on local beaches. Furthermore, it may result in an EPAW that is unnecessarily onerous on proposed development in the short to medium terms.

The threat of erosion to most foreshores can be summarised as being a result of:

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

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

The Queensland Department of Environment and Science (DES) has published a guideline to assist local governments in the preparation of shoreline erosion management plans (SEMPs) to proactively plan for erosion management within designated Erosion Prone Areas. That guideline advocates[2] that a SEMP should "*be based on a planning period of up to 20 years*".

The approach adopted for this SEMP is to adopt the maximum 20-year recommended planning horizon when determining appropriate erosion mitigation strategies.

Short-term storm erosion

The selection of a planning period also has an effect on the threat posed by short-term cyclone induced erosion. For example, the likelihood of a 1% AEP (100 year ARI) cyclone occurring in (say) a 50 year planning period is quite different to that for shorter or longer timeframes. Consequently, when determining risk, the implications of a 1% AEP cyclone could be considered unlikely for short planning periods – or alternatively, very likely for longer periods.

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[2] Clause 3.3 of Department of Environment and Science (2018)

Long-term erosion

The long-term erosion component (excluding sea level rise) of the calculation is irregular (that is, not constant) in nature and typically of a decadal scale. For this reason, DEHP (2013) consider the estimated annual rate of long-term erosion is only applied for a 20-year to 50-year period to avoid over-estimation, unless there is clear evidence to the contrary. Whilst some residential developments may have an intended design life of less than 50 years, it is necessary to consider that the use right of the land is permanent and development on the land is commonly maintained and upgraded well beyond its design life.

Future erosion due to climate change

Whilst the planning period (N) of the EPAW equation relates to both the sea level rise and the long-term erosion components, the DEHP Guidelines (DEHP, 2013) stipulate that these need to be treated differently. For the assessment of erosion due to sea level rise – the Queensland State Planning Policy (Natural hazards) requires that a planning period to the year 2100 must be adopted for EPAW calculations. This recognises that the primary issue needing to be addressed is the appropriate location of new urban development, which is permanent development and cannot be relocated. Hence, it requires consideration of 0.8 m of sea level rise by the year 2100.

4.1.3 Long Term Erosion

Shoreline recession is the progressive landward shift of the average long-term position of the coastline. The annual rate of long-term erosion occurring at any individual beach is not constant through time, but rather will vary depending on the period over which the average rate is assessed. Gradual and imperceptible long-term shoreline erosion may occur as the result of an imbalance in the net sediment budget, that is, a gradual, continuing net loss of sand from the beach system due to the local longshore and cross-shore sediment transport. This occurs when more sand is leaving than entering a particular beach compartment. This gradual net loss of sediments may occur because of differential longshore sediment transport rates (see Section 3.2.7), offshore transport processes moving sand to offshore "sinks" from which it does not return (see Section 3.2.8), anthropogenic gains and losses, transport and deposition of littoral drift into estuaries (Section 3.2.9).

The historical rate of long-term shoreline recession at Horseshoe Bay has been calculated based on the historical shoreline mapping undertaken by Aurecon (2015). As part of that study the seaward extent of the vegetated frontal dune was mapped based on aerial imagery from 1952 through to 2013. This mapping has been supplemented with more recent aerial imagery, as per Table 4-1 below.

TABLE 4-1 AERIAL IMAGERY FOR ANAYSIS OF LONG TERM SHORELINE RECESSION

Image Source	Year of Imagery
Aurecon (2015)	1959, 1971, 1976, 1982, 1985, 1992, 2000, 2005, 2009, 2011, 2013
GoogleEarth ©	2018

For each year of imagery, the position of the vegetation line relative to a constant back beach positional datum has been identified for 6 equally spaced shore-normal profiles (running east to west). Results are presented in Figure 4-1. The long-term trend of shoreline movement has been plotted in the form of a low-pass filter, and this shows that the beach at the study area has historically fluctuated between periods of erosion and accretion – with cycles of the order of decades. The following observations are made:

- All profiles exhibited around 5-10 m of shoreline recession between the late-1950’s and mid-to-late 1970’s. It is likely that this recession can be at least partly attributed to the influence of TC Althea which struck the island in December 1971.

- The shoreline exhibited a period of accretion from mid-1970's to mid-1990's, during which the shoreline relocated back to its late-1950's position; and
- The shoreline has experienced recession from the mid-to-late 1990's through to the mid-2010's.

The average annual long-term rate of movement of this position has been calculated through a linear regression analysis. The overall rate of shoreline movement is +0.04 m/yr, which equates to a very minor (gradual) shoreline accretion over a 60-year period.

Figure 4-1 shows that the inter-decadal fluctuation of the shoreline is linked to the El Niño Southern Oscillation (ENSO). The middle pane of that figure provides the yearly average southern oscillation index (measured July to June) and a back calculated 10-year average that demonstrates the longer-term trend in the relative prevalence of El Niño and Lan Nina conditions.

The results show that extended periods of shoreline recession have coincided with conditions that tended more towards La Niña, which generate stronger day-to-day wave energy and more frequent tropical cyclone activity. Conversely, the periods of shoreline accretion have coincided with prolonged periods tending to El Niño, which result in lower wave energy and less frequent cyclone activity. Further to this point, Figure 4-1 also shows a strong correlation with Figure 3-3 which depicts the frequency of tropical cyclones affecting the study area in each decade.

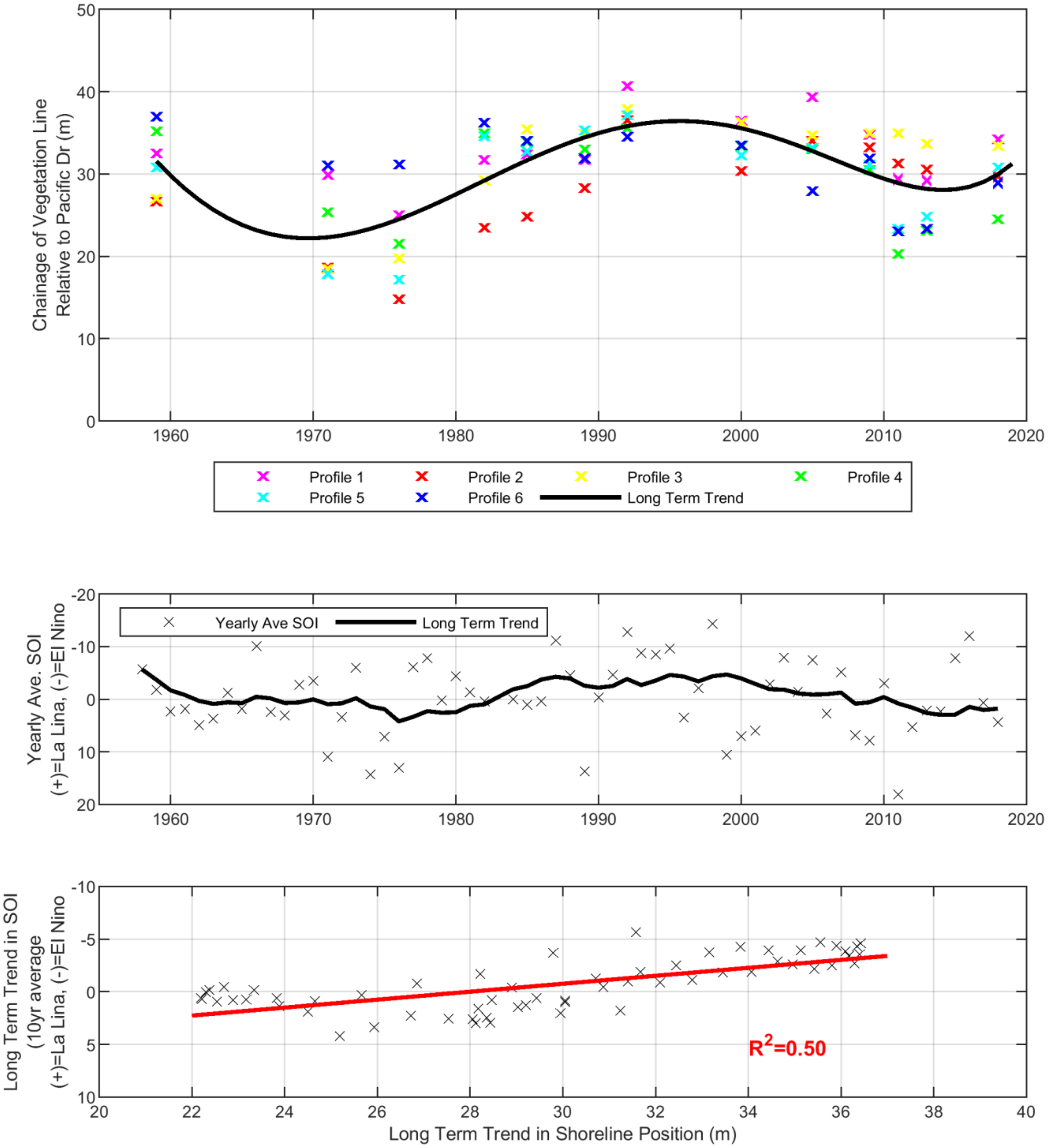

FIGURE 4-1 THE RELATIONSHIP BETWEEN HISTORICAL SHORELINE MOVEMENT AND SOI

Based on this, it can be deduced that much of the historical shoreline movement is related to the medium-term (decadal) frequency of tropical cyclones. During such cyclone events, storm tide and waves remove sand from the beach system and deposit it into offshore bars. Depending on the intensity of the cyclone, this can represent a significant volume of sand.

In typical open coast settings, sands deposited offshore during a storm event are delivered back onshore by long period swell waves over a period of weeks to months. As Horseshoe Bay is protected from this consistent long period swell wave energy, beach recovery takes significantly longer, and can take years or even decades

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to recover naturally. During this recovery time, there is a reasonable likelihood of another cyclone impacting the region, and so the shoreline can recede even further.

It is due to this process that interannual and decadal patters of tropical cyclone frequency (driven by ENSO cycles) influences the long term position of the shoreline at Horseshoe Bay. Of course, such processes act in addition to, and combine with, other land use issues contributing to erosion impacts and poor beach recovery.

4.1.4 Short Term Erosion

Sections 3.2.8 and 3.2.11 provided discussions on short-term storm (tropical cyclone) induced erosion for the 1% AEP storm event. This resulted in predicted shoreline recession distances for the 1% AEP event as shown in Table 3-10.

4.1.5 Future Shoreline Recession due to Sea Level Rise

As discussed previously, the assessment of the rate of long-term erosion (R) is based on the extrapolation of past and present trends, and therefore does not consider the effects of a possible accelerated rate of sea level rise. A progressive rise in sea level may cause shoreline recession through two mechanisms: first by drowning of low lying coastal land, and second, by shoreline readjustment to the new coastal water levels.

There are several models available that relate shoreline retreat to an increase in local sea level. The best known of these is the Bruun Rule (Bruun,1962) which is a popular approach based on the concept that an equilibrium beach profile is maintained during sea level rise, but is translated upward and landward. Higher water levels (and greater nearshore depths) allow larger waves to come closer to shore, resulting in erosion of the upper beach profile as an adjustment to more energetic wave conditions. Sediment removed from the upper beach profile and dune during this process is deposited onto the adjacent nearshore zone, maintaining both the original beach profile and nearshore shallow water conditions - see Figure 4-2.

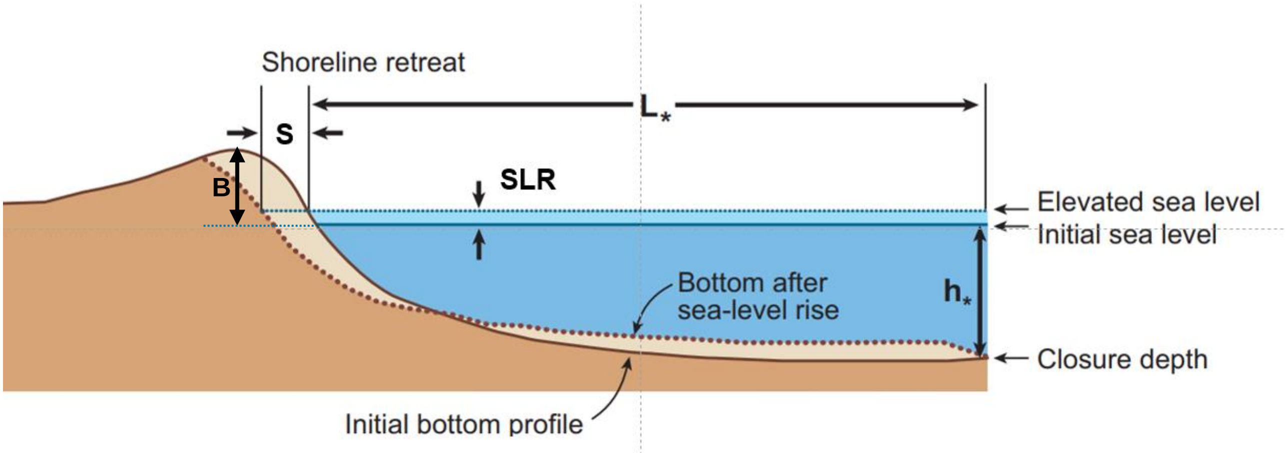

FIGURE 4-2 THE BRUUN RULE (IMAGE SOURCE COOPER AND PIKEY, 2004)

The Bruun rule equation is provided below.

$$S = SLR\frac{L_*}{h_* + B} \qquad \textbf{Equation 4.2}$$

The Bruun rule states that the shoreline recession is related to the "mean beach slope" and vertical sea level rise. The mean beach slope is measured at its seaward extent, which is considered to be at the *depth of*

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closure (a fixed depth below LAT beyond which there is negligible beach profile evolution over a specified time interval). The closure depth can be estimated by the method of Hallermeier (1981):

$$h_* = 1.6\ H_{s,12}$$ **Equation 4.3**

Where $H_{s,12}$ is the significant wave height exceeded for only 12 hours per year, on average.

There are a number of widely discussed limitations to the traditional Bruun Rule approach – and it has been criticised for some of its assumptions. One such criticism is that the rule assumes that all eroded sediment is distributed along the profile in the cross-shore direction, and that there is an overall balanced sediment budget. Furthermore, the rule is also only applicable to sandy open-coast shorelines, is not valid where particular shoreline features are present (Cooper and Pilkey, 2004), such as nearshore rock shelves and underlying rock/clay strata, amongst others. Despite these limitations, the Bruun rule has been considered suitable for application in this SEMP.

The results of the numerical wave modelling undertaken for this assessment showed that $H_{s,12}$ at the study area is approximately 1.8m. Based on this, the closure depth at the study area is around 7.7 m below LAT. This results in a nearshore profile slope of around 0.03 (say 1 in 30). The resulting shoreline recession due to sea level rise as estimated by the Bruun rule is given in Table 4-2.

TABLE 4-2 ESTIMATED FUTURE SHORELINE RECESSION DUE TO MSLR

Planning Timeframe	Sea Level Rise (m)	Shoreline Recession due to SLR (m)
2050	0.3	11
2070	0.5	18
2100	0.8	28

4.1.6 Overall Erosion Threat

As previously discussed, the designated EPAW along the Horseshoe Bay foreshore is 125 m, as determined during the Townsville Coastal Hazard Adaptation Strategy (GHD, 2012).

4.2 Storm Tide Inundation

Storm tide inundation has been mapped for the entire Townsville region by GHD as part of the Townsville Storm Tide Mapping Update completed in 2017. This mapping exercise built on previous work completed by GHD within the Townsville-Thuringowa Storm Tide Study undertaken in 2007. The 2017 report was commissioned due to the availability of better quality topographic data (LiDAR) for the region allowing more accurate storm tide mapping to be undertaken. The initial report undertook detailed storm tide modelling using Monte Carlo analysis to simulate 50,000 years of cyclones and storm tides along the coastline.

That study provided Council with ESRI geodata bases for the storm tide mapping presented within the 2017 report. These data sets were released by Council for the purpose of this SEMP. Two storm tide scenarios have been adopted for the analysis within this report as detailed below and seen in Figure 4-3. These are due to the 1% AEP storm tide event occurring under present-day climate scenario and that in the year 2100 (with a 0.8m sea level rise).

FIGURE 4-3 STORM TIDE INUNDATION

The inundation observed within Figure 4-3 is characterised by a notable amount of inundation along Beeran Creek the most significant of which occurs within the Horseshoe Bay Lagoon located north of Corica Crescent. Significant flooding is also predicted on the north side of Henry Lawson Street. No significant flooding is seen within the foreshore area of Pacific Drive as the ocean water level does not exceed the dune crest (noting that the storm tide inundation mapping does not include transient inundation due to wave run-up and overtopping of the foredune).

Several properties along Pacific Drive are impacted by inundation due to storm tide overtopping of Berean Creek to the south under both storm tide scenarios. Properties which back onto Horseshoe Bay Lagoon are also predicted to experience some level of inundation under these storm tide scenarios. Inundation of a number of properties to the east of Beeran Creek mouth is also predicted.

It should be noted that these inundation maps do not include the effect of rainfall or catchment flooding.

4.3 Threatened Assets

A number of properties within Horseshoe Bay are at risk of either inundation (Section 4.2), erosion (Section 4.1) or both. In order to determine the number of threatened assets, the cadastral map of the area was overlayed with the erosion prone area width and inundation extents and the resulting exposure map can be found below within Figure 4-4.

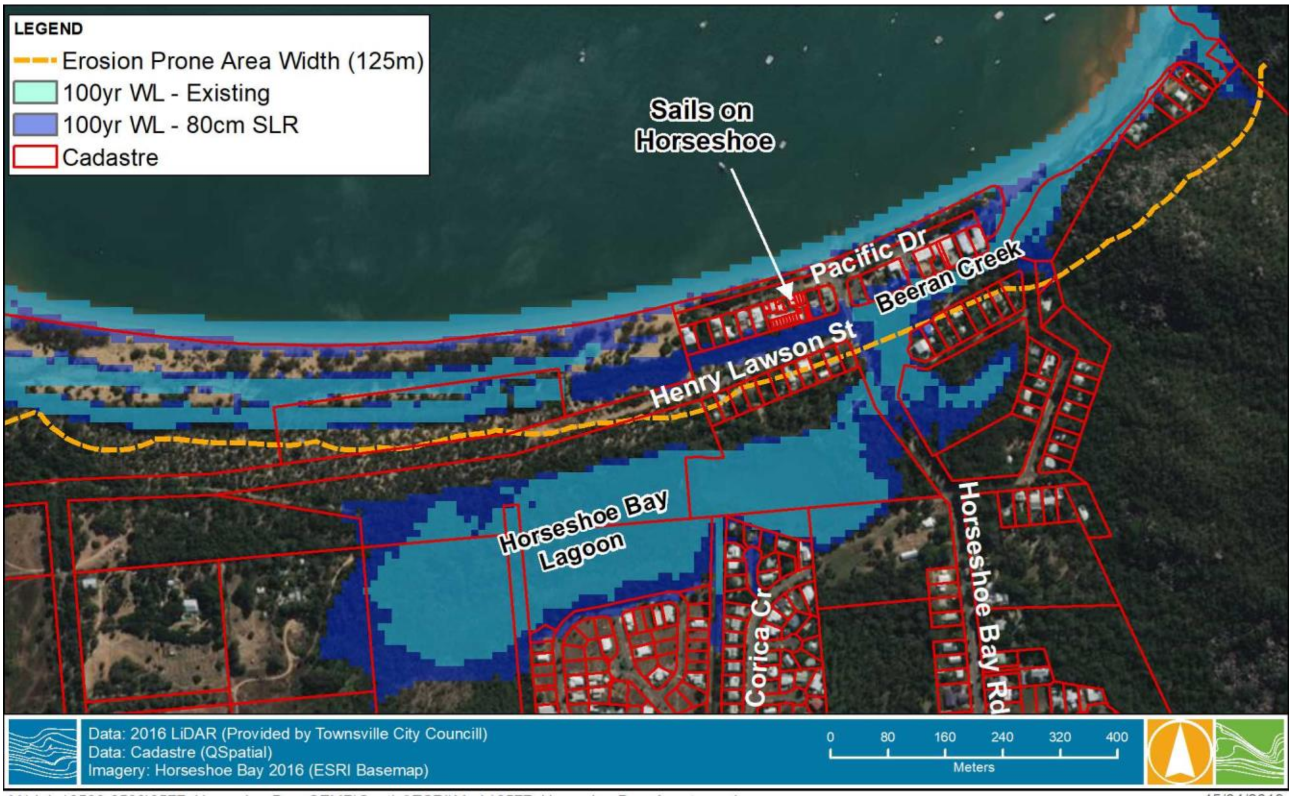

FIGURE 4-4 THREATENED ASSETS – STORM TIDE AND EROSION

Cadastral lots which are impacted by either flooding or erosion have been identified. Land parcels classified as reserves or national parks have been excluded from the assessment. Lots were categorised as either developed or undeveloped (or vacant) – based on cadastral information and aerial imagery. Any cadastral lots affected by the EPAW or inundation extends were identified as being "at risk" - even if the inundation/erosion area was not in the vicinity of any buildings/infrastructure on the parcel. The results of the analysis are presented below within Table 4-3.

TABLE 4-3 THREATEND ASSETS

Hazard	Undeveloped Lots Affected	Develop Lots Affected	Total Lots Affected
Erosion Prone Area Width	6	57	63
1% AEP Storm Tide Inundation - Present-day	2	5	7
1% AEP Storm Tide Inundation for +80cm SLR	4	22	26
Total Lots Affected (including Lots affected by more than one hazard)	8	65	73

Under the existing 1%AEP storm tide inundation event only a small number of parcels are impacted by storm tide inundation. These being some properties off Pacific Drive and the small pocket of land parcels east of Beeran Creek entrance. It is expected that additional lots would be affected by wave run-up, though it has not been assessed as part of this SEMP.

Under the 1% AEP storm tide event with 80cm of sea level rise, three times as many lots with buildings are at risk. Under this scenario land parcels immediately south of Henry Lawson Street would be inundated along with a number of lots north of the Horseshoe Bay Lagoon.

The lots located within the erosion prone area width (EPAW) of 125m are more easily delineated than those subject to inundation. They comprise most of the lots adjacent to and all lots north of Henry Lawson Street. A significant portion of the total lots identified as being at risk within the EPAW analysis are located within the resort “Sails on Horseshoe”, which is comprised of 26 discrete lots accounting for 41% of the total lots identified.

5 SHORELINE EROSION MANAGEMENT OPTIONS

5.1 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 State Coastal Management Plan provides a logically sound and robust approach to the problem by requiring all planning for Queensland's coastal areas to address potential impacts through the following hierarchy of approaches:

- *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

5.2 Coastal Defence Line

When considering foreshore protection measures, it is necessary to define a Coastal Defence Line which represents the landward limit of acceptable erosion. In other words, it forms the landward boundary of any erosion buffers to protect the Horseshoe Bay shoreline, or alternatively the alignment of any protection structure such as a seawall.

Property and infrastructure landward of the Coastal Defence Line remains protected throughout the 20 year planning period, whereas foreshore areas seaward of the line lie within the active beach system (i.e. within the erosion buffers).

Defining the position of the Coastal Defence Line therefore requires consideration by Council and other stakeholders as to what assets are to be defended. Options could include a Coastal Defence Line on an alignment alongside the seaward edge of the Esplanade and Pacific Drive, or along the seaward edge of the foreshore parkland, or even along the toe of the existing dune.

5.3 Existing Management Practices

Since around 2014, Sand Scraping has been undertaken by the Townsville City Council as a means to protect the shoreline from erosion. This involves 'scraping' sand from one part of the system and placing it on the beach in front of at-risk developed areas. Council currently has Development Approval for erosion management to undertake sand scraping on Horseshoe Bay Beach on an annual basis. The permit is for the scraping of up to 5,000m^3 of sand material in any single campaign.

The typical sand scraping program that has been implemented by Council is presented within Figure 5-1. It is characterised by the transfer of sand from the accumulation zone at the eastern end of Horseshoe Bay (the nearshore sand lobes at the Beeran Creek entrance) to the section of beach in front of the Esplanade and Pacific Drive.

Council commonly deploys three excavators to the island for the purpose of re-nourishing Nelly Bay Beach annually. The opportunity to use this equipment for sand scraping works at Horseshoe Bay is frequently adopted. The redistribution of existing sand reserves within Horseshoe Bay is only a temporary solution, and generally only provides relief until a storm tide or heavy rainfall event occurs.

FIGURE 5-1 SCHEMATIC OF CURRENT SAND SCRAPING WORKS

Since 2014/15 there have been four separate beach renourishment campaigns, the details of which are described within Table 5-1. The works are typically undertaken by a truck in combination with an excavator. The excavator is used to load the truck with sediment as well as to redistribute the sediment across the beach profile in the beach nourishment location. The truck is used to transport the sand from the eastern sediment source location to the beach nourishment location where it is spread around by a small bulldozer. The photos presented within Figure 5-3 to Figure 5-7 show several components of the beach nourishment components during the 2016 and 2018 works.

TABLE 5-1 RECENT BEACH NOURISHMENT WORKS AT HORSESHOE BAY

Financial Year	Approx. Volume of Sand Nourishment	Description of the Works
2014/15	5,000 m^3	Direct transfer of sand from south-eastern corner of Horseshoe Bay. Around 20m^3/m of sand placed along The Esplanade, east of the boat ramp.
2015/16	4,000 m^3	Direct transfer of sand from south-eastern corner of Horseshoe Bay. Approximately 2,000m^3 placed along The Esplanade, east of the boat ramp, and 2,000m^3 placed west of the boat ramp. Around 10m^3/m of sand placed in total along the foreshore.
2016/17	1,800 m^3	Direct transfer of sand from south-eastern corner of Horseshoe Bay. Around 10m^3/m of sand placed along The Esplanade, east of the boat ramp.
2017/18	5,000 m^3	Direct transfer of sand from south-eastern corner of Horseshoe Bay. Around 20m^3/m of sand placed along The Esplanade, east of the boat ramp.

Table 5-1 shows that, depending on the excavated/scraped volume, either around 10 m^3/m or 20 m^3/m is placed along the foreshore. A conceptual depiction of this placement is provided in Figure 5-2. It shows that the scraping generally provides between 5 to 10 metres of additional beach width immediately after placement. This can also be seen in Figure 5-6 and Figure 5-7.

Generally, the cost of such beach scraping campaigns is of the order of \$45,000 - \$60,000 per campaign. This equates to around \$10 / m^3.

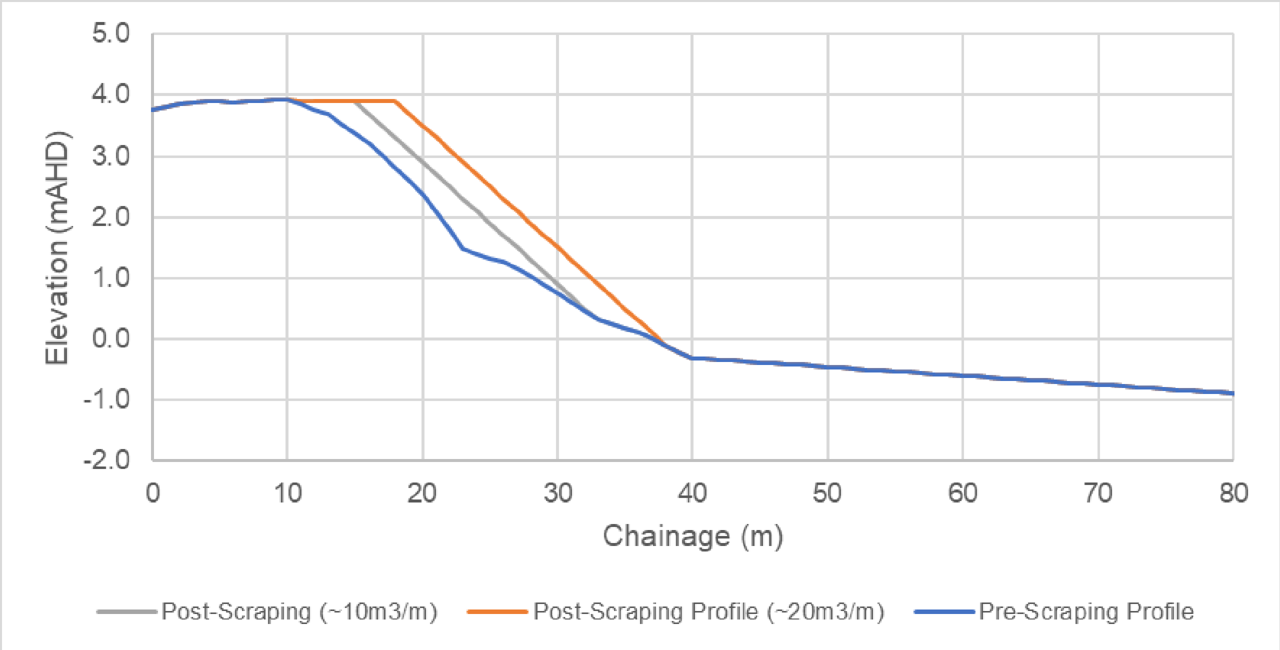

FIGURE 5-2 PRE AND POST-SCRAPING BEACH PROFILES

FIGURE 5-3 2016 BEACH NOURISHMENT WORKS – DURING WORKS

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FIGURE 5-4 2016 BEACH NOURISHMENT WORKS – DURING WORKS

FIGURE 5-5 2016 BEACH NOURISHMENT WORKS – DURING WORKS

FIGURE 5-6 2018 BEACH NOURISHMENT WORKS – DURING WORKS

FIGURE 5-7 2018 BEACH NOURISHMENT – POST WORKS

5.4 Generic Management Options

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

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

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

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

- Seawalls - which act as physical barriers to prevent shoreline recession;
- Seawalls with beach nourishment - where the seawall defines the inland extent of erosion, whilst sand is intermittently placed in front of the wall for improved beach amenity;
- Groynes / offshore breakwaters - used to inhibit the natural longshore movement of sand, thereby retaining sand on the eroding foreshore for longer periods;

- Groynes / offshore breakwaters with beach nourishment - where the structure assists in maintaining sand on the beach, and beach nourishment reduces the downdrift erosion caused by the groyne's interruption to longshore sand supply.

In some cases the optimum management strategy may include a combination of "soft" and "hard" solutions.

An appraisal of each generic erosion management option and its potential application to the Horseshoe Bay shoreline is set out below. This is followed by a summary of the advantages and disadvantages of each.

5.5 Non-Structural Management Options

5.5.1 Do Nothing

A "do nothing" strategy of coastal management can be appropriate where foreshore land is undeveloped, or assets and property are of only limited value. It is well suited to situations where available erosion buffers are sufficient to accommodate long-term and short-term erosion over the nominated planning period. However, on foreshores where existing development and infrastructure is threatened by erosion, the high social and financial costs associated with their loss are generally unacceptable.

As stated previously, the foreshore along the Esplanade frontage of Horseshoe Bay is threatened by erosion in a 20 year planning period. A Do Nothing strategy on this shoreline would potentially lead to the loss of the Esplanade itself along with the private dwellings which are located north of Henry Lawson Street.

This scenario would therefore lead to considerable social trauma and substantial economic loss. Consequently, it is not a viable management option for this erosion prone foreshore.

5.5.2 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 west of the Esplanade since this primarily constitutes undeveloped land which is primarily in public ownership. The erosion risk for this area as described by the EPAW (as defined by DEHP) is the same as that of the Esplanade foreshore area.

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

Presently any foreshore protection works or re-zoning applications within designated Erosion Prone Areas trigger an approval requirement from the Department of Environment and Science. This foreshore is also classified as a Reserve under the Townsville Planning Scheme and therefore is unavailable for development anyway.

5.5.3 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.

There are a number of private properties at Horseshoe Bay that are currently threatened by a 1% AEP inundation event. In conjunction with this, Pacific Drive itself is at risk of erosion during a 1% AEP storm erosion event occurring within the planning period. The likelihood of a 1% AEP event occurring over a 20 year planning period is roughly 18%. However, these properties will become increasingly exposed over the next few decades due to sea level rise and shoreline recession. A planned retreat strategy would require resumption of these private properties; and abandonment of them (and the Esplanade easement) to erosion processes.

Horseshoe Bay has land available for development that is suitable for relocation of housing and other assets; though the available land is at an elevation where future sea levels rise may pose inundation risks at some time in the future.

This solution was nominated as the preferred long-term strategy for Horseshoe Bay in the GHD study of coastal hazards for the Townsville region (GHD, 2012). The option involves modification of the council planning scheme to reflect a change in the designated land-use, to facilitate a staged long-term retreat. Based on a broad review of the cost implications of this option, the optimal year of adaptation implementation for the retreat was nominated as 2036 (GHD, 2012). However, it should be noted that the asset values used in the analysis were typically not risk-informed or risk-adjusted. AECOM (2015) notes that implementing this option will require careful consideration of distributional issues and exposure to legal recourse (Gibbs 2015).

The financial costs involved in such a strategy would be considerable given current property values of foreshore land on Magnetic Island. Adverse community response to the social cost of a retreat strategy on this foreshore is also very likely, and this is reflected in the community survey responses provided in Section 2.4.

Nevertheless, an aspect of planned retreat which could be implemented relates to any existing power and telecommunications infrastructure that is located within the erosion prone areas. Outages and emergency works could be averted if a strategy of retreat was implemented by power and telecommunication suppliers as part of planned upgrading or relocation works.

5.5.4 Beach Nourishment

A strategy of beach nourishment entails the placement of sand that is sourced from outside the sedimentary system 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 for recreational amenity.

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 ongoing commitment to further renourishment. Nevertheless, most other forms of direct intervention (even those of a “hard” structural nature like 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.

However, because the Horseshoe Bay embayment is effectively acting as a closed system, beach nourishment on a large scale may be a viable longer term solution (AECOM, 2015). The primary issue with this solution is finding a suitable source of sand that has the right characteristics (similar to the existing beach sand) and can be delivered to the site in sufficient quantities at a reasonable price.

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

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

The buffer characteristics of sand volume and width are basically the volumes and widths that would be removed by short-term erosion processes. These characteristics were presented earlier for present-day climate conditions in Table 3-10.

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

As discussed previously, 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 Horseshoe Bay shoreline. Property and infrastructure landward of the Coastal Defence Line will remain protected throughout the 20 year planning period, whereas foreshore areas seaward of the line fall within the dynamic erosion buffer.

AECOM (2015) estimated that to make a permanent difference, in excess of 100,000m^3 would be required to nourish the whole bay. However, it may be more practical to nourish the 1 km stretch in front of the esplanade and Pacific Drive, and the immediately surrounding environs. For this task, an additional beach width of 25 m would require a volume of around 50 m^3/m, for a total of 50,000 m^3.

This one off nourishment would provide a net increase of sediment into the system. If accompanied with adequate dune fencing and a revegetation program, then this would allow for a natural progradation of the dune vegetation, and would provide the local dunes with the means to replenish itself. This additional beach width would allow for enhanced coastal vegetation and a traditional dune and swale system to be established.

This would also require importing sand from a suitable source. Sand may be available from an existing stockpile of around 100,000m^3 presently available (as of June 2019) at the Port of Townsville, though the characteristics of this sediment would need to be investigated before it could be approved for use. If it is material dredged from the port, then it may be too fine to use on the Beach at Horseshoe Bay.

Some high level costings have been provided for this exercise. Assuming that sand can be sourced at approximately \$20/m^3, and then transported over to the Island from the mainland at \$70 per tonne (which equates to around \$25/m^3), the cost of this work would be around \$2,500,000 or more.

The placement of such a large volume of sand onto the eastern region of Horseshoe Bay's dynamic coastal system will need to be further investigated prior to it being adopted. The implications to the complex processes of natural opening and closing of Beeran Creek entrance would be of particular focus to identify any special entrance management strategies that might be required to mitigate any possible adverse impacts.

5.5.5 Beach Scraping

The concept of beach scraping entails moving sand from elsewhere within the local sedimentary system to the region of interest. Such sand is typically sourced from:

- lower levels of the cross-shore beach profile (typically from tidal flats immediately in front of a beach); or
- other locations along the foreshore downdrift of the study area

In essence it is simply redistributing sand that is already within the active beach profile and as such does not provide a net long-term benefit.

Beach 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 – which at Horseshoe Bay could take years to decades.

As discussed in Section 5.3, this practice is already undertaken by Council on an annual basis, with a high level of success. However, the efficacy of such an option is dependent upon wave and weather conditions, as material can be lost shortly after placement due to storm activity – necessitating the need for another campaign of beach scraping. The cost of this sand scraping is currently around $\$10/m^3$, and around $45,000 - $60,000 per campaign.

5.5.6 Dune and Foreshore Management

The Horseshoe Bay Esplanade Park consists of reclaimed and compacted land forming a relatively narrow strip of heavily trafficked green-space between the road and the beach. Therefore, there is only limited scope to establish a full natural self-sustaining foreshore with native ground cover vegetation and a functioning dune-ridge. However the potential exists to develop a solution with at least some elements of this approach to be applied.

This work could comprise a number of elements, outlined below.

Revegetate the Esplanade Park

The Esplanade Park currently comprise compacted fill, and soils overlain by short grassed green-space, interspersed with paved walkways. These park grasses do not catch sand and build dunes like coastal vines and grasses do, and this hampers the local beach recovery after erosion events. Where possible it would be beneficial to establish species such as Birds Beak Grass (Thuarea involuta), Goat's Foot Morning Glory (Ipomea pes-caprae), Beach Bean (Canavalia rosea), and Beach Spinifex (Spinifex sericeus). These coastal vegetation species allow for good drainage and have a growth habit that allows for trapping of wind-blown sand and beach re-building process to accelerate beach recovery. This revegetation would create a densely vegetated green zone, that provides a dense sward of root systems able to provide optimal stabilisation and will act as a barrier to trap wind-blown sand.

Due to the social amenity impacts of having to temporarily close off the section of park being revegetated, it is likely that such work would occur in a staged program, by sectioning off and revegetating small sections of the Esplanade park one at time. This would likely entail working on a 10m x 5m area of park, and allowing around 2-3 months for growth and stabilisation, before reopening it and moving on to another section. This would minimise the impact on recreational use of the Esplanade.

It should be noted that Council has already undertaken some revegetation work along the foreshore with success. Re-vegetation of coastal species (such as Goat's Foot Morning Glory) in the vicinity of the destroyed toilet blocks at the eastern end of the Esplanade was undertaken in 2015, along with placement of bollards to restrict pedestrian access – see Figure 5-8. This strategy has proven successful at rebuilding the local dune.

Based on previous revegetation work at The Esplanade, the estimated cost of the revegetation work would be around $\$35/m^2$. This estimate includes labour and supply of vegetation materials such as seedlings and tubestock.

FIGURE 5-8 EXAMPLE OF REVEGETATED FORESHORE AT EASTERN END OF THE ESPLANADE. BEFORE THE WORKS IN 2015 (LEFT) AND AFTERWARDS IN 2018 (RIGHT)

Regrade and Reshape the Esplanade Park and Frontal Dune

Where possible/appropriate it would be beneficial to establish a gradient across the park - draining overland flow from the park landwards towards the road and into the local stormwater system. This would include earthworks to reshape the frontal dune, so that the leading edge of the frontal dune is reformed around 1 metre higher than the surrounding foredune/esplanade park. The dune crest would need to be vegetated with native coastal vegetation such as those species identified above. After the reinstatement of the foredune at the northern end, water flowing from the road may be linked into a constructed swale behind the foredune, assisted with revegetation works to maintain the natural shape and stability of the swale. This swale could redirect some overland flow westwards past the end of Pacific Drive and into Beeran Creek. The swale will also promote water infiltration through the sand/soil of the park rather than relying completely on overland flow.

This could be integrated into the option of upgrading the local drainage and stormwater system (see Section 5.6.3), and would need to be designed in such a way so as not to worsen the existing stormwater flooding of properties along Pacific Drive. This could be achieved through application of water sensitive urban design and integrated stormwater management, and a stormwater management study would be needed in order to design the optimised overland flow paths and ensure these mechanisms are of sufficient capacity.

The cost of reshaping the frontal dune would likely be similar to that of the current annual sand scraping operations.

Redesign the Esplanade Park Accessways

Currently, the impermeable concrete and paved walkways along the Esplanade exacerbate overland flow and erosion issues since they prevent rainfall infiltration, and direct overland flow onto the Beach. In order to mitigate this erosion mechanism, the existing paved stone and brick walkways could be replaced with permeable paving materials that allow for infiltration of surface run-off.

Such permeable paving solutions can be based on porous asphalt, concrete pavers (permeable interlocking concrete paving systems), or even polymer-based grass pavers. Such porous pavements and concrete pavers (or rather, the voids between them) enable stormwater to drain through a stone base layer for on-site infiltration and filtering. Some porous paving materials appear nearly indistinguishable from the more common, non-porous materials. Additionally, drainage capacity could also be built into paved accessways through implementation of drainage gates and trench gates.

Typical installed costs for permeable paving vary depending on the nature of the material – but is typically in the range of $150-180/m^2.

Limit and Formalise Pedestrian Access

The Esplanade Park is heavily trafficked by locals and visitors alike. In order to assist in building and maintaining a vegetated Esplanade Park, there would be benefits to limiting access across the park to a number of formalised accessways (provided in the form of a permeable paving as described above). This would prevent the uncontrolled movement of pedestrians over the frontal dune. In particular, the 240 m stretch of the Esplanade Park to the west of the boat ramp could be fenced off and beach access could be limited to say a small number of beach accessways at around 50 m spacings.

Dune vegetation is particularly susceptible to damage from pedestrian traffic. Fencing could preserve both revegetated and naturally vegetated areas. Plain wire fencing, or Post-and-Rail fencing could provide the necessary protection from pedestrian traffic whilst maintaining a low visual impact (DECCW, 2010). Fencing would be around 1-1.2 m high and comprise treated pine posts. As the fencing is likely to be exposed to wave run-up and energetic storm waves from time-to-time, the fencing should be of simple construction and easily maintained.

As an approximate guide, a 2-person team can erect approximately 100 metres of plain wire fencing, or around 60 metres of post and rail fencing per day (2 rail) (DECCW, 2010).

FIGURE 5-9 EXAMPLES OF PLAIN WIRE FENCING (LEFT) AND POST AND RAIL FENCING (RIGHT) (SOURCE: DECCW, 2010)

Install Educational Signage

Signage on or near beaches are an increasingly common feature of coastlines. Signage can serve several purposes and can be designed as a temporary or lasting component of the rehabilitated foreshore landscape. It can be used to enhance public safety, to control undesirable behaviour, or to educate the community by raising awareness and understanding of the local environment and of efforts to protect or enhance it. In this instance, signage could accompany the Esplanade Park fencing, both to explain the need for controlling beach access points and the importance that this can play in managing beach erosion.

5.6 Structural Management Options

5.6.1 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 the Horseshoe Bay 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 behind the wall. In other words, seawalls can protect property behind the wall, but they do not prevent in any way the erosion processes continuing on the beach in front of them. In fact, they very often exacerbate and accelerate the erosion.

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

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

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

Another typically adverse impact of seawalls is that the original erosion problem that they were meant to solve is simply relocated further along the shore. Natural beach processes can no longer access the sand reserves in the upper part of the active beach that are behind the seawall. Consequently, this sand cannot be moved downdrift by longshore sand transport processes to replenish the sand that these same processes are moving along the shoreline beyond the end of the seawall. The deficit in sand supply to these downdrift sections initiates greater erosion, ultimately requiring extension of the seawall along the entire downdrift shoreline in order to protect it. In other words, the construction of a seawall does not in itself typically resolve the erosion problem, but merely transfers it further along the beach.

Seawalls have an impact 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.

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 or geotextile sandbag units 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 seawalls constructed in this manner require significant maintenance to prevent structural failure and the re-establishment of the original erosion problem.

Despite their disadvantages, 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. Their subsequent failure or damage can not only lead to the re-establishment of the original erosion problem, but the scattering of removed rocks can adversely affect foreshore use and visual amenity.

If a seawall was to be constructed on a Coastal Defence Line along the at-risk section of the Horseshoe Bay foreshore, it would be buried beneath The Esplanade park, and likely not be exposed to any wave action until the occurrence of a design (1% AEP) storm event. The wall would need to be around 600 m long to protect Pacific Drive and the adjacent properties, with an adequate turn-back at each end to prevent outflanking from waves during a storm event. It should be noted that since this wall would be buried, it would not adversely affect the visual amenity of the foreshore, which is highly valued by locals and visitors (see Section 2.4).

It should be noted that a buried seawall underneath the Esplanade park would need to be a relatively low-crested structure to minimise its visual impact and restriction of beach access. Therefore, the structure would not reduce wave overtopping or storm tide inundation along the Esplanade. Furthermore, there may be constructability and approvals issues associated with the need to remove a number of large trees along the Esplanade park in order to install a buried seawall.

The seawall would likely be constructed of either:

- Rock Armouring;
- Concrete Seabee Units; or
- Geotextile Sand Containers (GSC).

Some preliminary design requirements have been estimated based on the design wave and water level conditions determined in Section 3.2. These design parameters are to be considered as indicative only, and would require refinement if such options were taken into a concept and then detailed design phase. These options are outlined below.

Rock Armoured Seawall

A rock armoured seawall generally has a longer design life than a GSC structure. When properly designed, rock armoured seawalls can have a design life of 50 years or longer. The preliminary assessment of armour requirements provided in Table 5-2 has been developed using the method of Van Der Meer (1998), assuming a 0.5% AEP design still water level (plus sea level rise to 2070), depth limited wave conditions and a breaker index of 0.6. Scour at the toe of the structure has been assumed to extend down to -1 m AHD, with a permissible damage factor of 2.

Based on this, the wall would need to be constructed of two layers of approximately 1.5 tonne (0.8 m diameter) rocks overlying two layers of smaller rocks of around 0.15 tonne (0.4 m diameter) each. This armoured slope should be no steeper than 1V:2H; and founded no higher than approximately RL -1m AHD.

A layer of geotextile fabric would need to be laid between the secondary rock armour (and above the core material) in order to prevent migration of sand through the seawall armour. All lap joints between adjoining sheets should be no less than 400mm, or alternatively sheets be mechanically joined in accordance with the manufacturer's recommendations. The material should meet the specifications of Texcel 600R or equivalent.

TABLE 5-2 APPROXIMATE ROCK AMOUR SEAWALL REQUIREMENTS

Design Parameter	Value
Crest Level	3.7 mAHD (existing Esplanade level)
Toe Level	-1 m AHD
Structure Slope	1V:2H
Primary Layer Armour M_{50} (2 layers)	1,400 kg
Secondary Layer Armour M_{50} (2 layers)	150 kg

Given the approximate dimensions required above, the 600 m long seawall would require some 30,000 to 35,000 tonnes of armour rock.

It should be noted that there may be some financial / logistical limitations associated with this option. In order to source suitable quality rock armour for the wall, a commercial rock quarry will be required within an economically viable transport distance. Although Magnetic Island has a sufficient supply of natural igneous rock, there is not an established quarry on the Island, and the scale of the works does not warrant establishing a quarry for the purpose of building a seawall.

Consultation with local contractors has provided an estimate of the cost of transporting rock from existing quarries on the mainland. Rock material could be transported using around 12 to 16 truckloads per day, by using say 4 trucks, doing 3 loads per day and another 2 trucks doing 2 loads per day. A mix of truck and dogs and semi tippers is envisaged - with an average haul of 28 tonnes per load. Based on this, around 400 t of material could be transported to Horseshoe Bay per day. At an approximate cost of $75 per tonne for transportation, this equates to around $2.5 million for transportation alone.

In addition to this, the additional costs of design, construction and supply of materials would be around $3 million. Hence, the total cost of the seawall would be around $5.5 to $6 million.

Maintenance requirements of such seawalls typically occur on an as needed basis but for a buried wall periodically exposed to erosion, may be estimated at 0.5% of the capital cost per annum.

Seabee Seawall

Due to the non-availability of suitable armour rock on the island, and relatively small wave heights (compared to more open coast settings), a pattern placed concrete armoured structure may be considered an appropriate alternative. A suitable armour type would be the Seabee unit, which is a hexagonal block with a hollow core. An example is provided in Figure 5-10. The purpose of the system is to capture sand and to discharge wave energy on the shoreline.

Pattern placed armour behaves as a mattress, with the units held in place by gravity and the interlocking with the surrounding units. This allows significant reductions in the volume/mass of armour required when compared to rock armoured structures in order achieve an equivalent level of protection. AECOM (2015) noted that because of the relatively light units involved and reduced volumes of material required, seawalls of this type can be an attractive option in locations such as Magnetic Island. That report notes that one of the benefits of a Seabee wall is the opportunity for local labour to assist in the construction process, hence possibly reducing the cost of the project. For this to occur though, the individual Seabee units need to relatively light (say less than 40-50 kg each).

The thickness of concrete armour required for a Seabee seawall was assessed based on formula provided in the Seabees For Coastal and Embankment Protection: Design Manual (WRL 1997). From a conceptual design perspective, the Seabee units required for stability will be 350 mm units in both depth and width and weigh about 43 kg each. They need some form of footing. A concrete toe is sometimes used as illustrated in the left hand image of Figure 5-10. If the footing is concrete, it needs to be assured that it will not be undermined. Rock would be placed beneath the Seabee units to a thickness of about 350 mm. Geotextile would be placed beneath that underlying rock layer..

Using a formed concrete cost of $500/m^3 and a cost of $150/tonne for rock (including sourcing, transporting it to the island, and placing it) it is estimated the cost of a Seabee seawall would be about $3 million. The option would require a suitably sized area for the Seabee casting operations, which may not be available in the immediate vicinity of the seawall.

TABLE 5-3 APPROXIMATE SEABEE SEAWALL REQUIREMENTS

Design Parameter	Value
Crest Level	3.7 mAHD (existing Esplanade level)
Toe Level	-1 m AHD
Structure Slope	1V:1.5H
Seabee Unit Depth	350 mm
Seabee Unit Radius	350 mm
Seabee Unit Radius of Hole	95 mm
Seabee Unit Weight	43 kg
Seabee Density	12.5 units / m^2

FIGURE 5-10 CONCRETE SEABEE SEAWALL - POSSIBLE TOE DETAIL (LEFT) AND SEABEE WALL DESIGNED BY WATER TECHNOLOGY (2016) (RIGHT)

GSC Seawall

A geotextile sand container (GSC) comprises a pillow formed by sewing geotextile fabric that is then filled with sand. GSC structures have a long history of seawall applications in Australia, and around the world. They can be a cost-effective alternative to rock and concrete armoured seawalls and revetments. Over the last 20 years, the use and adoption of GSC structures has increased as improvements have been made in the durability and UV resilience of geotextile fabrics.

Durability for high-quality GSC's exposed to UV and wave action is typically 15 to 20 years, although this can be reduced due to debris damage or vandalism. However, they can achieve a significantly longer design life in situations where the GSC units are not exposed to UV, wave action or vandalism – such as when buried beneath the local dune. Under these conditions a design life of up to 40 years could be expected.

A main benefit of this type of structure is that the GSC units would be comprised of locally available sand – and would not require additional sand to be brought to the Island. The sourcing of locally available materials would remove the need for large quantities of material to be barged over from the mainland, and would therefore represent a significantly lower cost option than a rock armoured seawall.

The overall volume of material required to fill the bags would be of the order of 6,000-7000 m^3, which is a sufficiently small volume to be sourced locally from within the bay. Sand to fill the GSC units would primarily be comprised of sand excavated to make way for the wall.

Commonly available sizes of GSC units in Australia are 0.75 m^3 and 2.5 m^3, although smaller bags can be manufactured. Empty containers are light and can be transported readily. The smaller 0.75 m^3 bags can be dry filled using fill frames supplied by the manufacturer (see Figure 5-11), however the larger 2.5 m^3 bags (which weigh around 4 tonnes when filled) require filling frames and slurry pumps with mechanical plant to assist in placement.

FIGURE 5-11 EXAMPLE OF DRY-FILLING A GSC WITH A FRAME (SOURCE: CORBELLA, 2012)

The hydraulic processes affecting the stability of GSC structures were extensively investigated by Oumeraci et al. (2003), and others. Nevertheless, GSC is still an emerging technology and no proper guidelines are available for the design of GSC structures on a sound scientific basis. A preliminary assessment of the required GSC units sizing for the wall was undertaken by using the formula provided in Wouters (1998).

Results are presented in Table 5-4 below, and show that in order to achieve the required stability, either a layer of 0.75 m^3 units, or a single layer of 2.5 m^3 units would be required.

TABLE 5-4 GSC UNIT LAYERING FOR STABILITY

Layers	0.3m^3 Container	0.75m^3 Container	2.5m^3 Container
1	**Unstable**	**Unstable**	**Stable**
2	**Unstable**	**Stable**	**Stable**

The modular nature of these structures is such that they will remain structurally coherent when up to 2% of individual containers are damaged or removed, especially if a double layer is used.

Concept design information of a 2 layer, 0.75m^3 GSC seawall are provided in Table 5-5 below.

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TABLE 5-5 APPROXIMATE GSC SEAWALL REQUIREMENTS FOR TWO LAYERS OF 0.75M³ UNITS

Design Parameter	Value
Crest Level	3.7 mAHD (existing Esplanade level)
Toe Level	-1 m AHD
Structure Slope	1V:1H
GSC Unit Size	0.75m³ Container
GSC Unit Mass	1,400 kg
GSC Unit Filled Height	400 mm
GSC Unit Filled Width	1,350 mm
GSC Unit Filled Length	1,800 mm
GSC Layers	2 layers

The estimated cost of this option is of the order of $2.5 million dollars (around $4,000 per metre length). This would represent a cheaper option than the rock armoured or concrete Seabee seawalls, since it would not require the expensive transportation of materials to Magnetic Island from the mainland.

This structure would be buried, and as such a design life of up to 40 years could be expected. It would therefore be "quasi-permanent" rather than "permanent". These structures are seen as suitable where there is an erosion threat but also a high degree of uncertainty about the level of threat or how best to respond. i.e. it can buy time to allow community/authorities to assess issues as they emerge (AURECON, 2015).

5.6.2 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 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. Such intervention can have a significant impact on the visual amenity of the 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

At Horseshoe Bay, a groyne solution would entail the construction of a groyne on the foreshore near the eastern end of the Esplanade. This would retain sand to its west, thereby intercepting the east to west sediment transport that delivers sand from in front of the Esplanade to the eastern corner of the bay near the Beeran Creek Entrance. The groyne would need to be sufficiently long so as to prevent sand bypassing the end of the groyne. In this location, the groyne would not be permitted to extend beyond the Mean Low Water Mark (-0.68 m AHD) since this represents the boundary of the Great Barrier Reef Marine Park. This would be sufficiently long to trap much of the longshore transport; however some sand would still be swept around the end of the groyne. Due to the large tidal range and relatively flat nearshore slopes, the groyne would need to be around 100 m long.

In order to minimise visual impacts, the crest height of the structure would need to be lower than that required to prevent damage by overtopping. Therefore, it is anticipated that significant maintenance work may be required after a cyclonic storm event.

There are a number of issues related to the implementation of a groyne at the Horseshoe Bay foreshore. These include:

- **Erosion to the East of the Groyne:** Whilst the groyne would gradually result in an accretion of beach width on the shoreline to its west, the shoreline to the east of the groyne would start to experience erosion because it would no longer receive sand naturally transported from in front of the Esplanade. In other words, the erosion problem along the Esplanade would be alleviated by simply transferring it eastward. This may result in a gradual shoreline recession in front of nearby properties - thereby increasing their exposure to storm erosion and long-term shoreline recession. Increasing the erosion threat to existing properties is considered an unacceptable outcome.
- **Visual Amenity and Community Acceptance:** The Community Survey (see Section 2.4) showed that the visual and scenic amenity of the foreshore is highly valued by locals and visitors alike. In order to be effective the height and length of the groyne structure would have a pronounced visual impact on the foreshore, and would drastically affect the natural character of the area. Furthermore, the community survey also showed very little support for the implementation of hard structures on the beach.
- **Issues with a Rock Armoured Groyne:** As discussed above, the sourcing and transportation of rock armour from the mainland would be an expensive process. The groyne would need to be over 100 m long, requiring some 5,000 to 6,000 tonnes of armour rock. It would cost approximately $1 million to build (including transportation of rock to the island).
- **Issues with a GSC Groyne:** This structure would comprise GSC units that would be exposed to nearly constant UV deterioration and high wave loads. As discussed above, GSC units that are exposed to UV and weathering have a design life of 10-15 years. Therefore, this solution would require significant maintenance, or partial reconstruction after this time period. A GSC groyne would therefore be a relatively expensive option over the 20 years life cycle planning period.
- **Disruption of Creek Processes:** The groyne would disrupt the longshore sediment transport regime. It would also impact the transfer of sediment into and out of Beeran Creek. This would affect the natural cycle of opening and closing of the creek. However, it would likely result in the entrance remaining open for longer periods since the supply of sediment to close the entrance would be reduced.

For the reasons given above, the implementation of a groyne is not recommended.

5.6.3 Stormwater Management

As discussed in Section 3.3, the stormwater infrastructure along The Esplanade and Pacific Drive is currently not functioning adequately to prevent sediment loss in the parkland, and to prevent overland flows further acting on the front of the exposed scarp. Therefore, a practical and effective erosion mitigation option for the

Horseshoe Bay foreshore would be to formalise and/or upgrade the current stormwater system along the Esplanade and Pacific Drive. This may comprise the following elements:

- Redirecting overland flow away from the beach and back towards the stormwater system along Pacific Drive (previously discussed in Section 5.5.6);
  - Provides opportunity to revegetate with native coastal species;
  - Possibility for integration of constructed swale behind the foreshore dune and/or a bio-filtration system to promote groundwater recharge;
- Formalising pedestrian pathway and promoting infiltration with the use of permeable, polymer-based grass pavers (refer to Section 5.5.6);
- Diversion of this stormwater into Beeran Creek, so that the stormwater outfalls along Horseshoe Bay can be decommissioned and removed; and
- Upgrading the stormwater system along Pacific Drive to better accommodate high intensity rainfall events and minimise overland flow across the Esplanade park. (also discussed in Section 5.5.6). This may consist of:
  - Upgrade pipes and other stormwater drainage assets as required to prevent flooding from a 50% AEP storm event. This may potentially include using permeable concrete pipes, such as HydroCon pipes, to further promote groundwater recharge. The Horseshoe Bay Drainage Management Plan (Flanagan et. al., 2007) states that the design ARI for minor events in residential areas should be 2 years ARI;
  - Extend the stormwater network to properties which are currently without service;
  - Integrating a kerb along the western side of Pacific Drive to contain/manage overland runoff, including peak 2% AEP flows. The Horseshoe Bay Drainage Management Plan (Flanagan et. al., 2007) states that the design ARI for major events and major systems should be 50 years (i.e. Level of Service);
- Providing leaky rainwater tanks to upstream properties (as shown in Figure 5-12), with a priority to unconnected properties. Under intense rainfall conditions, these tanks would soon be overflowing, but it would help to buffer the first flush rainfall.

FIGURE 5-12 EXAMPLE OF A LEAKY TANK (SOURCE: WWW.STORMWATER.ASN.AU)

It should be noted that a Drainage Management Plan was undertaken for Horseshoe Bay in 2007 by Flanagan Consulting and C&R Consulting (Flanagan et al, 2007). This report aims to develop a strategic approach to drainage management in the Horseshoe Bay catchment that will alleviate any existing problems and allow developers to plan drainage works in a coordinated, efficient fashion. Whilst the report doesn't make specific recommendation for the stormwater drainage along Pacific Drive, it does state that any future development along Pacific Drive is to utilise water sensitive urban design principals in the implementation of stormwater drainage solutions.

It is anticipated that this option would require a Stormwater Management Study to assess the potential options in detail and to inform the design of the necessary stormwater infrastructure. It is anticipated that the cost of this study would be around $20,000. A high level cost estimate of the design and construction work for diversion of local stormwater into Beeran Creek and upgrading the stormwater system along Pacific Drive is around $300,000 – based on discussions with stormwater engineers.

The provision of leaky rainwater tanks to upstream properties would occur at a cost of around $5,000 per tank.

5.7 Options Assessment

In order to identify a preferred option(s) for addressing the erosion issues at Horseshoe Bay, the potential options outlined in Section 5 were assessed using a high level, semi-quantitative multi-criteria matrix framework. The matrix provides a methodical and transparent approach to comparing different options that is readily understood by stakeholders and the community. Options have been assessed considering a number of criteria, including:

- Performance and Construction Criteria:
  - Effectiveness at protecting the foreshore and related infrastructure;
  - Durability;
  - Constructability.
- Environmental Impacts
  - Impact on local coastal processes (such as waves, currents and sediment transport);
  - Impact on local ecology (flora and fauna);
  - Compatibility with future climate change impacts (such as sea level rise).
- Social and Community Impacts;
  - Impact on local scenery and visual amenity;
  - Social and cultural impact;
  - Level of community support.
- Compliance with State and regional plans

For each option, scores ranging from -3 (strongly negative) to 0 (neutral or no impact) and +3 (strongly positive) were allocated for each criterion. It should be noted that for some criteria, a score of -3 may result in the option not being feasible. The total net benefit score was calculated for each option based on the total sum of their individual criteria scores.

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Additionally, high level estimates of the capital cost and ongoing maintenance costs for each option have been developed based on preliminary concept designs, and typical unit rates for materials, construction and transportation. These estimates have been based previous experience and supplemented by discussions with local contractors. Then a 20-year net present value life cycle cost has been estimated which includes the capital cost and ongoing maintenance costs for each option calculated using a 7% discount rate. This incorporates the different spans of design life and frequency of maintenance for each of the various options. At this early stage these estimates must be considered as indicative only since no detailed design has been undertaken.

A summary of the results of the assessments is provided in Table 5-6. Detailed results for the scoring of each option are provided in Table 5-7 through to Table 5-14. Some comments on the results are provided herein:

- The results show that the highest scoring option from a cost-benefit perspective, is Dune and Foreshore Management. This represent a relatively inexpensive option (compared to hard structures), that will increase the resilience of the local foreshore, have a positive impact on local coastal processes and not adversely affect the local ecology (flora and fauna). It is also the most popular option identified by the community consultation.
- Integrated stormwater management also scored quite highly. Given the contribution of local overland flow and stormwater processes to the erosion issues observed at the site, this option would be effective in improving the resilience of the local dune and foreshore area. This option is comparatively inexpensive and simpler from a logistical perspective (constructability and approvals etc). In order to be fully effective, this option would need to be implemented in conjunction with Dune and Foreshore Management.
- Council's existing programme of beach scraping is a well rated option. Whilst this strategy is not considered a long term solution on its own and has an overall lower benefit score than a wider beach nourishment campaign, the option is considerably less expensive over a 20-year life-cycle. Therefore it has a higher cost-benefit ratio. Beach scraping also has a high level of community support.
- The seawall options typically scored quite low. The more permanent structures such as rock armouring and concrete Seabee seawalls in particular provide to be very expensive – particularly due to the cost of shipping construction materials to Magnetic Island from the mainland. If a higher degree of protection is required in the future, consideration could be given to a quasi-permanent geotextile sandbag seawall. Given that the wall would be buried, it would have an acceptably long service life. It would therefore represent a significantly cheaper implementation cost than a rock or Seabee structure.
- A groyne rock armoured groyne at the eastern end of The Esplanade scored low. The need for it to remain outside of the GBRMPA means that the groyne would only be partially effective. Furthermore, its adverse impacts on visual amenity (which is highly valued by locals and visitors alike) would likely be unacceptable to the community.
- Longer term management strategies such as avoiding development and planned retreat scored low in this assessment. Nevertheless, they may represent more sustainable long term management strategies for Council – as identified in the Townsville City Council Coastal Hazard Adaptation Strategy.

TABLE 5-6 OPTION ASSESSMENT SUMMARY

Option⇩	Protection of Infrastructure	Durability	Constructability or Implementability	Impact on Coastal Processes	Impact on Flora and Fauna	Compatibility with Climate Change and Sea Level Rise	Social and Cultural Impact	Visual Amenity Impact	Level of Community Support	**Net Benefit Score**	**Estimated Capital Cost**	**Estimated 20-Tear NPV Cost (7% discount rate)**	**Cost/Benefit Index**
Do Nothing	-3	-3	+3	-1	-2	-3	-3	0	-3	**-15**	$0	$0	Negative
Avoid Development	-2	+2	+2	-1	-2	-2	0	0	-2	**-5**	$0	$0	Negative
Planned Retreat	+3	+3	-3	+2	-2	+3	-3	0	-3	**0**	$0	$10M+	Negative
Beach Nourishment	+2	+1	-1	+2	+1	+1	+2	+2	+2	**+12**	$2,500,000	$2,500,000	0.5
Beach Scraping	+1	-2	+3	0	0	+1	+1	+1	+2	**+7**	$50,000	$580,000	**1.2**
Dune & Foreshore Management	+1	+1	+3	+2	+1	+1	+2	+2	+3	**+16**	$205,000	$290,000	**5.5**
Seawall - Rock Armoured	+2	+3	-2	-1	-2	-1	0	0	+1	**0**	$6,000,000	$6,300,000	0.0
Seawall - Concrete Seabees	+2	+3	-2	-1	-2	-1	0	0	+1	**0**	$3,200,000	$3,500,000	0.0
Seawall - GSC Units	+2	+2	+1	-1	-2	-1	0	0	+1	**+2**	$2,500,000	$2,800,000	0.1
Groyne - Rock Armoured	+1	+2	-1	-2	0	-1	-2	-3	0	**-6**	$1,200,000	$1,500,000	Negative
Integrated Stormwater Management	+1	+2	+3	+1	0	+2	+2	+1	+1	**+13**	$350,000	$420,000	**3.1**

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TABLE 5-7 OPTIONS ASSESSMENT – BEACH NOURISHMENT

Criteria	Score	Notes
Protection of Infrastructure	+2	This option would provide a substantial erosion buffer in the short to medium term – as it provides a net gain of sediment into the system. The buffer created by the additional sand would be sufficient to protect the Esplanade and infrastructure on Pacific Drive
Durability	+1	This represents a medium-term solution. Over time this buffer would be reduced by periodic storm erosion and shoreline recession due to mean sea level rise. Given the slow rate of natural beach recovery, future renourishment campaigns may be required after large storm events.
Constructability	-1	As the sand would need to be obtained from outside the Horseshoe Bay sediment compartment, it would need to be transported from the mainland. Sand would likely need to be trucked over, as the bay is quite shallow and barging in the sand is unlikely to be feasible.
Impact on Coastal Processes	+2	This option has no significant impact on the coastal processes, and it would enhance the build-up of the dune.
Impact on Flora and Fauna	+1	The nourishment would promote growth of coastal dune vegetation, thereby also promoting local dune habitat formation.
Compatibility with Climate Change and Sea Level Rise	+1	This option would provide a medium-term buffer against shoreline recession caused by sea level rise. It would allow for the enhancement of the local dune system which can adapt to changing sea levels.
Social and Cultural Impact	+2	The beach nourishment would provide an increased area of dry beach width along the foreshore – providing greater opportunities for recreational amenity.
Visual Amenity Impact	+2	Beach nourishment has a positive visual impact as the beach appears very natural. It gives a very natural aspect and totally preserves the natural character of the beach.
Level of Community Support	+2	Beach nourishment options such as this, and local sand scraping have a reasonably strong level of community support. See Section 2.4.
Net Benefit Score	+12	
Estimated 20yr NP Cost	$2.5 M	This cost is based on importing sand from the mainland.
Total Cost/Benefit Score	0.5	This options ranks as the 4th highest scoring option.

TABLE 5-8 OPTIONS ASSESSMENT – BEACH SCRAPING

Criteria	Score	Notes
Protection of Infrastructure	+1	This option would provide a short-term erosion buffer. However it would provide only moderate protection again a severe erosion event.
Durability	-2	This option is required on an on-gong annual basis.
Constructability	+3	From a constructability perspective the works are straight-forward, and all of the sand can be obtained from within the bay.
Impact on Coastal Processes	0	This option has minimal net impact on the coastal processes.
Impact on Flora and Fauna	0	This option has minimal net impact on the local flora or fauna.
Compatibility with Climate Change and Sea Level Rise	+1	The configuration of the sand placement can be modified over time to adjust to sea level rise (by providing a high beach berm etc). However, due to the temporary and ongoing nature of its implementation, it is not considered to be a long-term solution to shoreline recession caused by sea level rise.
Social and Cultural Impact	+1	The beach nourishment would provide an increased area of dry beach width along the foreshore – however, the benefits are relatively temporary in nature.
Visual Amenity Impact	+1	Beach nourishment by sand scraping has a positive visual impact since the beach appears very natural. It gives a very natural aspect and preserves the natural character of the beach. However, the benefits are relatively temporary in nature.
Level of Community Support	+2	This option has a reasonably strong level of community support. See Section 2.4.
Net Benefit Score	+7	
Estimated 20yr NP Cost	$580 K	This cost is based on importing sand from the mainland. Compared to the high costs of other options, this represent a relatively inexpensive solution using a 20 year NPV.
Total Cost/Benefit Score	1.2	This options ranks as the 3rd highest scoring option.

TABLE 5-9 OPTIONS ASSESSMENT – DUNE AND FORESHORE MANAGEMENT

Criteria	Score	Notes
Protection of Infrastructure	+1	This option would provide improved growth and stability of the frontal dune, which will improve local erosion protection for the Esplanade and Pacific Drive. However, it would offer only moderate protection again a severe erosion event.
Durability	+1	This option is semi-durable, in that it will assist natural beach recovery after small to moderate erosion events. However, significant erosion of the vegetated dune is expected during a severe erosion event.
Constructability	+3	From a constructability perspective, the works are straight-forward. All of the sand can be sourced from within the bay, and other materials (fencing etc) are easily obtained and transported to the island.
Impact on Coastal Processes	0	This option has no significant impact on the coastal processes, and it would enhance the natural build-up of the dune.
Impact on Flora and Fauna	0	The nourishment would promote growth of coastal dune vegetation, promoting local dune habitat formation.
Compatibility with Climate Change and Sea Level Rise	+1	Providing a more robust and resilient vegetated dune system will allow for the local foreshore to better adapt to sea level rise.
Social and Cultural Impact	+2	A highly vegetated dune system will provide for better dune stability and will minimise erosion from stormwater and overland flow, thereby improving beach amenity.
Visual Amenity Impact	+2	Enhancing the local dune vegetation gives a natural aspect and preserves the natural character of the beach.
Level of Community Support	+3	This option has a strong level of community support, and was the most popular option identified in the community consultation exercise. See Section 2.4.
Net Benefit Score	+16	
Estimated 20yr NP Cost	$290 K	This is the least expensive option over a 20-year planning period. Ongoing maintenance may be needed in the form of revegetation and reconstruction of fencing after storm erosion events.
Total Cost/Benefit Score	5.5	This options ranks as the highest scoring option.

TABLE 5-10 OPTIONS ASSESSMENT – ROCK ARMOURED SEAWALL

Criteria	Score	Notes
Protection of Infrastructure	+2	This option would provide a last line of defence for Pacific Drive and associated infrastructure against storm erosion. However, the structure would need to be buried so as not to adversely affect local visual amenity. As a result, the wall is expected to be overtopped during a design storm event, and therefore may not provide protection from overtopping waves during major storm tides.
Durability	+3	A rock armoured structure is the most durable of the seawall options. If properly designed, a service life of over 50 years could be expected. Due to the low crest level it would need to be designed to prevent/minimise damage from inundation and overtopping behind the crest.
Constructability	-2	This would involve the relatively expensive exercise of shipping rock to the island from a mainland quarry. If buried under the esplanade park, its construction would require the removal of many well established trees and existing park infrastructure (pavilion etc). A temporary staging area may be required nearby in order to stockpile construction materials such as quarry rock.
Impact on Coastal Processes	-1	Since the seawall would be buried underneath the esplanade park, it is not expected to have the same adverse impacts that exposed seawalls typically offer – at least not in the short term. However, as the shoreline recedes in future due to sea level rise, this process may gradually emerge.
Impact on Flora and Fauna	-2	If buried under the esplanade park, it would require the removal of many well-established trees to construct the wall.
Compatibility with Climate Change and Sea Level Rise	-1	The seawall can be designed to accommodate increased wave energy and high storm tides due to future climate change. However, since its crest level would be relatively low - the wall may need to be raised in the future to accommodate sea level rise and to prevent damage caused by overtopping and inundation.
Social and Cultural Impact	0	The seawall would be buried beneath the esplanade park, and therefore would have minimal impact on recreational amenity in the short to medium term.
Visual Amenity Impact	0	The seawall would be buried beneath the esplanade park, and therefore would have minimal visual impact.
Level of Community Support	+1	This option has a moderate level of community support. See Section 2.4.
Net Benefit Score	0	
Estimated 20yr NP Cost	$6 M	This is the most expensive option, and there are significant expenses associated with transport of construction materials (quarry rock) from the mainland.
Total Cost/Benefit Score	0.0	This options ranks as the second lowest scoring option.

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TABLE 5-11 OPTIONS ASSESSMENT – CONCRETE SEABEE SEAWALL

Criteria	Score	Notes
Protection of Infrastructure	+2	This option would provide a last line of defence for Pacific Drive and associated infrastructure against storm erosion. However, the structure would need to be buried so as not to adversely affect local visual amenity. As a result, the wall is expected to be overtopped during a design storm event, and therefore may not provide protection from overtopping waves during major storm tides.
Durability	+3	If properly designed, a design life of over 50 years could be expected. Due to the low crest level it would need to be designed to prevent/minimise damage from inundation and overtopping behind the crest.
Constructability	-2	Concrete units could be cast on the island (saving shipping of units from the mainland). However all construction materials to form the Seabee units (concrete, aggregate, etc) would likely be sourced from the mainland. Furthermore, this option would require significant space for casting and storage of units. If buried under the esplanade park, its construction would require the removal of many well-established trees and existing park infrastructure.
Impact on Coastal Processes	-1	Since the seawall would be buried underneath the esplanade park, it is not expected to have the same adverse impacts that exposed seawalls typically offer – at least not in the short term. However, as the shoreline recedes in future due to sea level rise, this process may gradually emerge.
Impact on Flora and Fauna	-2	If buried under the esplanade park would require the removal of many well-established trees in order to construct the wall.
Compatibility with Climate Change and Sea Level Rise	-1	The seawall can be designed to accommodate increased wave energy and high storm tides due to future climate change. However, since its crest level would be relatively low - the wall may need to be raised in the future to accommodate sea level rise and to prevent damage caused by overtopping and inundation.
Social and Cultural Impact	0	The seawall would be buried beneath the esplanade park, and therefore would have minimal impact on recreational amenity in the short to medium term.
Visual Amenity Impact	0	The seawall would be buried beneath the esplanade park, and therefore would have minimal visual impact.
Level of Community Support	+1	This option has a moderate level of community support. See Section 2.4.
Net Benefit Score	0	
Estimated 20yr NP Cost	$3.6 M	This is the second most expensive option.
Total Cost/Benefit Score	0.0	This options ranks as the third lowest scoring option.

TABLE 5-12 OPTIONS ASSESSMENT – GSC SEAWALL

Criteria	Score	Notes
Protection of Infrastructure	+2	This option would provide a last line of defence for Pacific Drive and associated infrastructure against storm erosion. However, the structure would need to be buried so as not to adversely affect local visual amenity. As a result, the wall is expected to be overtopped during a design storm event, and therefore may not provide protection from overtopping waves during major storm tides.
Durability	+2	Typically, GSC structures have a shorter service life than rock or concrete armoured seawalls - generally only 15-20 years. However, as the structure is buried, and only exposed in the event of a severe storm, then a longer 40+ years' service life could be expected. Due to the low crest level it would need to be designed to prevent/minimise damage from inundation and overtopping behind the crest.
Constructability	+1	The overall volume of material required to fill the bags would be of the order of 6,000-7000 m3, which is a sufficiently small volume to be sourced locally from within the bay – and would not require additional sand to be brought to the Island. The sourcing of locally available materials would remove the need for large quantities of material to be barged from the mainland. The smaller 0.75 m^3 bags can be dry filled on site using fill frames supplied by the manufacturer.
Impact on Coastal Processes	-1	Since the seawall would be buried underneath the esplanade park, it is not expected to have the same adverse impacts that exposed seawalls typically offer – at least not in the short term. However, as the shoreline recedes in future due to sea level rise, this process may gradually emerge.
Impact on Flora and Fauna	-2	If buried under the esplanade park would require the removal of many well-established trees in order to construct the wall.
Compatibility with Climate Change and Sea Level Rise	-1	The seawall can be designed to accommodate increased wave energy and high storm tides due to future climate change. However, since its crest level would be relatively low - the wall may need to be raised in the future to accommodate sea level rise and to prevent damage caused by overtopping and inundation.
Social and Cultural Impact	0	The seawall would be buried beneath the esplanade park, and therefore would have minimal impact on recreational amenity in the short to medium term.
Visual Amenity Impact	0	The seawall would be buried beneath the esplanade park, and therefore would have minimal visual impact.
Level of Community Support	+1	This option has a moderate level of community support. See Section 2.4.
Net Benefit Score	+2	
Estimated 20yr NP Cost	$2.8 M	This is the third most expensive option.
Total Cost/Benefit Score	0.1	This options ranks in the middle of the options, with a relatively low benefit yield for its cost.

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TABLE 5-13 OPTIONS ASSESSMENT – ROCK ARMOURED GROYNE

Criteria	Score	Notes
Protection of Infrastructure	+2	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.
Durability	+2	A rock armoured structure is the most durable of the seawall options. If properly designed, a design life of over 50 years could be expected.
Constructability	-1	This would require the expensive exercise of shipping rock to the island from a mainland quarry. A temporary staging area may be required nearby in order to stockpile construction materials such as quarry rock.
Impact on Coastal Processes	-2	A groyne would disrupt the natural littoral drift along the beach and would likely result in erosion of downdrift areas.
Impact on Flora and Fauna	0	Elevated turbidity is likely during construction, though this may be mitigated through use of silt curtains.
Compatibility with Climate Change and Sea Level Rise	-1	The groyne can be designed now to accommodate the future increased wave energy due to storm intensification and sea level rise. However, as the crest level would be relatively low - the crest of the groyne may need to be raised in the future to accommodate sea level rise, to continue to capture and retain longshore sand transport, and to prevent damage due to significant overtopping and inundation.
Social and Cultural Impact	-2	A groyne could result in accretion of sand updrift of the structure which would improve the existing recreational amenity of the area. However, loss of access along the beach and erosion downdrift of the structure may occur.
Visual Amenity Impact	-3	In order to be effective, the height and length of the groyne structure would have a pronounced visual impact on the foreshore, and would drastically affect the natural character of the area.
Level of Community Support	0	This option has a low level of community support. See Section 2.4.
Net Benefit Score	-6	
Estimated 20yr NP Cost	$1.5 M	
Total Cost/Benefit Score	-0.4	This option has a negative net benefit score, largely owing to the pronounced social, recreational, and visual impacts.

TABLE 5-14 OPTIONS ASSESSMENT – INTEGRATED STORM WATER MANAGEMENT

Criteria	Score	Notes
Protection of Infrastructure	+1	This option would reduce the significant overland flow and stormwater related erosion that currently occurs at Horseshoe Bay beach. This process is a major contributor to erosion along the foreshore, consequently implementation of this option would also help the development and retention of a stable dune along the foreshore.
Durability	+2	Once designed and constructed, the stormwater system would have a high level of durability over future planning timeframes.
Constructability	+3	The implementation of this stormwater network would be relatively straightforward.
Impact on Coastal Processes	+1	This would reduce the impacts of beach erosion from stormwater runoff and overland flow.
Impact on Flora and Fauna	0	This impact is expected to be minimal. Improving overland flow management may assist in the development and retention of coastal dune vegetation.
Compatibility with Climate Change and Sea Level Rise	+2	The design of the stormwater system can account for rainfall intensification associated with future climate change. Since it involves decommissioning the existing stormwater outfalls on the beach, the network and outfalls will not be exposed to erosion and shoreline recession.
Social and Cultural Impact	+2	The reduction in stormwater erosion will provide for greater beach amenity through less frequent (and less severe) erosion during intense rainfall events.
Visual Amenity Impact	+1	Removal of stormwater outfalls from the beach will improve the visual amenity along the foreshore.
Level of Community Support	+1	This option has a moderate level of community support. See Section 2.4.
Net Benefit Score	+13	
Estimated 50yr NP Cost	$420 K	Compared to the high costs of other options, this represent a relatively inexpensive solution using a 20 year NPV.
Total Cost/Benefit Score	3.1	This options ranks as the 2nd highest scoring option.

6 RECOMMENDED SHORELINE EROSION MANAGEMENT

6.1 Components of the Recommended Strategy

Following a review of the environmental and social values of the Horseshoe Bay foreshore, the prevailing coastal processes, the causes and extent of the erosion risk, along with an evaluation of possible erosion mitigation options, the recommended future management of the Horseshoe Bay coastal reach has emerged. It incorporates a number of strategies, namely:

- Beach Dune and Foreshore Management.
- Stormwater Management;
- Ongoing Sand Scraping (on an annual and as-needed basis); and
- Periodic Monitoring Surveys.

Whilst providing for appropriate mitigation of the erosion threat along Horseshoe Bay Beach, the recommended strategies also achieve the following important outcomes:

- Preserves the visual character of the foreshore; and improves areas where the visual amenity has been diminished;
- Maintains convenient access to the beach while managing the impacts of increasing numbers of beach users on the stability of The Esplanade Park and its associated vegetation;
- Maintains the long-term stability of the foreshore, while acknowledging that long-term, short-term and seasonal fluctuations in erosion patterns occur; and
- Preserves the environmental values of the foreshore area and restores these values when/where appropriate.

6.1.1 Sand Scraping

Council currently has Development Approval for erosion management to undertake sand scraping on Horseshoe Bay Beach on an annual basis. The permit is for the scraping of up to 5,000m^3 of sand material. On its own, sand scraping does not provide an enduring solution to those sections of shoreline experiencing ongoing and long-term erosion processes. Nevertheless, it has been implemented effectively at Horseshoe Bay Beach to reinstate the local beach after erosion events, and for short-term recharging of sand buffers in the upper beach profile. This then assists in reducing timeframes for the natural reinstatement of the pre-storm profile (which as discussed, can take many years due to the low energy wave climate).

Whilst this Development Approval is for up to 5,000m^3 of sand, there is merit in amending the approval to permit a higher volume of sand scraping to better enable nourishment to extend further west, to include the region to the west of the boat ramp. A permit of 8,000 to 10,000 m^3 would allow for a larger 20m^3/m of nourishment along the full 460 m long stretch of the Esplanade – both east and west of the boat ramp. This additional volume of scraping would provide a larger storm erosion buffer for the frontal dune, and in doing so would facilitate the natural growth of local dune vegetation. It would also provide greater recreational amenity benefits.

There is also merit in applying beach scraping at Horseshoe Bay Beach as a proactive strategy of erosion management, rather than just the present approach of it being reactive. In other words, it could be better used to prepare for, and partially mitigate, expected storm erosion. For example, when the monitoring surveys undertaken prior to the onset of the Queensland cyclone season identify that the beach foreshore is in a depleted condition, then beach scraping could be undertaken to reinforce the sand buffers in the upper beach area. The trigger for such proactive works would be where 10 m^3/m or less of sand per lineal metre of beach above the level of Highest Astronomical Tide exists immediately seaward of the row of palm trees along the seawards face of the Esplanade Park. This would not only provide an adequate buffer to protect Pacific Drive infrastructure against the 1%AEP storm = 20m3/m, but would also provide additional protection to The Esplanade Park and Palm Trees.

However, it does not add extra sand to the local littoral system. It is simply redistributing sand within the beach profile. Therefore, beach scraping exercises cannot be considered as delivering long-term robust solutions to erosion problems. However, the 20 years life-cycle cost of this option is relatively inexpensive compared to hard structured alternatives and provides tangible (albeit relatively short lived) benefits in terms of beach protection and amenity.

Furthermore, if the dune management and stormwater management components are also implemented, then erosion events generated by overland flow and stormwater scour are expected to become less frequent and less severe over time – and that the local dune system will have greater ability to naturally recover. This may potentially reduce the frequency and size of the periodic sand scraping campaigns over the 20-year planning period.

6.1.2 Dune and Foreshore Management

The dune system at the study area needs to be effectively managed in a manner consistent with natural processes. Appropriate dune and foreshore management will assist in maintaining the natural ecosystem and ensure the structural integrity of the frontal dune as an erosion buffer. This option is discussed in detail in Section 5.5.6, but generally includes the following:

- **Revegetation of The Esplanade Park:** The planting of coastal vegetation species would allow for good drainage and have a growth habit that allows for trapping of wind-blown sand and beach re-building process to accelerate beach recovery. This revegetation would create a densely vegetated green zone, that provides a dense sward of root systems able to provide optimal stabilisation, and act as a barrier to trap wind-blown sand. This would increase the resilience of the local dune system, and improve the capacity of the local beach and dune system to recover after storm events.
- **Regrade and Reshape the Esplanade Park and Frontal Dune:** Where possible/appropriate it would be beneficial to establish a gradient across the park - redirecting overland flow away from the beach and back towards the stormwater system along Pacific Drive. This would include earthworks to reshape the frontal dune with a traditional dune and swale formation, so that the leading edge of the frontal dune is reformed around 1 metre higher than the surrounding foredune/esplanade park. This constructed dune and swale system would reduce overland flow impacts on the beach and promote groundwater recharge (as a bio-filtration system). The dune crest would need to be vegetated with native coastal vegetation. Some low height sand fencing may also assist in developing initial dune stability after construction.
- **Redesign Esplanade Accessways:** The existing paved stone and brick walkways along The Esplanade park could be replaced with permeable paving materials that allow for infiltration of surface run-off. This would decrease surface run-off and overland flow during rainfall events and reduce the impact of these processes on local beach erosion.
- **Limit and Formalise Pedestrian Access:** In order to assist in building and maintaining a vegetated Esplanade Park, there would be benefits to limiting access across the park to a number of formalised accessways (provided in the form of a permeable paving as described above). This would prevent the uncontrolled movement of pedestrians over the frontal dune, which currently contribute to dune erosion and surface runoff. In particular, the 240 m stretch of the Esplanade Park to the west of the boat ramp could be fenced off and beach access could be limited to a small number of accessways at around 50-100 m spacings. The stretch of Esplanade park east of the boat ramp could also be fenced to some extent, with consideration given to other park uses.

6.1.3 Stormwater Management

A practical and effective erosion mitigation option for the Horseshoe Bay foreshore would be to formalise and/or upgrade the current stormwater system along the Esplanade and Pacific Drive. This is discussed in more detail in Section 5.6.3, but would generally comprise upgrading the stormwater system along Pacific Drive to better accommodate high intensity rainfall events and to minimise overland flow across the esplanade park. This would include:

- **Upgrades:** Upgrading existing pipes and assets as required to prevent flooding during severe storm (rainfall) events, including potentially with permeable concrete pipes, such as HydroCon pipes, to further promote ground water infiltration;
- **Extensions:** The local stormwater network should be extended to properties which are currently without service. Furthermore, integrating a kerb along the western side of Pacific Drive would assist in the containment and management of overland runoff, including surface run-off diverted to Pacific Drive from the Esplanade Park.
- **Diversion:** The local stormwater system could be redirected/diverted so that it fully discharges into Beeran Creek, instead of partly discharging to the stormwater outfalls on Horseshoe Bay Beach. This would allow the stormwater outfalls along Horseshoe Bay can be decommissioned and removed, and would mitigate the current erosion issue of beach scour at those stormwater outlets.

It is anticipated that this option would require a local, site specific Stormwater Management Study - in order to assess the potential options in detail and inform the design of the requisite stormwater infrastructure and upgrades.

An additional option suggested by this SEMP is the provision of leaky rainwater tanks to upstream properties, with a priority to unconnected properties. These tanks promote the principles of water sensitive urban design under intense rainfall conditions, and would help the local stormwater system buffer against the first flush rainfall during intense rainfall events.

6.2 Project Design and Approvals

The implementation of the SEMP will need to incorporate the following:

- Prepare and submit appropriate approval applications based on designs for the proposed works. A review of relevant legislation and likely approval requirements are offered in Appendix D.
- Prepare and submit appropriate applications to extend the limit of the currently approved beach scraping permit to increase the permitted volume to 8,000 m^3.

6.3 Project Monitoring

Once implemented, monitoring the performance of the SEMP ensures that potential threats to project outcomes can be addressed in a proactive manner. Given that the primary objective of the SEMP is to manage the erosion threat along Horseshoe Bay Beach, regular surveys of the foreshore should be undertaken as part of the Plan. It is recommended that a survey campaign be undertaken as follows:

- Ten transect lines should be established at approximately 50 metre spacings, covering the full east-to-west span of Pacific Drive. Surveys should be conducted twice annually - both at the same time each year. Ideally this would be in late-October or early-November (immediately prior to the cyclone season), then again in late-March or early-April (immediately following the cyclone season). The location of these transects would be determined during detailed engineering design phase of project implementation.
- All beach transect surveys should extend well offshore beyond the toe of the beach to ensure that as much of the littoral system is captured by the survey. This will require planning to ensure that surveys are undertaken during periods of low spring tides.

- The monitoring surveys should commence prior to implementation of any physical works recommended by this SEMP, thereby providing a pre-project foreshore condition as a baseline reference.
- The monitoring survey program should be reviewed every three years and modified as required to ensure seasonal and annual changes to beach profiles are being appropriately captured, and that the survey program is providing the necessary technical support to maintaining SEMP outcomes.

As discussed in Section 3.2.11, in coming decades the foreshores of Horseshoe Bay are expected to experience the effects of climate change - which are likely to include gradual increases in sea level and volumes of sand being transported on beaches by natural processes. There remains significant 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 the recommended strategies in coming years and to guide future action.

6.4 Accommodating Future Climate Change

To better highlight how the effects of future climate change have been considered in the recommended Shoreline Erosion Management Plan (SEMP) for Horseshoe Bay Beach, it is perhaps appropriate to offer the following summary.

- A planning horizon of 20 years has been adopted for the SEMP. This is the longest of the range in planning horizons recommended by the State Government in guidelines when preparing a SEMP.
- The options assessment provided in this SEMP has considered the compatibility of all options with future climate change impacts.
- The beach condition will be monitored by regular surveys to capture how the cross-shore profile subsequently changes.

6.5 Estimated Costs

The estimated costs for implementation of the SEMP are provided below in Table 6-1. It should be noted that these costs are to be considered estimates only, for planning purposes.

TABLE 6-1 ESTIMATED COSTS FOR IMPLEMENTATION OF THE SEMP

SEMP Component	Capital Cost	Recurring Annual Cost
Project Design and Approvals		
Stormwater Management Study	$20,000	
Obtain appropriate approvals	$25,000	
Sand Scraping		
Annual sand scraping	$50,000	$50,000
Dune and Foreshore Management		
Regrade and reshape the Esplanade Park & frontal dune (earthworks)	$90,000	Maintenance costs around 4% p.a ($8,000)
Revegetation of Esplanade Park	$35,000	
Redesign existing Esplanade accessways	$55,000	
Formalising Access (inc. fencing and new permeable paving accessways)	$25,000	
Stormwater Management		
Upgrading & extension stormwater system along Pacific Drive (design & construction costs)	$150,000	Maintenance costs around 2% p.a ($7,000)
Diversion of stormwater into Beeran Creek (design & construction costs)	$150,000	
Provision leaky rainwater tanks to upstream properties (nominally assume 10 properties)	$50,000	
Project Monitoring		
Biannual surveys of study area	$5,000	$5,000
subtotals	**$655,000**	**$70,000**
budget contingency (in %)	40%	12%
budget contingency (in $)	$260,000	$10,000
TOTALS	**$915,000**	**$80,000**

6.6 Implementation Strategy

The scheduling of the various tasks associated with the implementation of the SEMP is shown in Table 6-2.

TABLE 6-2 IMPLEMENTATION SCHEDUELE FOR SEMP

SEMP Component	Month								Ongoing Requirements
	1	2	3	4 to 12	1	2	3	4	
Project Design and Approvals									
Stormwater Management Study									
Design of stormwater upgrades, extensions etc									
Obtain appropriate approvals				*indeterminant*					
Site Surveys									Undertaken annually
Sand Scraping									
Annual sand scraping									Undertaken annually
Dune Management									
Tender for Works									
Dune and Foreshore Management Site Works									
Stormwater Management									
Stormwater upgrades, extensions and diversions									
Provision leaky rainwater tanks to upstream properties									May be undertaken in a piecemeal fashion annually

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APPENDIX A
EPBC ACT PROTECTED MATTERS REPORT

APPENDIX B
SEDIMENT SAMPLING & TESTING RESULTS

APPENDIX C
CALCULATED EPAW AT HORSESHOE BAY

APPENDIX D
PLANNING AND LEGISLATION REVIEW

D-1 Background

This SEMP sits within the context of Commonwealth and State legislation and Townsville City Council's local planning policies. This section provides a summary of the key legislative and planning requirements that may impact how coastal erosion is managed in the study area, and how the recommendations of the SEMP are affected by those requirements.

The basis and control of management of Queensland's coast is governed by the *Coastal Protection and Management Act 1995* (Coastal Act) and the *Planning Act 2016*. Under these Acts, the Coastal Management Plan (CMP), the Coastal Protection State Planning Regulatory Provision (Coastal SPRP), the State Planning Policy (SPP) and the State Development Assessment Provisions (SDAP) are the primary statutory planning instruments for development planning and assessment.

Legislation and policies considered in this SEMP require consideration of issues including, but not limited to:

- The use of coastal structures for property protection,
- Protection of species listed under State and Commonwealth legislation and conservation of their habitat,
- Management of shoreline erosion in a manner that is not detrimental to the adjacent Great Barrier Reef Marine Park, and
- The maintenance of local biodiversity.

These legislative and policy considerations are described in more detail in the following sections.

D-2 Coastal Protection and Management Act 1995

The *Queensland Coastal Protection and Management Act 1995* (Coastal Act) governs the way coastal land is managed in Queensland. The main objects of this Act are to:

- Provide for the protection, conservation, rehabilitation and management of the coastal zone, including its resources and biological diversity; and
- Have regard to the goal, core objectives and guiding principles of the National Strategy for Ecologically Sustainable Development in the use of the coastal zone; and
- Ensure decisions about land use and development safeguard life and property from the threat of coastal hazards; and
- Encourage the enhancement of knowledge of coastal resources and the effect of human activities on the coastal zone.

The primary means of achieving these management objectives under the Coastal Act is through regulation of developments and allocations, and the preparation of management plans.

The coastal zone includes Queensland's coastal waters (to 3 nautical miles from the coast); as well as land and waters landward of coastal waters to a limit of 5 km from the coast, or to 10 m AHD elevation, whichever is further inland. The entire study area of the Horseshoe Bay SEMP is within the coastal zone.

A Coastal Management District (CMD) has been declared under the *Coastal Act* over lots which are likely to be subject to inundation by tidal water or increased coastal erosion under future climate change. The CMD defines an area in which the Department of State Development, Manufacturing, Infrastructure, and Planning (DSDMIP) has assessment manager or referral agency powers and responsibilities to assess certain development applications. The Department of Environment and Science (DES) is a technical advice agency to DSDMIP for development proposals in coastal management districts.

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Coastal Management Districts are shown on development assessment maps held by DSDMIP, as well as on coastal hazard maps prepared by DES. The coastal hazard maps of relevance to Horseshoe Bay are included in Appendix C of this SEMP.

Erosion prone areas are also declared over land vulnerable to short-term and long-term coastal erosion and tidal inundation. Such declarations are made under Part 4, section 70 of the *Coastal Act* by reference to erosion prone area plans that have previously been prepared by EHP (now DES). A 125 metre wide erosion prone area has been declared over most of the Horseshoe Bay coastal zone under the *Coastal Act*.

The Queensland Government currently manages the coastal zone using the Coastal Management Plan (CMP) and the State Planning Policy (SPP). The Coastal Management Plan (prepared under the *Coastal Act* and commenced in 18 March 2014) provides non-regulatory policy guidance to coastal land managers (primarily local government) for the management of the coastal zone and works that are not assessable development under the *Planning Act 2016*.

The State Planning Policy (SPP) provides State interests with policies to be considered by land managers particularly when preparing planning schemes. State interests include the coastal environment, biodiversity and natural hazards (i.e. coastal erosion). In addition, the SPP also provides development assessment criteria. The policy applies to a range of interests relevant to the SEMP, including coastal protection, water quality, native vegetation clearing, Queensland heritage, wetlands and environmentally relevant activities.

D-3 Planning Act 2016

In July 2017, Queensland began operating under new planning legislation – the *Planning Act 2016*, which replaced the *Sustainable Planning Act 2009* (SPA). Development within the coastal zone is regulated under the *Planning Act 2016*. The Act provides a framework to integrate planning and development assessment so that development and its effects are managed in a way that is ecologically sustainable.

The *Planning Act 2016* mandates a state-wide, applicant-driven development assessment system, by which local governments (and state agencies in some circumstances) assess and make decisions on the various land-use and development proposals.

The *Planning Act 2016* provides for the crafting of documents that guide strategic planning and development throughout Queensland. The foremost document is the planning scheme, which is created by local government taking into account the aspirations of their communities and the state's interests. Each scheme specifies the levels of assessment for all defined land uses, and the assessment requirements for each. The local planning scheme identifies what development and land-use proposals require an approval from council and what proposals do not need an approval.

The *Planning Regulation 2017* supports the principal legislation by outlining the mechanics for the operation of the Planning Act. It deals with practical matters such as: how development is categorised, who will assess a development application, and the state interest matters for development. In most cases, local government is the assessment manager. However, where the state identifies that it has a particular interest through the Planning Regulation, the state assesses those aspects of the development through the State Assessment and Referral Agency (SARA).

There are two statutory state planning instruments. These being:

- State Planning Policy (SPP) This instrument sets out the state planning matters considered as crucial to responsible land-use planning and development across the state. Councils must consider the state interests that apply to their local government areas when making, amending and implementing their planning schemes.

- Regional Plans. A regional plan focuses on the growth and development of a specific part of Queensland. Regional planning matters are identified in collaboration with local governments, key industry groups and the wider community. Where a regional plan exists, the local government must consider it when making or amending its planning scheme. The *North Queensland Regional Plan* (DSDMIP, 2017) includes the local government area of Townsville City Council, including Horseshoe Bay.

A summary of the Queensland planning framework is shown in Figure D-1 (reproduced from Figure 28 of DLGP, 2017).

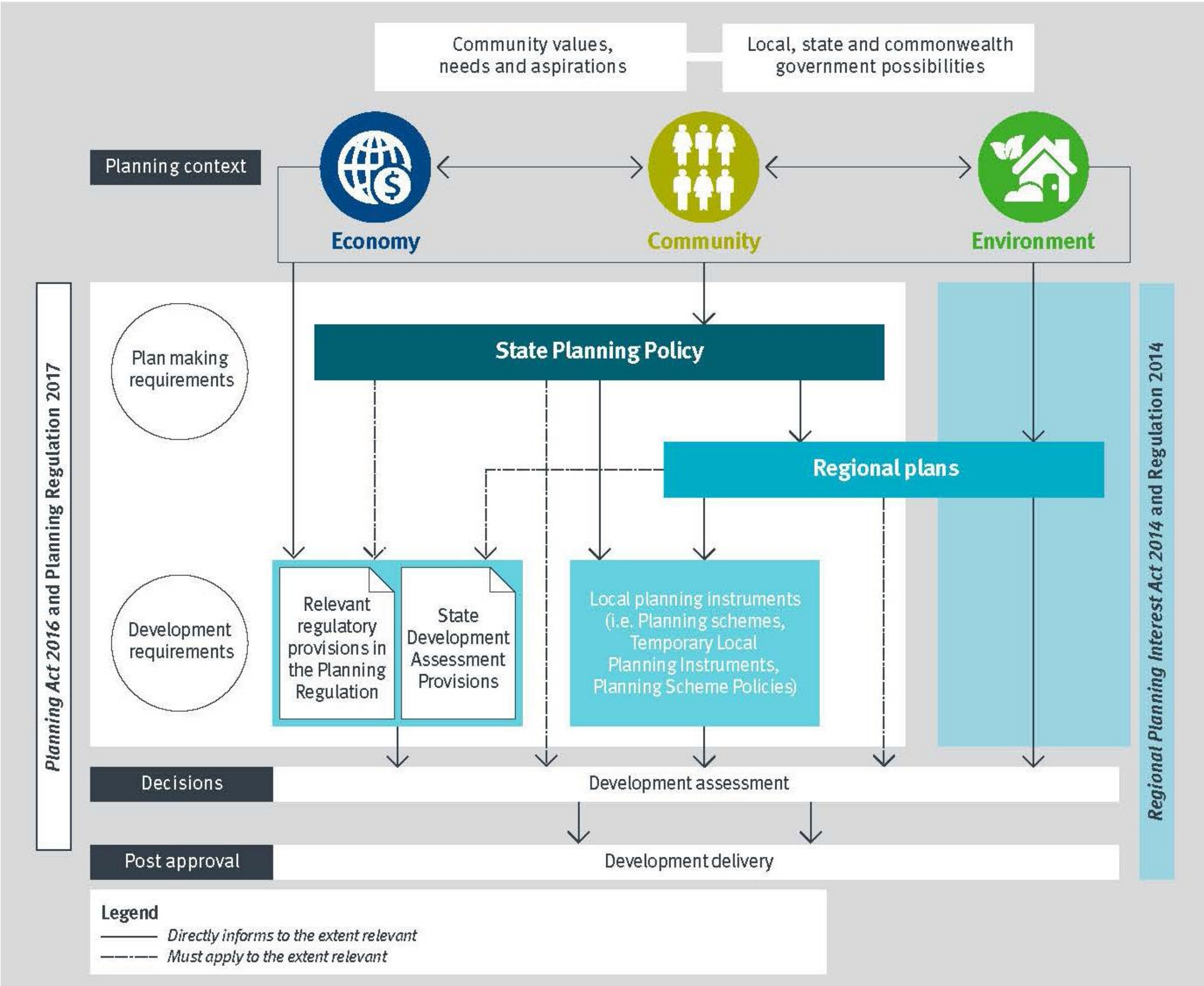

FIGURE D-1 QUEENSLAND'S PLANNING FRAMEWORK

D-3-1 State Planning Policy (SPP) 2017

A new State Planning Policy (SPP) was introduced in July 2017 to replace a number of former state planning policies and instruments. The SPP is a statutory instrument which defines the Queensland Government's policies about matters of state interest in land use planning and development.

The SPP includes 17 state interests that must be considered in every planning scheme across Queensland. Each of the 17 state interests in the SPP is supported by guidelines which help councils to implement the SPP provisions. State interests are arranged under five broad themes. Those relating to this SEMP include:

Environment and heritage

- *Biodiversity*
  - Matters of environmental significance are valued and protected, and the health and resilience of biodiversity is maintained or enhanced to support ecological integrity
- *Coastal environment*
  - The coastal environment is protected and enhanced, while supporting opportunities for coastal-dependent development, compatible urban form, and maintaining appropriate public use of and access to (and along) state coastal land.
- *Cultural heritage*
  - The cultural heritage significance of heritage places and heritage areas, including places of Aboriginal and Torres Strait Islander cultural heritage, is conserved for the benefit of the community and future generations.
- *Water quality*
  - The environmental values and quality of Queensland waters are protected and enhanced.

Safety and resilience to hazards

- *Natural hazards, risk and resilience*
  - The risks associated with natural hazards, including the projected impacts of climate change, are avoided or mitigated to protect people and property and enhance the community's resilience to natural hazards.

Liveable communities and housing

- *Liveable communities*
  - Liveable, well-designed and serviced communities are delivered to support wellbeing and enhance quality of life.

The Department of State Development, Manufacturing, Infrastructure, and Planning (DSDMIP) provides mapping that spatially represents matters of state interest in the planning system. This is provided by way of two GIS (Geographic Information Systems) platforms: The *State Planning Policy Interactive Mapping System* (SPP IMS), which is a standalone mapping system, and the *Development Assessment Mapping System* (DAMS), which incorporates mapping used for a number of different functions in development assessment.

Both the SPP IMS and DAMS are updated as required to reflect the latest information and any relevant government policy and legislative changes.

D-3-2 State Development Assessment Provisions

Development applications concerning certain matters of interest to the state are referred to the State Assessment and Referral Agency (SARA). In assessing applications, the state refers to both the SPP and the State Development Assessment Provisions (SDAP). The SDAP is a statutory instrument prescribed by the Planning Regulation 2017, which sets out the matters of interest to the State government when assessing a development application as either an assessment manager or a referral agency for a development application.

The state uses SDAP to deliver a coordinated, whole-of-government approach to the state's assessment of development applications.

State Code 8: Coastal development and tidal works of the SDAP provides a state code for development in the coastal management district or for tidal works. The criteria outlined in State Code 8 will need to be followed in a development application for coastal erosion protection works, as such works will be located within the coastal management district. The assessment criteria in relation to erosion prone areas generally emphasise avoiding new development and intensification, avoiding disruption to existing coastal processes and adopting "soft" solutions to coastal protection in preference to "hard" erosion control structures. Relevant performance outcomes (assessment criteria) include:

- Natural processes and the protective function of landforms and vegetation are maintained in coastal hazard areas.
- Erosion prone areas in a coastal management district are maintained as development free buffers, or where permanent buildings or structures exist, coastal erosion risks are avoided or mitigated.
- Development avoids or minimises adverse impacts on coastal resources and their values, to the maximum extent reasonable.
- Coastal protection work is undertaken only as a last resort where erosion presents an imminent threat to public safety or permanent structures.
- Development avoids adverse impacts on matters of state environmental significance, or where this is not reasonably possible, impacts are minimised, and an environmental offset is provided for any significant residual impacts to matters of state environmental significance that are prescribed environmental matters.

Coastal protection work is only to be undertaken to protect permanent structures which cannot reasonably be relocated or abandoned from imminent adverse coastal erosion impacts. Coastal protection work should involve beach nourishment as a first priority. The construction of an erosion control structure should only be considered if it is the only feasible option for protecting permanent structures from coastal erosion and those structures cannot be abandoned or relocated. Coastal protection work to protect private structures should be located on private land where possible and should not increase the coastal hazard risk for adjacent areas.

D-3-3 North Queensland Regional Plan Regional Plan

The *North Queenslad Regional Plan* (DLGP, 2011) is currently being prepared. The purpose of the plan will be to set out clear goals that will protect the region's unique lifestyle, provide well-connected transport, communication and social networks, safeguard the natural environment, and embrace diversity through a range of community, housing and employment and development styles.

The region includes five local government areas:

- Burdekin
- Charters Towers
- Hinchinbrook
- Palm Island
- Townsville.

The regional plan provides context for local level planning. The regional plan is implemented by the coordinated actions of state and local government and the community to achieve this shared vision for the future. The regional plan identifies the regional framework and desired regional outcomes for the North Queensland region. The regional plan is the pre-eminent plan for the region, and once finalised will take precedence over all planning instruments, other than state planning regulatory provisions.

The regional plan is a "whole-of-region" document. It is intended that the regional framework and desired regional outcomes in the plan will be additionally informed by more detailed and local assessment of issues by state and local governments, and more specific state planning policies and local government planning schemes.

D-4 Coastal Management Plan

The Coastal Management Plan (CMP) seeks to manage all coastal land and coastal resources within the coastal zone as defined by the *Coastal Act*. It applies to all management planning, activities, decisions and works that are not assessable development under the SP Act, including the development of a SEMP.

The guiding principle for the management of coastal landforms and processes is to preserve the long-term stability of dunes and other natural coastal landforms; and to allow physical coastal process including erosion, accretion and the movement of sediment to occur without interruption. However, the plan acknowledges that erosion can threaten communities and infrastructure. In this case, the CMP specifically calls for a Shoreline Erosion Management Plan (SEMP) to deliver a science-based solution to the erosion problem that considers social, environmental and economic issues.

Other matters on which the CMP provides policy guidance include:

- Conserving matters of state environmental significance (MSES),
- Maintaining and enhancing the connection of Aboriginal People and Torres Strait Islanders to coastal and marine resources,
- Maintaining and enhancing public access and use of the coast,
- Ensuring continuous improvement in management outcomes through planning, monitoring, reporting and review, and
- Sharing knowledge of coastal resources and management with the community and engaging the community in decision making processes.

D-5 Commonwealth Legislation

D-5-1 EPBC Act

The *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act*) is the Federal Government's central piece of environmental legislation. Approval from the Minister responsible for the EPBC Act is required to take any action (e.g. project, development, activity) that is likely to result in a significant impact on a *matter of national environmental significance* (MNES).

The one threatened ecological community, the twenty-four listed threatened species and the fourty-three migratory species protected by the *EPBC Act* within the study area are listed in Appendix A.

D-5-2 Native Title Act 1993

The *Native Title Act 1993* provides for the recognition and protection of native title in Australia. It is a recognition by Australian law that indigenous people have rights and interests to their land that derive from their traditional laws and customs. Native title determinations are undertaken in the Federal Court, upon application by a native title claimant.

The *Native Title Act 1993* sets out procedures for dealing with "future acts", which are proposals to use land or change administration or legislative arrangements in a way that affects native title rights and interests.

Examples include grazing, horticulture, water diversion, mining licences and construction of public infrastructure. The procedures for future acts depend on the nature of the act, and generally require more consultation and negotiation for acts that have higher impact on native title rights and interests.

In July 2012, the Queensland government granted native-title rights to a six-hectare parcel of Magnetic Island to the Wulgurukaba people. The land is situated at West Point on the western side of the Island. It was transferred under the Aboriginal Land Act 1991 and is the result of an Indigenous Land Use Agreement between the State Government and the Wulgurukaba People.

The recommendations in this SEMP have no direct or indirect implications to the exercise of the Wulgurukaba peoples' native title rights.

D-6 State Legislation and Instruments

D-6-1 Matters of State Environmental Significance

Matters of State Environmental Significance (MSES) are a component of the state's biodiversity interests that are defined under the State Planning Policy. MSES include certain environmental values that are protected under Queensland legislation, including the:

- Protected areas (including all classes of protected area except coordinated conservation areas) under the *Nature Conservation Act 1992*.
- Marine parks and land within a 'marine national park', 'conservation park', 'scientific research', 'preservation' or 'buffer' zone under the *Marine Parks Act 2004.*
- Areas within declared fish habitat areas that are management A areas or management B areas under the *Fisheries Regulation 2008.*
- Threatened wildlife under the *Nature Conservation Act 1992* and special least concern animal under the Nature Conservation (Wildlife) Regulation 2006.
- Regulated vegetation under the *Vegetation Management Act 1999* that is:
  - Category B areas on the regulated vegetation management map, that are 'endangered' or 'of concern' regional ecosystems;
  - Category C areas on the regulated vegetation management map that are 'endangered' or 'of concern' regional ecosystems;
  - Category R areas on the regulated vegetation management map;
  - Areas of essential habitat on the essential habitat map for wildlife prescribed as 'endangered wildlife' or 'vulnerable wildlife' under the *Nature Conservation Act 1992;*
  - Regional ecosystems that intersect with watercourses identified on the vegetation management watercourse map;
  - Regional ecosystems that intersect with wetlands identified on the vegetation management wetlands map.
- Strategic Environmental Areas under the *Regional Planning Interests Act 2014*.
- Wetlands in a wetland protection area or wetlands of high ecological significance shown on the Map of Referable Wetlands under the *Environmental Protection Regulation 2008*.
- Wetlands and watercourses in high ecological value waters as defined in the *Environmental Protection (Water) Policy 2009, Schedule 2.*

- Legally secured offset areas.

MSES mapping represents the definition for MSES under the SPP. The mapping generates individual layers using information from data including, but not limited to:

- marine parks
- fish habitat areas
- regulated vegetation mapping
- Queensland wetland mapping
- protected areas
- legally secured offsets included in the 'offsets register'.

The State Government's MSES mapping product is a guide to assist planning and development assessment decision-making. Its primary purpose is to support implementation of the SPP biodiversity policy. While it supports the SPP, the mapping does not replace the regulatory mapping or environmental values specifically called up under other laws or regulations. Similarly, the SPP biodiversity policy does not override or replace specific requirement of other Acts or regulations.

Nature Conservation Act 1992

The *Nature Conservation Act 1992* (the NC Act) relates to the protection of native flora and fauna and the declaration of protected areas.

Essential Habitat is vegetation in which a species that is Endangered or Vulnerable under the Nature Conservation Act (1992) has been known to occur.

The removal or destruction of native flora or fauna is unlawful unless it is authorised by a permit. If vegetation clearing is necessary for the purposes of implementing coastal protection works (including clearing to gain foreshore access) an appropriate permit under the NC Act must first be obtained. However, this does not apply to flora protected under the provisions of other Acts (e.g. marine plants).

No clearing of native coastal vegetation will be required as part of this SEMP.

Environmental Protection Act 1994

The *Environmental Protection Act 1994* (the EP Act) and the *Environmental Protection Regulation 2008* provide the main framework for controlling environmental harm and pollution resulting from development.

The EP Act establishes an environmental duty requiring entities to not cause adverse environmental effects unless all reasonable and practicable measures are undertaken to avert or lessen such harm. In the context of this SEMP, Townsville City Council is under an obligation to not undertake any activities that cause, or are likely to cause, environmental harm unless it takes reasonable and practicable measures to prevent or minimise harm. Environmental protection policies (EPPs) are also prepared under the EP Act to protect Queensland's environment. The objective of an EPP is to protect the environmental values and quality objectives for several attributes of the environment - including water, noise, air and waste management.

Environmental values and water quality objectives within the *Environmental Protection (Water) Policy 2009*.

Great Barrier Reef Marine Park Act 1975

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

- Establish the Great Barrier Reef Marine Park itself;

- Establish the Great Barrier Reef Marine Park Authority (GBRMPA), a Commonwealth authority responsible for the management of the Marine Park;
- Provide a framework for planning and management of the Marine Park, including through zoning plans, plans of management and a system of permissions;
- Prohibit mining operations (which includes prospecting or exploration for, as well as recovery of, minerals) in the Great Barrier Reef Region (unless authorised to carry out the operations by a permission granted under the Regulations, for the purpose of research or investigations relevant to the conservation of the Marine Park);
- Require compulsory pilotage for certain ships in prescribed areas of the Great Barrier Reef Region;
- Provide for regulations, collection of Environmental Management Charge, enforcement etc.

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

Within the study area of this Shoreline Erosion Management Plan, the Park's landward boundary is along the low water mark. Mean low water mark at the Horseshoe Bay is defined as RL-0.69 mAHD.

Zoning plans prepared in accordance with the Great Barrier Reef Marine Park Act define activities that may be undertaken within specific zones. In the vicinity of Horseshoe Bay, the adjoining area of the Park is predominantly Habitat Protection Zone.

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

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

Marine Parks Act 2004

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

The Marine Parks (Great Barrier Reef Coast) Zoning Plan 2003 (Zoning Plan) defines the zoning arrangements, including the objectives for each zone, the allowable and prohibited activities, and those that require a marine park permit.

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

"…high water means the mean height of the highest high water at spring tide."

When considering erosion mitigation strategies for this Shoreline Erosion Management Plan, it is likely that any works or activities below the high water line (and therefore within the State Marine Park) – a level at Horseshoe Bay of +2.14 mAHD will require approval under the State Marine Parks Act 2004. Permits are obtained for such works from the Queensland Parks and Wildlife Service (QPWS) of the Department of Environment and Science.

Fisheries Act 1994

The *Fisheries Act 1994* sets out Queensland's Department of Agriculture and Fisheries responsibilities for the economically viable, socially acceptable and ecologically sustainable development of Queensland's fisheries resources.

A declared fish habitat area (FHA) is an area protected under the Act against physical disturbance from coastal development, while still allowing legal fishing. Queensland's FHA network ensures fishing for the future by protecting all inshore and estuarine fish habitats (e.g. vegetation, sand bars and rocky headlands) contained within declared FHAs, which play the key role of sustaining local and regional fisheries.

Development works in declared FHAs require application for a resource allocation authority under *the Fisheries Act 1994* and a development approval under the *Planning Act 2016*, unless the works comply with accepted development requirements. There are no PHA’s in the vicinity of Horseshoe Bay, and no works proposed under this SEMP will impact any FHAs.

Native Title (Queensland) Act 1993

The *Native Title (Queensland) Act 1993* is state legislation which ensures that Queensland law is consistent with the Commonwealth *Native Title Act 1993* and validates pre-existing rights of the state. Certain past acts of the state, such as freehold grants, some leasehold grants, and public works are validated, such that they extinguish native title in relation to the land or waters concerned. Other rights such as existing ownership of natural resources, water and fishing access rights and public access to and enjoyment of beaches and other public places are confirmed by the act. Native title determinations and ILUAs made under the commonwealth’s *Native Title Act 1993* are valid under this state Act.

Aboriginal Cultural Heritage Act 2003

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

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

Land Act 1994

The *Land Act 1994* regulates the management of non-freehold land for the benefit of the people of Queensland. The Act invokes principles of sustainable resource use and development, consideration of land capability, allowing sustainable development in the context of the State’s planning framework, ensuring land is allocated to people or bodies who will facilitate the most appropriate use for the benefit of the people of Queensland, retention of land for community purposes, and protection of environmentally and culturally valuable and sensitive areas and features.

In coastal areas, this means that any development of land other than private freehold land must demonstrate a clear public benefit or demonstrate resource allocation.

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

Vegetation Management Act 1999

The *Vegetation Management Act 1999* prohibits clearing of regional ecosystems (i.e. native vegetation communities) unless it is for a relevant purpose. Clearing may be exempt from the approval process where listed under Schedule 24 of the SP Regulation. One of the purposes of the Act is to regulate vegetation clearing in a way that prevents the loss of biodiversity. To fulfil this obligation, Vegetation Management within Department of Natural Resources, Mines and Energy (DNRME) uses essential habitat mapping as a tool when assessing vegetation clearing applications to assist in determining whether the vegetation is habitat for Endangered or Vulnerable species.

Vegetation communities throughout Queensland are characterised and mapped by a procedure known as *Regional Ecosystems*. A Regional Ecosystem is a specific vegetation community occurring in conjunction with a particular combination of geology, soil type and landform within a specific bioregion of Queensland.

Many people would have a colloquial name for the vegetation type on their properties (such as open scrub, or coastal vine thicket) and know the land type (e.g. floodplains or rocky slopes). A Regional Ecosystem basically defines a grouping of land types and vegetation. Defining Regional Ecosystems assists in classifying biodiversity, ecological processes and vegetation communities on a landscape scale.

Regional Ecosystems are used to provide a consistent approach to planning, vegetation management and legislation across Queensland. Regional ecosystem data is reported every two years to provide statistics on the extent of Queensland's remnant vegetation and regional ecosystems.

Each Regional Ecosystem (RE) is classified by a three-part code (e.g. 11.2.5). The first number of the RE classification is the bioregion, the second part signifies the geology, soil and landform, while the third part refers to the vegetation. The grouping of these three factors produces a Regional Ecosystem.

As noted above, the first part of the RE classification is the bioregion. Queensland has been divided into thirteen different bioregions which are based on broad landscape patterns that indicate major differences in climate, geology, animals and plants across Queensland. *Brigalow Belt* (of which the Magnetic Island is a part) is designated as bioregion number 11.

The second number of a RE is the land zone. Twelve land zones have been defined in Queensland. Land zones represent considerable differences in geology, landforms and soil types. Land zones largely match broad geological types and can therefore be identified using geological maps. The area covered by this SEMP is typically either:

- Land Zone 1: Tidal Flats and Beaches – which is land that is subject to tidal inundations (e.g. mangroves, beaches, tidal flats) or
- Land Zone 2: Coastal Dunes - such as coastal dunes, coastal lakes and swamps that do not get inundated by seawater.

The third number of a RE describes the vegetation type. A Regional Ecosystem describes vegetation by its structure (e.g., grassy woodland, open forest or wet heathland), the dominant plants in the canopy, and associated plants in the understorey. Scientific names are used since common plant names vary from one locale to another; and can sometimes be unreliable.

Regional ecosystems around the Horseshoe Bay Esplanade include:

- 11.1.4 - Mangrove low open forest and/or woodland on marine clay plains
- 11.2.1 - Corymbia tessellaris woodland on flat coastal dunes

- 11.2.2 - Complex of Spinifex sericeus, Ipomoea pes-caprae subsp. brasiliensis and Casuarina equisetifolia grassland and herbland on fore dunes
- 11.2.3 - Microphyll vine forest ("beach scrub") on sandy beach ridges and dune swales
- 11.2.4 - Lagoons in coastal dune swales

Queensland's Regional Ecosystem Description Database lists the biodiversity status (BD Status) and the vegetation management class (VM class) of each regional ecosystem. The biodiversity status is used for a range of planning and management applications. It is based on an assessment of the condition of remnant vegetation, in addition to the criteria used to determine the class under the *Vegetation Management Act 1999*. The VM class is listed in the *Vegetation Management Regulation* under the Act.

Almost all of the freehold land at Horseshoe Bay Beach is either cleared or is non-remnant vegetation. However, the study area is surrounded by high-value remnant terrestrial ecosystems of state significance. Regional ecosystems around the area include those listed above.

Queensland Heritage Act 1992

The object of the *Queensland Heritage Act 1992* is to provide for the conservation of Queensland's cultural heritage for the benefit of the community and future generations. This is achieved in part by the establishment of a register of places and areas of State cultural heritage significance called the Queensland Heritage Register. Any development that will occur in (or in association with) a heritage place listed on the Register by the Queensland Heritage Council requires assessment. However, no State heritage places have been identified within the SEMP study area.

D-6-2 Other Considerations

Consultation with the following agencies may be required regarding the legislation detailed previously:

- Department of Environment and Science (DES) for matters concerning foreshore protection works, conservation values, tidal quarry material allocations, management under the QCP; marine parks and NC Act permits;
- Department of Natural Resources, Mines and Energy (DNRME) for matters concerning the allocation and use of State Land, vegetation management, indigenous cultural issues and land title;
- Department of Agriculture and Fisheries (DAF) for matters concerning fisheries resources, marine plants, FHAs, and quarry operations.

D-7 Local Government

The Horseshoe Bay SEMP lies within the local government jurisdiction of Townsville City Council. Under *the Local Government Act 2009* (LG Act) this jurisdiction extends offshore to the high tide mark. However, Council also has jurisdiction for development assessment over its local tidal area.

The LG Act permits local governments to acquire jurisdiction from the State Government over the foreshore between the low-water and high-water lines for special purposes such as foreshore protection works. Townsville City Council controls land use and activities under the local planning scheme (under the SP Act) and Local Laws (LG Act).

D-7-1 Townsville City Council Planning Scheme

On October 2014, Townsville City Council adopted the *Townsville City Council Planning Scheme* (Townsville City Plan). It is the primary local planning instrument governing all planning and development within the Townsville City Council area. It includes the following the following planning scheme policies:

- Character residential planning scheme policy
- Cultural heritage planning scheme policy
- Development manual planning scheme policy
- Economic impact assessment planning scheme policy
- Emerging community planning scheme policy
- Flood hazard planning scheme policy
- Mitigating bush fire hazard planning scheme policy
- Natural assets planning scheme policy
- Parking rates planning scheme policy

The purpose and general effect of the planning scheme policies is to support the land use outcomes outlined in the Townsville City Plan. Local plans, codes, zones and overlays are used to achieve the outcomes identified in the Planning Scheme. The relevant Zone Map for the Horseshoe Bay township is shown in Figure D-2. The foreshore frontage is zoned as open space for recreational uses. The land to the immediate east and west of The Esplanade is zoned for environmental management and conservation.

FIGURE D-2 PLANNING SCHEME – ZONING MAP FOR HORSESHOE BAY TOWNSHIP

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