Coochiemudlo Island Shoreline Erosion Management Plan and Operational Plan

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Executive Summary

The Coochiemudlo Island foreshore is an important asset to residents, the wider community, the islands' Traditional Owners, and has high environmental, cultural, economic and social value. BMT has been engaged by Redland City Council to complete a Shoreline Erosion Management Plan (SEMP) for Coochiemudlo Island to provide strategic direction for the sustainable use of the Islands coastal zone and facilitate coordinated planning of their long-term shoreline erosion management obligations.

The Coochiemudlo Island SEMP program, as laid out by Redland City Council, has the following 5 key stages:

Stage 1 – Project initiation

Stage 2 – Shoreline erosion management study

Stage 3 – Draft SEMP Plan and Operational Plan

Stage 4 – Revised draft SEMP and Operational Plan

Stage 5 – Presentation of revised draft SEMP and Operational Plan to the Community Reference Group.

An investigation of coastal process related issues together with other environmental, social, economic, and cultural needs was undertaken to inform assessment of management options appropriate to Coochiemudlo Island and is detailed in a separate Stage 2 report (Coochiemudlo Island Shoreline Erosion Management Plan: Stage 2 - Shoreline Erosion Management Study, BMT 2020).

Most of Moreton Bay is designated within the Moreton Bay Marine Park (MBMP) and the land and waters of Coochiemudlo Island below high water are part of the Moreton Island to Broadwater habitat protection zone (HPZ) of the MBMP. A similar area of Moreton Bay is also designated under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) as Wetland of International Importance ('Ramsar wetland'), declared due to their importance as habitat for migratory shorebirds. This includes the intertidal areas of Coochiemudlo Island as well as the Melaleuca Wetlands Reserve.

While a Native Title determination has not been finalised over Coochiemudlo Island, this area is covered under the current Quandamooka Coast Claim (QC2017/004).

The Emerald Fringe was recently included in the local heritage listing for the Redland City Council on the basis of the following three criteria (Redland City Council, 2018):

- Criteria A: The place is important in demonstrating the evolution or pattern of the region's history.
- Criteria E: The place is important to the region because of its aesthetic significance.
- Criteria G: The place has a strong or special association with a particular community or cultural group for social, cultural or spiritual reasons important to the region.

Coochiemudlo Island is a low energy coastal environment, sheltered from ocean swell waves by North Stradbroke and Moreton Islands. An assessment of available data including historical aerial imagery found minimal long-term changes to most of the Island's beaches with measured recession or growth of the shoreline often within the order of accuracy of the georeferencing. The exception is North-eastern Norfolk Beach which has experienced approximately 20m of erosion between 1955 and 2018, however images from intervening years indicate that this is not a lineal process.

The study has confirmed that sand transport can occur in both directions on Norfolk Beach, varying seasonally depending on prevailing conditions. A weak net southerly transport is indicated long term under the influence of stronger north-easterly events occurring over summer months. Movement of sand northwards from north-eastern Norfolk Beach onto the tidal flat adjacent to Morwong Beach can occur under high tides and south-easterly conditions. Sand transport is westerly along Main Beach, with a low rate of loss indicated past the golf course. Overall, the predicted wave climate and pattern of longshore sand transport suggests sand transport on all beaches will largely be sporadic and dominated by episodic storm events, with very low rates of net longshore transport occurring under ambient conditions. The ferry terminal was rebuilt in 2015 and the barge ramp upgraded in 2018, which may disrupt westerly transport of sand in the short term. Assessments indicate that it is unlikely that sand is arriving at Coochiemudlo Island from sources within Moreton Bay.

The impact of storm wind and surge has been documented in recent times, including erosion caused by ex-TC Oswald. Erosion caused by storm events is expected to be the critical erosion process acting on Coochiemudlo Island and recommendations have been made to assist in beach recovery and increasing resilience against subsequent events. Due to the thin layer of sand covering bedrock on Coochiemudlo Island, movement of small volumes of sand from one location to another may involve comparatively significant horizontal movement of the shoreline and localised movement of sand due to storm events can show as noticeable erosion in one location when there has been a similar volume of accretion on an adjacent beach.

Beach profile surveys have previously been completed on Main Beach east of the Ferry Terminal and Norfolk Beach fronting Victoria Parade East. The surveys indicate that the width of the upper beach fluctuates annually, however were insufficient to confidently identify trends of beach recession or accretion. An Island wide annual survey program has been initiated, with the first survey undertaken in the second quarter of this year (2020). Seven of the profiles are in approximately the same location as previous surveyed profiles and comparison with 2018 surveys indicates recent erosion has occurred on Norfolk Beach. In addition, members of the community have reported erosion on Norfolk Beach with photos showing erosion at the berm between 2015 and 2020. Photos from July 2020 show active beach recovery is occurring, however in order to supplement recovery processes and provide a buffer against future erosion immediate beach nourishment is been recommended for Norfolk Beach.

As discussed in the Stage 2 report and section 2.1 of this report management should preference ‘soft’ approaches (e.g. beach nourishment, reprofiling), with ‘hard’ engineering approaches only adopted where these softer approaches are not feasible. Hard engineering structures are not generally used to protect assets that are not built or trunk infrastructure.

Immediate beach nourishment of 3m^3/m (2400m^3 total) is recommended to repair remnant existing erosion on Norfolk Beach and return the beaches to functional units.

Beach reprofiling or beach nourishment are then recommended following each erosion event to accelerate natural processes, restore beach amenity and, in the case of beach nourishment, provide an additional buffer against future erosion events. Beach specific recommendations are provided in section 6 and section 8, however the general recommended approach is that beach profiling is undertaken to restore beach amenity following a minor erosion event where sand is retained on the beach above Mean Sea Level (MSL). Beach nourishment is recommended following more severe erosion events where sand is moved to below MSL and in areas where beach reprofiling is not suitable. Sand used for beach nourishment should be the same size or coarser than the native beach sand.

Groynes and an artificial reef or offshore breakwater have been suggested by members of the community as potential erosion control structures suitable for Norfolk Beach. Neither of these options have progressed through the multi-criterial analysis.

Seawalls have been considered for Norfolk Beach and are not recommended. While a properly designed and constructed seawall can protect the landward assets from erosion, it effectively isolates the sand located behind the wall from the active beach system and may lead to other adverse consequences, including loss of beach amenity in front of the seawall. Beach nourishment following an erosion event would still be required at the same frequency and in the same volumes to maintain beach amenity, leading to extra costs over nourishment alone.

While the existing seawalls on Norfolk Beach have strong support from some members of the community overall opinions are mixed, as evidenced by feedback received on this project. These seawalls were constructed as emergency works to provide protection to mature trees. Council has lodged an application with the State Government requesting approval of these structures, the outcome of which has not yet been finalised.

A plan to address maintenance and safety issues and complementary measures noted in the individual beach assessments is provided along with an initial indication of potential costs to assist in determining appropriate budgets.

An Operational Plan for response to storm erosion is provided with indicative beach nourishment volumes and costs for each beach compartment.

Ongoing Island wide monitoring is strongly recommended to better understand the detail of coastal processes and inform future management actions.

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1 Introduction

The Coochiemudlo Island foreshore is an important asset to residents, the wider community, the islands' Traditional Owners, and has high environmental, cultural, economic and social value. BMT has been engaged by Redland City Council to complete a Shoreline Erosion Management Plan (SEMP) for Coochiemudlo Island to provide strategic direction for the sustainable use of the Islands coastal zone and facilitate coordinated planning of their long-term shoreline erosion management obligations.

The Coochiemudlo Island SEMP program, as laid out by Redland City Council, has the following 5 key stages:

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An investigation of coastal process related issues together with other environmental, social, economic, and cultural needs has previously been undertaken (Stage 2 of the SEMP) to inform assessment of management options appropriate to Coochiemudlo Island (Stage 3 and revised in Stage 4) as presented in this report.

2 Planning and Legislative Framework

The planning and legislative context of the Coochiemudlo Island SEMP was detailed in the stage 2 report (BMT 2020) and is reproduced below for convenience.

2.1 Planning and Permissibility

A SEMP is a tool prepared under the Coastal Management Plan (CMP) that, if endorsed, can be relied on to support applications for coastal work approvals (see below). Coastal management outcome (CMO) 1.5 in the CMP provides the basis for the development of SEMPs:

> *Where there is an imminent threat to the community or infrastructure from coastal erosion, development of a shoreline erosion management plan (SEMP) is recommended to deliver a science-based solution to the erosion problem that considers social, environmental and economic issues.*

Further, the CMP notes that 'a SEMP s used to investigate the causes and expected future impacts of erosion, analyse management options, and recommend a solution, with consideration to social, economic and environmental issues.'

The SEMP, and associated management options, should be prepared in accordance with the CMP and other prevailing planning instruments. Thus, any actions proposed for shoreline erosion management should be compatible with the policy and regulatory framework set under state and federal instruments. The relevant elements of this framework in the context of the SEMP are set out below:

- Management should preference the maintenance of natural processes as far as practicable, with protection typically only acceptable where needed to protect the safety of people and integrity of assets or infrastructure. Management options should not be costlier than the infrastructure or assets they intend to preserve.
- Where retreat and/or relocation are not possible, management should preference 'soft' approaches where possible (e.g. beach nourishment, reprofiling), with 'hard' engineering approaches only adopted where these softer approaches are not feasible. Hard engineering structures should generally not be used to protect assets that are not built or trunk infrastructure.
- No works should be undertaken that will cause reclamation. This include construction of hard structures significantly below the high-water mark and backfilling. Reclamation works such as these are not supported in the Moreton Bay Marine Park without significant justification and amendment to regulated boundaries (i.e. legislative changes).
- The values of Ramsar wetlands, including those of the Melaleuca Wetlands Reserve, should be preserved from impacts associated with anthropogenic activities.
- Sand for beach nourishment must be sourced from outside of the marine park, if possible, or taken from navigation channels as part of maintenance dredging works.

- Management should avoid works that disturb or obscure items of Aboriginal cultural heritage. If such disturbance is necessary, it requires consultation and agreement with the relevant Aboriginal parties.
- Where possible, natural assets and public use areas, including beaches, should be retained as part of shoreline management works. However, this should be managed in balance with the principles above.
- Similarly, the local heritage values of the Emerald Fringe should be protected where possible due in line with the values identified in the heritage citation for this site (Redland City Council 2018). Some relevant values for consideration in management include the location of remnants of tourism infrastructure within the Emerald Fringe (e.g. possible tramway remnants, a cutting, lookout site) and vegetated coastal areas that provide significant aesthetic beauty and cultural value.
- Management should avoid works that, if undertaken, would cause the loss of important breeding and nesting habitat for threatened species.

Additionally, all management actions should be developed in consultation with the Quandamooka Yoolooburrabee Aboriginal Corporation (QYAC) as the representatives of the Quandamooka Traditional Owners, and subject to any Cultural Heritage Management Plan (CHMP) already in place between QYAC and Council. While a Native Title determination has not been finalised over Coochiemudlo Island, this area is covered under the current Quandamooka Coast Claim (QC2017/004).

Note that the above is the current prevailing framework. The authorisation of a SEMP and the approval of specific management actions requires further assessment from relevant regulatory agencies, including the Department of Environment and Science. Thus, there are opportunities for further discussion of preferred policy rules at these points. Therefore, except where an action is explicitly prohibited or not preferred under legislation (which is unlikely to change), management measures not completely aligned with the framework can be considered.

2.2 Approvals and Duties

Shoreline management works in Queensland are regulated primarily under the following systems:

- *Environmental Protection Act 1994* (Qld) – establishes a general environmental duty of care and pollution licencing conditions. This prevents taking action that could cause environmental harm except where licenced under the Act or other legislation, or (if not licencing regime exists) where all reasonable and practical measures are taken to avoid harm. Any works not requiring a licence, therefore, must account for the potential environmental harm they could cause. There is no duty, however, to undertake action to prevent natural loss of environmental values (e.g. erosion causing loss of coastal vegetation).

  The Act establishes a framework for Environmental Authorities required for environmentally relevant activities (ERAs) including dredging and placement. Works involved with sourcing and placing sand for beach nourishment purposes, therefore, may require an Authority under the Act.

- *Planning Act 2016* (Qld) – establishes a system for obtaining planning permits, including those triggered under some other legislation and local planning scheme. For shoreline erosion management relevant triggers for permits include:
  - Tidal works, including beach nourishment, groynes and seawalls.
  - Works interfering with state coastal land, including dune management works.
  - Disturbance of marine plants, including seagrass, mangroves, saltmarsh, melaleucas (where occurring below highest astronomical tide) and dead or fallen trees in tidal areas.
  - Bulk earthworks.
  - Disturbance of state-listed heritage features.
- *Coastal Protection and Management Act 1995* (Qld) – requires Quarry Material Allocation for sand that is to be removed from below high-water mark (e.g. placement of dredged material onshore).
- *Marine Parks Act 2000* (Qld) – requires Marine Park Permit for works within the marine park, including any works below high-water mark.
- *Aboriginal Cultural Heritage Act 2003* (Qld) – establishes a duty of care to not impact on known and unknown cultural heritage items. Where there is a risk of activities causing impacts (e.g. fresh excavations, works around scar trees) works must either adhere to the duty of care guidelines or be undertaken in agreement with the relevant Aboriginal party.
- *Nature Conservation Act 1992* (Qld) – requires permits for works that may impact on protected species, especially where works relate to relocating species and breeding habitat (e.g. nests).
- *Environment Protection and Biodiversity Conservation Act 1999* (Cth) – requires referral, assessment and potential permits for any works that could significantly impact on matters of national environmental significance.

3 Generic Management Options

3.1 Generic Option Considerations

A range of generic management options are available for consideration, which may be classified in terms of their consistency with natural coastal and environmental processes and the natural character and values of the coastline as follows:

"Soft" Options: Options which restore and/or preserve the natural character, behaviour and values of the coastal system. These will ensure the sustainable existence and natural character of the shoreline and foreshore such that future erosion, both during short term storms and over the longer term, can be accommodated in a coastal buffer zone without threat to development requiring protective works.

Soft options may include works such as beach nourishment with sand, re-vegetation of foreshore areas and/or planning solutions that require development to be outside the zone of potential erosion (buffer zone), including:

- Regulatory controls on building in undeveloped areas;
- Removal controls on building in undeveloped areas; and
- Works aimed at restoration of the shoreline/foreshore system seaward of the development to provide an adequate buffer width to accommodate erosion.

"Hard" Options: Options that involve construction of works either to form a barrier to natural coastal erosion to protect development (seawalls) or to alter the natural processes to change the way in which the shoreline behaves (groynes and breakwaters).

Combinations of options or "hybrid" management approaches are often the most suitable where existing development lies within the erosion prone area. For example, works options such as terminal protection (seawalls) are sometimes combined with partial set-back of development, or may be augmented with ongoing beach nourishment to offset associated undesirable environmental and recreational amenity impacts. In addition, most options need to be supplemented with relevant amendments to local planning controls.

Thus, engineering works options for the shoreline may include "soft" or "hard" solutions, or a combination of both. The most common feasible works options for overcoming beach erosion problems include the following and are discussed in more detail below:

- Beach nourishment with sand to restore the beach and dune system;
- Seawalls to protect assets;
- Groynes to control the longshore movements of sand; and
- Offshore breakwaters or submerged reefs to modify wave processes which erode the beach.

Such works options are generally expensive, typically in the range $3,000 to $8,000 per metre length of beach to construct for adequate protection, and the hard structural options typically have adverse side effects on the beach system. Ongoing maintenance requirements must be considered in both the design and financing. Experience indicates that careful design in full cognisance of the prevailing coastal and ocean processes and the short and longer term effects is essential for success and cost-effectiveness of such works.

For example, it is known that seawalls constructed on retreating shorelines may give protection to land based assets but will eventually cause loss of the adjacent beach. There is a need to ensure that the foundations of the seawall are sufficiently deep for stability to cater for the loss of the beach, typically requiring deeper foundations the more seaward the seawall is located. Similarly, beach nourishment must be designed and implemented to provide for the cross-shore and longshore movements of sand affecting the area for long term effectiveness in providing property protection while maintaining the recreational amenity of sandy beach systems.

3.2 Decision Matrix

It is convenient to consider beach protection options in the broad terms of the simple matrix illustrated in Table 3-1. This matrix, in effect, represents a decision tool based on criteria relating to:

- ‘Natural’ versus ‘Altered’ character; and
- ‘Non-works’ (planning) versus ‘Works’ options.

Table 3-1 Matrix of Beach System Management Options

Options	Preserve Natural Beach System Character	Accept Change to Natural Beach System Character
Non-Works Options (planning, management and regulation)	Development free buffer zones via planning or land use regulation; Resumptions of erosion prone development; Set-back of buildings; and Building guidelines and controls; Land use guidelines and controls; Management including dune care activities.	Accept development on vulnerable erosion prone land, but prevent any protection works (allow loss of buildings and facilities as erosion occurs).
Works Options	Beach nourishment with sand to restore the beach and dune system; Multi-purpose submerged reefs for shoreline protection and recreation (e.g. fishing, snorkelling, and surfing).	Seawalls to protect assets; Groynes to control the longshore movements of sand; and Offshore breakwaters to modify patterns of sand transport and shoreline shape.

To be consistent with coastal management policy guidelines and the priorities generally adopted by the community in areas where beach amenity and ecological integrity[1] is important, the options in the column headed ‘Preserve Natural Beach System Character’ would normally have highest ranking in any assessment criteria. Consideration may also be given to other low cost temporary works

[1] The ecological impacts of erosion control and beach nourishment from a fisheries resources point of view are discussed in (Batton, 2007) and will be considered in this SEMP.

options and hybrid options that combine the beneficial characteristics and offset undesirable characteristics of specific individual options.

The likelihood of success (or the risk of failure) is a key consideration in the selection of possible solution options. The options adopted involving expenditure of public funds should preferably be tied to proven techniques for dealing with beach erosion problems. There are a number of other (generally lower cost) options that are commonly put forward, covering a wide range of operational modes and with various claims of success. Most of these options typically have limited theoretical backing, have limited potential for providing significant long term benefits and/or have generally not been proven as an effective means of beach stabilisation. Such options would be ranked as low feasibility of success and would not be recommended.

3.3 Generic Shoreline Erosion Management Options

The options to deal with an erosion problem at a specific location depend on the nature and level of threat and consequences if it is left unchecked. The most appropriate shoreline management options may vary throughout the study area.

It must be recognised that some options aimed primarily at protection of assets located within the erosion prone area (e.g. seawall construction) may be detrimental to the shoreline amenity and recreational value. Considerations are set out below in the context of the nature of the erosion threat and the priority objective to be achieved.

3.3.1 Undeveloped Areas

In presently undeveloped areas, the key objective is to prevent an erosion problem from occurring in the future. That is, allowing the natural shoreline processes of erosion and accretion, including any progressive long term trend of shoreline retreat to occur without threat to assets.

Often the most successful coastal management strategy is to prevent development within the erosion prone area. The natural processes, including shoreline fluctuations, will thus be allowed to continue unimpeded and the natural amenity and character of the shoreline will be retained.

This may require a set-back control on any future development. To achieve this, the following coastline management strategies would need to be adopted:

- Ensure appropriate planning controls are in place to prevent infrastructure and residential development occurring in erosion prone areas which are presently undeveloped (preferably over a 100-year planning timeframe);
- Allow natural processes to occur with ongoing monitoring of coastline behaviour; and
- Continue dune/foreshore management and protection works and controlled access to the shoreline as required.

3.3.2 Areas with Existing Development

Where present development is not under immediate erosion threat, but may potentially come under threat over time, forward planning is needed to prevent future problems. The degree of natural variability in the coastal processes and the level of uncertainty in predicting future shoreline behaviour over long timeframes are such that the need for and nature of any future action will be dependent on uncertain factors such:

- Realisation of the erosion threat and the likelihood of ongoing recession;
- Effects of potential climate change impacts (e.g. sea level rise); and
- Future opportunities and attitudes towards coastline management and options for dealing with erosion threat.

The potential future threat from erosion should be recognised in present planning and appropriate strategies put in place that will not compromise future management decisions.

There are two basic strategic approaches for dealing with the problems of erosion threat to the development and loss of the shoreline, namely:

- Undertake works to hold or improve the present shoreline alignment, thereby preventing future recession; or
- Allow the shoreline to recede in such a way that the natural processes would maintain the beach characteristics and amenity, but at the expense of existing land and infrastructure.

There are alternative approaches within these two categories, as discussed below.

3.3.3 Retreat Options

The intent of retreat options is to remove the development under threat and allow the beach and dune to behave in the natural manner, thus restoring and retaining the natural character and amenity of the beach as the shoreline recedes. The planned retreat option acknowledges that erosion is an ongoing phenomenon and seeks to address the issue by removal of threatened facilities rather than trying to protect them. This would release a quantity of sand into the active beach from the receding dune system and provide some additional space for the natural beach movements to occur.

At some beaches there may be scope for setting back (retreating) some assets. Generally there are two different approaches to planned retreat which essentially relate to the ownership of the land and the responsibility for removal of structures. There are substantial differences between these options in terms of cost, who pays, likelihood of success and ultimate ownership of the beach as discussed below.

3.3.3.1 Retreat under Public Ownership

This option involves the upfront transfer of ownership of all land with an erosion risk to the Crown so that it is under public ownership as recession occurs. Key factors for consideration of planned retreat under public ownership are as follows:

- Transfer of ownership to the Crown should be controlled and implemented via a voluntary acquisition process by government;
- 100% of the affected properties must be obtained in any one beach location for this option to be effective;

- Coastal land values have increased over recent times and could increase further, which may result in high acquisition cost;
- Once implemented, a need would subsequently arise to address the erosion threat of the “new erosion prone area” (as the shoreline progressively moves landward) and this may entail further significant expenditure to purchase. Unless this land was also purchased, all previous money spent on acquisition could be wasted; and
- At some locations, this retreat option could provide opportunities to establish or enhance public access to and along the beach as land ownership is transferred to the Crown.

3.3.3.2 Retreat under Private Ownership

This option involves the land remaining in private ownership as recession occurs. Key factors for consideration of planned retreat under private ownership are as follows:

- The affected land (currently privately owned) would remain in private ownership when it is lost to erosion and private individuals would be responsible for their own planning in terms of loss of buildings, infrastructure and relocation.
- This option would require regulations to prevent implementation of erosion protection structures by private property owners that comprise principles set out in the CMP. This includes consideration of properties with ambulatory boundaries (which change with natural processes, such as shoreline recession) and those with ‘right line’ boundaries (which are unaffected by natural processes).
- Ad-hoc loss of private property to erosion typically causes significant adverse visual impacts.
- As a public shoreline progressively erodes, the beach could become private property, which could privatise access to and along the beach.
- In terms of equity, it is relevant that the beachfront allotments were historically created by the community (i.e. their representative being the government of the time) for residential use, prior to recognition of the erosion hazard.
- It is noted that experience at other coastal townships where the retreat option has been implemented (e.g. Byron Shire) has learnt that residents are reluctant to leave their beachfront locations and will utilise legal and practical means to protect their properties.

3.3.4 Protection Options

Options to hold the present coastal alignment generally fall into the following sub-categories:

- Beach re-profiling through the redistribution of the existing sand across the beach profile and active dune/foreshore restoration;
- Sand recycling or relocation of sand within the beach system;
- Beach nourishment to rebuild the beach with sand imported from outside the active beach system to make up the deficit, either alone or with other control structures to improve the longevity and give added protection; and

- Structural measures such as seawalls, groynes or offshore breakwaters/reefs to either directly protect assets or trap sand to rebuild the beach in front.

These protection options are discussed in more detail below.

3.3.4.1 Shoreline Reprofiling Options

Beach reprofiling, or “beach scraping”, generally involves relocating sand from the lower part of the beach to the upper beach and dune system using mechanical equipment (refer Figure 3-1 and Appendix C). The action is assumed to mimic natural beach recovery processes, albeit at an increased rate.

Figure 3-1 Beach Re-profiling using Mechanical Equipment (Carley et al., 2010)

Beach reprofiling can be successfully used to restore beach amenity, widen the upper beach and rebuild dunes. These actions will temporarily improve the protection of adjacent assets by increasing the beach width. Such works are relatively inexpensive, can be implemented quickly and are often undertaken in response to a significant beach erosion event. The main shortcoming of beach reprofiling as an erosion control measure is it needs to be repeated frequently and may only offer limited shoreline protection.

Beach reprofiling does not involve relocating sand from one beach compartment to another. Such an activity can be classified as either sand recycling or beach nourishment.

3.3.4.2 Sand Recycling

Sand recycling or relocation refers to moving sand within the beach system. Sand recycling differs from beach nourishment as no additional sand is added to system, rather the sand is simply redistributed to help maintain beach amenity or protect a section of shoreline susceptible to storm erosion. Sand relocation works are most successful on beaches where the direction of longshore sand transport is evident and sand accumulates at a location where it can be readily accessed. Groynes often trap suitable quantities of sand that can be relocated to updrift shoreline locations.

3.3.4.3 Beach Nourishment Options

The primary intent of beach nourishment is to ensure existence of the recreational beach and provide protection to the development by rebuilding the beach with sand imported from outside the active beach system. This effectively replaces the loss of sand from the system and/or the deficit in the supply of sand that is causing the erosion. In this way a natural beach and its associated values will be returned and maintained while providing a buffer of sand to accommodate natural beach fluctuations and protect the assets and facilities behind.

The quantity of sand required will depend on the level of initial and ongoing protection, the grain size of the material and the use of structures to enhance the longevity of the works. Sufficient sand should ideally be provided to be able to accommodate short term storm erosion and a period of long term recession associated longshore sediment transport differentials and sea level rise.

Provision should be made for the placed sand to extend across the full beach profile to nourish depleted nearshore areas as well as the upper beach, the total quantity of sand being determined accordingly. If the sand is placed only on the upper visible portion of the beach, redistribution will quickly occur to establish an equilibrium profile giving the impression that the sand is ‘lost’ and the project is a failure. In such a case, the sand is, in fact, not ‘lost’ but remains in the active system providing an overall net gain commensurate with the quantity placed after cross-shore distribution.

Dune construction and stabilisation works to prevent sand loss due to wind erosion usually needs to form part of any substantial beach nourishment scheme aimed at restoring the beach and dune system. In that case, it would incorporate design provisions to prevent dune overtopping and oceanic inundation as well as to accommodate the effects of climate change including sea level rise. Where the aim of the nourishment is to re-establish a beach in front of an existing seawall without provision of a dune, the need for stabilisation works such as establishment of native dune vegetation would depend on the potential for wind erosion resulting from the works.

While beach nourishment may affect the ecological values of the beach and nearshore areas, it needs to be recognised that the nourishment sand would be placed in the active zone where the natural environment is one of substantial fluctuations and disturbances to which the ecological communities adapt naturally. Furthermore, the nourishment would effectively rebuild the beach and nearshore profile to where they once were. As such, while there may be some short term ecological impacts, in the longer term the environment will adapt and recolonise to behave as a natural beach system.

One of the inherent advantages of beach nourishment is that it maintains the natural character and recreational amenity of the beach while also providing protection of coastal assets. As such, where the beach is severely depleted, it provides many intangible benefits to the general community, as well as a direct economic benefit to those businesses that rely on tourism and the presence of a usable beach.

However, identification and access to sources of suitable nourishment sand is usually a key issue, as is the ongoing cost to maintain this protection and amenity. When suitable marine sand sources are in close proximity project areas, the transport of sand to the beach is most cost-effectively achieved by dredging procedures. This method of sand delivery is not always operationally feasible and requires consideration of the vessel characteristics (e.g. draft, pumping distance) and environmental conditions (e.g. nearshore depth, wave climate).

3.3.5 Structural Protection Options

Structural options provide protection of assets against ongoing erosion either directly through the construction of a seawall or by rebuilding of the beach through the construction of groynes. They are options that could be considered in the event that sufficient beach nourishment sand is not available and/or retreat options are not viable. However, there are always some adverse impacts of such an approach where no additional sand is provided, as outlined below.

Such structures would typically be of flexible rubble mound design with rock being sourced and trucked to the site from quarries in the region. While they may be effective in protecting assets or providing a localised wider beach, they are generally accompanied by associated costs related to adverse impacts on the adjacent beaches. This cost is typically made up of direct costs associated with lost income from the tourist industry and other intangible costs associated with the natural coastal amenity, beach access, loss of recreational beach area and degradation of ecological values.

3.3.5.1 Seawalls and Revetments

Seawalls or rock revetments are commonly built with the intent of providing terminal protection against shoreline retreat. Seawalls are robust structures constructed along the shoreline which provide a physical barrier separating the erodible material immediately behind the structure from wave and current forces acting on the beach itself. They are typically constructed of loosely placed rock to allow for some flexible movement and need to be designed to withstand severe wave attack. Figure 3-2 provides an example cross-section of a rock revetment on a sandy shoreline with the toe of the structure down to the bedrock (impermeable layer).

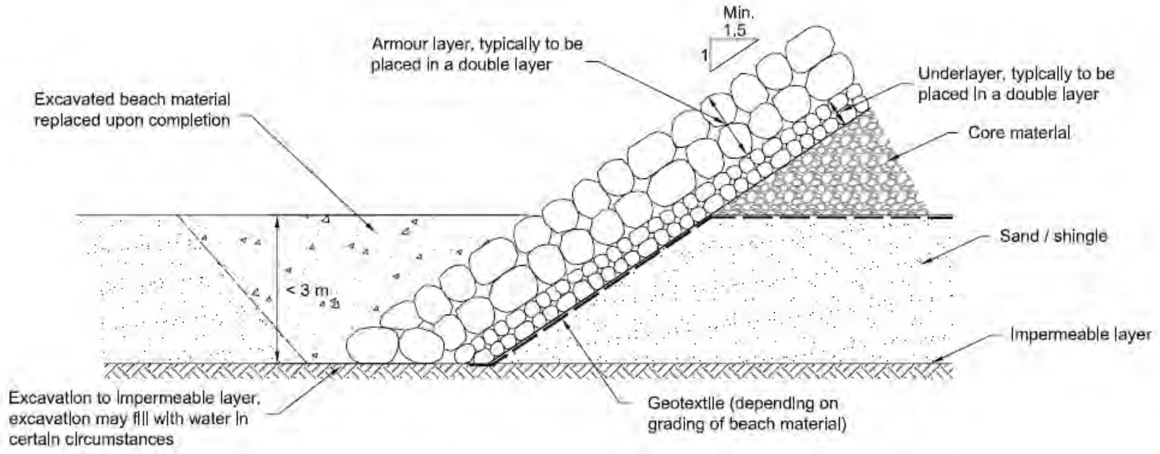

Figure 3-2 Cross-section of a Typical Rock Revetment Seawall (CIRIA, 2007)

Where possible, seawalls should be continuous to prevent end effects and/or discontinuities that could threaten the overall integrity of the wall. They also have to be suitably founded for stability against scour at the toe of the structure, particularly on a receding shoreline. Haphazardly placed rock and/or the use of inappropriate materials intended to provide shoreline erosion protection can have the opposite affect by accelerating the erosion problem.

While a properly designed and constructed seawall can protect the landward assets from erosion, it effectively isolates the sand located behind the wall from the active beach system and may lead to other adverse consequences. Examples are given in Appendix C.

On a receding shoreline, the seawall becomes progressively further seaward on the beach profile over time. This leads to a gradual increase in the quantity of sand effectively lost from the beach system, with:

- Lowering and eventual loss of the beach in front of the wall; and
- Exacerbation of the erosion on the downdrift end of the wall where the losses are transferred and concentrated.

Scour and lowering of the beach in front of the wall ultimately exposes it to higher wave attack and can lead to slumping and the need for ongoing maintenance. Such maintenance is typically in the form of topping up of the wall with additional rock. However, where the seawall is not adequately designed or constructed, complete reconstruction may be needed.

3.3.5.2 Groynes

Groynes and artificial headlands are impermeable structures typically constructed perpendicular to the shoreline and extend across the beach and the nearshore surf zone. Their function is to trap sand moving along the shoreline under longshore transport processes to build up and stabilise the alignment of the beach on the updrift side. By necessity they starve the beach of sand supply on the downdrift side causing erosion (an example is given in Appendix C).

The sand trapped on the updrift side provides a buffer of sand to accommodate short term storm erosion. The shoreline alignment will also change providing greater stability and reduced long term erosion immediately updrift of the structure. The extent of accretion and length of shoreline affected is dependent on the length of the structure as well as the characteristics of the longshore transport processes. Generally, the longer the groyne, the more sand it will trap over a longer distance with decreasing influence away from the structure.

There is a physical limit to the length of shoreline affected and therefore a number of structures may be needed if substantial benefit or protection is required over a long stretch of shoreline. In such a case, there is a balance between the length and spacing of groynes that needs to be optimised as part of a detailed design process.

An artificial headland is a substantial groyne type structure that has a physical width at its head in comparison to a conventional narrow groyne. It is believed that this width alters the mechanisms of sand transport past the end of the structure and may allow a wider/longer beach to be retained on the updrift side for the same protrusion offshore. This could have the benefit of minimising the need for, or maximising the spacing of, additional structures to provide protection for a long stretch of coastline. However, such headland type structures would be larger and more expensive to construct.

Groynes or artificial headlands can thus be used to rebuild a beach and stabilise the shoreline against ongoing recession on the updrift side. However, in the absence of other works such as beach nourishment, this comes at the cost of exacerbated erosion on the downdrift side to where the erosion trend is transferred.

Another significant consideration associated with groynes is their potential visual intrusion to the vista of a long sweeping beach and interruption to direct access along the beach. There are various design options with respect to the style and crest height of the structures that could be considered to minimise such adverse effects.

3.3.5.3 Offshore Breakwaters

Emergent offshore breakwaters (with crest level above the water surface at some or all stages of the tide) are commonly used to reduce wave induced beach erosion in the United States, Europe and Japan. Offshore breakwaters are typically constructed parallel to the shoreline and slightly seaward of the surf zone. The structure is intended to dissipate part of the incident wave energy and reduce the direct impact of storm waves. Under prevailing conditions, the presence of a breakwater will modify wave, flow and sediment transport patterns in the lee of the structure may promote the growth of a shoreline salient or tombolo. This effectively widens the target area of the beach and provides an additional erosion buffer. Offshore breakwaters are often constructed in a series to protect long sections of coastline, similar to a groyne field however with the advantage of not completing blocking longshore sediment transport (unless tombolos form).

Figure 3-3 Offshore Breakwater Series and Salient Formation (U.S. Army Corps of Engineers, 2002)

A major problem associated with the construction and maintenance of offshore breakwaters is their significant design requirements and large cost. By design, offshore breakwaters must be placed in the most energetic part of the nearshore zone which leads to operational difficulties during construction and renders them prone to damage during severe wave conditions.

3.3.5.4 Submerged Artificial Reefs

Submerged artificial reefs are designed to dissipate wave energy and/or rotate the average wave direction. The reduction in wave energy and/or induced wave refraction modifies the nearshore sediment transport patterns and can lead to the formation of a salient in the lee of the reef and therefore widens the beach. In this regard, a submerged artificial reef is intended to function in a similar way to an offshore breakwater (noting that the crest of a traditional breakwater is above the water surface). Some submerged reefs, such as 'The Twins' at Narrowneck on the Gold Coast (see Figure 3-4), attempt to combine shoreline protection with recreational surfing and/or snorkelling/SCUBA diving benefits and are referred to as 'multi-purpose submerged reefs'. Submerged reefs don't intrude on the beach and have the advantage of low visual impact. Consequently, the scenic amenity of an area is not altered.

Figure 3-4 Geotextile Sand Container Artificial Reef at Narrowneck, Gold Coast (Source: NearMap, 2011)

It is important to consider that a submerged artificial reef aims to take sand from the total sediment budget in order to form a salient and rebuild a targeted section of the beach. This typically moves the erosion problem to downdrift areas as observed with other shoreline structures that interrupt the natural sediment transport such as groynes or artificial headlands. To avoid undesired downdrift erosion beach nourishment should be undertaken to balance the material stored in the salient. Like offshore breakwaters, submerged artificial reefs may be considered a feasible option when there is a sufficient source of beach nourishment sand to balance any losses from the sediment budget.

It should be noted that the key environmental and/or structural parameters governing shoreline response to submerged structures remain uncertain. A fundamental research challenge is to establish and understand the mechanisms that cause erosion or accretion in the lee of such structures (Ranasinghe and Turner, 2006). The performance of offshore artificial reefs, from a shoreline protection perspective, is difficult to quantify due to the necessary complementary beach nourishment (e.g. Prenzler 2013, pers. comm.). For this reason, offshore artificial reef design requires detailed assessment and demonstration of an available source of nourishment material (to balance any potential adverse shoreline responses) to be considered as part of a viable shoreline erosion management strategy.

3.4 Material Sources and Costing Considerations

The implementation of coastal protection works is dependent on suitable material being able to be obtained and placed in a practical, economical and environmentally acceptable manner. General considerations associated with sourcing, cost and applicability of different material types are discussed below, including preliminary estimates in terms of unit costs for capital and ongoing maintenance works provided on the basis of available information.

Cost estimates for the various options are based on these unit rates for comparison purposes. Specific recommended works would be subject to detailed design, impact assessment and tendering processes that may influence the final cost. There will also be on-costs associated with the design, impact assessment and approval processes for the recommended options.

3.4.1 Shoreline Nourishment

The feasibility of shoreline nourishment is dependent on the practical and cost-effective availability of a suitable source of sand. Sand should be of suitable quality (grain size and colour) and would ideally match the existing beach sand. When nourishment sand is imported from outside the beach system, sufficient quantities of sand should be available for both initial and ongoing nourishment.

Sand for beach nourishments should be able to be obtained and placed without adverse environmental impacts. In environment sensitive areas, this may be challenging. Potential nourishment sand sources have been considered in terms of their location as discussed below.

3.4.1.1 Marine-based Sources

General considerations with respect to use of offshore sand sourcing sites include:

- Identification of sand source(s);
- Suitability of the sand;
- Quantity required for initial campaign and ongoing maintenance;
- Transport of the sand to the site;
- Rezoning and approval for sand extraction; and
- Potential environmental impacts.

Possible offshore sources of sand for beach nourishment purposes have not been investigated in detail, however it is possible that sand could be available from navigation channel dredging maintenance in lower Moreton Bay through the Gold Coast Waterways Authority (GCWA). Sand from offshore areas is typically dredged with a trailing arm suction hopper dredge that also transports the material to the deposition site where it would be pumped ashore or discharged to a nearshore area. The precise logistics for delivery depends on the location and how close the dredge can approach the shore. Ideally, the dredge would pump sand onto the beach, where it would be moved directly into design profiles by earthmoving machinery. Alternatively, it could be delivered elsewhere and trucked to the site.

Costs of such sources, if viable, are typically around $10-$30/m^3, depending on the distance and method of transport. This cost estimate does not consider the associated project costs such as environmental studies, beach profiling, pre and post construction surveys and ongoing monitoring.

Port of Brisbane Pty Ltd maintenance dredge material is currently used by Council to nourish the beach at Woorim (refer Figure 3-5).

Figure 3-5 Nourishment Sand being Delivered ‘over-the-bow’ to Woorim Beach

3.4.1.2 Land-based Sources

Considerations with respect to use of such sites include:

- Identification of sand source(s);
- Suitability of the sand;
- Quantity required for initial campaign and ongoing maintenance;
- Transport of the sand to the site;
- Possible need to purchase the property involved;
- Rezoning and approval for sand extraction;
- Potential environmental impacts including acid sulfate soil considerations; and
- Site rehabilitation.

Possible onshore sources of sand for beach nourishment purposes have not been investigated in detail on Coochiemudlo Island and beach nourishment material would likely need to be sourced from mainland locations. Sand from such sources would be transported to site by conventional equipment and trucks. If viable, the costs of such sources are typically around \$20-\$50/m^3 depending on the distance and method of transport.

While this is a proven method transportation of the sand by truck may be an issue, particularly if large quantities are involved. For beach nourishment operations where larger quantities are involved, a specific management plan is required to avoid/manage environmental and traffic concerns.

3.4.2 Shoreline Structures

Shoreline protection structures are typically of a flexible mound construction type to allow for some movement and to absorb some of the wave energy. Rock is the dominant material used in such structures and is dependent on suitable local sources being available. Alternative construction materials such as concrete armour units and sand filled geotextile bags could also be considered for such structures but have limitations such as high cost and poor visual amenity of concrete units and comparatively short practical life due to decay, failure and vandalism of geotextile units. However, this latter type of shoreline protection method has been successfully implemented at a number of locations throughout southeast Queensland.

Rock armour units would need to be obtained from local hard rock quarries. While the specific extent and limitations of the available resource is not known, it is evident that sufficient rock would be available but would need to be sourced by truck from quarries at substantial distance and cost. A significant constraint associated with rock armour is the need to truck the material to the site over local roads. For large projects, this can mean frequent truck movements over an extended time frame.

Geofabric containers will require sand to be imported for filling although the quantities are relatively smaller than rock. A favoured aspect of the geofabric container option is that they can be easily split and removed leaving the sand for future protection. The cost of geofabric containers is often only marginally less that rock.

Typical coastal structure costs including design costs and on-site placement are estimated as follows:

- Seawall (toe level -1m AHD, crest +4m AHD) ~ \$5,000/m; and
- Groyne (toe 2m below seabed, crest +3.0m AHD) ~ \$6,000/m.

Structures by their nature are subject to movement and settlement over time. They are also subject to damage during storm events although they are designed to withstand major wave attack. As such, ongoing maintenance will be required to ensure the structural stability is not compromised.

This will necessitate maintaining access to the top of any seawall to allow 'top up' works to be carried out. Minor slumping of land based or offshore structures after initial construction may not be an issue provided that the function and structural stability are retained. An ongoing maintenance cost of 1% per year is typically adopted for rock structures subject to storm wave attack.

3.4.3 Comparison Summary

A brief comparison of the various alternative means of combating erosion problems is shown in Table 3-2.

In many practical cases, a combination of methods may be more applicable than relying on any single approach. For example, a commonly used combination is beach nourishment and groyne construction. From the viewpoint of beach protection only, those approaches which do not involve direct interference with the beach system, namely “do nothing" and “planned retreat", are the most desirable. For most developed areas these options are not viable because of low public acceptance for lack of long-term property protection and/or prohibitive long-term costs.

Structural solutions such as rock revetments, groynes and offshore breakwaters are effective in some cases but all cause adverse impacts unless used in conjunction with beach nourishment. Beach nourishment does not cause adverse impacts with regard to long-term or short-term erosion at the beach nourishment site, or adjacent beaches and has been carried out with success on many beaches worldwide. The only real limitation of beach nourishment is its reliance on the local availability of a sand source from which material can be economically extracted and transported to the beach site and the funding commitment needed by Council.

Table 3-2 Comparison of Erosion Control Measures

Erosion Control Measures	Advantages		Disadvantages		Comments
1.Do nothing/Maintain Status Quo	(a)	Beach continues to behave naturally	(a)	Assets and improvements are lost by continued erosion	This approach is only practical where threatened assets are of limited value and the loss can be accepted
	(b)	No direct expenditure required on protective measures – removal of debris may be required	(b)	Limited application in developed areas	
2.Planned Retreat	(a)	Effectively solves the beach erosion problem	(a)	Public reaction against relocation is usually strong	In spite of the apparent drawbacks may be more cost effective over long term
	(b)	Beach continues to behave naturally	(b)	Compensation payments may be prohibitive	
3.Seawalls	(a)	Well suited to emergency erosion control	(a)	Only effective if properly designed and constructed	Should only be used in emergency situations or when an immediate threat to property and/or public safety exists; protects asset but not the beach
	(b)	Provides direct asset protection	(b)	Potential to adversely affect (lower) the beach during extreme erosion event	
			(c)	Decreased scenic amenity	

Erosion Control Measures	Advantages		Disadvantages		Comments
4.Groynes	(a)	Generally effective in building beach on updrift side	(a)	Does not prevent erosion – merely transfers it	Only useful in conjunction with beach nourishment or if erosion on downdrift side is acceptable
	(b)	Construction and maintenance is shore based and comparatively more cost effective that offshore operations	(b)	High level of maintenance	
			(c)	Intrusion on beach and high visual impact	
5.Offshore Breakwater	(a)	May promote the growth of a shoreline salient or tombolo and therefore widen beach	(a)	Construction and maintenance are offshore operations and typically difficult and expensive in areas exposed to wave activity	Commonly used in low wave energy environments in US, Europe and Japan however not typically found on the east coast of Australia
	(b)	Shelters beach from storm-induced wave attack	(b)	Results in downdrift erosion, nourishment usually required in lee of structure to balance sand lost to salient	
6. Submerged Artificial Reef	(a)	No intrusion on beach or impact to scenic amenity	(a)	Uncertainty regarding the mechanisms that lead to accretion or erosion of target shoreline	The key environmental and/or structural parameters governing shoreline response to submerged structures remain uncertain
	(b)	Potential recreational benefits (e.g. enhanced surfing and/or snorkelling/SCUBA diving conditions)	(b)	Construction and maintenance are offshore operations and typically difficult and expensive in areas exposed to wave activity	
			(c)	Nourishment usually required in lee of structure to balance sand lost to salient	
7.Beach Nourishment	(a)	Widens beach and therefore improves protection against coastal erosion events	(a)	Sources of nourishment sand not always close to nourishment site	Generally effective at alleviating local erosion problems
	(b)	Visually consistent with natural sandy shoreline	(b)	Requires viable sand reserves and necessary commitment to quickly renourish beach following erosion event	

3.5 Environmental Considerations

As well as the cost and effectiveness of each management option, environmental impact issues also need to be considered. Applicable legislation (Refer Stage 2 Report) may require detailed environmental assessments (e.g. Environmental Impact Assessments), and approvals processes and government authorities may require additional studies. Note that a comprehensive list of environmental issues for each site and recommended shoreline erosion management measures cannot be determined until the final details of proposed works are known. However, an indication of likely environmental issues is provided below as a guide.

3.5.1 Shoreline Nourishment

Beach nourishment is dependent on being able to source and place suitable sand in an environmentally acceptable, practical and economic manner. Sand can either be obtained from land or marine-based sources with specific considerations as outlined below.

3.5.1.1 Marine-based Sand Extraction

The following is a summary of the potential environmental impacts of marine sand extraction in the study area. This assessment does not include noise, traffic and transport associated impacts, and social and cultural aspects.

Water Quality

The disturbance of the substrata by sand extraction activities generally results in the remobilisation of sediments. The creation of turbid plumes can have indirect effects on aquatic biota and their habitats (e.g. smothering of benthic communities, reduced light in the water column and altered sediment-water dynamics). The extent and magnitude of such increases in turbidity depends on the type of equipment used, the volume and nature of any overflow from the dredge, the material being excavated and the currents present at the excavation site.

The material that would be excavated in marine-based sand supply is typically clean sand from highly active shoal areas with negligible fines content. Hence, turbidity plumes are expected to be of limited spatial and temporal extent.

In areas where there are other materials underlying the clean sands, extraction may result in elevated turbidity, and may potentially release contaminants or elevated oxygen demand into the water column. Wherever possible, disturbance of fine material should be avoided. This requires knowledge of the depths, quantities and characteristics of sand to be dredged.

Ecological Factors

The ecological impacts of sand extraction will vary according to the spatial/temporal scale being considered and the intensity of the disturbance, as well as the resilience of the populations and assemblages to disturbance. Generally, ecological impacts of sand extraction may include:

- Changes to biotope (habitat) structure associated with changes to the morphology of the dredged area. In this regard, shallow banks may be replaced by deep holes/channels.
- Direct effects on seagrass and mangroves due to removal and/or smothering, or indirect effects due to increases in turbidity.
- Disturbance of megafauna. Various cetaceans (dolphins and whales) may occur offshore. The slow speed of vessels used in sand extraction activities is not anticipated to cause mortality of megafauna from boat strike.

- Six species of marine turtles are known to occur in the region. These include the green (*Chelonia mydas*), loggerhead (*Caretta caretta*), hawksbill (*Eretmochelys imbricata*), leatherback (*Dermochelys coriacea*), olive ridley (*Lepidochelys olivacea*) and flatback (*Natator depressus*). Environment management actions are required to ensure turtles are not harmed by proposed dredging activities, and a strategy to manage nests and hatchlings would be required to be developed in conjunction with DES.
- Changes to the diversity, abundance, and structure of macrobenthic assemblages in and adjacent to the dredged area. Some species of benthic macroinvertebrates are of commercial importance (e.g. mud worms *Marphysa sanguinea* cf.) and are collected by recreational harvesters for use as bait (e.g. yabbies *Trypea australiensis*).
- Changes to the fish assemblages in and adjacent to the dredged area, with potential impacts to commercial and recreational fisheries.
- Changes to the population structure of species (e.g. sand crabs *Portunus pelagicus*, that utilise different habitat according to sex).
- Changes to the migration patterns of animals (e.g. crustaceans such as prawns and crabs), with potential impacts to commercial and recreational fisheries.
- Changes to the recruitment dynamics of fish and macrobenthic species. Impacts to recruitment dynamics potentially may have flow-on effects to recreational and commercial fisheries.
- Mobilisation of contaminants and nutrients following disturbance of sediments.

3.5.1.2 Land-based Sand Extraction

There are a wide range of potential environmental issues associated with land-based extraction, from the natural, social and economic perspectives. Potential impacts to natural environment are considered below.

Groundwater and Surface Water

Sand extraction operations on land have the potential to influence both groundwater and surface water through the release of toxicants and turbidity. The potential for disturbance of acid sulfate soils and the mobilisation of heavy metals is of concern. These contaminants may impact on either the underlying groundwater or surface water adjacent to the operations.

Ecological Impacts

Land-based extraction has the potential to have effects on fauna and flora communities and supporting ecological processes through a variety of means including:

- Loss of species as a direct consequence of habitat removal, reduction in habitat area (e.g. decreased habitat suitability for species requiring large home ranges) and habitat isolation (e.g. reduced opportunity to escape the effect of environmental perturbations and recolonise after such events). This may include impacts to species, habitats or ecological communities listed under the Commonwealth and State legislation.

- Alterations to ecosystem processes due to the development of edge environments, especially areas adjacent to small remnants. This usually involves changes in abiotic and biotic conditions such as microclimate changes (wind, radiation, soil moisture regimes) and increased presence of introduced flora and predatory fauna and disturbance-tolerant aggressive native species).
- Disturbance of acid sulfate soils, which when exposed to air produce sulfuric acid and may release toxic quantities of associated metals into the surrounding environment. Disturbance of other contaminated sediments may also be an issue.
- Negative pressures accompanying development and operations, including disturbance through increased human activity, traffic, noise and light pollution, etc.
- Potentially, large scale disturbances such as:
  - Reduction of population viability and genetic diversity resulting from disruption of ecological connectivity and population isolation. This results from decreases in, and/or cessation of regular successful dispersal between populations; and
  - Alterations to ground water levels (e.g. rising water table and increased salinity) and surface water hydrology (e.g. changes to runoff patterns and increased erosion). These effects may result in waterway degradation through increased salinity, turbidity and nutrient pollution.

3.5.1.3 Placement of Sand for Shoreline Nourishment

Change in Benthic Communities and Habitat Loss

The placement of sand on the shoreline has the potential for immediate impacts associated with burial of existing surface sediments and biota (macroinvertebrates and seagrasses). Sandy material that is placed onshore is unlikely to cause significant changes in the composition of surface sediments and habitat type, but would result in the burial of organisms that have colonised the area. Some buried organisms may be able to migrate through appreciable depths of placed material, but other organisms are likely to be lost. Assuming the surface sediments are similar to those prior to nourishment, recolonistation of the placement area would occur within a short time. Opportunistic and/or mobile species would recolonise the nourishment area within a relatively short period of time.

Further Ecological Considerations

Any loss of benthic macroinvertebrates and/or seagrass associated with burial from nourishment would represent a short-term reduction in available food/habitat resources for fish. Most fish species that inhabit the area would be capable to move from the placement area to forage in other parts of the study area.

Further, placement of sand for beach nourishment may temporarily disturb roosting, breeding or feeding activities of wading birds. Throughout southeast Queensland, the highest number of waders has been recorded in October, during the southern migration when population densities of migratory birds reach an annual peak. The lowest counts are typically recorded during August, a time when mainly resident and juvenile migratory birds (<one year old) stay in the region rather than migrate to breeding grounds in the Northern Hemisphere. In tidally influenced areas, waders forage across the exposed sand and mudflats at low tide (both day and night). At high tide, they move to higher ground to roost on beaches, salt marshes, claypans and artificial ponds.

Where nourishment is recommended, studies would need to be conducted to determine species using the impacted areas, and periods when roosting and breeding periods for these species can be avoided.

3.5.2 Shoreline and Offshore Structures Considerations

Historically, constructed features have been added throughout the study area and consequently the extent of artificial habitats increased. No known studies have been carried out on the flora and fauna assemblages of artificial shoreline habitats within the region. This is probably due to the fact that constructed features are not regarded as high priority conservation areas. However, in general, artificial structures in the coastal zone contribute to the maintenance of coastal ecosystems and the local richness of habitats and species in the region.

The erosion management options involving constructed features are:

- Replacement of existing rock seawalls;
- New rock seawall construction;
- Groyne construction;
- Offshore breakwater construction; and
- Submerged artificial reef construction.

Environmental considerations associated with these works are outlined below.

3.5.2.1 Terrestrial Vegetation

Replacement or construction of rock walls and groynes would require access to the foreshore. In many cases, there is vegetation in foreshore areas that would have to be removed.

Removal of vegetation for construction will cause a temporary loss of habitat and long term habitat change if there are limited opportunities for re-vegetation. Rebuilding of rock walls is likely to require a corridor of about 10 metres and construction of new rock walls could require a 10-20 metre corridor along the foreshore. In developed areas, removal of unprotected vegetation is likely to have a low impact on regional environmental values. However, these areas are important given the encroachment of urban areas on remaining patches of vegetated habitat.

3.5.2.2 Disturbance of Marine Habitat

Replacement of rock walls and construction of new rock walls, groynes, offshore breakwaters and offshore artificial reefs would impact on inter-tidal and/or marine communities. For example, where unvegetated soft sediments would be replaced by artificial substratum, different assemblages of biota would colonise the surface and may cause a change in biodiversity of the area.

The initial removal of rock required for the replacement of a wall would cause disturbance to benthic communities at the base of the wall and in nearby areas from physical removal and elevated levels of turbidity when works are conducted at high tide. Any adjacent beds of seagrass may also be affected. The effects would depend on the characteristics of the community and the nature of the disturbance. It is likely however, that natural coastal processes such as waves and currents disturb these areas on a regular basis, and as such, are likely to support opportunistic (early successional) communities comprised of species that are capable of rapid recolonisation. Likewise, disturbance to communities by the construction of new rock walls, groynes or offshore structures would have a similar effect, with nearby areas recolonising in a short period of time. Changes in current velocities and wave influences due to the construction of rock walls, groynes or offshore structures may potentially change the habitat type/substrata and, thus, result in a change in benthic community structure. Further, changes to water and sediment quality and depth of water may have significant effects on the nature of the system.

Flow on effects may occur in areas used for roosting/feeding by wading birds. The sensitivity of wading birds to disturbance and habitat loss, and the potential for future effects on the viability of local populations should be considered.

Although benthic communities used as food resources by fish and crustaceans may be removed (temporarily/permanently), it is expected that the high mobility exhibited by most common species in the area may result in fish temporarily moving elsewhere if food is in short supply to forage in other parts of the study region.

3.5.2.3 Creation of New Habitat

The artificial structures in the inter-tidal and sub-tidal zone would result in the creation of a new, albeit artificial, substratum that would eventually be colonised by a range of rocky shore associated species. Studies elsewhere have shown that assemblages that colonise artificial structures differ from those that may occur on natural reefs and substrata and that epibiota occurring on vertical surfaces can differ from that occurring on horizontal surfaces. Options promoted that involve the creation of new habitat may require additional studies to determine the potential beneficial and adverse impacts.

3.5.3 Managed Retreat Considerations

Planned retreat or the “do nothing” approach would affect terrestrial communities through the physical loss of vegetation due to erosion. Where vegetation of conservation value occurs in close proximity to the shoreline, there is a possibility that retreat may cause loss of this vegetation. However, it should be recognised that retreat is a natural process. Fauna species using the vegetation as habitat would be likely to move elsewhere as this gradual natural process occurs.[2]

Retreat would also be likely to result in the disturbance of marine fauna species associated with intertidal areas and dune areas. It is probable that these areas would be recolonised by similar fauna as presently occurs. Such a process would occur in association with natural movement of the shoreline. In this regard, impacts resulting from retreat would be short-term and localised.

3.6 Climate Change Considerations

Planning and management agencies are likely to be faced with undesired impacts of climate change and sea level rise, particularly on developed coastlines. It is convenient to consider appropriate climate change adaptation measures using the simple tool developed by BMT WBM (described in

[2] Note: there may be limited areas of available habitat with an increase in climate change and associated impacts.

Fisk and Kay, 2010). The tool works by establishing a time continuum for each climate change parameter or impact being assessed and identifies three key stages for the parameter or impact:

- The baseline (current condition) of the climate change parameter being examined at the time of plan preparation;
- The identification of one or more trigger points along the time continuum that flags to planners and/or responsible management agencies that more aggressive or decisive adaptation actions need to occur prior to the undesirable impact occurring; and
- The undesirable impact or end-state of the climate change parameter being examined (e.g. what are the impacts from climate change that are trying to be avoided?).

The tool can help decision-makers align perceived risk to infrastructure with the selection of the most appropriate adaptation measures and actions. In this regard, the tool is not limited to only climate change studies but can also be used to guide more immediate shoreline planning and management decisions. The tool is illustrated in Figure 3-6.

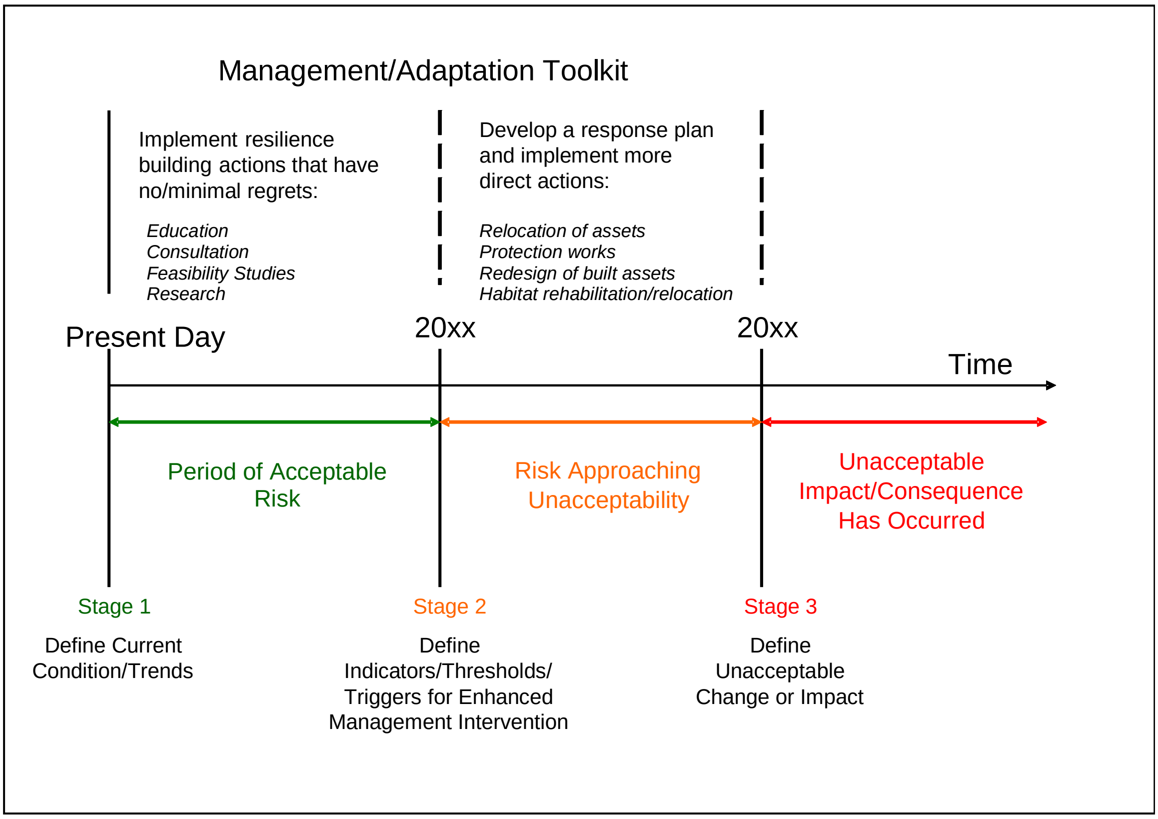

Figure 3-6 Application of Adaptation Actions along the Climate Change Risk Continuum

As discussed by Fisk and Kay (2010), using the tool to characterise climate change risks (and associated impacts) has a number of advantages, including:

- It provides a starting point in terms of establishing the context or the current condition of the risk parameter at the present day (on the left hand side of the continuum – Stage 1).

- It can be used to define and obtain agreement about the undesirable future impact that is trying to be avoided (on the right hand side of the continuum – Stage 3). An undesirable impact may be defined any number of ways but could include, for example, defining what is unacceptable in terms of regular inundation of critical infrastructure by tidal incursion and flooding or the loss of a particular coastal habitat type.
- It starts to try and define the risk over time and introduces the idea of one or more trigger points (between the two end points) that serve as flags for enhanced management action or consideration.

3.6.1 Future Climate Hazards

Statutory erosion prone areas are declared under section 70 of the *Coastal Protection and Management Act 1995* (Coastal Act) by reference to an erosion prone area plan. These plans have been developed to assist development assessment and to inform the preparation of planning instruments, such as planning schemes and regional plans under the *Planning Act 2016*.

The erosion prone areas apply to land subject to inundation by the Highest Astronomical Tide (HAT) by the year 2100 or at risk from sea erosion. On land adjacent to tidal water the erosion prone area is defined by whichever of the following methods gives the greatest width:

(1) 40 m buffer from the present-day HAT contour.

(2) Calculated erosion distance shown in Table 1 of the statutory plan.

(3) Permanent inundation due to sea level rise in 2100 (defined by present-day HAT plus 0.8 m).

The 40 m buffer from present-day HAT (component 1) generally applies within estuarine areas not exposed to open coast processes. This approximate method is intended to account for the migration of channels within tidal waterways with natural (undeveloped) shorelines.

The calculated erosion distance (component 2) is intended to cater for the potential loss of land for open coast locations (as Coochiemudlo Island is excluded from the State open coast erosion prone area mapping the methodology described in the Coastal Hazard Technical Guide (DEHP, 2013) has not been reproduced here).

The permanent inundation due to SLR (component 3) represents the HAT coastline (or elevation contour) in 2100 in the absence of any adaptation response to treat the risk, such as filling land to an elevation above the threshold water level.

For Coochiemudlo Island the erosion prone area is defined by the greater of (1) and (3) and is shown in Figure 3-7.

BMT has been advised that, as part of the $QCoast_{2100}$ program, Redland City Council is adopting a projected sea level rise of 0.4 m by 2070 for planning purposes. Contours of HAT and HAT + 0.4m were extracted from the 2009 LiDAR and are shown in Figure 3-8, along with the State mapped HAT + 0.8m line. For most of the Island the landward transition of the shoreline by 2070 does indicate major encroachment of the Emerald Fringe. None of the shoreline management options assessed in Section 6 of this report have a design life approaching 50 years and it is not anticipated that climate change impacts in shorter timeframes will be significant enough to require further detailed consideration.

LEGEND:

- Topographical feature
- Erosion Prone Area (All Components)
- 40m Buffer on HAT
- HAT+0.8m Sea Level Rise

Title:

State Declared Erosion Prone Area

Figure: 3-7

Rev: A

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 125 250m

Approx. Scale

BMT

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Filepath: I:\B23255_I_JLB Coochiemudlo SEMP MA\DRG\COA_029_200513_ErosionProneArea.wor

Legend

- Topographical Features
- HAT
- HAT + 0.4m Sea Level Rise
- HAT + 0.8m Sea Level Rise

Title:	Figure:	Rev:
Projected 2070 and 2100 Sea Level Rise	**3-8**	**A**

N

0 125 250m
Approx. Scale

BMT
www.bmt.org

Filepath: I:\B23255_I_JLB Coochiemudlo SEMP MA\DRG\COA_030_200518_HAT_plus_SLR.wor

4 Summary of Shoreline Erosion Assessments

Assessments to identify erosion and causes are detailed in the Stage 2 report (BMT, 2020) and are summarised below. Beach profiles were surveyed by Redland City Council officers on Main Beach east of the ferry terminal in 2016 to 2018 and Norfolk Beach fronting Victoria Parade East in 2013 to 2018. The most landward surveyed point is not fixed between surveys and the survey extent is limited to the portion of the beach above the water level at the time of the survey, ranging between approximately -0.5 m to -1.5 mAHD. The surveys indicate that the width of the upper beach fluctuates annually, however were insufficient to confidently identify trends of beach recession or accretion.

An assessment of historical aerial imagery found minimal long-term changes to most of the Island's beaches with measured recession or growth of the shoreline often within the order of accuracy of the georeferencing. North-eastern Norfolk Beach shows approximately 20m of recession between 1955 and 2018. Intervening aerial photos from 1997 and 2013 suggest that this is not a lineal process, with the relatively close locations of the 2013 and 2018 shoreline indicating that a new equilibrium alignment may be close to being achieved. Main Beach showed erosion of up to 10m east of the ferry terminal and accretion of up to 12 m west of the Ferry Terminal between 1997 and 2018, indicating that sand is transported west along the beach.

Modelling of longshore transport has qualitatively confirmed that sand transport patterns vary seasonally. The direction of sand transport may be northerly or southerly along Norfolk Beach, depending on prevailing conditions and tends to be northerly in winter and southerly in summer. A weak net southerly transport is indicated long term under the influence of stronger north-easterly events occurring over summer months. Sand transport northwards from north-eastern Norfolk Beach onto the tidal flat adjacent to Morwong Beach is possible under high tides and south-easterly conditions. Sand transport is westerly along Main Beach, with a low rate of sand loss past the golf course. Overall, the predicted wave climate and pattern of longshore sand transport suggests sand transport on all beaches will largely be sporadic and dominated by episodic storm events, with very low rates of net longshore transport occurring under ambient conditions. The ferry terminal was rebuilt in 2015 and the barge ramp upgraded in 2018, which may disrupt westerly transport of sand in the short term.

The impact of storm wind and surge has been documented in recent times, including erosion caused by ex-TC Oswald. Erosion caused by storm events is expected to be the critical erosion process acting on Coochiemudlo Island. Erosion resulting from an extreme event (using the present day 1 in 100-year design water level and significant wave height) was modelled using two median grain sizes (BMT, 2020). It should be noted that this modelling assumes an unlimited supply of sand available to be mobilised and does not consider the effects of vegetation on reducing erosion, or erosion controls such as the presence of bedrock or man-made coastal erosion protection structures. As the 1 in 100 year event is an extreme event and erosion volumes are likely to far exceed those resulting from what appear to be 1:10 year (or less) storm volumes, approximately half of the less conservative model results (median grain size of 0.36 mm) have been used to estimate nourishment volumes. These are still considered conservative. It should also be noted that due to the thin layer of sand covering bedrock on the Coochiemudlo Island movement of a small volumes of sand from one location to another may involve comparatively significant horizontal movement of the shoreline. As such, localised movement of sand due to smaller storm events can show as noticeable erosion in one location when there has been a similar volume of accretion on an adjacent beach.

It appears unlikely that sand is now arriving at Coochiemudlo Island from sources within Moreton Bay, however this assumption has not been confirmed by any particle identification or measurement methodology.

An Island wide annual survey program has been initiated, with the first survey undertaken in the second quarter of this year (2020). Three surveyed profiles on Main Beach and four surveyed profiles on Norfolk Beach are in approximately the same location as previous surveyed profiles. These are presented in Appendix D with June 2018 surveys for Main Beach and June and December 2018 profiles for Norfolk Beach. It should be noted that earlier surveys have not maintained a consistent profile location. While the comparison of surveys is indicative only, it is sufficient for an approximate estimation of beach change.

Members of the community have reported erosion on Norfolk Beach and photographs have been provided by Coastcare that show erosion at the berm occurring sometime between 2015 and 2020. These are provided in Appendix E.

Based on this information it is apparent that there has been recent unaddressed storm erosion on Norfolk Beach. However, photos taken by BMT in July 2020 (see Figure 4-1 and Appendix F) show active beach recovery and significant recovery of the beach is likely given sufficient time. As concerns have been raised by community members that if no action is taken erosion will be exacerbated by future storms, remedial action is recommended to accelerate recovery of Norfolk Beach and provide a greater buffer against future events. This is discussed further in section 6.3.5 and section 8.

Figure 4-1 Active beach recovery, Norfolk Beach, July 2020

4.1 Hazard Risk Rating Review

The Hazard Risk Ratings for Coochiemudlo Island beaches presented in the CAS (Draft Coastal Adaptation Strategy, RCC 2017) have been reviewed following the same methodology. The reviewed hazard risk ratings are presented in Table 4-1. Criteria scores that have been changed are indicated in **bold** and detailed below. Hazard risk ratings extracted from Appendix 3 of the CAS are presented Table 6-2. All tables referred are provided in Appendix G of this report.

The following changes were made to the criteria scoring:

- Environment (Table on page 20 of the CAS):
  - Criteria: Loss of the foreshore area from an erosion event (m2)
    - Score was reduced from 3 (1000m2 to 1,999m2) to 2 (100m2 – 999m2) for Red Cliff & Golf Links Beach.
    - Score was increased from 2 to 3. Norfolk Beach and Melaleuca Beach.
  - Remaining environment values are maintained at the current values.
- Social (First table on page 21 of the CAS):
  - Criteria: Recreational value of foreshore area
    - Score was increased from 2 (Low recreational value to local community) to 3 (Medium recreational value to local community, but low to minimal to broader community) for Norfolk, Melaleuca, Southeast and Morwong Beaches.
    - Score was increased from 1 (Minimal recreational value) to 2 for Red Cliff & Golf Links Beach.
    - Score has been maintained at 2 for Northeast Beach.
  - Criteria: Cultural Heritage
    - Score has been set to 3 (Locally important cultural heritage value identified) for all locations based on the local heritage status of the Emerald Fringe.
- Economic (Second table on Page 21 of the CAS):
  - No changes have been made to these values. It is noted that a rating of 5 for Infrastructure Value (>$1,000,000) for Red Cliff & Golf Links Beach seems to be high however, as reducing this rating to 1 will still result in a Medium consequence (and so not alter the hazard risk rating) and asset valuation data used for the CAS has not been made available, the rating it has been left as is.
- Erosion Factor (Second table on Page 22 of the CAS) :
  - Norfolk Beach – rating has been decreased to 2 (Low level of erosion occurring (i.e. recession and regeneration or continual fluctuation of shoreline).
  - Northeast Beach – rating has been increased to 3 (Medium level of erosion occurring (i.e. transformation of location – natural process of recession occurring in one location and progression at another).

- Overall assessment results:
  - Consequence ratings have remained the same beaches (please see first table on Page 22 of the CAS for calculation method).
- Risk ratings have changed for Norfolk Beach and Northeast Beach as follows (please see first table on Page 23 of the CAS for Risk Matrix):
  - M18 to M12 for Norfolk Beach
  - L8 to M12 for Northeast Beach.

Table 4-1 Updated Coochiemudlo Island Hazard Assessment Matrix

#	Location	Suburb	ENVIRONMENT								SOCIAL					ECONOMIC						
			Foreshore	Ecological Value					Nature Conservation Act		Visual Amenity	Recreation	Cultural Heritage	Population		Infrastructure value ($)	Property value ($)					
			The loss of the foreshore area from an erosion event (m2)	Adjoining terrestrial value (BPA 3.5) & VMA regulated vegetation	Marine Park Zoning	Ramsar listed	Fish habitat area	EPBC-listed endangered ecological community	Nature Conservation Act Species Present	Total (averaged)	Public viewing locations seen landscapes view corridors	Loss of recreation use	Listed Aboriginal heritage, European heritage sites	The number of properties directly affected by the identified hazard	Total (averaged)	Value of public infrastructure	Unimproved land value	Total (average)	Total average score	Consequence Rating	Erosion Factor	Risk Rating
2	Norfolk Beach	Coochiemudlo Island	**3**	1	3	5	1	1	3	**2.43**	3	**3**	3	1	**2.50**	2	1	1.50	**6.43**	Medium	**2**	**M12**
3	Main Beach	Coochiemudlo Island	4	1	3	5	1	1	3	2.57	3	3	3	1	2.50	4	1	2.50	7.57	Medium	2	M12
4	Southeast Beach	Coochiemudlo Island	2	1	3	5	1	1	3	2.29	2	**3**	3	1	**2.25**	1	1	1.00	**5.54**	Low	2	L8
5	Melaleuca Beach	Coochiemudlo Island	**3**	4	3	5	1	1	3	**2.86**	3	**3**	**3**	1	**2.50**	1	1	1.00	**6.36**	Low	2	L8
6	Northeast Beach	Coochiemudlo Island	2	1	3	5	1	1	3	2.29	2	2	**3**	1	**2.00**	1	1	1.00	**5.29**	Low	**3**	**M12**
7	Morwong Beach	Coochiemudlo Island	2	1	3	5	1	3	3	2.57	2	**3**	**3**	1	**2.25**	1	1	1.00	**5.82**	Low	1	L4
8	Red Cliff & Golf Links Beach	Coochiemudlo Island	**2**	4	3	5	1	3	3	**3.00**	3	**2**	3	1	**2.25**	5	1	3.00	**8.25**	Medium	2	M12

Table 4-2 Hazard Assessment Matrix (extracted from Appendix 3 pages 57 and 58 of the Draft Coastal Adaptation Strategy (RCC 2017))

#	Location	Suburb	ENVIRONMENT – Foreshore: Amount of land at direct risk of erosion (at current rate)	ENVIRONMENT – Ecological Value: Adjoining terrestrial value (BPA 3.5) & VMA regulated vegetation	ENVIRONMENT – Ecological Value: Marine Park Zoning	ENVIRONMENT – Ecological Value: Ramsar	ENVIRONMENT – Ecological Value: Fish Habitat Area	ENVIRONMENT – Ecological Value: EPBC listed endangered ecological community	ENVIRONMENT – Nature Conservation Act: Nature Conservation Act Species Present	ENVIRONMENT – Total (average)	SOCIAL – Visual Amenity: Public viewing locations seen landscapes view corridors	SOCIAL – Recreation: Loss of recreation use	SOCIAL – Cultural heritage: listed Aboriginal heritage, European heritage sites	SOCIAL – Population: The number of properties directly affected by the identified hazard	SOCIAL – Total (average)	ECONOMIC – Infrastructure value ($): Value of public infrastructure	ECONOMIC – Property value ($): Unimproved land value	ECONOMIC – Total (average)	Total average score	Consequence Rating	Erosion Factor	Risk Rating
2	Norfolk Beach	Coochiemudlo Island	2	1	3	5	1	1	3	2.29	3	2	3	1	2.25	2	1	1.50	6.04	Medium	3	M18
3	Main Beach	Coochiemudlo Island	4	1	3	5	1	1	3	2.57	3	3	3	1	2.50	4	1	2.50	7.57	Medium	2	M12
4	Southeast Beach	Coochiemudlo Island	2	1	3	5	1	1	3	2.29	2	2	3	1	2.00	1	1	1.00	5.29	Low	2	L8
5	Melaleuca Beach	Coochiemudlo Island	2	4	3	5	1	1	3	2.71	3	2	2	1	2.00	1	1	1.00	5.71	Low	2	L8
6	Northeast Beach	Coochiemudlo Island	2	1	3	5	1	1	3	2.29	2	2	1	1	1.50	1	1	1.00	4.79	Low	2	L8
7	Morwong Beach	Coochiemudlo Island	2	1	3	5	1	3	3	2.57	2	2	2	1	1.75	1	1	1.00	5.32	Low	1	L4
8	Red Cliff & Golf Links Beach	Coochiemudlo Island	3	4	3	5	1	3	3	3.14	3	1	3	1	2.00	5	1	3.00	8.14	Medium	2	M12

5 Multi-criteria Analysis Description

The proposed process to undertake a multi-criteria analysis of potential shoreline management options for Coochiemudlo Island is outlined below.

The option list will be assessed against a set of weighted criteria. A staged approach has been adopted for the assessment with options needing to achieve a minimum score before proceeding to the next stage of the assessment.

Each stage has sub-criteria with variable weightings. The proposed criteria and their weightings are given in the Multi Criteria Analysis (MCA) matrix and include:

- Stage 1 – Effectiveness and Technical Feasibility - whether an option is an effective erosion treatment and if the option is technically feasible.
- Stage 2 – Environmental and Community Impact – whether an adaptation option will benefit or adversely impact terrestrial and marine environmental values and social and community values, including Heritage values, Tourism and local business and Beach access and amenity.
- Stage 3 – Implementation Considerations – consideration of initial and ongoing costs, whether an option is consistent with current planning policy and/or legislative requirements, whether an option can be ‘reversed’ or adapted to cater for future needs, and whether or not community organisations can assist in delivery.

A ‘rating’ has been developed to apply to options available for different beach compartments, to indicate:

- “Very Positive” (rating = +2) where an adaptation option has very positive outcome
- “Positive” (rating = +1) where an adaptation option has a somewhat positive outcome
- “Neutral” (rating = 0) where an adaptation option has neither a positive or negative outcome
- “Negative” (rating = -1) where an adaptation option is has a somewhat adverse outcome
- “Very Negative (rating = -2) where an adaptation option has a significantly adverse outcome.

Once a rating has been assigned to each criterion and the weightings applied, a total score is calculated, and the scores are ranked in order of preference (i.e. highest score is ranked 1st, lowest score is ranked last).

Options with a “Very Negative” rating in either category of stage 1 (option is either ineffective at managing erosion or option is not technically feasible) of the assessment will not be progressed to Stage 2.

Options with a total stage 2 score of below zero (indicating an overall negative impact to environmental and community values) will not be progressed to stage 3.

Financial inputs to the MCA have been provided by Council. The rationale for the ranges adopted for initial and ongoing cost is as follows:

- Initial (Capital) costs: values are based on a percentage of the average annual city wide capital works budget for foreshore works over the past 3 years (5%, 15%, 30%, 50%, and 75%. This is so that the values are linked to a realistic estimate of that budget that might be available.
- Ongoing (Annual) costs: values are based on an annualised equivalent of the present values of the capital cost increments using an applicable timeframe and discount rate (20 years and 7%). This is so that there is a clear relationship between the capital costs and ongoing costs.

Table 5-1 Multi Criteria Analysis matrix

	Stage 1[3]		Stage 2					Stage 3				
	Effectiveness and feasibility		Environmental and Community Impact					Implementation Considerations				
	Effectiveness	**Technical feasibility**	**Terrestrial Values**	**Marine Values**	**Heritage**	**Tourism/Local Business**	**Access and use of beach**	**Initial Cost**	**Ongoing Costs (per year)**	**Consistency with State Policy**	**Reversible / Adaptable in the future**	**Community org. involvement**
	Will the option help manage erosion impacts?	Is the option technically viable?	Will it have a positive or negative impact?	Will it have a positive or negative impact?	Will it help protect heritage values?	Will it help protect tourism or business?	Will it preserve access and use of the beach?	Are the initial costs low, medium or high?	Are ongoing costs low, medium or high?	How likely that approvals can be secured?	Can the option be reversed or adapted for future circumstances?	Can community orgs assist in delivery?
Weighting	50%	50%	20%	20%	20%	20%	20%	25%	25%	25%	20%	5%
Very Negative (-2)	Option is ineffective at managing erosion.	Is not technically viable.	Will have significant adverse impact on terrestrial environmental values (i.e. Melaleuca Wetlands)	Will have significant adverse impact on marine environmental values (i.e. Moreton Bay Marine Park)	Will significantly impact negatively on heritage values (i.e. complete loss)	Will significantly impact negatively on tourism and/or local business	Will significantly impact negatively on beach access and/or amenity	Very High Economic Cost ($750,000 to 1,200,000)	Very High Economic Cost (75,000 to 120,000)	Is very unlikely to achieve approval under existing planning/legislative requirements	Option is completely irreversible once implemented; or option limits any alternative options in the future	N/A
Negative (-1)	Option provides a temporary solution (<1 year); or option requires further resources / changes to be effective over the short term.	Is only technically viable with substantial engineering (or other) design investigation and capabilities for implementation	Will have somewhat adverse, but not significant impact on terrestrial environmental values	Will have somewhat adverse, but not significant impact on marine environmental values	Will have somewhat adverse, but not significant impact on heritage values	Will have somewhat adverse, but not significant impact on tourism and/or local business	Will have somewhat adverse, but not significant impact on beach access and/or amenity	High Economic Cost ($450,000 to 750,000)	High Economic Cost ($45,000 to $75,000)	Will require an EIS and/or Govt program to implement; or there is a residual risk that approval will not be obtainable for the proposed works / strategy.	Option is difficult to reverse once implemented, but can be done with effort; or option does limit some alternative options in the future	N/A
Neutral (0)	Option provides a short term solution (1-5 years); or option requires further resources / changes to be effective over the medium term; or option is a complementary measure	Is likely to be technically viable at the site, but would require further investigations to clarify.	No net impact	No net impact	No net impact	No net impact	No net impact	Medium Economic Cost ($225,000 to $450,000)	Medium Economic Cost ($25,000 to $45,000)	Will require Govt approvals to be implemented, or assistance through existing Govt program; or generally approvals/assistance would be granted assuming requirements are met	Option is reversible or adaptable, but at some cost / effort	Community organisations are not able to assist in delivery
Positive (+1)	Option provides a medium term solution (5-10 years); or option requires further resources / changes to be effective over long term	Is technically viable with some effort.	Will slightly benefit terrestrial environment	Will slightly benefit marine environment	Will slightly benefit heritage values	Will slightly benefit tourism or local business	Will slightly improve beach access and/or amenity	Moderate cost ($75,000 to $225,000)	Moderate cost ($10,000 to $25,000)	Minimal government approvals required to implement	Option can be adapted for future circumstances or would have only minor impact on future generations	Option can be partially implemented by community organisations
Very Positive (+2)	Option provides a long-term solution (10-20 years)	Is technically viable and easily implementable at the site / location.	Will significantly benefit environment, (e.g. improve habitat value/increase total available habitat.)	Will significantly benefit environment, (e.g. improve habitat value/increase total available habitat.)	Will significantly benefit heritage values (i.e. preserve values for the future)	Will significantly benefit tourism or local business	Will significantly improve beach access and/or amenity	Limited cost (<$75,000)	Limited cost (<$10,000)	No government approvals required to implement or can be implemented under existing approvals.	Option can be easily adapted for future circumstances or should impacts not occur; or option would positively impact future generations	Option can be implemented by community organisations

[3] Options with a score of -2 for Effectiveness or Technical viability will not be progressed to Stage 2.

6 Option Assessments

6.1 Management Guidelines and Implications

The Queensland government legislation, as detailed in the Stage 2 report (BMT 2020), generally advises that where there is a natural buffer zone protecting property and built infrastructure from coastal hazards a "do nothing" approach would be the most appropriate option, as this results in a more natural beach and shoreline.

While this buffer can be considered to exist on Coochiemudlo Island in the form of the Emerald Fringe, it has been made clear by members of the CRG and Council that this parkland is to be considered as "green infrastructure" and protected. In addition, the Emerald Fringe was recently included in the local heritage listing for the Redland City Council on the basis of the following three criteria (Redland City Council, 2018):

- Criteria A: The place is important in demonstrating the evolution or pattern of the region's history.
- Criteria E: The place is important to the region because of its aesthetic significance.
- Criteria G: The place has a strong or special association with a particular community or cultural group for social, cultural or spiritual reasons important to the region.

While relatively sheltered compared to an open coast location the Island's beaches are still a dynamic environment and will experience periodic erosion and recovery as part of the natural processes. If multiple erosion events occur without sufficient time for recovery in between then loss of vegetation is highly likely, particularly on Norfolk Beach.

Following on from this there are two overarching management strategies that could be adopted:

- Firstly, acceptance that a natural process is occurring with cyclic erosion and recovery depending on the frequency and severity of storm events. If long term erosion occurs, even at a very low rate, the eastern beach will slowly roll back but retain a natural beach amenity; or
- Secondly, hold the current shoreline position. This can be with beach nourishment, which will retain beach amenity, or by structures such as seawalls, which will result in loss of the beach in front of the structures and exposed bedrock in many areas. If long term erosion occurs this loss of beach will be permanent.

While the Emerald Fringe provides the buffer to development required to allow natural processes to occur there is a strong community desire to hold the existing shoreline and prevent any loss of vegetation. As discussed (Stage 2 report, BMT 2020 and briefly in section 2.1) management should preference 'soft' approaches where possible (e.g. beach nourishment, reprofiling), with 'hard' engineering approaches only adopted where these softer approaches are not feasible. As such, the current study has recommended post-storm beach nourishment to hold the existing shoreline by accelerating natural recovery processes and, in the case of extra beach nourishment, providing a buffer against future erosion. Post storm nourishment should be done in a timely manner i.e. within 3 months as a second event occurring before any natural recovery has taken place may exacerbate erosion and vegetation losses.

6.2 Broad Complementary Measures

This SEMP is assessing management options for all shorelines of Coochiemudlo Island and these face four different directions and have a varied range of foreshores and exposure to coastal processes. As such each of the shorelines have different erosion pressures and therefore have different options available for erosion management.

However, there are a range of management measures that are similar for many beaches and these are described in this section. Unless noted otherwise in individual beach assessments these complimentary measures apply.

6.2.1 Beach Condition Monitoring

The coastal processes on Coochiemudlo Island are low energy by usual coastal process standards. Typical sand transport rates are several orders of magnitude lower than a typical exposed Queensland beach, even in storm conditions. Therefore, traditional means of assessment, including detailed numerical modelling, are not able to reliably capture and define these processes. The goal of any assessment is to predict the impact of sand movements on the beach, i.e. how much it might change in the future. The most accurate way to begin this assessment is to measure the changes in the beach over time with particular notice given to erosion events. For this to be effective it needs to encompass the areas where sand moves from and to so that absolute quantities are reconciled. This monitoring will make change assessment available in a quantified form and will support the less robust assessments currently available, such as interpretation of photographs and observations, to inform management actions. This was the primary method of assessment before numerical modelling became an accurate tool and in the recent past there were more than 160 full time survey stations located along Queensland’s coastline.

Beach profile surveys have been previously undertaken on Norfolk Beach fronting Victoria Parade East and Main Beach east of the Ferry Terminal. The surveys indicate that the width of the upper beach fluctuates annually, however were insufficient to confidently identify trends of beach recession or accretion, or lack thereof (BMT 2020). Regular surveying was not undertaken on Morwong Beach, Norfolk Beach north of control point 3, or Main beach west of the Ferry Terminal.

Therefore, detailed survey monitoring of the beaches on Coochiemudlo Island is vital to both understand and quantify beach changes and to measure the success of management actions. As the changes in beach levels on Coochiemudlo Island are small monitoring needs to be very accurate. A survey specification was provided to Council in November 2019 and has been included in Appendix A. It is recommended that monitoring is carried on an annual basis on all beaches, with additional surveys immediately after an erosion event. These additional surveys will be required to inform locations and quantities of beach nourishment and/or beach reprofiling.

CoastSnap type photo points at key locations have been discussed at CRG meetings. This may be a good idea for a few critical locations and would likely be inexpensive to install, although Council would have to manage photo uploads and storage. This would not decrease the need for surveys to assess beach movement trends, however it could inform beach condition between surveys.

Areas to prioritise for photo monitoring are as follows:

(1) Norfolk Beach. Photo monitoring of this beach could assist in confirming the extent and severity of reported erosion issues and inform beach condition between surveys. Beach access may provide suitable locations for photo monitoring, giving a view along the beach in both directions.

(2) North-eastern Norfolk Beach/Control Point 5. Photo monitoring of this area may assist in informing how much sand moves on and off the beach and help inform erosion rates and confirm if erosion is gradual or event driven. If a photo monitoring point is installed on the north-eastern rock outcrop it may possible to use the same point to cover Morwong Beach. Morwong Beach appears to be accreting, not eroding so it is less critical. Note that it is expected that permits would be required to install any structure on the rock outcrop.

(3) Main Beach. Photo monitoring points to provide coverage of the entire beach would be ideal, however priority locations are the heavily trafficked areas east of the barge ramp. While Main Beach is not showing signs of consistent erosion the area is heavily frequented with more infrastructure. If photo monitoring points can be installed on the ferry terminal it might be possible to good coverage to the west along Main Beach to the Red Cliffs.

It should be noted that to have benefit such a program will require ongoing data management and analysis.

6.2.2 Underlying Bedrock

The volume of sand on Coochiemudlo's beaches is very limited due to underlying bedrock in some locations. Storm erosion is typically assessed as a volume i.e. m^3/m and therefore thin layers of sand will show more horizontal movement than thicker layers. Also, where longshore transport is being modelled or calculated, it is the potential for transport which is the calculated result and this assumes that sand is always available for transport, i.e. an unlimited supply of sand. If a rock strata exists then there may be insufficient sand to meet the transport need and as such the result will be incorrect.

Therefore, a geotechnical investigation to determine sand thickness and locations and extent of underlying rock, mainly on the eastern beaches would be very useful to inform storm erosion estimates and potential beach nourishment volumes and support possible future investigations into structural erosion controls. It is recommended that this investigation covers the whole of the island, including the western foreshore where possible.

6.2.3 Beach Access

The high level of usage of the beaches on Coochiemudlo Island requires them to be safe to access and walk along. Therefore, it is a matter of priority to upgrade existing beach accesses to safer flexible structures (e.g. board and chain or locally devised methods) which follow lowering beach levels during storms and can be removed temporarily when beach repair works are carried out. Repairs should be prioritised to existing damaged beach access structures and high traffic locations, such as Norfolk Beach south of the Melaleuca Wetlands and Main Beach east of the barge ramp. Upgrades at other locations should be carried out as needed or as part of councils ongoing maintenance activities.

6.2.4 Vegetation Management

Ongoing dune and habitat management and maintenance activities are currently undertaken with significant involvement from community groups. The value of these actions in maintaining a healthy foreshore is recognised and it is hoped they have the support to continue. BMT have been advised that DES have suggested discussing development of an overall vegetation management/revegetation plan to guide works by local groups and help to minimise future problems like loss of trees from erosion (triggering requests for council to protect the trees) in areas where trees have been planted too close to erosion scarps (S. Sultmann, personal communication, 3 July 2020).

In addition to ongoing work immediate revegetation is recommended following beach reprofiling or beach nourishment to stabilise the dune and assist in retaining sand.

Where fallen trees pose a safety risk they should be, if possible, placed along erosion scarps to assist in reducing beach erosion and aid recovery. While removing unstable trees before they fall would have the added benefit of reducing disturbance to adjacent vegetation approval to remove vegetation, unless already fallen and deemed a safety hazard, is unlikely to be granted. It is noted that under the Fisheries Act a marine plant includes anything that grows on or adjacent to tidal land, whether alive, standing, dead or fallen, and removal will require a permit unless there is risk is posed to public infrastructure or safety. This activity will be applicable for all sections of Norfolk Beach and Main Beach fronting the Golf Course.

6.2.5 Stormwater management

Management of stormwater flow across the beach is recommended to prevent scouring and removal of sand from the upper beach and is considered a core Council responsibility. Where appropriate this measure has been included in the beach specific assessment.

6.3 Individual Beach Assessments

In this section each of the beaches on Coochiemudlo Island are described, issues identified, and management options assessed using a Multi-criteria Assessment matrix. Prioritised recommendations are then reported.

6.3.1 Morwong Beach

Morwong Beach is the Islands only north-facing beach and is protected from northerly events by a wide and shallow intertidal flat. Note that the changes at the very eastern end have been included in the discussion of past severe erosion in the section on North-eastern Norfolk Beach below (section 6.3.3). Numerical modelling has indicated that a small volume of sand transport occurs in both directions along the beach. Aerial photos indicate an increased volume of sand transported from Norfolk Beach onto the intertidal flats at the eastern end of the beach in recent years. Inspection of historical aerial imagery indicates accretion of Morwong Beach of up to 14m between 1955 and 2018.

There is an old and damaged concrete boat ramp at the eastern end of the beach. Scour around the structure is very localised and there is no indication the structure is having any impact on broader coastal processes. A small ephemeral creek outlet channels stormwater and drains the dune system following heavy rainfall, with a build up of sand visible on the intertidal area in the centre of the beach.

The proximity of this build-up close to the creek mouth indicates that the sand may have been scoured from the upper beach by creek flows.

Survey monitoring of the beach has not been previously undertaken by Council.

For current management practices Council has existing permits for beach reprofiling of up to 5 m^3 per lineal meter of beach and sand nourishment of up to 5000 m^3 per year.

Figure 6-1 Morwong Beach (Nearmap 2020)

6.3.1.1 Option Assessment

Current assessments do not indicate longer-term erosion issues on Morwong Beach and management actions are focused on addressing the short-term effects of erosion resulting from storm events.

Council have requested that the SEMP consider options for the existing boat ramp on Morwong Beach. Based on the information provided we understand that this structure was constructed without approvals and is currently closed due to safety concerns. Due to the short nature of the boat ramp and its location at the top of the beach current interaction with coastal process is minimal and any impacts are localised to the immediate vicinity of the boat ramp.

Figure 6-2 Morwong Beach Boat Ramp, March 2019

A full Multi Criteria Assessment for the beach is given in Appendix B. A summary of main points is given in Table 6-1 below.

It is recommended that Council prioritise maintenance options for Morwong Beach as per the MCA outcomes, noting that beach nourishment is only recommended to aid recovery following an erosion event. This information will be integrated into an Operation Plan for Coochiemudlo Island.

Table 6-1 MCA results summary – Morwong Beach

Description	Notes	Stage 1 and 2 score (1 + 2)	Overall score (1 + 2 +3)	Overall rank
Remove boat ramp and close access path to vehicles	Prevent any erosion impacts associated with the boat ramp, including vehicle access to the beach. Benefit to environmental and heritage values by removing vehicle access to the beach and through the Emerald Fringe.	2.6	4.5	1
Formalise/maintain access paths	*Complementary measure*. Recommended if access is damaged by a storm event or if upgrades are planned. Prevent damage to the Emerald Fringe through ad-hoc beach access and improve all condition access.	1.6	3.5	2
Beach nourishment in response to storm erosion	No identified ongoing erosion problems so beach nourishment is recommended in response to storm erosion only. Immediate dune revegetation is recommended following beach nourishment to stabilise the dune.	1.2	2.85	3

Description	Notes	Stage 1 and 2 score (1 + 2)	Overall score (1 + 2 +3)	Overall rank
Stormwater management	*Complementary measure*. Preventing sand from washing onto the tidal flat may improve beach amenity, otherwise no impact.	0.2	2.1	4
Beach reprofiling	*Option not progressed past stage 2.* Due to the narrow width of the beach and overhanging trees, benefit in restored beach amenity would be negligible and not sufficiently outweigh negative environmental impacts from machinery on the beach and disturbed vegetation.	-	-	N/A
Repair/upgrade boat ramp	*Option not progressed past stage 1.* It is expected that any work to formalise the boat ramp would increase the size of the structure and result in increased interaction with coastal process and possible erosion issues, as well as increase vehicle traffic on the beach and through the Emerald Fringe. In addition, use would be restricted to high tide due to the shallow nature of the intertidal flats.	-	-	N/A

6.3.2 Norfolk Beach

Norfolk Beach is the 1.5 km long easterly facing beach. Council has existing permits for beach reprofiling of up to 5 m^3 per lineal meter of beach and sand nourishment of up to 5000 m^3 per year at two locations on Norfolk Beach.

Groynes and an artificial reef or offshore breakwater have been suggested by members of the community as potential erosion control structures suitable for Northeast Norfolk Beach. Neither of these options have been progressed through the multi-criterial analysis and the reasons are discussed below.

An artificial reef or offshore breakwater would require a significant supply of sand to be effective at capturing sand. The Stage 2 report (BMT, 2020) on coastal processes concluded that there is no new sand moving onto the Island's beaches from the broader Bay environment. In addition, a significant design issue is that for a structure to mitigate wave action, necessary to locally reduce sand transport i.e. hold sand, it will need to sit high in the water (at storm water levels) particularly at Coochiemudlo Island where the event wave period is short (longer period waves as on the Gold Coast "feel" the bottom in greater water depths). On Coochiemudlo Island the events which cause the most sand movement are north-east wind events which result in an associated surge of up to 1m. Therefore, to be effective against event waves the structure would likely need to be placed such that it was only 0.5 to 1 m below water surface during an event i.e. about spring high tide level. This will have significant impact on local processes during ambient conditions and this impact would need to be assessed. Such a structure would introduce a safety hazard to boats and other watercraft and may reduce visual amenity.

Groynes, including any seaward extension of existing control points, depend on a consistent longshore sand transport rate to be effective. Assessments suggest the current longshore transport rate is low and seasonally inconsistent, making this option unsuitable for Norfolk Beach. In addition, groynes would significantly alter the current mostly natural state of the beach and may reduce visual amenity.

6.3.3 North-eastern Norfolk Beach

North-eastern Norfolk Beach is the easterly facing section of beach north of the wetlands to the northern end of Norfolk Beach. The beach is fronted by significant rocky intertidal flats and reef.

Aerial photographs from 1955 and 1997 show the rock outcrop connected to Morwong and Norfolk beaches by a sand spit forming a tombolo. Loss of vegetation on the rock outcrop and sand spit occurred between 1955 and 1997, with subsequent erosion of the connecting spit occurring between 1997 and 2013. Aerial photography indicates erosion of up to approximately 20 m since 1955. Minimal change in the vegetation line has occurred in the vicinity of Control Point 4 at the southern end of the beach segment.

Figure 6-3 North-eastern Norfolk Beach (Nearmap 2020)

It is not known what occurred historically at this location to cause such a dramatic change in the shoreline. It is likely to have either been a significant storm causing immediate change or a slow progression of natural processes which reached a breaking point. The area is complex with both north and east facing beaches and an extensive offshore shoal. The wave actions and currents during a storm event such as ex-TC Oswald would be complex and not able to be modelled in detail without extensive focused data collection and significant calibration. This lack of detailed knowledge of the localised processes hinders any attempt to assess options to mitigate any ongoing changes. Remnant mangroves offshore might indicate that the area was never sandy. Past erosion on north-eastern Norfolk Beach has been conservatively estimated at 1 to 1.5 m^3/m per year. It should be noted that this approach assumes a sandy beach of full depth and is not able to take into account the presently exposed rocky substrate which has not been mapped. Inspections of the site noted vegetation rooted in a thin layer of sand, as shown in Figure 6-4. A geotechnical investigation to determine the depth of the sand layer and extent and composition of the rocky substrate will be required for more accurate erosion estimates and to inform feasibility and design of structural erosion control options.

Numerical modelling has shown that sand transport occurs in both directions depending on the prevalent wind direction.

Survey monitoring of the beach has not been previously undertaken by Council.

Figure 6-4 Exposed rock substrate North-eastern Norfolk beach (October 2018)

6.3.3.1 Option Assessments

While north-eastern Norfolk beach eroded for some time after the event in 1950s which caused significant change in the vegetation and processes it is uncertain if erosion is occurring at a consistent rate. However it is noted that changes occur periodically because of the north-eastern exposure and thin layer of sand over bedrock. It is possible that the impact of the historical perturbation is now approaching a new equilibrium and erosion under current conditions is driven by storm events. Significant shoreline changes may still be seen after storms because of the thin layer of sand over rocky substrate. Aerial photos indicate minimal change between January 2013 (pre TC Oswald) and

November 2018 indicating either minimal erosion during TC Oswald or erosion with subsequent recovery. This supports the theory that a dynamic equilibrium allowing for storm erosion and recovery has been achieved with the current beach alignment.

Estimates have been made of losses of between 170 and 255 m^3 per year however these estimates assume sand is always available to be eroded and do not take into account the presence of the rock substrate, as the extent and location has not been quantified.

It is considered that any attempt to restore the beach to an approximate 1955 state using large scale sand nourishment and extensive dune planting would not likely be successful because of the coastal process regime i.e. the “new” regime established for the current beach alignment. Therefore, any consideration of such an exercise would require extensive design both for the intervention works and the impacts. The resulting works would also likely be very expensive.

Structural options have been included in the MCA assessment including both a seawall along the vegetation line and a groyne type structure between north-eastern Norfolk Beach and Morwong Beach, with the intent of preventing westerly sand transport onto the tidal flats of Morwong Beach. Both these options have achieved low scores in the MCA. Modelling of longshore transport indicates sand is transported in both directions, dependant on the prevailing conditions at the time, with transport to Morwong Beach only occurring at higher tides. Due to this two-way sand transport a groyne structure is unlikely to be effective at preventing erosion and is not recommended. A seawall is not recommended without ongoing nourishment and so there would be a double cost in providing a seawall and nourishment, as opposed to nourishment alone. Uncertainty as to the extent of the exposed rock substrate increases design difficulty and a geotechnical investigation is required to confirm feasibility, as well as to quantify future erosion potential before this option can be considered further. Additionally, such a structure would significantly change the nature of the beach.

A program of ongoing beach monitoring and a geotechnical investigation to determine the extent and nature of the rock substrate are recommended by the SEMP. If this provides future additional information to warrant consideration of structural erosion control measures these measures will require extensive individual assessment to avoid unwanted impacts.

Recommended options for north-eastern Norfolk Beach are as follows:

- Surveys as specified (Appendix A) on an annual basis and following storm events.
- Geotechnical investigation to determine the extent and composition of the rock substrate if sand movement is to be quantified or structural options considered in the future. Such an investigation should extend landward to the road (approximately 40 m).
- Beach nourishment to replace lost offshore sand following a storm event. Volumes will need to be determined by survey, however as annual losses have been conservatively calculated at 250 m3 or less and it is expected that maximum volumes required to recover from a given storm would not be significantly greater.

Ongoing monitoring of this area is critical and a review of indicative erosion rates is recommended as and when repeated survey data is available.

A full Multi Criteria Assessment for the beach is given in Appendix B. A summary of main points is given in Table 6-2 below. This information will be integrated into an Operation Plan for Coochiemudlo Island.

Table 6-2 MCA results summary – North-eastern Norfolk Beach

Description	Notes	Stage 1 and 2 score (1 + 2)	Overall score (1 + 2 +3)	Overall rank
Beach nourishment in response to storm erosion	Volumes will need to be determined by survey, however as annual losses have been conservatively calculated at 250 m3 or less and it is expected that maximum volumes required to recover from a given storm would not be significantly greater. Immediate dune revegetation is recommended following beach nourishment to stabilise the dune.	1.2	2.85	1
Larger scale beach nourishment and extensive dune planting	Not recommended at this stage. Ongoing monitoring is required to better determine beach changes before effectiveness and impacts of this option can be determined.	0.1	0.35	N/A
Seawall (with large initial nourishment and ongoing nourishment)	Not recommended at this stage. Ongoing monitoring is required to better determine beach changes before effectiveness and impacts of this option can be determined.	0.2	-0.3	N/A
"Dune enhancement" with sandbags and nourishment between morwong and NE Norfolk to stop sand loss to the north and prevent further beach rotation	Option not progressed past stage 2. This option is not expected to be effective and other potential impacts are unknown. Ongoing monitoring is required to better determine beach changes before effectiveness and impacts of this option can be determined.	-	-	N/A
Beach reprofiling	Option not progressed past stage 1. As there is a lack of sand available for reprofiling option would be both ineffective and not technically feasible.	-	-	N/A

6.3.4 Norfolk Beach fronting the Melaleuca Wetlands

This beach segment is east facing beach with adjacent beaches to the north and south able to supply sand from either direction. Minimal long term changes are indicated by analysis of aerial photography. Variations of up to 5 m are indicated, however this is within the order of accuracy of the image georeferencing. Sand transport occurs in both directions in accordance with wind directions, tending southerly in the summer months and northerly in the winter months.

Aerial images up to 2013 show a periodic widening of the beach fronting the wetlands directly seaward of the creek, possibly indicating a supply of sand scoured out from the upper beach in times of high flow.

Concern has been raised by the community regarding the potential for saltwater intrusion into the wetlands if the current dune is breached or overtopped. Monitoring is needed to determine whether this is a seasonal or a longer-term trend. It is likely that fresh water outflow after heavy rain will erode the dune, allowing salt water intrusion until natural processes again close the entrance, as shown occurring in Figure 6-5. If a longer-term trend is indicated then the underlying physical process change will need to be identified before a mitigation action can be formulated.

Regular surveying has not previously been undertaken for this section of Norfolk Beach.

Figure 6-5 Melaleuca Wetland and beach (Nearmap 2020)

6.3.4.1 Option Assessment

No clearly defined long term erosion has been identified. Indications are that changes are minor (within 5 m) and cyclic mostly relating to storm events noting that recovery from storm events may take several years. Good quality repeated surveys are needed to determine whether any longer-term processes occur and therefore management actions have been focused on addressing the short-term effects of erosion resulting from storm events and appropriate maintenance actions.

Suggestions have been made by CRG members that ‘reinforcing’ or ‘reinstating’ control points 3 and 4 with groyne type structures should be considered. Such an option has been excluded from the MCA. Given these are low lying rocky structures and unlikely to be damaged or “lost”, then if there is sufficient sand on the beach the control points will continue to function as they have in the past. For an intervention of this nature to be justified ongoing monitoring would need to identify long-term erosion issues and confirm that the existing rock outcrops were not effective in holding beach alignment.

Note that a seawall option has been included in the MCA for completeness, however is not recommended at this stage. If repeated monitoring indicates long term recession not related to storm erosion and a high risk to the wetland the option may be reconsidered if ongoing beach nourishment is not favoured. This option would require individual assessment of impacts as part of a future approvals process.

An option has been considered for dredge material taken from the Main Beach ferry channel and barge ramp to be placed slightly offshore of Norfolk Beach and moved onshore by natural processes. This option would provide additional sand to the system and no additional costs are expected to be associated with works. Approvals/permits are required and placement of material is not acceptable where it will result in long-term impact to local marine habitat features, i.e. seagrass beds. A focused study and survey will be required to determine a suitable location for placement. This option has also been included for Norfolk Beach fronting Victoria Parade, as placement offshore of either of these beach segments will be beneficial.

Initial beach nourishment is recommended to rectify existing unaddressed erosion on this beach segment and Norfolk Beach fronting Victoria Parade East and is discussed in section 6.3.5.

A full Multi Criteria Assessment for the beach is given in Appendix B. A summary of main points is given in Table 6-3 below.

It is recommended that Council prioritise maintenance options for this beach segment as per the MCA table, noting that beach nourishment is only recommended to aid recovery following an erosion event, and that a regular survey program is implemented immediately. This information will be integrated into an Operation Plan for Coochiemudlo Island.

Table 6-3 MCA results summary – Norfolk Beach fronting the Melaleuca Wetlands

Description	Notes	Stage 1 and 2 score (1 + 2)	Overall score (1 + 2 +3)	Overall rank
Formalise/maintain access paths	*Complementary measure*. Beach access at the north of the beach segment is currently damaged. Initial and maintenance costs expected to be low.	1.6	3.5	1
Dredge material from Main Beach ferry channel and barge ramp placed slightly offshore	This option would provide additional sand to the system to be moved onshore by coastal processes. No additional costs expected to be associated with works. Approvals/permits required for placement of material. Placement of materials is not acceptable where there is long-term impact to local marine habitat features, i.e. seagrass beds.	1.9	3.3	2
Beach reprofiling	To aid recovery following an erosion event. Immediate dune revegetation is recommended following beach reprofiling to stabilise the dune.	1.2	3.1	3
Beach Nourishment in response to storm erosion	Expected to be a maximum of 5m3/m repeated every 5-10 years as needed. Immediate dune revegetation is recommended following beach nourishment to stabilise the dune.	1.4	2.55	4
Seawall (with ongoing beach nourishment)	This option would significantly change the nature of the beach and may have unintended impacts on the wetlands. Not recommended at this stage.	1.2	0.25	N/A

6.3.5 Norfolk Beach fronting Victoria Parade East

No clearly defined long term erosion other than unrectified storm losses has been identified. Erosion assessments have indicated that beach fluctuations are minor (within 5 m) and cyclic mostly relating to storm events (BMT, 2020) and therefore management actions have been focused on addressing the short-term effects of erosion resulting from storm events and other appropriate maintenance actions.

The statement that there is no ongoing long-term erosion has been disputed by members of the community. This section of beach was monitored between 2013 and 2018 however while the surveys indicate that the width of the upper beach fluctuates annually, they were insufficient to confidently identify trends of beach recession or accretion not related to storm erosion. Good quality repeated surveys are needed to determine whether any other longer-term processes occur and an annual whole of Island survey program has been recommended.

Currently there are unapproved existing geotextile container seawalls, constructed as an emergency measure to protect trees. The Norfolk Beach track has also been closed to cars following TC Oswald and beach access has been protected by geotextile containers.

Sewer infrastructure is located in this area with a sewer pipe approximately 20m behind the beach (seaward edge of vegetation) and a sewer pump station set approximately 40 m back from the beach This infrastructure is outside of the modelled 1% AEP storm erosion area and not currently at risk from coastal processes and so has not been addressed by the SEMP. If monitoring indicates recession of the beach then these assets will eventually need relocating or protecting.

Community members have reported stormwater run-off collects in the trench of the James Street sewer line and discharges onto the beach from under the northern geotextile seawall. As this is a drainage/sewer issue and located well behind the beach this issue needs to be investigated by Council.

Figure 6-6 Sewer pipe and pump station, Norfolk Beach (Red-e-Map, 2020)

Figure 6-7 Norfolk Beach fronting Victoria Parade East (Nearmap 2020)

6.3.5.1 Option Assessment

BMT has been requested by Council to make recommendations regarding the existing unapproved existing geotextile container seawalls, constructed as an emergency measure to protect trees. While not currently causing any interruption to coastal processes, such as exacerbating erosion at the end of the structures, the protective role of these structures is minimal as the beach in front of the seawalls has subsequently recovered, as shown in Figure 6-8 and Figure 6-9 below. It is noted that while the walls have strong support from some members of the community overall opinions are mixed, as evidenced by feedback received on this project.

An option for additional seawalls has been included in the MCA for completeness, however it is not recommended at this stage. As discussed in section 3.3.5.1, while a properly designed and constructed seawall can protect the landward assets from erosion, it effectively isolates the sand located behind the wall from the active beach system and may lead to other adverse consequences. On a receding shoreline, the seawall becomes progressively further seaward on the beach profile over time and, without ongoing beach nourishment, will result in total loss of the beach. Examples of this process are provided in Appendix C.

This report recommends beach nourishment to replace storm losses. If repeated monitoring indicates long term recession which is not related to storm losses and if increased beach nourishment is not favoured the option for seawalls may be reconsidered, however subsequent long term loss of the beach will occur and must be accepted. Seawalls are not recommended above beach nourishment to respond to erosion resulting from a storm event. Beach recovery naturally occurs following erosion of this nature and beach nourishment accelerates this process, as well as adding resilience to the beach against future events.

For the reasons discussed above the SEMP does not support seawalls for Norfolk Beach. While the overall score of options to remove or formalise the existing seawalls is equal in the MCA, retaining the existing seawalls is dependent on State Government approval. Council has lodged an application with the State Government requesting approval of these structures, however the outcome of this application has not yet been finalised. If removal of these structures is required, and if the sand is suitable for beach nourishment purposes, the geofabric containers should be emptied in situ.

While there is a cost associated with removal it should be noted that the design life expectancy of a geotextile structure is in the order of 15-20 years and the structure will require removal or replacement at some time in the future.

Figure 6-8 Northern geotextile container seawall - October 2018

Figure 6-9 Geotextile container seawall Norfolk Beach - March 2019

As discussed in section 6.3.4.1 an option has been considered for dredge material taken from the Main Beach ferry channel and barge ramp to be placed slightly offshore of Norfolk Beach, to be moved onshore by natural processes. This option has also been included for Norfolk Beach fronting the Melaleuca Wetlands, as placement offshore of either or both of these beach segments will provide benefit. This option would provide additional sand to the system and no additional costs are expected to be associated with works. Approvals/permits are required along with a focused study and survey to determine a suitable location for placement. Offshore placement is preferred due to possible silt inclusion in the material and allows natural processes to optimally distribute the sand onshore.

A full Multi Criteria Assessment for the beach is given in Appendix B. A summary of main points is given in Table 6-4 below.

It is recommended that Council prioritise maintenance options for this beach segment as per the MCA table, noting that beach nourishment is recommended to aid recovery following an erosion event, and that a regular survey program is implemented immediately. This information will be integrated into an Operation Plan for Coochiemudlo Island.

As noted in section 4 the recently completed survey and photos provided by Coastcare indicates the beach is currently in an eroded state. Comparison of the recently completed survey with 2018 surveys, shown in Appendix D, indicates that sand has been removed from the berm with the majority redistributed across the profile. Data available is insufficient to quantify exact changes, however it is estimated that losses from the berm are less than 3 m^3/m on average. While photos from July 2020 (provided in Appendix F) indicate beach recovery is currently occurring, to supplement natural recovery processes and provide additional resilience to the beach against possibly future erosion immediate beach nourishment of 3 m^3/m (2400 m^3 total) is recommended between control point 2 and control point 4. Survey profiles along the nourished section of beach should be resurveyed following nourishment to allow accurate future interpretation of changes.

Table 6-4 MCA results summary – Norfolk Beach fronting Victoria Parade East

Description	Notes	Stage 1 and 2 score (1 + 2)	Overall score (1 + 2 +3)	Overall rank
Formalise/maintain access paths	*Complementary measure*. Initial and maintenance costs expected to be low.	1.6	3.5	1
Dredge material from Main Beach ferry and barge ramp placed slightly offshore	This option would provide additional sand to the system to be moved onshore by coastal processes. No additional costs expected to be associated with works. Approvals/permits required for placement of material. Placement of materials is not acceptable where there is long-term impact to local marine habitat features, i.e. seagrass beds.	1.9	3.3	2
Recycle sand from the barge ramp back onto the beach.	This action is also appropriate for Main Beach east of the ferry terminal and that should be the priority location if additional sand is required. Immediate dune revegetation is recommended following sand placement to stabilise the dune.	1.4	3.3	3
Stormwater Management	*Complementary measure*. Manage stormwater runoff from Norfolk Beach track and sewer line.	1.2	3.1	4

Description	Notes	Stage 1 and 2 score (1 + 2)	Overall score (1 + 2 +3)	Overall rank
Beach reprofiling	To aid recovery following an erosion event. Immediate dune revegetation is recommended following beach reprofiling to stabilise the dune.	1.2	3.1	5
Beach Nourishment in response to storm erosion	Expected to be a maximum of 5m^3/m repeated every 5-10 years as needed. Immediate dune revegetation is recommended following beach nourishment to stabilise the dune.	1.4	2.8	6
Remove existing emergency works seawalls	Minimal associated cost. If sand is suitable for beach nourishment geotextile containers should be emptied in situ. Disturbance associated with works and possibility of destabilising trees	1.0	2.5	7
Retain and existing emergency works seawalls	Minimal associated cost. State Government Approval required. Note that structures will likely need removing or replacing within 20 years (end of design life).	2.0	2.5	7
Seawall (with ongoing beach nourishment)	This option would significantly change the nature of the beach and may have unintended impacts on the wetlands. Not recommended at this stage.	1.4	0.95	N/A

6.3.6 South-eastern Norfolk Beach

Minimal shoreline change was observed on south-eastern Norfolk Beach (between control points 1 and 2). This relatively short, south-east facing section of beach would be expected to have overall low shoreline variance based on the dominance of ambient winds directly onshore from this direction, combined with the relative closeness of the two control points (refer Figure 3-7).

The following points are noted for this beach:

- This section of beach has a permit for beach reprofiling of up to 5 m^3 per lineal meter of beach and sand nourishment of up to 5000 m^3 per year;
- Regular surveying has not previously been undertaken for this section of Norfolk Beach;
- It is considered that Control Point 2 is important and if it were to be out-flanked there may be longer term alignment changes to this beach and possibly Norfolk Beach to the north.

Figure 6-10 South-eastern Norfolk Beach (Nearmap 2020)

6.3.6.1 Option Assessment

A full Multi Criteria Assessment for the beach is given in Appendix B. A summary of main points is given in Table 6-5 below.

It is recommended that Council prioritise maintenance options for this beach segment as per the MCA table, noting that beach nourishment is only recommended to aid recovery following an erosion event, and that a regular survey program is implemented immediately. This information will be integrated into an Operation Plan for Coochiemudlo Island.

While the use of geotextile containers for dune enhancement or reinforcement of control points 1 and 2 has been included in the MCA it is not recommended at this stage. This option refers to specifically to structural reinforcement of the dune and not ongoing vegetation management and enhancement activities, which it is hoped will continue. Recent photos from July 2020 (BMT) shown in Figure 6-11 and Appendix G do not indicate severe erosion to warrant this type of intervention at this time as broader beach nourishment is recommended.

If post storm beach nourishment is carried out as recommended in this report it is expected that the overall beach and control point condition and functionality will improve. If repeated monitoring indicates persistent longer term recession not related to storm erosion or surveying following a storm indicates the integrity of Control Point 1 or 2 has been severely threatened the option for dune reinforcement with geotextile containers could be reconsidered. This option would require individual assessment as part of a future approvals process. It should be noted that beach nourishment with dune revegetation is the preferred option for response to storm erosion.

Figure 6-11 Control Point 2 (looking south-west), July 2020

Table 6-5 MCA results summary – South-eastern Norfolk Beach

Description	Notes	Stage 1 and 2 score (1 + 2)	Overall score (1 + 2 +3)	Overall rank
Formalise/maintain access paths	*Complementary measure*. Initial and maintenance costs expected to be low.	1.6	3.5	1
Stormwater Management	*Complementary measure.* Manage stormwater runoff from Norfolk Beach track.	1.2	3.1	2
Beach reprofiling	To aid recovery following an erosion event. Immediate dune revegetation is recommended following beach reprofiling to stabilise the dune.	1.2	3.1	3
Beach Nourishment in response to storm erosion	Expected to be a maximum of 5m3/m repeated every 5-10 years as needed. Immediate dune revegetation is recommended following beach nourishment to stabilise the dune.	1.2	2.6	5

Description	Notes	Stage 1 and 2 score (1 + 2)	Overall score (1 + 2 +3)	Overal l rank
Dune enhancement with nourishment and geotextile containers at control points 1 and 2.	Assumes ongoing nourishment as needed (small volumes) Community groups can assist in planting/maintenance. Not recommended at this stage.	0.5	1.05	N/A

6.3.7 Main Beach

Main beach covers the entire southern foreshore from the rock outcrop east of the ferry terminal to west of the golf course. The southerly orientation means that the beach is sheltered from the stronger north-easterly storm events. However, it is exposed to the ambient south-easterly winds that dominate the Queensland weather and therefore sand transport occurs slowly to the west.

Council has existing permits for beach reprofiling of up to 5 m^3 per lineal meter of beach and sand nourishment of up to 5000 m^3 per year at two locations on Main Beach.

6.3.8 Main Beach East of the Ferry Terminal

Because of its location this beach is the immediate beneficiary of any storm induced southerly sand transport from Norfolk Beach. Therefore, it is expected that there will be some low cyclical accumulation and erosion of this beach as sand moves off and back onto the beach during and after storm events and then moves westward over time. This is evidenced by the occasional formation of a small intertidal lagoon at this location. The beach may also suffer a loss of sand when dredging to support the ferry terminal takes place. Loss of vegetation of up to 10 m east of the ferry terminal was observed from 1997 to 2018, however this is a highly trafficked area and vegetation changes may be related to usage rather than coastal erosion. The ferry terminal was rebuilt in 2015 with associated channel dredging with the dredged material being taken away to the Mud Island spoil ground, resulting in a loss of sand from the system.

Visitor amenities are concentrated in the vicinity of the ferry terminal, including park infrastructure such as BBQs, shelters and a playground. Business is also concentrated in this area, with boat hire and two cafes.

This section of beach was surveyed in 2016, 2017 and 2018. The surveys indicate that the width of the upper beach fluctuates annually, however were insufficient to confidently identify trends of beach recession or accretion, or lack thereof.

Figure 6-12 Main Beach East of Ferry Terminal (Nearmap 2020)

6.3.8.1 Option Assessment

A full Multi Criteria Assessment for the beach is given in Appendix B. A summary of main points is given in Table 6-6 below.

It is recommended that Council prioritise maintenance options for this beach segment as per the MCA table, noting that beach nourishment is only recommended to aid recovery following an erosion event, and that a regular survey program is implemented immediately. This information will be integrated into an Operation Plan for Coochiemudlo Island.

Table 6-6 MCA results summary – Main Beach East of the Ferry Terminal

Description	Notes	Stage 1 and 2 score (1 + 2)	Overall score (1 + 2 +3)	Overall rank
Recycle sand from the barge ramp back onto the beach.	Placement on Main Beach if needed before placement on Norfolk Beach	2.1	4	1
Beach nourishment in response to storm erosion	Expected to be a maximum of 5m^3/m repeated every 5-10 years as needed. Immediate dune revegetation is recommended following beach nourishment to stabilise the dune.	2.1	3.5	2
Beach reprofiling	To aid recovery following an erosion event. Immediate dune revegetation is recommended following beach reprofiling to stabilise the dune.	1.6	3.5	3

Description	Notes	Stage 1 and 2 score (1 + 2)	Overall score (1 + 2 +3)	Overall rank
Formalise/maintain access paths	*Complementary measure*. Initial and maintenance costs expected to be low.	1.6	3.5	4
Stormwater Management	*Complementary measure*. Manage stormwater runoff from park hard surfaces	1.4	3.3	5

6.3.9 Main Beach between the Ferry Terminal and Barge Ramp

Visitor amenities are again located in this area with park infrastructure, car park and a toilet block.

Aerial photography indicates an accretion of up to 12 m from 1997 to 2018. The barge ramp upgraded in 2018 and has had accumulations of sand on its eastern edge since completion.

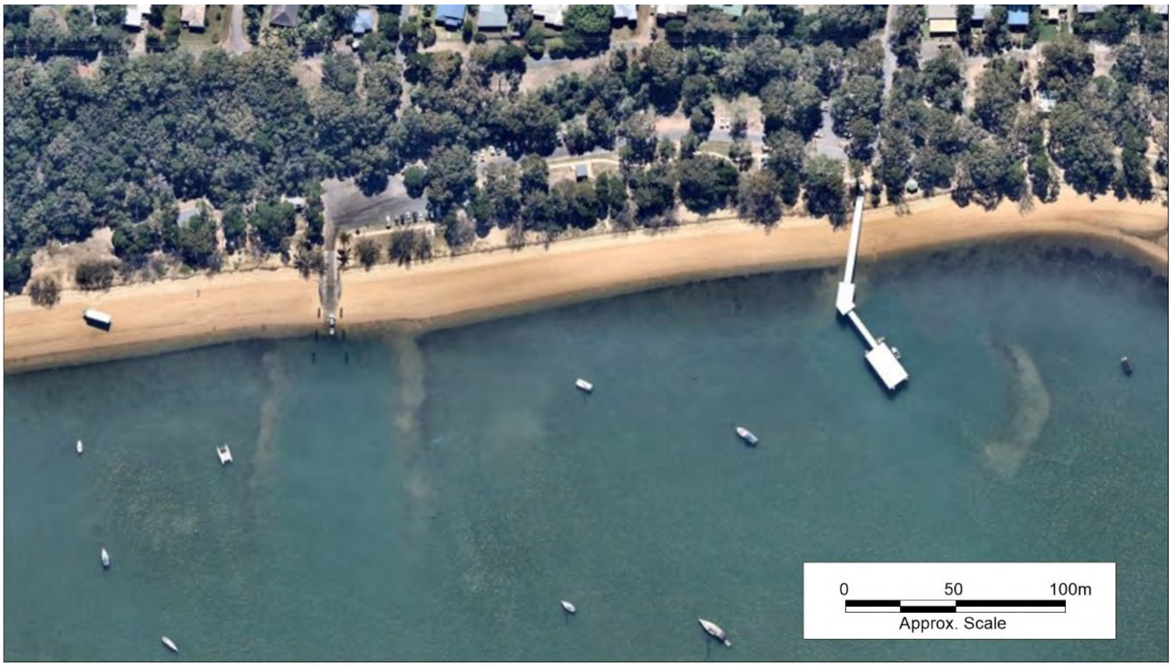

Figure 6-13 Main Beach between Ferry Terminal and Barge Ramp (Nearmap 2020)

6.3.9.1 Option Assessment

Given the indication that the beach is accreting, including sand accumulation against the barge ramp that requires relocation, nourishment has not been considered.

A full Multi Criteria Assessment for the beach is given in Appendix B. A summary of main points is given in Table 6-7 below.

It is recommended that Council prioritise maintenance options for this beach segment as per the MCA table and that a regular survey program is implemented immediately. This information will be integrated into an Operation Plan for Coochiemudlo Island.

Table 6-7 MCA results summary – Main Beach between the Ferry Terminal and Barge Ramp

Description	Notes	Stage 1 and 2 score (1 + 2)	Overall score (1 + 2 +3)	Overall rank
Formalise/maintain access paths	*Complementary measure*. Initial and maintenance costs expected to be low.	1.6	3.5	1
Beach reprofiling	To aid recovery following an erosion event. Immediate dune revegetation is recommended following beach reprofiling to stabilise the dune.	1.6	3.5	2
Stormwater Management	*Complementary measure*. Manage stormwater runoff from park and hard surfaces.	1.4	3.3	3

6.3.10 Main Beach between the Barge Ramp and Red Cliffs

Some park infrastructure is in place just west of the barge ramp. The barge ramp was upgraded in 2018 and the new barge ramp may interrupt westerly transport of sand in the short term.

The Curlew Creek outlet runs behind this section of beach and the alluvial fan at its entrance is clearly seen in the aerial photographs. This creek outlet will naturally move in response to longshore sand transport, storm erosion and rainfall events so the beach may appear to accrete or erode in different locations in response to flows in the creek. Vegetation immediately adjacent to the beach (between the creek and the beach) is mostly ground cover/grasses as opposed to large trees. Comparison of the seaward edge of vegetation (BMT, 2020) shows minimal change between 1955 and 1997 (with subsequent increase in vegetation from 1997 to 2013). Unless safety concerns or immediate threats to infrastructure emerge in the future these natural processes should be allowed to continue.

Figure 6-14 Main Beach between Barge Ramp and Red Cliffs (Nearmap 2019)

6.3.10.1 Options Assessment

Indications are that the beach is stable or accreting so erosion management action is not considered. There has been no previous monitoring of the beach and as such the recommended monitoring program will help assess longer term trends.

Before considering beach reprofiling or beach nourishment for any location west of the barge ramp sand should be relocated to the western side of the ramp and natural westerly transport allowed to continue. Curlew Creek should be allowed to fluctuate naturally unless safety hazards or threat of loss of infrastructure occurs.

A full Multi Criteria Assessment for the beach is given in Appendix B. A summary of main points is given in Table 6-8 below.

It is recommended that Council prioritise maintenance options for this beach segment as per the MCA table and that a regular survey program is implemented immediately. This information will be integrated into an Operation Plan for Coochiemudlo Island.

Table 6-8 MCA results summary - Main Beach between Barge Ramp and Red Cliffs

Description	Notes	Stage 1 and 2 score (1 + 2)	Overall score (1 + 2 +3)	Overall rank
Formalise/maintain access paths	*Complementary measure*. Initial and maintenance costs expected to be low.	1.8	3.5	1

Description	Notes	Stage 1 and 2 score (1 + 2)	Overall score (1 + 2 +3)	Overall rank
Stormwater Management	*Complementary measure*. Manage stormwater runoff from park and hard surfaces	1.4	3.1	2
Beach reprofiling	To aid recovery following an erosion event. Immediate dune revegetation is recommended following beach reprofiling to stabilise the dune.	1	2.9	

6.3.11 Red Cliffs

The possibility of undercutting at water level and the slope stability of the higher section of Red Cliffs, particularly in relation to the safety of the Community Hall, is of concern to the broader community. As this is a rock/cliff formation these concerns can only be assessed by geotechnical engineers. Council previously engaged Soil Surveys in 2013 who made recommendations regarding the stability of this area, discussed in the Stage 2 report Section 3. If further assessments or recommendations are required, including indicative rates of erosion of rock, then it will be necessary to re-engage geotechnical consultants.

6.3.12 Main Beach fronting the Golf Course

This beach is the ultimate beneficiary of any natural longshore sand transport westwards along Main Beach and there is some evidence of sand moving to the west of the Island. This is the result of the dominant south-easterly winds which occur in SE Queensland. This process will be slow because of the low energy wave climate and will be significantly influenced by man-made structures along the way such as the ferry terminal and barge ramp and associated dredging as well as the natural processes of creek movements and shoal formation. Because of the slow progression of these processes the results of an action either natural or man-made may take years or decades to become apparent at this location.

The analysis of aerial images was inconclusive regarding long term erosion at this site although there are obvious cycles of accretion and erosion as indicated above and as a result trees have fallen over some time in the past.

There also appears to be some issues with cable and electric wires and associated warning signs being inadequately maintained by the appropriate agencies (Figure 6-16).

There has been no previous monitoring of the beach and as such the recommended monitoring program will help assess longer term trends.

Before considering beach reprofiling or beach nourishment for any location west of the barge ramp sand should be shifted to the western side of the ramp and natural westerly transport allowed to continue.

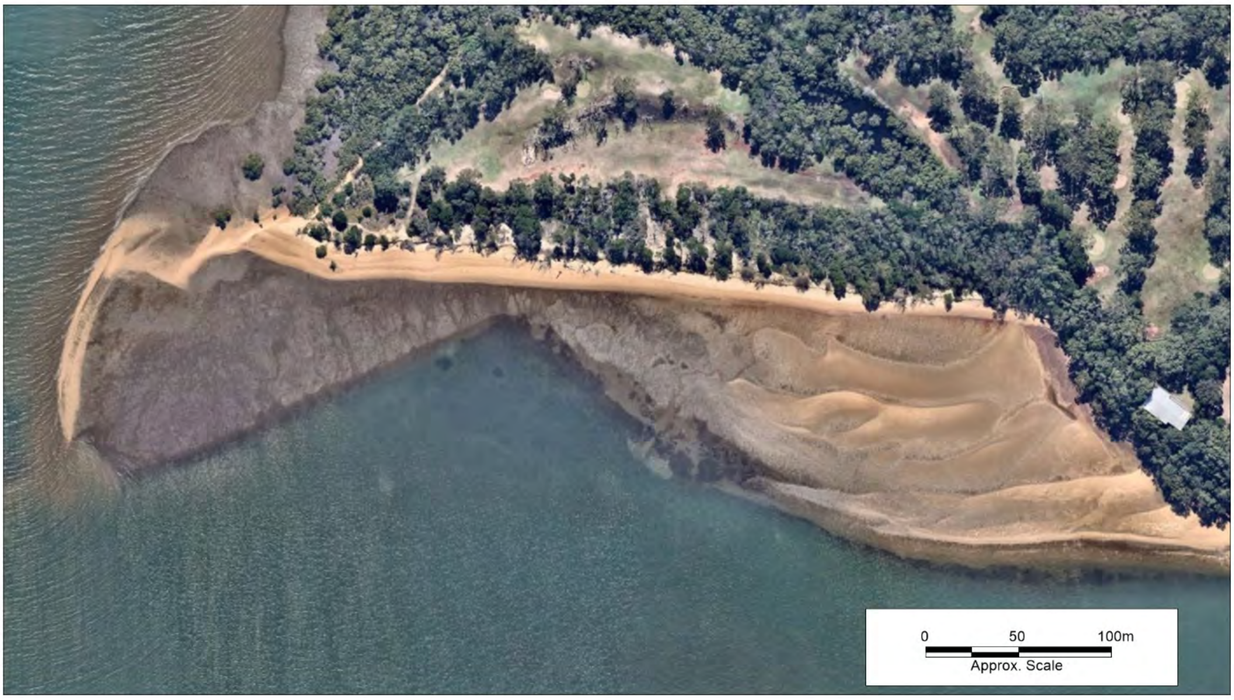

Figure 6-15 Main Beach fronting the Golf Course (Nearmap 2020)

Figure 6-16 Main Beach fronting the Golf Course - fallen warning sign in the centre of the photo (October 2018)

6.3.12.1 Options assessment

A full Multi Criteria Assessment for the beach is given in Appendix B. A summary of main points is given in Table 6-9 below.

This is a remote and reasonably pristine part of the Island so any nourishment or beach reprofiling will have a larger relative environmental impact with less social benefits than other beaches. These options are not progressed past stage 2 of the MCA.

It is recommended that Council prioritise maintenance options for this beach segment as per the MCA table and that a regular survey program is implemented immediately. This information will be integrated into an Operation Plan for Coochiemudlo Island.

Table 6-9 MCA results summary – Main Beach fronting the Golf Course

Description	Notes	Stage 1 and 2 score (1 + 2)	Overall score (1 + 2 +3)	Overall rank
Formalise/maintain access paths	*Complementary measure*. Beach access doesn't currently seem to be an issue. Maintenance work only. Initial and maintenance costs expected to be low.	1.6	3.5	1
Beach reprofiling	Option not progressed past stage 2. May be reconsidered if surveys indicate an ongoing erosion problem.			
Beach nourishment	Option not progressed past stage 2. May be reconsidered if surveys indicate an ongoing erosion problem.			

6.3.13 Western Foreshore

This part of the Island is sheltered from all easterly winds, including the occasional storms, and is characterised by established mangroves and intertidal flats. The mangroves provide valuable habitat with the additional benefit of providing shoreline protection from boat traffic waves.

There are a couple of ad hoc boat/kayak tracks through the mangroves, one of which is shown in Figure 6-18. The tracks appear to be well defined with the lack of vegetation suggesting frequent use, however as the surrounding mangroves appear healthy and undamaged these are not considered cause for concern at present. Any intensification of use is likely to cause further damage. Similarly for the walking track which does not appear to be heavily used at present but may result in damage to the surrounding vegetation if the use intensifies.

Large patches of invasive plants are present, including Ground Asparagus (Asparagus aethiopicus), shown in Figure 6-19. An Integrated Weed Management Plan for Coochiemudlo Island (Ecosure, 2017) was prepared for Council and contains recommendations for weed management and monitoring.

At present no major actions are required for the western foreshore. It is recommended that a weed management strategy is implemented (if not already) to support maintenance of the existing ecosystem. Inspection of the ad hoc tracks through the mangroves and walking tracks on an annual basis is recommended to identify any intensification of use and/or increased damage to the mangroves. If this occurs intervention should be in the form of community education and, if required, fencing to deter access to areas other than defined pathways.

Figure 6-17 Western Foreshore

Figure 6-18 Track through mangroves

Figure 6-19 Invasive weed (Ground Asparagus)

7 Recommended Maintenance Action Plan

The following table represents a combined plan for action to address maintenance and safety issues and complementary measures noted in the individual beach assessments in Section 6.3. An initial indication of potential costs has been provided to assist in determining appropriate budgets.

Table 7-1 Recommended maintenance action plan

Priority	Location	Management action	Notes/Timeframe	Stage 1 & 2 score	Overall score	Approvals requirements	Permissibility	Environmental considerations	Indicative cost
1	Norfolk Beach fronting the Melaleuca Wetlands Norfolk Beach fronting Victoria Parade	Beach nourishment	2400m^3 immediately between control points 2 and 4 (3m^3/m) to address existing erosion.	1.4	2.55/2.8	Covered under existing permits.	-	-	$170,000.
2	Whole Island	Monitoring	Annual surveys as per specification given in Appendix B.	-	-	-	-	-	Costs expected to be consistent with recent 2020 survey. Details held by council.
3	Whole Island	Monitoring	Establish photo monitoring points where feasible. Within 1 year with ongoing data management.	-	-	Not required if affixed to existing structures.	-	-	$10,000 for installation. Data management and analysis costs dependant on method and collaboration with universities or other organisations.
4	Morwong Beach All Norfolk Beach All Main Beach	Vegetation Management	Ongoing dune and habitat management and maintenance. Currently ongoing with a high level of involvement from community groups.	-	-	-	-	-	Required Council funding to be determined with community groups.

Priority	Location	Management action	Notes/Timeframe	Stage 1 & 2 score	Overall score	Approvals requirements	Permissibility	Environmental considerations	Indicative cost
5	All Norfolk Beach Main Beach	Remove fallen trees where posing a safety hazard and relocate to erosion scarp	Ongoing on an as needed basis as part of regular maintenance activities	-	-	Not required if removing terrestrial trees that have already fallen and are posing a risk to public infrastructure or safety. Development Permit required otherwise.	Depends on risk posed by the trees to non-infrastructure and safety matters – see State Code 11 PO1	-	$500 per fallen tree
6	Morwong Beach	Remove boat ramp and close access path to vehicles	Within 1 year as currently closed due to safety concerns.	2.6	4.5	No permit as long as works comply with requirements in Part B.5 of EPP/2017/3930	-	-	$10,000
7	Norfolk Beach fronting the Melaleuca Wetlands Norfolk Beach fronting Victoria Parade South-eastern Norfolk Beach	Formalise/maintain access paths	Prioritise damaged beach access at the north of the Melaleuca wetlands as current safety issue. Immediate (within 3-6 months) for this and any other existing damaged beach access. Upgrade remaining beach access on Norfolk Beach within 1 year.	1.6	3.5	Accepted Development	-	-	Up to $5,000 per access path.

Priority	Location	Management action	Notes/Timeframe	Stage 1 & 2 score	Overall score	Approvals requirements	Permissibility	Environmental considerations	Indicative cost
8	Main Beach east of the Ferry Terminal Main beach between the Ferry Terminal and Barge Ramp	Formalise/maintain access paths	Prioritise upgrades for high use areas within 1 year.	1.6	3.5	Accepted Development	-	-	Up to $5,000 per access path.
9	Main beach between the Barge Ramp and Red Cliffs Main Beach fronting the Golf Course	Formalise/maintain access paths	Upgrades on an as needed basis if damaged or as part of planned maintenance.	1.6	3.5	Accepted Development	-	-	Up to $5,000 per access path.
10	Morwong Beach	Formalise/maintain access paths	Upgrades on an as needed basis if damaged or as part of planned maintenance.	1.6	3.5	Accepted Development	-	-	Up to $5,000 per access path.
11	Norfolk Beach fronting the Melaleuca Wetlands Norfolk Beach fronting Victoria Parade	Dredge material from Main Beach ferry and barge ramp placed offshore	This option would provide additional sand to the system to be moved onshore by coastal processes and would in effect be recycling sand back to where it came from. No additional costs expected to be associated with works. Approvals/permits	1.9	3.3	Amendment to Marine Park Permit	Needs to be consistent with objects for Habitat Protection Zone. Placement of materials is acceptable where there is no long-term impact to local marine habitat features, i.e. seagrass beds	Seagrass does occur offshore periodically; need to consider temporal and spatial presence of seagrass in context of works	$50,000 for seagrass survey, sediment testing and assessment of suitable locations. No extra costs expected for placement of material.

Priority	Location	Management action	Notes/Timeframe	Stage 1 & 2 score	Overall score	Approvals requirements	Permissibility	Environmental considerations	Indicative cost
			required for placement of material.			Development Permit, unless works comply with requirements of Part B.4 of EPP/2017/3930 (i.e. volume <5,000m^3/yr).	Consistent with State Code 8 PO8. Requires sediment testing and management under PO21 in accordance with National Assessment Guidelines for Dredging.	Testing of material will determine whether it can be used for placement and associated controls.	
12	Norfolk Beach fronting Victoria Parade Main Beach east of the ferry terminal	Recycle sand from the barge ramp back onto the beach.	Prioritise Main Beach east of the ferry terminal if additional sand is required to maintain beach amenity. Placement of excess on Norfolk Beach As required when build-up against the barge ramp becomes an issue.	1.4	3.3	Already approved	-	-	Ongoing activity. Costs expected to be in line with previous work. Details held by council.
13	Norfolk Beach fronting Victoria Parade South-eastern Norfolk Beach	Stormwater Management	Manage stormwater runoff from Norfolk Beach track and sewer line. Prioritise upgrades for high use areas within 1 year.	1.2	3.1	-	-	-	Where non-structural options are used $3,000 per site. If pipework is required costs to be confirmed with Council engineers.

Priority	Location	Management action	Notes/Timeframe	Stage 1 & 2 score	Overall score	Approvals requirements	Permissibility	Environmental considerations	Indicative cost
14	Main Beach east of the Ferry Terminal Main beach between the Ferry Terminal and Barge Ramp Main beach between the Barge Ramp and Red Cliffs	Stormwater Management	Manage stormwater runoff from park and hard surfaces Prioritise upgrades for high use areas within 1 year.	1.2	3.1	-	-	-	Where non-structural options are used $3,000 per site. If pipework is required costs to be confirmed with Council engineers.
15	Morwong Beach	Stormwater management	Upgrades as part of planned maintenance work or if surveys indicate significant sediment loss.	0.2	2.1	-	-	-	Where non-structural options are used $3,000 per site. If pipework is required costs to be confirmed with Council engineers.
16	Western Foreshore	Monitoring	Annual inspections of existing tracks. Potential for involvement of community organisations in works.	-	-	-	-	-	<$1000 per year
17	Western Foreshore	Vegetation Management (Weed removal and monitoring)	Ongoing activity. Potential for involvement of community organisations in works.	-	-	-	-	-	<$5000 per year.

Priority	Location	Management action	Notes/Timeframe	Stage 1 & 2 score	Overall score	Approvals requirements	Permissibility	Environmental considerations	Indicative cost
18	Whole Island	Geotechnical Investigation	Within 5 years. Required to inform feasibility of structural options or large scale sand replenishment on Norfolk beach.	-	-	-	-	-	$100,000 for whole of Island. To include assessment of erosion potential of Red Cliff rocks.

8 Operational Plan (Storm Erosion Response)

A combined plan for action to address storm erosion is presented in Table 8-2. The plan is focused on nourishment after storm erosion with an initial round of remedial nourishment on Norfolk Beach to make up for the deficiency related to events in the last 5 years. If long term erosion, i.e. not related to storm events, is identified in the future then beach nourishment can be increased to allow for this.

Actions are given in order of beach location used for assessments in Section 6.3. In the event that multiple areas are impacted it is recommended that works are prioritised to rectify safety hazards.

It is expected than beach nourishment and reprofiling volumes required will be small and covered under council's existing works permits. It is recommended that locations approved for works are reviewed to ensure all beach segments potentially requiring beach nourishment or reprofiling are covered. A summary of approval requirements is given in Table 8-1.

Triggers for beach nourishment and re-profiling have been informed by the conditions of the existing permits.

Sand used for beach nourishment should be the same grain size or coarser than existing sand. Sediment sampling was undertaken in 2018 across the Redland City Council local government area, including Norfolk Beach and Main Beach on Coochiemudlo Island (FRC Environmental 2018). Particle size analysis of sand samples on Norfolk Beach and Main Beach estimated a median grain size (d50) of 0.36 mm for the upper beach and an average of 0.52 mm for the lower beach. Samples from two quarry sites (including a Redland City Council quarry) were also analysed, with an average median grain size of 0.22 mm. It should be noted that if sand from these sources has previously been used for beach nourishment on Norfolk Beach or Main Beach then the assessed median grain size may not be representative of natural conditions.

Immediate dune revegetation is recommended following reprofiling or beach nourishment to stabilise the dune and help retain sand on the beach and can be supported by community organisations.

The design profile would aim to replace sand relocated from the berm, as indicated by the erosion scarp, and will vary from storm to storm and beach to beach. One of the benefits of ongoing monitoring will be to better understand and inform a working beach profile for each beach unit. Until a design profile can be determined it is recommended that sand is placed against the erosion scarp and sloped to meet the existing profile over a distance of 5 to 10 meters. This sand will naturally redistribute across the beach profile in accordance with prevailing coastal processes.

This study has found erosion is not likely to be beyond the existing approved Council nourishment regime. If monitoring indicates ongoing long term erosion or that more severe storm erosion is likely other options such as larger scale beach nourishment, dune enhancement or seawalls may be investigated using this newfound knowledge.

Costs for beach nourishment are based on response to events where reasonably large volumes are involved (assumed to be on the order of 1000 m^3). If small (100-200m^3 spread across multiple beach segments) volumes are involved these costs may increase substantially.

Indicative costs are given below are per beach unit, unless otherwise specified. As it is unknown which beach units will be affected by a given event or whether an event will trigger beach profiling or beach nourishment total costs have not been provided. It should also be noted that these are estimated costs and that actual costs may vary.

While it is not possible to predict future events, it is unlikely that the northern and southern beaches would be impacted by the same event. A conservative approach would be to allow for the full permitted nourishment of 5,000 m^3 for a single approved location as an annual rolling budget in case of a severe event. Based on an estimated cost of $70/$m^3$ this equates to $350,000 per year on a rolling basis. Indications from recent storm events suggest that this budget may be required every five (5) years.

As discussed in sections 4 and 6.3.5 reports and photos from community members, as well as the recent survey, indicate unrectified erosion on Norfolk beach fronting Victoria Parade East. Due to the similarity of beach characteristics and coastal processes it is expected that this erosion may extend to Norfolk Beach fronting the Melaleuca Wetlands. It is recommended that immediate beach nourishment of 3 m^3/m is undertaken along the section of Norfolk Beach between control points 2 and 4 (approximately 800 m), or 2,400 m^3 in total. The estimated cost for this work is $170,000. Immediate dune planting is recommended following beach nourishment to stabilise the dune. This recommendation has been included in Table 7-1.

Table 8-1 Approvals requirements

Activity	Approval requirements	Permissibility	Environmental considerations
Minor beach reprofiling	Development Permit unless works comply with requirements of Part B.4 of EPP/2017/3930 (sand movement <5m^3/m, excavation <0.5m)	Consistent with State Code 8	-
Minor beach nourishment	Development Permit unless works comply with requirements of Part B.4 of EPP/2017/3930 (sand movement <5m^3/m, excavation <0.5m)	Consistent with State Code 8 PO8. Requires sediment testing and management under PO21 in accordance with National Assessment Guidelines for Dredging.	Testing of material will determine whether it can be used for placement and associated controls.
	Allocation of Quarry Material (if placed above high tide)	Need to establish material is suitable for placement.	
	Amendment to Marine Park Permit	Needs to be consistent with objects for Habitat Protection Zone – likely no issue if placed onshore	-

Table 8-2 Operational Plan for response to storm erosion

Location	Management action	Trigger	Notes	Estimated Cost	Stage 1 & 2 score	Overall score
All affected beach segments	Surveying	Reported storm erosion resulting in an erosion scarp of 0.3m and/or greater or loss of vegetation	Council surveyors to survey a minimum of three (3) beach profiles for each affected beach segment to then be compared to the most recent whole of Island survey and inform sand loss volumes.	$1,500 per beach segment		
Morwong Beach	Beach nourishment	Sand removed from the upper beach will be deposited on the intertidal flats and returned to the beach by natural processes. As such beach nourishment is only required to rectify safety hazards or if immediate major loss of established vegetation is likely. Volumes are less than $5m^3/m$.	Volumes to be determined by survey however expected to be less than $1000m^3$.	$70,000	1.2	2.85
North-eastern Norfolk Beach	Beach nourishment	Storm erosion threatening further loss of vegetation.	Volumes to be determined by survey, however as annual losses have been conservatively calculated at 250 m3 or less and it is expected that maximum volumes required to recover from a given storm would not be significantly greater. Immediate dune revegetation is recommended following beach nourishment to stabilise the dune.	$17,500	1.2	2.85
Norfolk Beach fronting the Melaleuca Wetlands	Beach reprofiling	Survey indicates the majority of sand has been retained on the beach above MSL and volumes to be reprofiled are less than $5m^3/m$, excavation <0.5m.	Maximum of $5m^3/m$	$3,000	1.2	3.1
Norfolk Beach fronting the Melaleuca Wetlands	Beach Nourishment	Survey indicates the majority of sand has been deposited below MSL and erosion scarp > 0.3m or loss of vegetation.	Volumes to be determined by survey however expected to be less than $2,500m^3$.	$175,000	1.4	2.55
Norfolk Beach fronting Victoria Parade	Beach reprofiling	Survey indicates the majority of sand has been retained on the beach above MSL and volumes to be reprofiled are less than $5m^3/m$, excavation <0.5m.	Maximum of $5m^3/m$.	$3,000	1.2	3.1

Location	Management action	Trigger	Notes	Estimated Cost	Stage 1 & 2 score	Overall score
Norfolk Beach fronting Victoria Parade	Beach Nourishment	Survey indicates the majority of sand has been deposited below MSL and erosion scarp > 0.3m or loss of vegetation.	Volumes to be determined by survey however expected to be less than 1,500m^3.	$105,000	1.4	2.8
South-eastern Norfolk Beach	Beach reprofiling	Survey indicates the majority of sand has been retained on the beach above MSL and volumes to be reprofiled are less than 5m^3/m, excavation <0.5m.	Maximum of 5m^3/m.	$3,000	1.2	3.1
South-eastern Norfolk Beach	Beach Nourishment	Survey indicates the majority of sand has been deposited below MSL and erosion scarp > 0.3m or loss of vegetation.	Volumes to be determined by survey however expected to be less than 1,500m^3.	$105,000	1.2	2.6
Main Beach east of the ferry terminal	Beach reprofiling	Survey indicates the majority of sand has been retained on the beach above MSL and volumes to be reprofiled are less than 5m^3/m, excavation <0.5m.	Note that while Beach Nourishment scored higher in stage 2 of the MCA reprofiling is a less costly option and appropriate to restore beach amenity following less severe events.	$3,000	1.6	3.5
Main Beach east of the ferry terminal	Beach Nourishment	Survey indicates the majority of sand has been deposited below MSL and erosion scarp > 0.3m or loss of vegetation.	Volumes to be determined by survey however expected to be less than 1,000m^3.	$70,000	2.1	3.5
Main beach between the ferry terminal and barge ramp	Beach reprofiling	As required post storm event to rectify safety hazards, restore beach amenity or if immediate major loss of established vegetation is likely. Volumes to be reprofiled are less than 5m^3/m, excavation <0.5m.	Maximum of 5m^3/m.	$3,000	1.6	3.5
Main beach between the barge ramp and red cliffs	Beach reprofiling	As required post storm event to rectify safety hazards, restore beach amenity or if immediate major loss of established vegetation is likely. Volumes to be reprofiled are less than 5m^3/m, excavation <0.5m.	Maximum of 5m^3/m.	$3,000	1	2.9

9 Summary of Shoreline Management Actions

In summary the recommended Shoreline Management actions are;

- Initial nourishment of Norfolk beach of 2,400 m^3 to be applied before the end of 2020 to increase resilience of the beach before the 2021 storm season. Expected cost is $170,000.
- Proceed with the maintenance and safety measures as per Section 7 starting as soon as possible;
- Prepare for storm respose as per Section 8, i.e. making sure budget is available for works if needed, as soon as possible noting that storm events often occur in late summer i.e. early 2021.

Recommneded maintenance actions and safety measures are given in Table 7-1 with an operational plan for response to storm erosion detailed in Table 8-2. Figure 9-1 provides a summary of all recommended actions for each beach segment.

Title:

Summary of Recommended Shoreline Management Actions

Figure: 9-1

Rev: B

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N 0 250 500m Approx.Scale

BMT www.bmt.org

Filepath: I:\B23255_I_JLB Coochiemudlo SEMP MA\DRG\COA_028_200513_Final Beach Management Option Summary.wor

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Appendix A Beach monitoring specification

Survey for Beach Monitoring – Coochiemudlo Island

Survey Types

Coastal processes on Coochiemudlo beaches are generally very slow in comparison to an open coast beach where most normal monitoring methods have been developed. Therefore, the survey needs to be very accurate with about millimetre accuracy and at the very least sub-centimetre accuracy.

This is unlikely to be achievable with LiDAR or drone (around 15cm accuracy). Tree cover also may also limit accuracy for these.

It would also be preferable if the survey could be mobilised quickly say less than a week after events – again unlikely for remote surveys.

Future photogrammetry from geo-referenced low-level aerial photography is a possibility but experience suggests that this will be difficult to organise and costly. Note that due to the lack of accuracy in geo-referencing historical aerial photography it is unlikely that photogrammetry will be of sufficient accuracy for these previous dates.

Therefore, it is considered that land based conventional survey is best option.

Program Design Considerations

The survey program will need to consider: what are we expecting to be monitored, how often; repeatability (i.e. same lines every time and to a known datum); how will it be analysed / interpreted etc.

Also, we need to be aware that it may not always be possible to detect sand movement on beaches between surveys because of small changes and the reversible nature of most sand movement over time. It is likely to be possible to detect further erosion on NE corner (if it is still occurring) and accretion at eastern end of Main Beach at times.

Generally, the offshore movement (erosion causing a small scarp) and recovery over time on the eastern beaches during and after an event are likely to be small but will likely be captured. It is expected that the eroded sand will initially move quickly offshore then return onshore over time and the survey should be able to pick this up.

However, longshore transport along the beach will not generally be captured except possibly where significant volumes have moved. The most common method to do this is to have many profiles arranged in “bins” and try to interpret changes over time as sand movement from one bin to the next. This is mostly successful on exposed beaches where the sand movement is in one direction and of significant volume. Small quantities and two directions will likely to make this difficult on Coochiemudlo. The best location for this methodology would be to try to capture the loss around the SE corner onto Main Beach as this is likely to be the only long-term loss from the eastern beaches.

Suggested Land Based Survey Program

Suggested program is to have profiles at about 30 locations around the N, E and S beaches. The survey will require a pegged baseline to be set up and a nominated direction and distance (to MSLW) from each peg. This way allows repeatable surveys to be carried out and allows accurate interpretation of changes. The pegs should be located far enough back from the beach to be out of the erosion zone and in some cases pick up local berms or dunes. The profiles should specifically note: vegetation line; top of erosion scarp; bottom of erosion scarp; edge of rock, edge of silt / mud and any significant changes of grade. These should be surveyed every 3 months and immediately after events for the first 5 years or until some consistency in the interpretation is found.

BMT will nominate lines to coincide with areas where changes are possible with initial thoughts being about 30 profiles (approx. 5m landward of vegetation line to about MSLW):

- Northern Beach 5 profiles
- Eastern beaches 12 profiles
- Southern beaches 13 profiles with 5 at the eastern end to identify volume leaving eastern beaches, 3 along Main Beach, 2 at the red cliffs, 3 near the golf course.

Appendix B Individual Beach Multi-criteria Analysis

Table B-1 Multi-criteria Analysis - Morwong Beach

Option	Effectiveness	Technical feasibility	Stage 1 score	Notes	Terrestrial Values	Marine Values	Heritage	Tourism/ Local Business	Access and use of beach	Stage 2 score	Notes	Initial Cost	Ongoing Costs (per year)	Consistency with State Policy	Reversible / Adaptable in the future	Community org. involvement	Stage 3 score	Notes
Weighting	*50%*	*50%*			*20%*	*20%*	*20%*	*20%*	*20%*			*25%*	*25%*	*25%*	*20%*	*5%*		
Formalise/maintain access paths - including repairs/upgrades with flexible structures if current access is damaged	0	2	1	Complementary measure. Recommend if access is damaged by a storm event or if upgrades are planned	1	0	1	0	1	0.6	Prevent damage to the emerald fringe through ad-hoc beach access and improve all condition access	2	2	2	2	0	1.9	Low initial and ongoing costs
Stormwater management	0	0	0	Complementary measure	0	0	0	0	1	0.2	Preventing sand washing onto the tidal flat may improve beach amenity. Otherwise no impact	2	2	2	2	0	1.9	Low initial and ongoing costs
Remove boat ramp and close access path to vehicles	2	2	2	Removed any erosion impacts associated with the boat ramp, including vehicle access to the beach.	1	1	1	0	0	0.6	Benefit to environmental values as removed vehicles from the beach and vehicle access through the Emerald Fringe.	2	2	2	2	0	1.9	No ongoing cost, low initial cost.
Beach Nourishment (under existing permits)	0	2	1	Only recommended in response to severe storm erosion.	-1	0	1	0	1	0.2		2	1	2	2	0	1.65	Expectation would be for approximately 1000 m^3 repeated every 5-10 years (at most)
Repair/upgrade boat ramp	-2	-1	-1.5	Potential additional erosion from vehicles on beach, possible other unknown effects. Boat ramp would only be usable at high tide access due to the intertidal flats.	-	-	-	-	-	-	Option not progressed past stage 1	-	-	-	-	-	-	Option not progressed past stage 1
Beach reprofiling	-1	2	0.5	Very temporary measure. May be appropriate after storms.	-1	0	0	0	0	-0.2	Narrow beach so minimal improvement in beach amenity expected. Negative environmental impacts from machinery on the beach	-	-	-	-	-	-	Option not progressed past stage 2

Table B-2 Multi-criteria Analysis – North-eastern Norfolk Beach

Option	Effectiveness	Technical feasibility	Stage 1 score	Notes	Terrestrial Values	Marine Values	Heritage	Tourism/ Local Business	Access and use of beach	Stage 2 score	Notes	Initial Cost	Ongoing Costs (per year)	Consistency with State Policy	Reversible / Adaptable in the future	Community org. involvement	Stage 3 score	Notes
Weighting	*50%*	*50%*			*20%*	*20%*	*20%*	*20%*	*20%*			*25%*	*25%*	*25%*	*20%*	*5%*		
Beach Nourishment (under existing permits)	0	2	1	In repose to further erosion in a storm event.	0	0	1	0	0	0.2	Positive environmental impact offset (protection of trees) offset by negative impact from machinery on the beach. Some protection of heritage values (Emerald Fringe).	2	1	2	2	0	1.65	Assume nourishment on the order of 250m^3, may need repeating annually
Larger scale beach nourishment and extensive dune planting	0	-1	-0.5	Ongoing monitoring is required to better determine beach changes before effectiveness and impacts of this option can be determined.	0	0	1	0	2	0.6	Positive environmental impact offset (protection of trees) offset by negative impact from machinery on the beach. Some protection of heritage values (Emerald Fringe). Improved amenity.	-1	1	0	1	1	0.25	10000m^3 approx. initially, ongoing as per above + plants. Community groups can assist with planting.
Seawall (with large initial nourishment and ongoing nourishment)	1	-1	0	Not sure about technical feasibility. Would require further investigation	-1	0	1	0	1	0.2	Much the same as large scale beach nourishment except for environmental impact.	-1	1	-2	0	0	-0.5	Approvals expected to be difficult to obtain as not for protection of built infrastructure or property.
"Dune enhancement" with sandbags and nourishment between morwong and NE Norfolk to stop sand loss to the north and prevent further beach rotation	-1	-1	-1	Further investigation required to confirm effectiveness and technical feasibility, including ongoing monitoring.	-1	-1	0	0	0	-0.4	Negative environmental impact expected as it would alter natural processes. Full impacts unknown.	-	-	-	-	-	-	Option not progressed past stage 2. Ongoing monitoring is required to better determine beach changes before effectiveness and impacts of this option can be determined.
Beach reprofiling	-2	-2	-1.5	As there is a lack of sand available for reprofiling option would be both ineffective and not technically feasible.	-	-	-	-	-	-	Option not progressed past stage 1.	-	-	-	-	-	-	Option not progressed past stage 1.

Table B-3 Multi-criteria Analysis – Norfolk Beach fronting the Melaleuca Wetlands

Option	Effectiveness	Technical feasibility	Stage 1 score	Notes	Terrestrial Values	Marine Values	Heritage	Tourism/ Local Business	Access and use of beach	Stage 2 score	Notes	Initial Cost	Ongoing Costs (per year)	Consistency with State Policy	Reversible / Adaptable in the future	Community org. involvement	Stage 3 score	Notes
Weighting	*50%*	*50%*			*20%*	*20%*	*20%*	*20%*	*20%*			*25%*	*25%*	*25%*	*20%*	*5%*		
Beach Nourishment (under existing permits)	1	1	1	Only recommended in response to severe storm erosion.	0	0	1	0	1	0.4	Positive environmental impact offset (protection of trees) offset by negative impact from machinery on the beach. Some protection of heritage values (Emerald Fringe). Improve beach amenity.	1	0	2	2	0	1.15	Expect maximum of 5m^3/m repeated every 5-10 years.
Seawall (with large initial nourishment and ongoing nourishment)	2	0	1	Further investigation to determine technical feasibility and impacts	-1	0	1	0	1	0.2	Option would significantly change the nature of the beach and may have unintended impacts on the wetlands.	-1	0	-2	-1	0	-0.95	Approvals expected to be difficult to obtain as not for protection of built infrastructure or property.
Dredge material from main beach placed slightly offshore	1	2	1.5	This option would provide additional sand to the system to be moved onshore by coastal processes. Potential medium-long term benefit depending on frequency of dredging. Sand is retained within the system.	1	-1	1	0	1	0.4	Potential short term impact to marine environmental values from placing sand. Benefit to terrestrial environmental values as extra sand delivered to the beach without any disturbance on the beach itself.	2	2	0	2	0	1.4	No additional costs expected to be associated with works. Approvals/permits required for placement of material.
Beach reprofiling	0	2	0.5	To aid recovery following an erosion event.	-1	0	1	0	1	0.2	Minor and short term benefits.	2	2	2	2	0	1.9	Low costs.
Formalise/maintain access paths - including repairs/upgrades with flexible structures if current access is damaged	0	2	1	Complementary measure. Beach access at the north of the beach segment is currently damaged.	1	0	1	0	1	0.6	Prevent damage to the emerald fringe through ad-hoc beach access and improve all condition access	2	2	2	2	0	1.9	Low initial and ongoing costs.

Table B-4 Multi-criteria Analysis – Norfolk Beach fronting Victoria Parade East

Option	Effectiveness	Technical feasibility	Stage 1 score	Notes	Terrestrial Values	Marine Values	Heritage	Tourism/ Local Business	Access and use of beach	Stage 2 score	Notes	Initial Cost	Ongoing Costs (per year)	Consistency with State Policy	Reversible / Adaptable in the future	Community org. involvement	Stage 3 score	Notes
Weighting	*50%*	*50%*			*20%*	*20%*	*20%*	*20%*	*20%*			*25%*	*25%*	*25%*	*20%*	*5%*		
Beach Nourishment (under existing permits)	1	1	1	Only recommended in response to severe storm erosion.	0	0	1	0	1	0.4	Positive environmental impact offset (protection of trees) offset by negative impact from machinery on the beach. Some protection of heritage values (Emerald Fringe). Improve beach amenity.	1	0	2	2	0	1.15	Expect maximum of 5m^3/m repeated every 5-10 years.
Seawall (with large initial nourishment and ongoing nourishment)	2	0	1	Further investigation to determine technical feasibility and impacts	-1	0	2	0	1	0.4	Option would significantly change the nature of the beach and may have unintended impacts on the wetlands.	-1	0	-2	-1	0	-0.95	Approvals expected to be difficult to obtain as not for protection of built infrastructure or property.
Dredge material from main beach placed slightly offshore	1	2	1.5	This option would provide additional sand to the system to be moved onshore by coastal processes. Potential medium-long term benefit depending on frequency of dredging. Sand is retained within the system.	1	-1	1	0	1	0.4	Potential short term impact to marine environmental values from placing sand. Benefit to terrestrial environmental values as extra sand delivered to the beach without any disturbance on the beach itself.	2	2	0	2	0	1.4	No additional costs expected to be associated with works. Approvals/permits required for placement of material.
Recycle sand from the barge ramp back onto the beach.	0	2	1		0	0	0	1	1	0.4		2	2	2	2	0	1.9	
Maintain existing seawalls	2	2	2	Note that structures will need removing or replacing within 20 years (end of design life).	0	0	0	0	0	0		2	2	-2	0	0	0.5	Minimal associated cost. Approval required.
Remove existing seawalls	0	2	1	Sand from sandbags will continue to provide some short-medium term benefit	0	0	0	0	0	0	Disturbance associated with works and possibility of destabilising trees.	2	2	2	0	0	1.5	Low once off cost.
Beach reprofiling	0	2	1	To aid recovery following an erosion event.	-1	0	1	0	1	0.2	Minor and short term benefits.	2	2	2	2	0	1.9	Low costs.
Stormwater management	0	2	1	Manage stormwater runoff from Norfolk Beach track and sewer line.	0	0	0	0	1	0.2		2	2	2	2	0	1.9	
Formalise/maintain access paths - including repairs/upgrades with flexible structures if current access is damaged	0	2	1	Complementary measure. Prioritise existing damaged beach access	1	0	1	0	1	0.6	Prevent damage to the emerald fringe through ad-hoc beach access and improve all condition access	2	2	2	2	0	1.9	Low initial and ongoing costs.

Table B-5 Multi-criteria Analysis – South-eastern Norfolk Beach

Option	Effectiveness	Technical feasibility	Stage 1 score	Notes	Terrestrial Values	Marine Values	Heritage	Tourism/ Local Business	Access and use of beach	Stage 2 score	Notes	Initial Cost	Ongoing Costs (per year)	Consistency with State Policy	Reversible / Adaptable in the future	Community org. involvement	Stage 3 score	Notes
Weighting	*50%*	*50%*			*20%*	*20%*	*20%*	*20%*	*20%*			*25%*	*25%*	*25%*	*20%*	*5%*		
Beach Nourishment (under existing permits)	1	1	1	Only recommended in response to severe storm erosion.	-1	0	1	0	1	0.2	Positive environmental impact offset (protection of trees) offset by negative impact from machinery on the beach. Some protection of heritage values (Emerald Fringe). Improve beach amenity.	1	1	2	2	0	1.4	Expect maximum of 1000m^3/m repeated every 5-10 years.
Dune enhancement with nourishment and geotextile containers at control points 1 and 2.	0	1	0.5	May be justifiable for stable beach alignments – if connection is lost with these two outcrops the whole eastern beach alignment may change.	-1	0	1	0	0	0		1	2	-1	0	1	0.55	Assumes ongoing nourishment as needed (small volumes). Community groups can assist in planting/vegetation maintenance.
Beach reprofiling	0	2	1	To aid recovery following an erosion event.	-1	0	1	0	1	0.2	Minor and short term benefits.	2	2	2	2	0	1.9	Low costs.
Stormwater management	0	2	1	From Norfolk Beach Track	0	0	0	0	1	0.2		2	2	2	2	0	1.9	
Formalise/maintain access paths - including repairs/upgrades with flexible structures if current access is damaged	0	2	1	Complementary measure.	1	0	1	0	1	0.6	Prevent damage to the emerald fringe through ad-hoc beach access and improve all condition access	2	2	2	2	0	1.9	Low initial and ongoing costs.

Table B-6 Multi-criteria Analysis – Main Beach East of the Ferry Terminal

Option	Effectiveness	Technical feasibility	Stage 1 score	Notes	Terrestrial Values	Marine Values	Heritage	Tourism/ Local Business	Access and use of beach	Stage 2 score	Notes	Initial Cost	Ongoing Costs (per year)	Consistency with State Policy	Reversible / Adaptable in the future	Community org. involvement	Stage 3 score	Notes
Weighting	*50%*	*50%*			*20%*	*20%*	*20%*	*20%*	*20%*			*25%*	*25%*	*25%*	*20%*	*5%*		
Recycle sand from the barge ramp back onto the beach.	1	2	1.5		0	0	1	1	1	0.6		2	2	2	2	0	1.9	
Beach Nourishment (under existing permits)	1	2	1.5	Only recommended in response to severe storm erosion.	0	0	1	1	1	0.6	Area is already heavily trafficked so unlikely to have any additional environmental impact. Benefit will be more related to improved beach amenity.	1	1	2	2	0	1.4	Expect maximum of 1000m³/m repeated every 5-10 years.
Beach reprofiling	0	2	1	To aid recovery following an erosion event.	0	0	1	1	1	0.6	Minor and short term benefits.	2	2	2	2	0	1.9	Low costs.
Stormwater management	0	2	1	Manage runoff from hard park surfaces	0	0	0	1	1	0.4		2	2	2	2	0	1.9	
Formalise/maintain access paths - including repairs/upgrades with flexible structures if current access is damaged	0	2	1	Complementary measure.	0	0	1	1	1	0.6	Prevent damage to the emerald fringe through ad-hoc beach access and improve all condition access	2	2	2	2	0	1.9	Low initial and ongoing costs.

Table B-7 Multi-criteria Analysis – Main Beach between the Ferry Terminal and Barge Ramp

Option	Effectiveness	Technical feasibility	Stage 1 score	Notes	Terrestrial Values	Marine Values	Heritage	Tourism/ Local Business	Access and use of beach	Stage 2 score	Notes	Initial Cost	Ongoing Costs (per year)	Consistency with State Policy	Reversible / Adaptable in the future	Community org. involvement	Stage 3 score	Notes
Weighting	*50%*	*50%*			*20%*	*20%*	*20%*	*20%*	*20%*			*25%*	*25%*	*25%*	*20%*	*5%*		
Beach reprofiling	0	2	1	To aid recovery following an erosion event.	0	0	1	1	1	0.6		2	2	2	2	0	1.9	Low costs.
Stormwater management	0	2	1	Manage runoff from hard park surfaces	0	0	0	1	1	0.4		2	2	2	2	0	1.9	
Formalise/maintain access paths - including repairs/upgrades with flexible structures if current access is damaged	0	2	1	Complementary measure.	0	0	1	1	1	0.6	Prevent damage to the emerald fringe through ad-hoc beach access and improve all condition access	2	2	2	2	0	1.9	Low initial and ongoing costs.

Table B-8 Multi-criteria Analysis – Main Beach between the Barge Ramp and Red Cliffs

Option	Effectiveness	Technical feasibility	Stage 1 score	Notes	Terrestrial Values	Marine Values	Heritage	Tourism/ Local Business	Access and use of beach	Stage 2 score	Notes	Initial Cost	Ongoing Costs (per year)	Consistency with State Policy	Reversible / Adaptable in the future	Community org. involvement	Stage 3 score	Notes
Weighting	*50%*	*50%*			*20%*	*20%*	*20%*	*20%*	*20%*			*25%*	*25%*	*25%*	*20%*	*5%*		
Beach reprofiling	0	2	1	To aid recovery following an erosion event.	-1	0	0	0	1	0	Activity to have minimal impact on heritage values due to Creek between beach and Emerald Fringe	2	2	2	2	0	1.9	Low costs.
Stormwater management	0	2	1	Manage runoff from hard park surfaces	0	0	0	0	1	0.2		2	2	2	2	0	1.9	
Formalise/maintain access paths - including repairs/upgrades with flexible structures if current access is damaged	0	2	1	Complementary measure.	1	0	1	0	1	0.6	Prevent damage to the emerald fringe through ad-hoc beach access and improve all condition access	2	2	2	2	0	1.9	Low initial and ongoing costs.

Table B-9 Multi-criteria Analysis - Main Beach fronting the Golf Course

Option	Effectiveness	Technical feasibility	Stage 1 score	Notes	Terrestrial Values	Marine Values	Heritage	Tourism/ Local Business	Access and use of beach	Stage 2 score	Notes	Initial Cost	Ongoing Costs (per year)	Consistency with State Policy	Reversible / Adaptable in the future	Community org. involvement	Stage 3 score	Notes
Weighting	*50%*	*50%*			*20%*	*20%*	*20%*	*20%*	*20%*			*25%*	*25%*	*25%*	*20%*	*5%*		
Beach reprofiling	-1	-1	-1	To aid recovery following an erosion event.	-1	-1	0	0	0	-0.4	This is a remote and reasonably pristine part of the Island so any nourishment/beach reprofiling will have a larger relative environmental impact with less social benefits than other locations.	-	-	-	-	-	-	Option not progressed past stage 2.
Beach Nourishment (under existing permits)	1	-1	0	Following a storm event	-1	-1	0	0	0	-0.4	As above	-	-	-	-	-	-	Option not progressed past stage 2.
Formalise/maintain access paths - including repairs/upgrades with flexible structures if current access is damaged	0	2	1	Complementary measure.	1	0	1	0	1	0.6	Prevent damage to the emerald fringe through ad-hoc beach access and improve all condition access	2	2	2	2	0	1.9	Low initial and ongoing costs.

Appendix C Beach protection examples

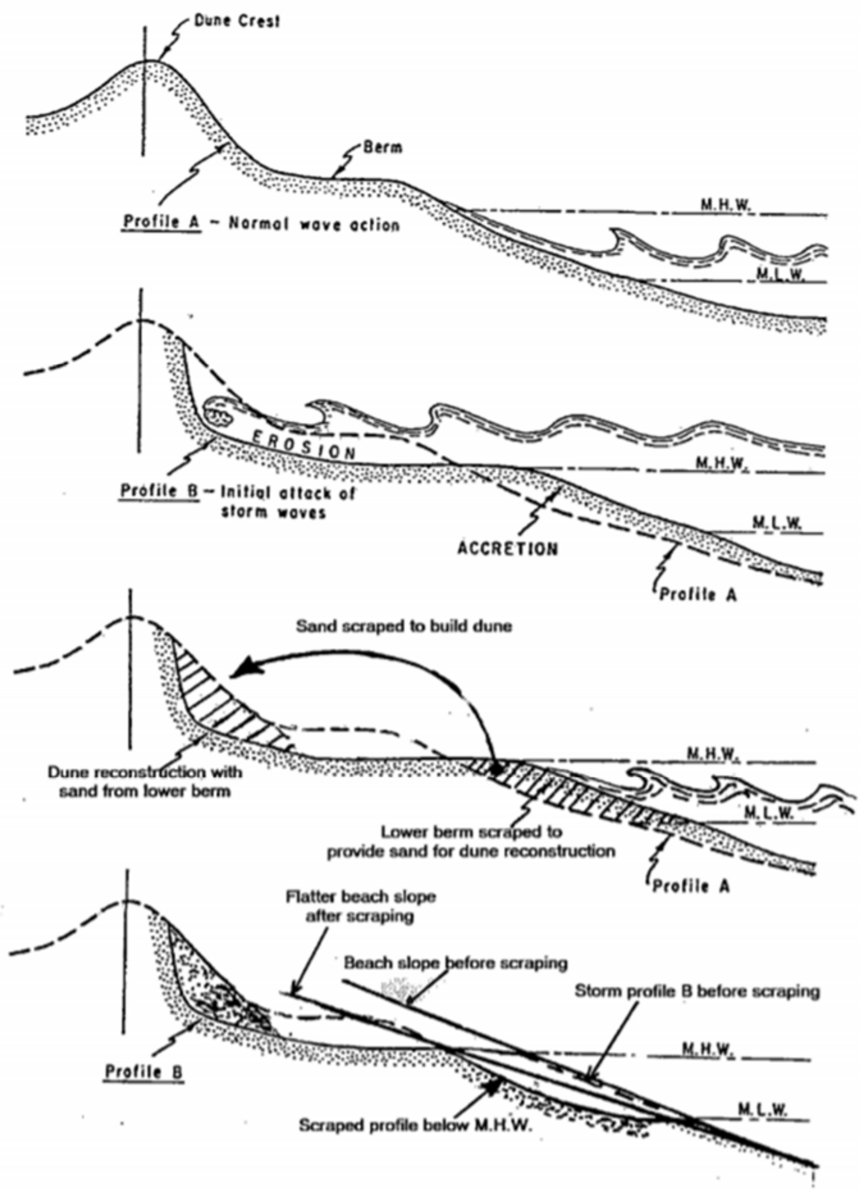

Figure C-1 Beach reprofiling concept

Figure C-2 Beach nourishment before (left) and after (right)

Figure C-3 Beach nourishment before (left) and after (right)

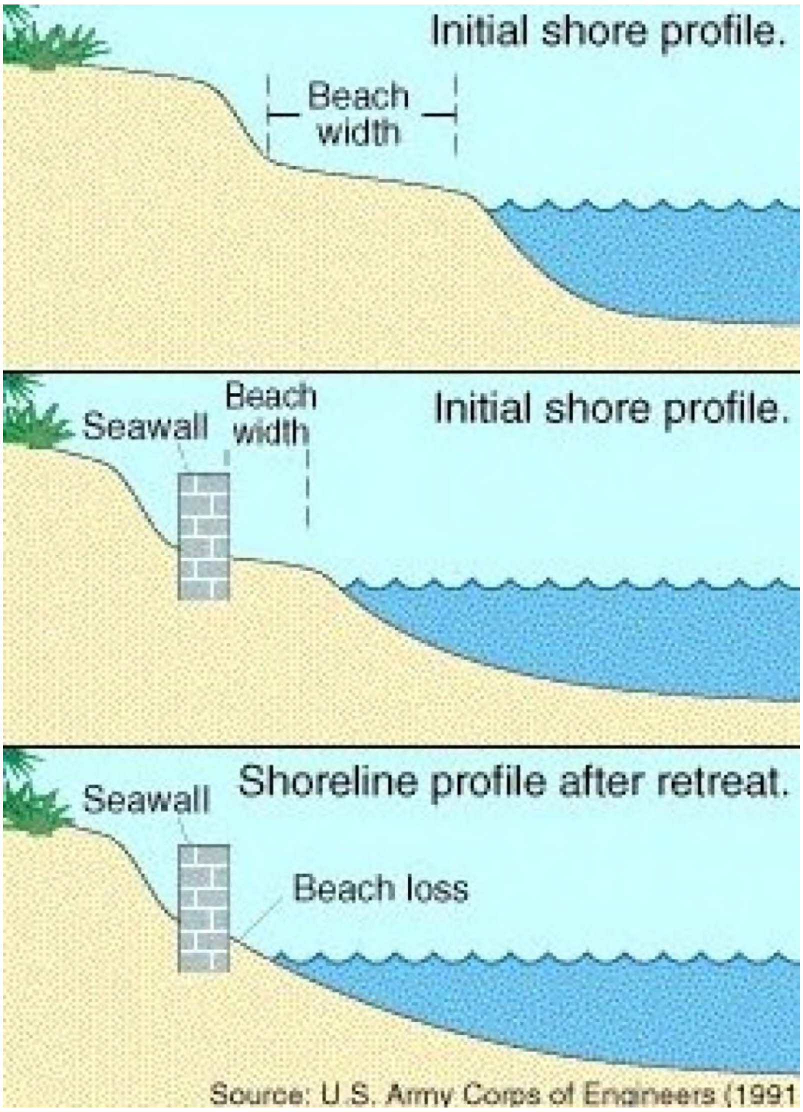

Figure C-4 Example of the processes by which a beach in front of a seawall is lost

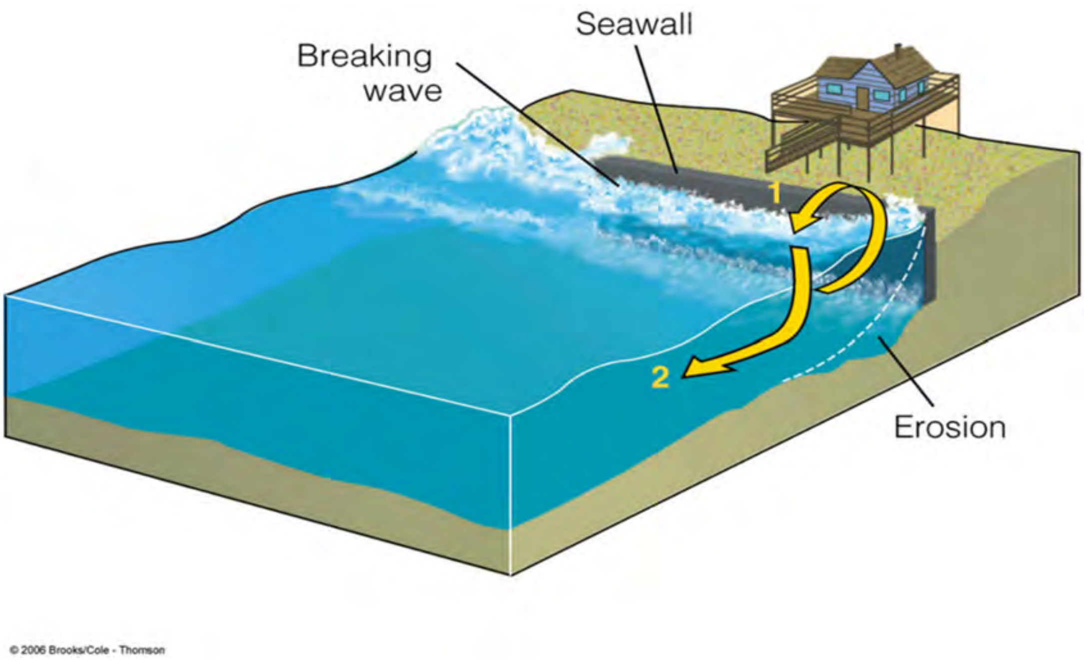

Figure C-5 Example of the processes by which a beach in front of a seawall is lost

Figure C-6 Eroded beach in front of a geotextile container seawall

Figure C-7 Eroded beach in front of a geotextile container seawall

Figure C-8 Typical groyne result with longshore transport. Arrow indicates direction of sand transport

Appendix D 2020 Survey profiles, selected Main Beach and Norfolk Beach locations

Figure D-1 2020 Survey, all points. Yellow indicates profiles that have been surveyed previously.

Figure D-2 2020 Survey, Main beach east of the Ferry Terminal, South-east Norfolk Beach and Norfolk Beach fronting Victoria Parade. Yellow indicates profiles that have been surveyed previously

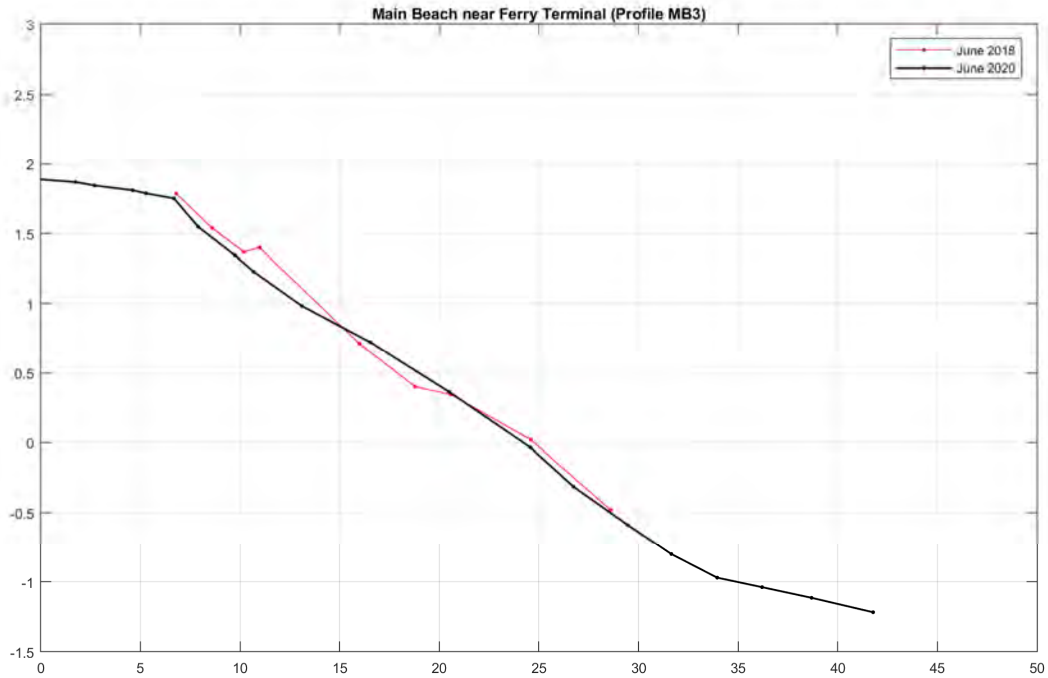

Figure D-3 June 2018 and June 2020 surveys, Profile MB3, Main Beach

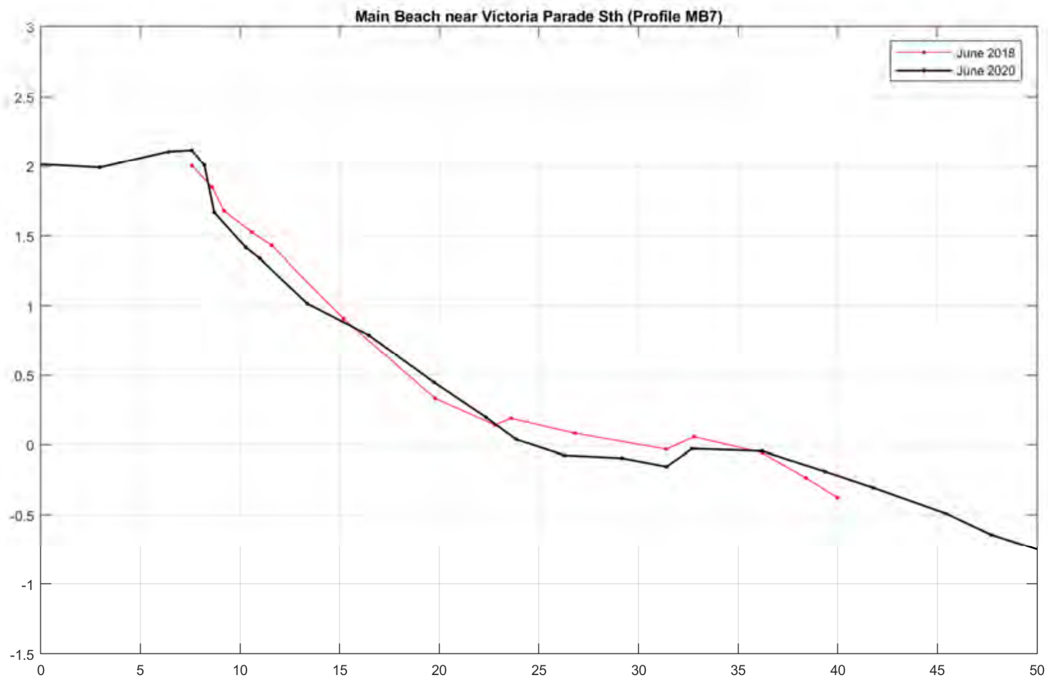

Figure D-4 June 2018 and June 2020 surveys, Profile MB7, Main Beach

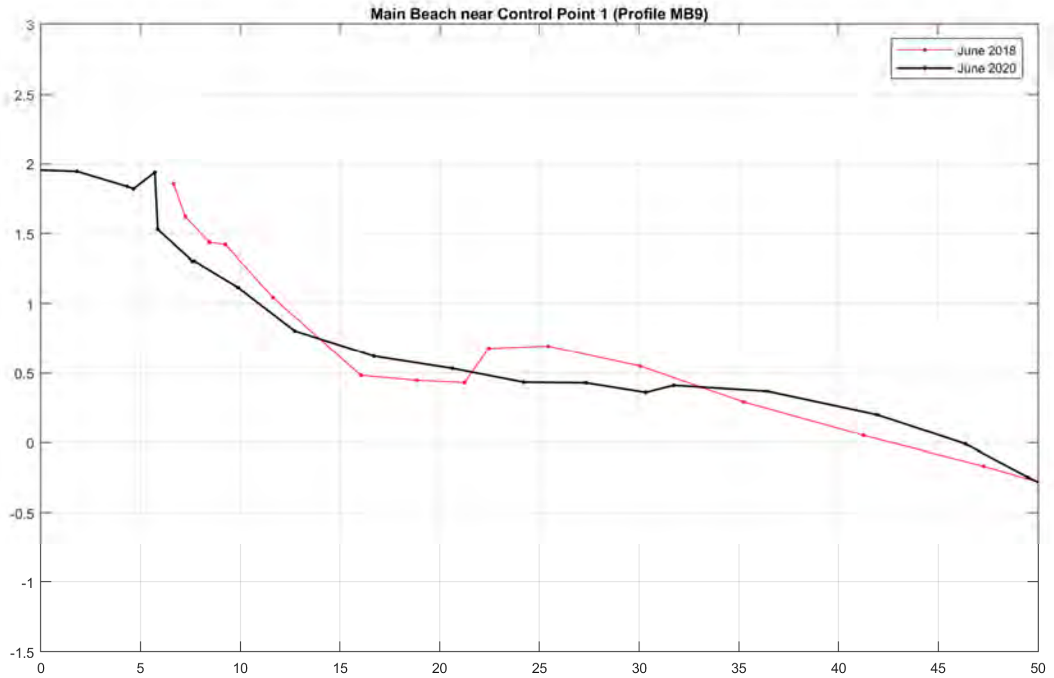

Figure D-5 June 2018 and June 2020 surveys, Profile MB9, Main Beach

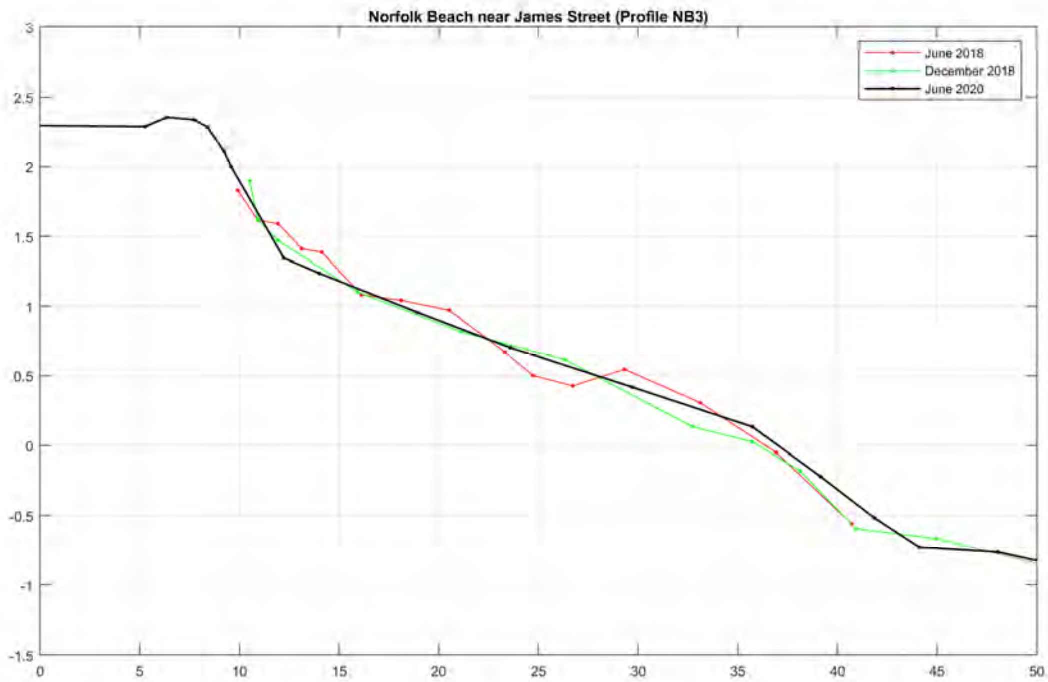

Figure D-6 June 2018, December 2018 and June 2020 surveys, Profile NB3, Norfolk Beach

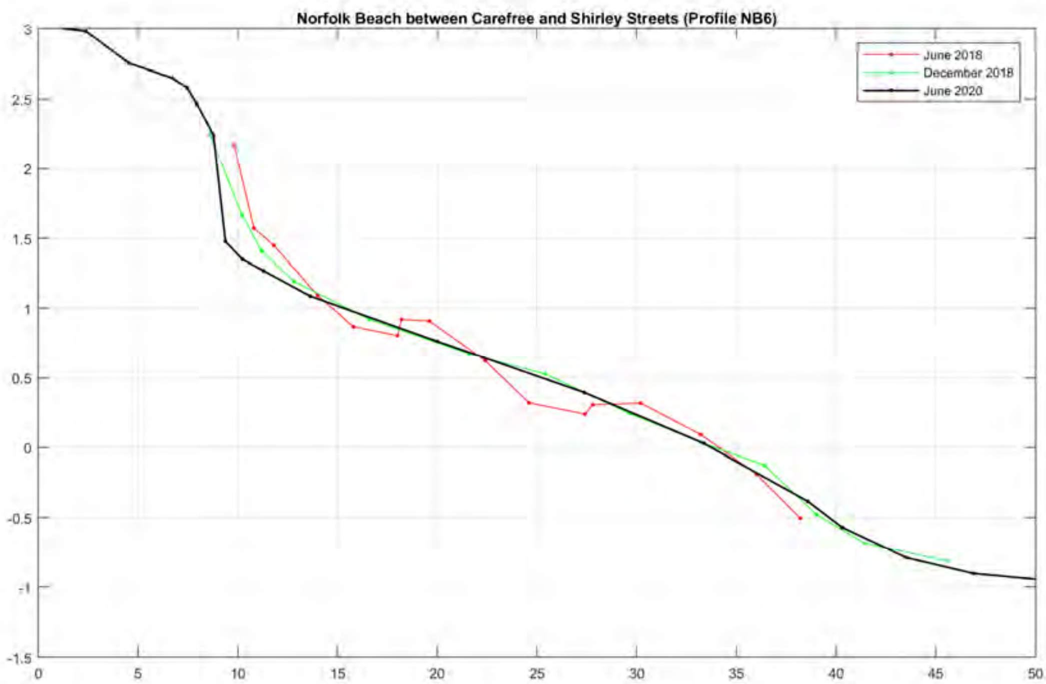

Figure D-7 June 2018, December 2018 and June 2020 surveys, Profile NB6, Norfolk Beach

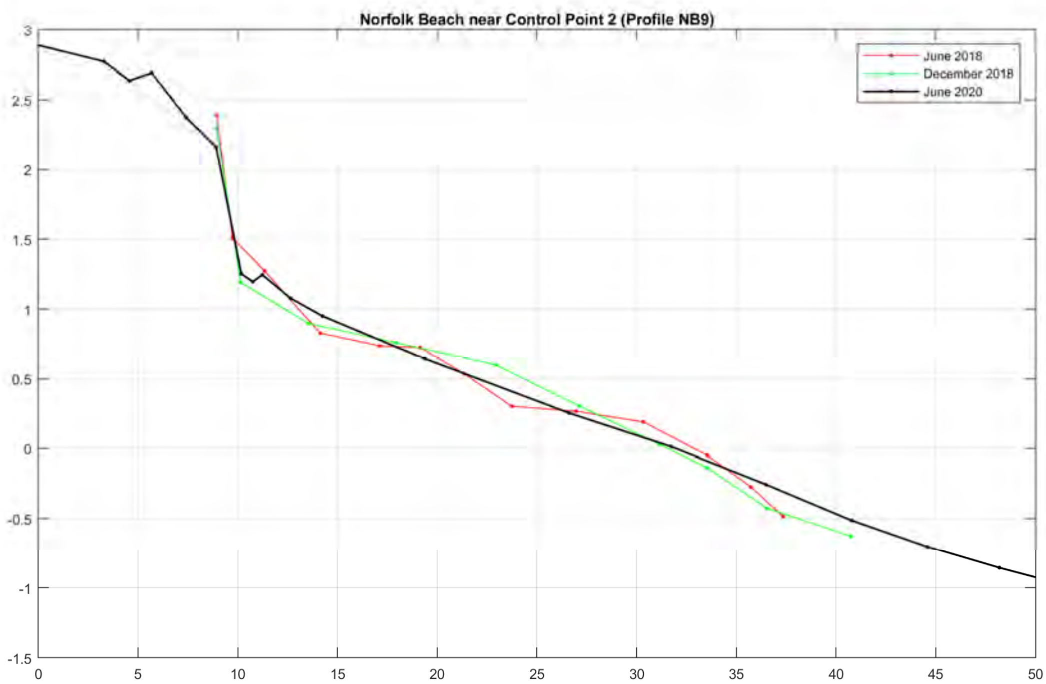

Figure D-8 June 2018, December 2018 and June 2020 surveys, Profile NB9, Norfolk Beach

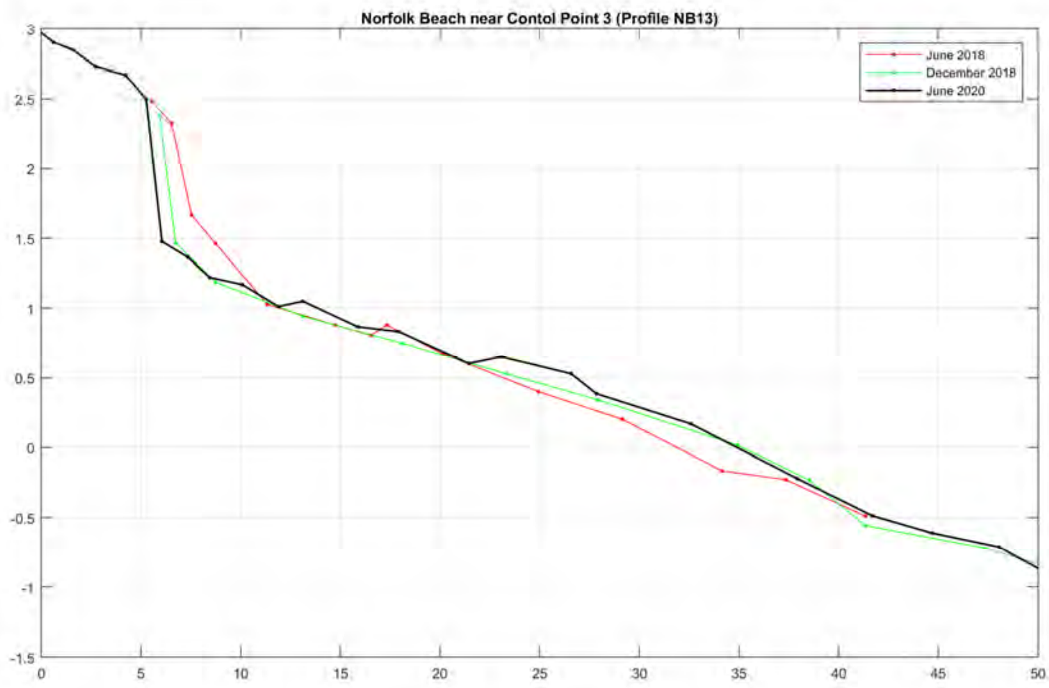

Figure D-9 June 2018, December 2018 and June 2020 surveys, Profile NB13, Norfolk Beach

Appendix E Photos of Norfolk Beach (courtesy of Coastcare)

Southern beach access to Heritage Precinct, Norfolk Beach 2 May 2015

Southern beach access to Heritage Precinct, Norfolk Beach 11 March 2020

Looking towards CP2 from the southern access to the Heritage precinct, Norfolk Beach - 5 May 2015. Note width of vegetated dune

Same spot 11 March 2020 – Note erosion & this is the least eroded section on Norfolk Beach today

Looking north to CP3. Compare the top photo from May 2015 to the bottom, 11 March.2020 - Note the loss of vegetated dune , particularly in front of the fence line

Northern access to Heritage precinct looking north – note top photo from 3 May 2015 lush vegetated dune compared to the eroded scarp 3 metres from the fence-line yesterday - 11 March 2020

Appendix F Photos 20 July 2020 (BMT)

Figure F-1 Mouth of Curlew Creek, Main Beach (looking west)

Figure F-2 Mouth of Curlew Creek, Main Beach (looking east)

Figure F-3 Control Point 2 (looking south-west)

Figure F-4 Control Point 2 (looking north-east)

Figure F-5 Active beach recovery – Norfolk Beach (shoe to indicate scale)

Figure F-6 Sand moving onshore (Photo taken from Norfolk Beach looking east).

Figure F-7 Beach recovery (Melaleuca Wetlands looking north to Control Point 4)

Figure F-8 North-eastern corner between Morwong Beach and North-eastern Norfolk Beach (looking south-west)

Figure F-9 Mature tree at the eastern end of Morwong Beach

Appendix G Hazard Risk Rating Assessment Tables

The following tables have been copied from the CAS (Draft Coastal Adaptation Strategy, RCC 2017).

Table G-1 Environment Criteria (Table on Page 20 of the CAS)

Criteria		Scoring Method					
		1	2	3	4	5	Score
Environment	The loss of the foreshore area from an erosion event (m^2)	<99m^2	100m^2 – 999m^2	1,000m^2 –1,999m^2	2,000m^2 – 3,999m^2	>4,000m^2	eg. 3
	Adjoining terrestrial value (BPA 3.5); or Vegetation regulated under the *Vegetation Management Act 1999*	Minimal ecological value (i.e. cleared land, invasive species, etc.)	Low ecological value / Category X: Vegetation not regulated under the *Vegetation Management Act 1999*	Near threatened species identified / Category C: High-value regrowth vegetation	Vulnerable species identified / Category B: Remnant vegetation	Endangered or critically endangered species identified / Category A: Declared areas, offset areas or an exchange area	
	Marine Park Zoning	No Marine Park	General Use Zone	Habitat Protection Zone	Conservation Park Zone	Marine National Park Zone	
	Ramsar listed	Not Ramsar				Ramsar listed	
	Fish habitat area	Not in				Fish habitat area	
	EPBC-listed endangered ecological community	Not present				Present	
	Nature Conservation Act Species Present	No species present		Vulnerable species present		Endangered species present	
Environment Score (Total Average)							

Table G-2 Social Criteria (First table on Page 21 of the CAS)

Criteria		Scoring Method					
		1	2	3	4	5	Score
Social	Refers to the visual quality and appreciation of the foreshore space by the public	Minimal visual amenity	Low value of visual amenity	Moderate level of visual amenity	Local Important visual amenity	Very high level of visual amenity	eg. 3
Social	Recreational value of the foreshore area receives	Minimal recreational value	Low recreational value to local community	Medium recreational value to local community, but low to minimal to broader community	High local recreational value to the local community and medium value to broader community	High recreational value to broader community, can be considered a recreation 'destination'	
Social	The presence of cultural heritage (Indigenous & European)	No cultural heritage identified	Minor cultural heritage value identified	Locally important cultural heritage value identified	Regionally important cultural heritage value identified	Significant cultural heritage site identified	
Social	The number of people residing in a location affected by the identified hazard	<10	10 to 19	20 to 49	50 to 99	>100	
						Social Score (Total Average)	

Table G-3 Economic Criteria (Second table on Page 21 of the CAS)

Economic	The total value of public infrastructure that is at risk of being impacted by the identified hazard	up to $49,999	$50,000 – $199,999	$200,000 – $499,999	$500,000 – $999,999	>$1,000,000	eg. 3
Economic	Approximate value of property impacted by the identified hazard *Private land is determined by the Unimproved Capital Value of the property *Public land is calculated at area of land within the erosion prone area[10]	up to $49,999	$50,000 – $199,999	$200,000 – $499,999	$500,000 – $999,999	>$1,000,000	
						Economic Score (Total Average)	
						Total Score (Environment average + Social average + Economic Average)	

Table G-4 Erosion Factor (Second table on Page 22 of the CAS)

	Scoring Criteria				
	1	2	3	4	5
Severity of Erosion	Minimal erosion occurring	Low level of erosion occurring (i.e. recession and regeneration or continual fluctuation of shoreline)	Medium level of erosion occurring (i.e. transformation of location – natural process of recession occurring in one location and progression at another)	High level of erosion occurring (i.e. permanent loss of shoreline)	Severe erosion occurring (i.e. significant permanent loss of foreshore, often resulting in sudden and significant events)

Table G-5 Consequence Rating (First table on Page 22 of the CAS)

Consequence	Total Score
Severe	12-15
Major	9-11
Medium	6-8
Low	4-5
Minimal	3

Table G-6 Risk Matrix (First table on Page 23 of the CAS)

		Prioritisation Score				
		1	2	3	4	5
Consequence Rating	Severe	M10	H20	H30	E40	E50
	Major	M8	M16	H24	E32	E40
	Medium	L6	M12	M18	H24	E30
	Low	L4	L8	M12	M16	H20
	Insignificant	L2	L4	L6	M8	M10

BMT has a proven record in addressing today's engineering and environmental issues.

Our dedication to developing innovative approaches and solutions enhances our ability to meet our client's most challenging needs.

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