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R1364 Rev 0

July 2020

City of Greater Geraldton

Bluff Point Coastal Adaptation Options Assessment

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0	Issued for Client use	J Costin	C Doak	C Doak	09/07/20

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Limitations of this Document

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1. Introduction

The shoreline within the Bluff Point Coastal Management Unit (CMU), as identified in the Geraldton Coastal Hazard Risk Management and Adaptation Plan (CHRMAP; Baird 2019), has been identified to be at extreme risk from coastal erosion over the immediate planning timeframe to 2030. This extreme risk arises due to the assessed annual shoreline erosion rates of between 0.3 to 0.9 m per year, coupled with the close proximity of assets to the shoreline within this area.

There are two locations, in particular, within this CMU that require implementation of coastal adaptation strategies to help manage these coastal hazard risks. The southern and northern sections of Bluff Point (refer Figure 1.1), contain both public and private assets which require short to medium term coastal adaptation measures to be implemented to ensure ongoing protection of the assets.

Figure 1.1 Location of Site

The City of Greater Geraldton (City) engaged M P Rogers & Associates Pty Ltd (MRA) to complete an adaptation options assessment for both of these areas. The desire of the City is for the adaptation options to be based on a 'no-regrets' approach which allows for short to medium term adaptation measures (that provide protection to 2030) to be easily removed in the future, if required. The scope of the works includes the following.

- Review existing site conditions, sediment transport, wave climate and locations of existing infrastructure.
- Review of the suitability of potential adaptation options in line with the City's 'no regrets' approach. This includes 'soft' and 'hard' engineering options.
- Prepare concept designs of medium term adaptation options, with the aim of providing sufficient protection to the entire lengths of shoreline at both Bluff Point North and Bluff Point South, to 2030. This includes estimates of construction costs and consideration of ongoing maintenance requirements.
- Review of medium term adaptation options against the City's available budget and providing recommendations regarding interim adaptation measures that can be implemented with the available budget. These interim adaptation options are to provide localised protection to vulnerable assets, as a first step towards providing protection to 2030.

This report presents a summary of the outcomes and recommendations of the Bluff Point adaptation options assessment.

2. Background & Site Settings

2.1 Site Setting

The shoreline within both sites is described as a sandy beach with shallow calcarenite reef that parallels most of the beach and extends up to 1 km offshore (Short 2006). These reefs can be seen in the nautical chart excerpt shown in the Figure below.

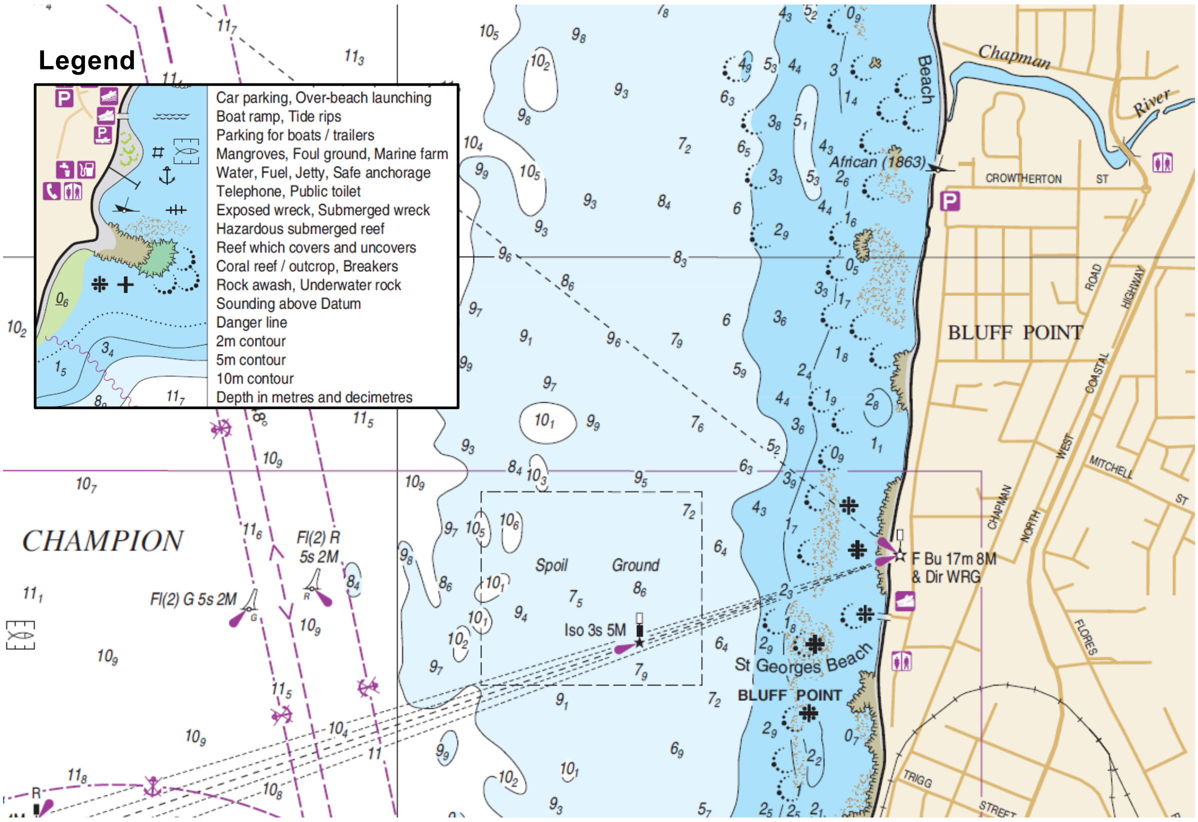

Figure 2.1 Bluff Point Nautical Chart Excerpt

It is noted that the location of the shipwreck labelled African (1863) is not correctly shown in Figure 2.1. The GPS coordinate location of this shipwreck noted by the Western Australian Museum (2008) lies to the north of the Chapman river.

Sediment along these sections of shoreline is generally relatively fine grained, with median grain sizes in the order of 0.2 to 0.25 mm.

Due to the restrictions associated with COVID-19 a site inspection for these works was not possible. Therefore, an inspection was completed by a representative from the City. A drone flyover was also completed by HTD Surveys to capture oblique aerial imagery. Data gathered from both of these inspection techniques was provided to MRA to assist with this review. The site conditions observed from these inspections are outlined in the following sections.

2.1.1 Bluff Point South

This shoreline fronts Rundle Park which provides shaded grassed areas, ablutions, barbecues and playground facilities. This beach is a popular recreational area and is generally well used. This is evidenced by the drone footage which showed people recreating along the beach, including swimming, stand-up paddle boarding and dog walking. Implementation of potential adaptation options should therefore seek to ensure that recreational uses of this area are not restricted wherever possible, whilst also ensuring that the necessary level of protection is provided to Rundle Park and other infrastructure, including freehold land.

The average distance from the vegetation line to the mean sea level contour ranges from approximately 10 – 15 m along this section of shoreline. From the drone footage as well as from the site photos provided by the City, dune and wind fencing are evident along the coastline, particularly at the south of the site (refer Figures 2.2 and 2.3).

Figure 2.2 Site photographs of Shoreline Fronting Bluff Point South

Figure 2.3 Oblique Drone Image of Shoreline Fronting Bluff Point South

In the northern section of this site – in the area fronting Rundle Park – no dune is present. This is a reflection of the extent of foot traffic that this area receives, but is also an outcome of previous erosion events that have caused erosion back to near the edge of the car park. Sand nourishment has been completed in this area to combat this erosion. Figure 2.4 shows an image of this area from July 2015 which depicts the narrow beach width in the area, even following the placement of beach nourishment. It is noted that this nourishment contains erosion channels caused by overland flow of the adjacent carpark.

Figure 2.4 Photograph of Bluff Point South from July 2015 showing Eroded Profile

Following erosion issues at the site a geosynthetic sand container (GSC) groyne was constructed at the northern end of the site in 2016. There is evidence of the effectiveness of this structure in helping to retain a sandy beach in the area to the south, however the low crest elevation and short length of the groyne limits the potential holding capacity of this structure. The GSC groyne is shown in the following figure.

Figure 2.5 Existing GSC Groyne (Nearmap, November 2016)

From the recent drone footage obtained of this location, there is a cutback section on the northern side of the groyne. Based on the overall northern sediment transport direction along this section of coastline, this is evidence of downdrift erosion and therefore indicates that sediment is successfully being trapped on the southern side of the structure. Figure 2.6 illustrates the impact of the groyne and the positive benefit that it provides by delivering a wider beach fronting Rundle Park. It is noted that despite the groyne serving its function by trapping sand on the southern side, this does not guarantee a generous beach width, as other factors such as elevated waves and water levels can still cause erosion of this beach profile in this area.

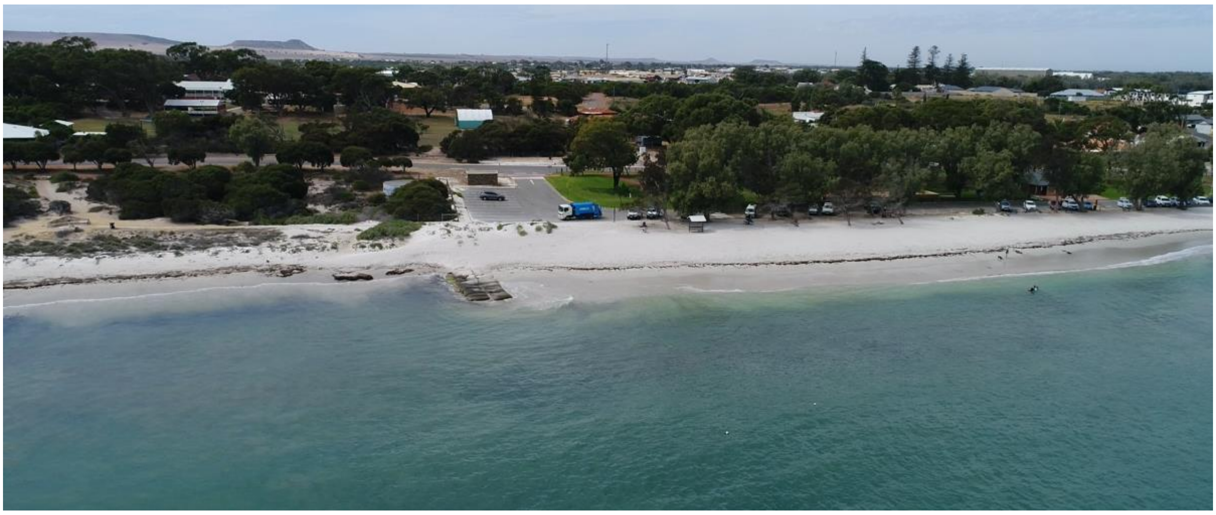

Figure 2.6 Oblique View of GSC Groyne

2.1.2 Bluff Point North

This section of shoreline is not used as extensively as the Bluff Point South area, and is more typical of a local level beach. No public facilities or amenities are provided in this area other than a small gravel carpark available for beach users.

There are two freehold lots in particular within this section of coastline that back directly onto the beach (refer Figure 2.7). Ad hoc protection has been provided to these lots to help provide protection against erosion effects (refer Figure 2.8).

Also present adjacent to these lots are a Water Corporation waste water pumping station and a drainage outfall structure. Water Corporation have previously expressed concern about the ongoing protection of their asset against coastal erosion risk. Rock armour has been used to protect the drainage outfall.

Figure 2.7 Infrastructure Adjacent to Coastline along Bluff Point North Site

Figure 2.8 Ad Hoc Protection of Freehold Development (far field) and Drainage Infrastructure (near field)

Large sections of the beach were covered in wrack during the time of the inspections, which is a frequent occurrence for this area. The ad hoc protection adjacent to the freehold lots appears to possibly be encouraging the trapping of wrack in this area. This can be seen below in Figure 2.9.

Figure 2.9 Site photographs of shoreline fronting Bluff Point (North)

The average distance from the vegetation line to the mean sea level contour ranges from less than 5 m to approximately 15 m along this section of shoreline. It is also noted that to the north of this area lies the mouth to the Chapman River. The Chapman River mouth opens intermittently which has an impact on the local coastal processes in the area. This is something that needs to be considered for the concept design of potential adaptation options.

2.2 Coastal Hazard Risk

In 2015, MRA completed the *Town Beach to Drummond Cove Inundation & Coastal Processes Study* (MRA 2016). This study completed assessments of both coastal erosion and inundation hazards, including cyclonic, non-cyclonic and tsunami. This assessment was completed in accordance with the requirements of State Planning Policy No. 2.6: State Coastal Planning Policy (SPP2.6) (WAPC 2013).

The outcomes from MRA (2016) were used to provide the foundation for the assessment of coastal risk along the Geraldton coastline in the CHRMAP completed by Baird (2019). The CHRMAP area extended between Cape Burney and Drummond Cove and considered the area as separate coastal management units to capture the varying coastal processes, land uses and recommended risk management and adaptation responses. The 12 coastal management units are shown in Figure 2.10 below. Areas potentially impacted by coastal hazard are shown in Figure 2.11, noting that while the erosion hazard impacts are shown for different timeframes, the potential inundation impacts are shown based on a 500 year ARI event occurring in 2110 – which is as required by SPP2.6.

The coastal hazard mapping for the Bluff Point CMU shows that the erosion impacts along this section of coastline are potentially much more severe than potential inundation impacts. The outcomes of the coastal hazard risk assessment included in Tables 2.1 and 2.2 confirm this. Thus, future adaptation strategies should focus mainly on limiting potential further impacts associated with coastal erosion of the sites.

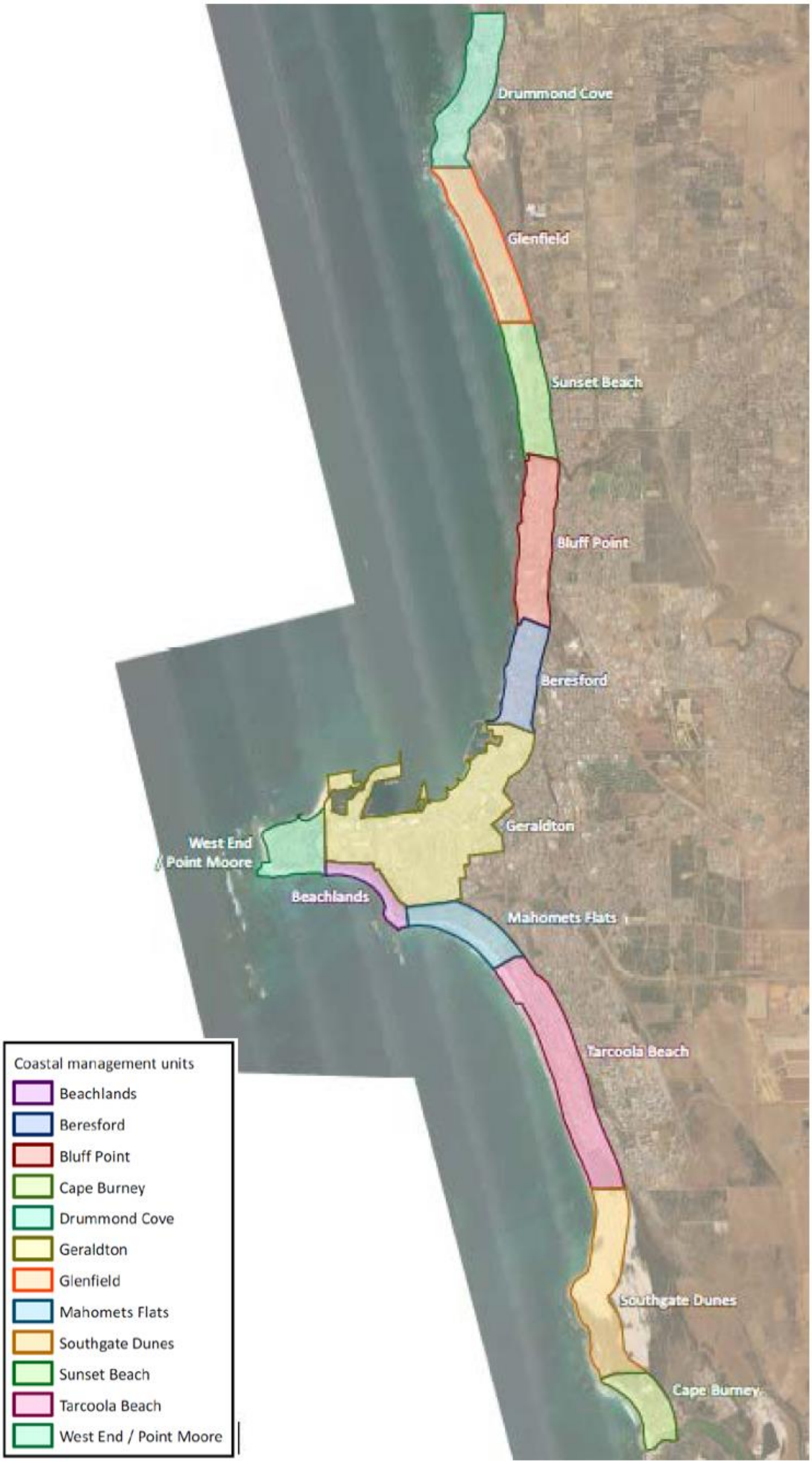

Figure 2.10 CHRMAP Coastal Management Units (Baird 2019)

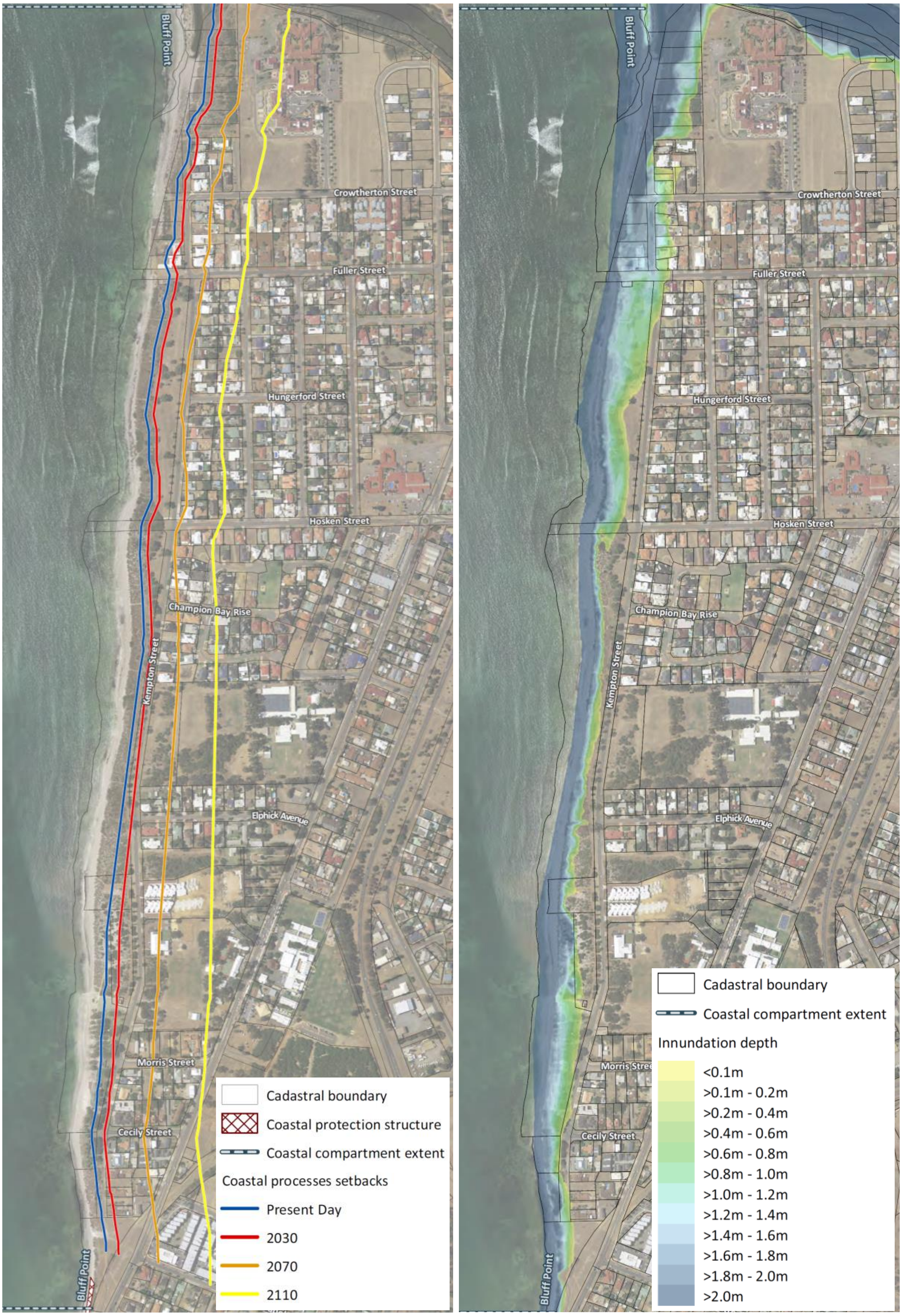

Figure 2.11 Coastal Erosion & Inundation Hazards for Bluff Point CMU (Baird 2019)

Table 2.1 Erosion Hazard Risk Assessment Results for Bluff Point CMU (Baird 2019)

	Erosion Risk			
Asset	**2018**	**2030**	**2070**	**2110**
Houses West of Kempton Street	E	E	E	E
Houses North Kempton / Crowtherton St	H	E	E	E
Houses East of Kempton Street	M	H	E	E
Houses Kempton St, South of Cecily St	H	E	E	E
Nazareth House	M	M	H	E
Roads - Kempton street	H	H	E	E
Roads - Cecily, Morris, Elphick, Crowtherton	M	H	H	E
Beaches	M	M	H	H
Foreshore Reserve	H	H	E	E
Beach St Georges	H	H	E	E
Toilets St Georges	H	E	E	E
Car Park St Georges	H	H	E	E
Rundle Park St Georges	H	H	E	E
Boat Ramp at St Georges	M	H	H	H
Carpark Bluff Point 'Leading Lights'	M	M	H	H
Carpark Opposite Crowtherton St	M	H	H	H
Cycling / Walking Tracks	M	H	H	E
Dunes	H	H	E	E
Trees	M	H	H	H
Midden Site, Bluff Point Kempton St	E	E	E	E
Watercorp Infrastructure - Fuller St West	H	E	E	E

Table 2.2 Erosion Hazard Risk Assessment Results for Bluff Point CMU (Baird 2019)

Inundation Risk				
Asset	**2018**	**2030**	**2070**	**2110**
Houses West of Kempton Street	M	M	H	H
Vacant Blocks North Kempton / Crowtherton	H	H	H	H
Houses East of Kempton Street	L	L	M	M
Roads - Kempton street	L	L	M	M
Beaches	M	M	M	M
Beach St Georges	M	M	M	M
Toilets St Georges	L	L	M	M
Rundle Park St Georges	M	M	M	M
Beach Access Paths	L	L	M	M
Dunes	L	L	M	M
Houses - Marina (Mayhill Quay, Stanford Cove, Windsor Ct)	L	L	M	M
Industrial / Commercial Chapman / Phelps St	L	L	M	M
Beaches	L	L	M	M
Foreshore Reserve Marina Park	L	L	M	M
Cycling and Walking Paths	L	L	M	M
Coastal Vegetation	L	L	M	M
Minor Infrastructure (bins, fences, signs)	L	L	M	M
Beach Access Paths	L	L	M	M

2.3 Local Sediment Dynamics

The sediment dynamics in the Geraldton region are heavily influenced by the prevailing wind regime. Average annual wind roses from 9 am and 3 pm are presented in Figure 2.12. These wind roses highlight the prevalence of offshore (easterly component) winds in the morning and onshore/alongshore south to south westerly winds in the afternoons.

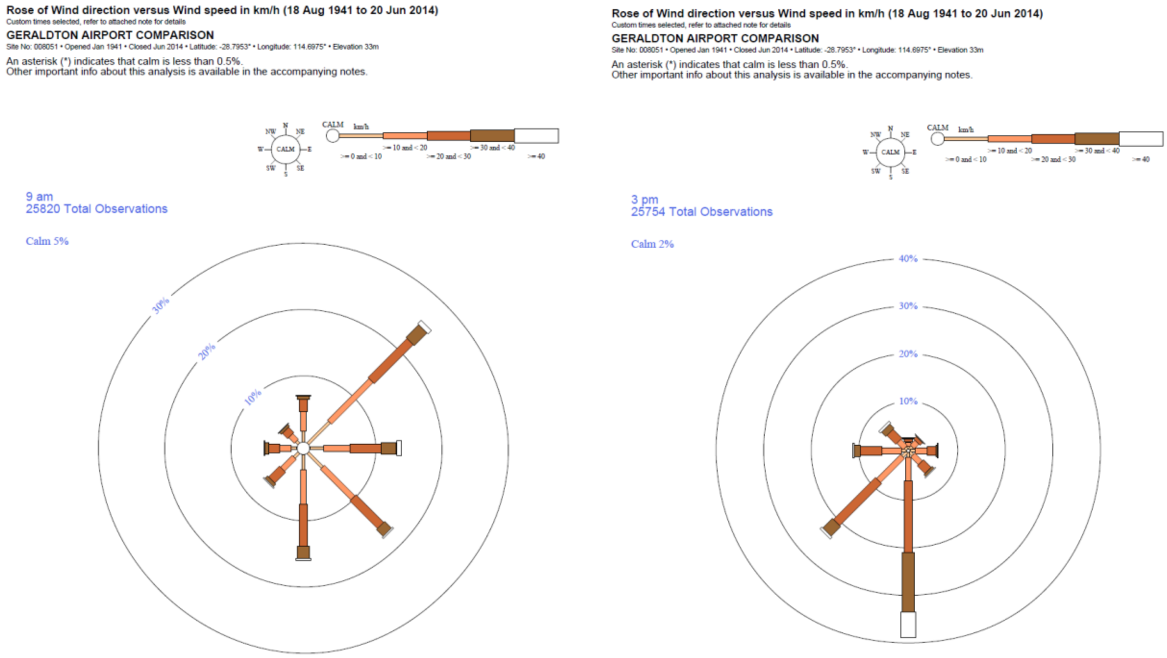

Figure 2.12 Geraldton average annual wind roses for 9am (left) and 3pm (right) (Source: Bureau of Meteorology, 2017)

These onshore/alongshore south to south westerly afternoon winds are one of the key drivers of sediment transport along the coastline and result in a predominately northerly net sediment transport. On a conceptual level, the following figure illustrates this sediment transport process.

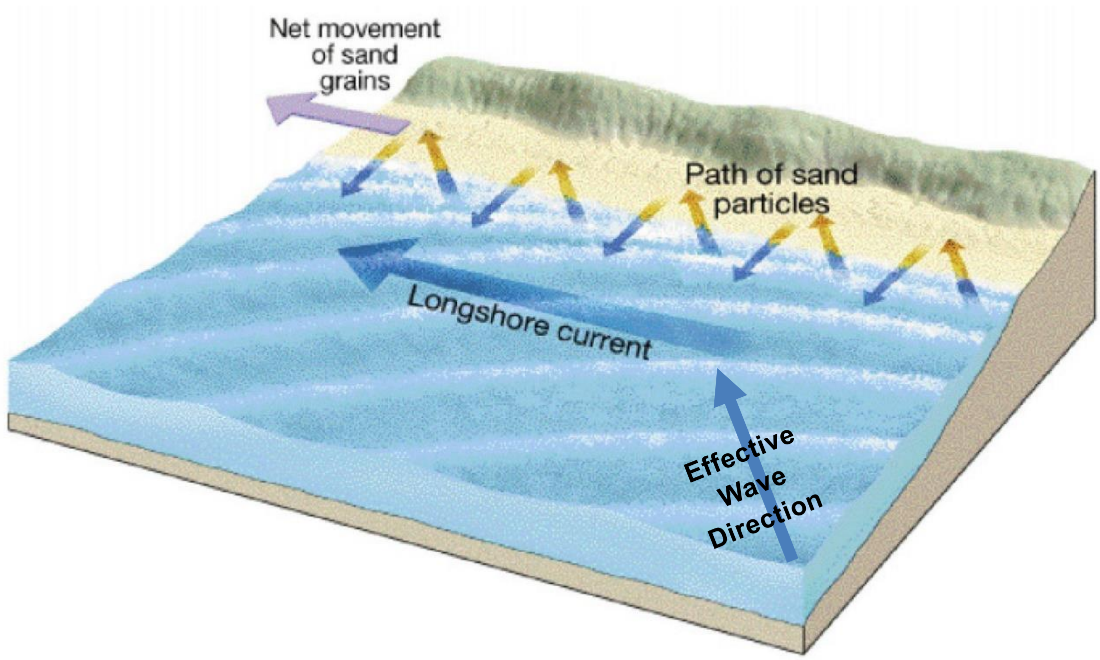

Figure 2.13 Northerly Longshore Drift during Afternoon Seabreeze Conditions (Norwich City School District n.d.)

From previous studies and investigations, it is expected that the net sediment transport pathway is predominately northerly in this area, with contributions to the alongshore transport coming from the erosion of the shoreline further south.

Further evidence of the net northerly transport rate is observed on review of the shoreline behaviour surrounding shoreline interruptions. For instance, the headland north of the Batavia Coast Marina, the GSC groyne in the Bluff Point South area and the Glenfield Beach Reef system all experience accretion on their southern side and erosion on their northern side.

Over the period since 2000, the Mid West Ports Authority (MWPA) has bypassed an average of 11,000 m^3 of sand per year. However, despite this volume of sand bypassing, the shoreline north of Batavia Coast Marina has experienced significant erosive pressure. The Town Beach to Drummond Cove Inundation & Coastal Processes Study (MRA, 2015) suggested that for the period from 2000 to 2014, between 5,000 and 10,000 m^3 of sand had been lost per year from the shoreline between Batavia Coast Marina and the Chapman River. Coincidentally over this same period the rate of sand accumulation at Pages Beach, in addition to the volume bypassed by MWPA, approximated around 10,000 m^3 per annum.

Based on review of the shoreline movement information in the area, the following indicative sediment transport pathway has been prepared. This sediment transport pathway suggests that erosion of the shoreline to the north of the Batavia Coast Marina, in combination with the material bypassed by MWPA, helps to provide a flux of sediment to shorelines to the north. However, this suggests that as shorelines to the south of the site are protected, such as the recent seawall construction along the Beresford Foreshore, the rate of shoreline erosion north of these sites will increase.

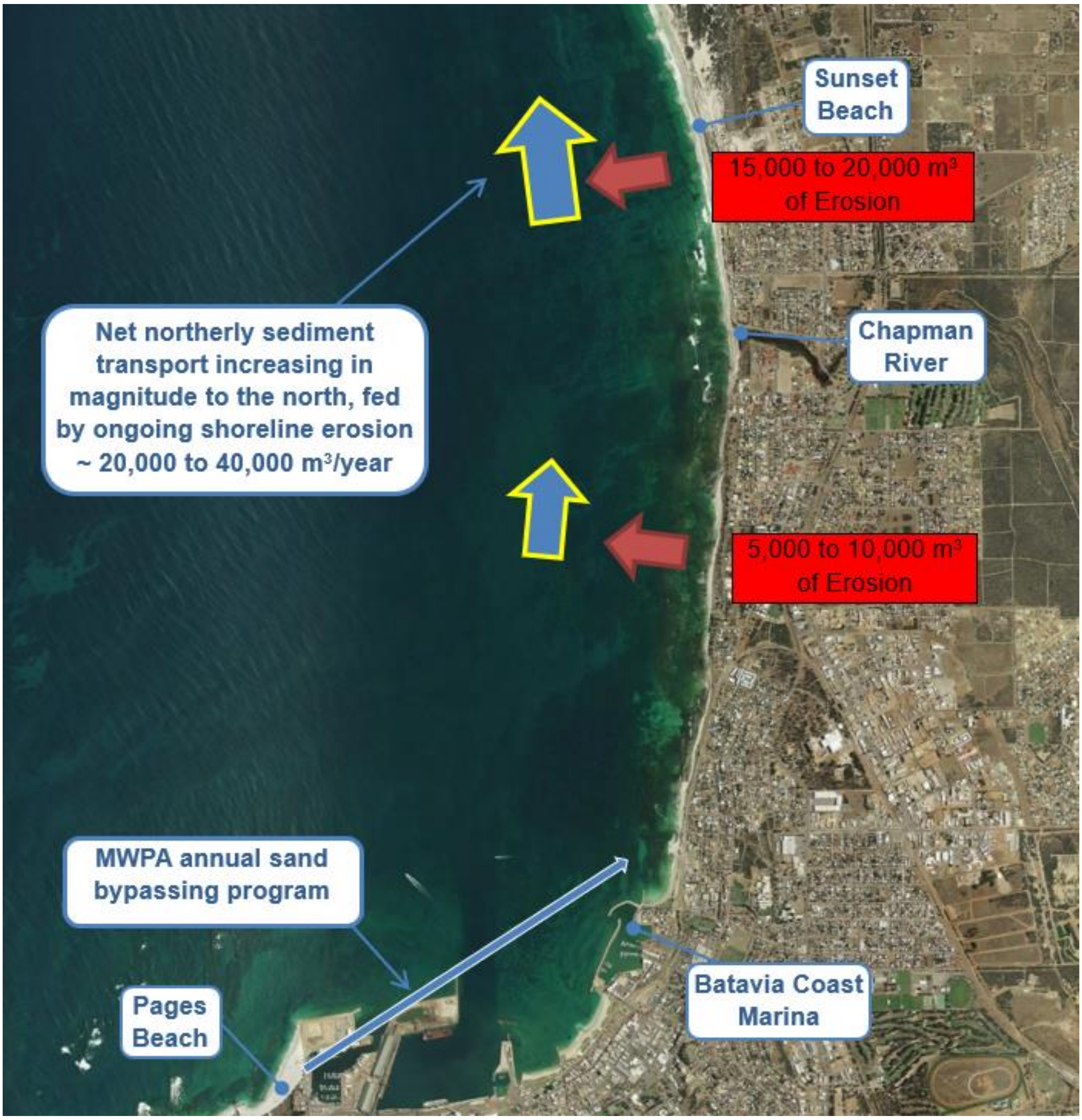

Figure 2.14 Indicative Annual Net Sediment Transport Pathway

2.4 Environmental & Heritage Considerations

2.4.1 Acid Sulfate Soils

MRA reviewed the Department of Water & Environmental Regulation (DWER) Acid Sulphate Soils (ASS) risk mapping of the study area. These maps are available at http://www.der.wa.gov.au/yourenvironment/acid-sulfate-soils/65-ass-risk-maps/. The relevant map showing the site is reproduced in Figure 2.15.

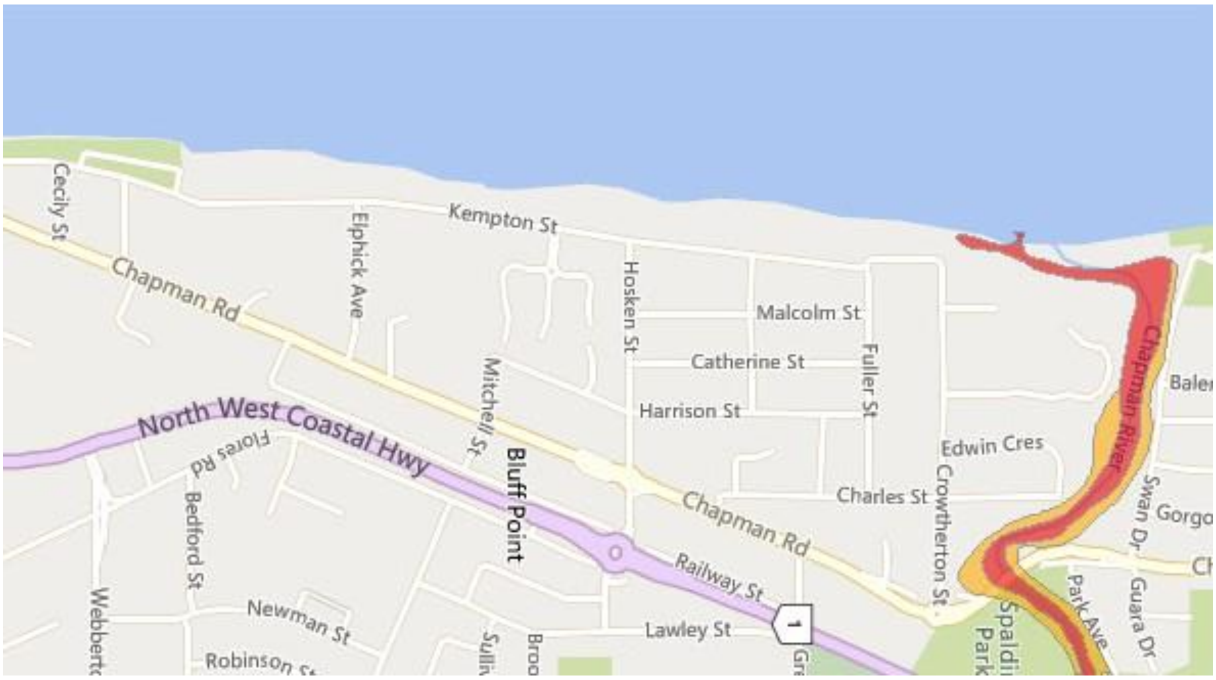

Figure 2.15 ASS Risk Mapping of Bluff Point Shoreline

The maps show a High (red) to Moderate (orange) risk (Class 1) of ASS occurring within 3 m of the natural surface level in the Chapman River and the reaches of the river mouth. This is within the study area and therefore, an ASS investigation would be required if soil or sediment disturbance of greater than 100 m^3 is to occur during coastal adaptation works.

In this regard, an ASS investigation and management plan is required.

2.4.2 Aboriginal Heritage

MRA completed an online search of Registered Aboriginal Sites using the Department of Planning Lands and Heritage (DPLH) Inquiry System. The search portal can be found at: https://maps.dia.wa.gov.au/AHIS2/.

The search returned two Registered Aboriginal Sites located within the Bluff Point North study area, Kempton Street Midden (Site #4762) and the Chapman River Mouth (Site #5561).

Figure 2.16 Aboriginal Heritage Sites within Works Area

The Aboriginal Site #5561 encompasses the Chapman River Mouth and is within the boundary of the northern area of this assessment. Approval will be required if excavation occurs within of the footprint of the heritage site.

2.4.3 Chapman River Estuary Sub-Tropical and Temperate Coastal Saltmarsh Threatened Ecological Community

The Chapman River Estuary is the site of a Sub-Tropical and Temperate Coastal Salt-Marsh which is a noted Threatened Ecological Community (TEC) under the federal Environment Protection and Biodiversity Conservation (EPBC) Act 1999.

The term, Sub-Tropical and Temperate Coastal Salt-Marsh, refers to an ecological community of plants that have the physiology to deal with highly saline environments. At the site, this includes salt-tolerant vegetation such as grasses, herbs, sedges, rushes and shrubs as well as species of non-vascular plants, including epiphytic algae, diatoms and cyanobacterial mats located within the Chapman River Estuary (DoE 2013).

It appears that some of these plant species are present near to the mouth of the Chapman River Estuary.

3. 'No Regrets' Adaptation Options

This section provides an introduction and general discussion of potential coastal adaptation options for Bluff Point. In line with the City's 'no regrets' approach to coastal adaptation, the following options have been investigated:

- 'Soft' engineering approaches.
  - Sand Nourishment.
  - Dune Building / Stabilisation.
- 'Hard' engineering structures.
  - Groynes.
  - Revetments.
  - Headlands.

3.1 Extent of Works

The *CHRMAP* identified two sections of coast within the Bluff Point CMU with assets at extreme risk to coastal erosion hazards in the short to medium term planning timeframe (2020 to 2030).

These sections, Bluff Point South and Bluff Point North, along with the coastal hazard lines are shown greater detail in Figures 3.1 and 3.2.

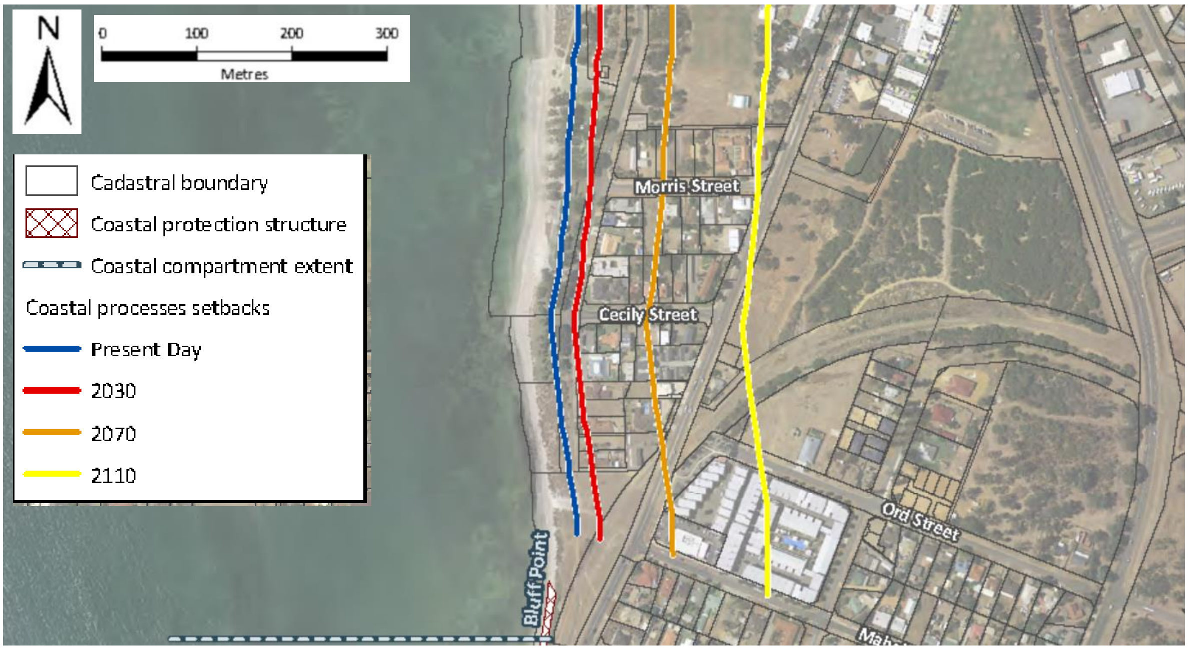

Figure 3.1 Bluff Point South – Coastal Hazard Lines (Baird 2019)

The Bluff Point South adaptation area spans from the north end of the Beresford revetment to immediately north of the existing GSC groyne.

Figure 3.2 Bluff Point North – Coastal Hazard Lines (Baird 2019)

The Bluff Point North adaptation area spans from south of the Fuller Street carpark to the mouth of the Chapman River Estuary.

3.2 'Soft' Engineering Approaches

As part of the short term, 'no regrets' approach to coastal adaptation, sand nourishment and dune building are options to consider. These are termed 'soft' engineering adaptation options as there are no coastal structures associated with them.

3.2.1 Sand Nourishment

Sand nourishment typically involves widening of the beach to create a more useable beach profile whilst also creating a sand buffer for absorbing longshore sand transport gradients and dissipating storm wave energy. The amount of additional width is determined based on the desired amenity, level of storm protection, long-term erosional trends, and the target renourishment interval. The design beach berm width is determined through an iterative process that evaluates economic benefits as a function of width. The elevation of the constructed berm is usually set at the same elevation as the natural berm, or slightly higher (USACE, 2006).

For practical and economic reasons, sand nourishment is usually placed on the visible portion of the beach. This enables economic use of standard earth moving equipment to carry out the sand nourishment. The result of this method means that the beach berm is initially considerably wider than the target final width. The artificially wide beach berm is subject to larger than normal longshore and cross shore transport rates and as a result, the placed sand will be redistributed until an equilibrium profile is developed. This is depicted in Figure 3.3.

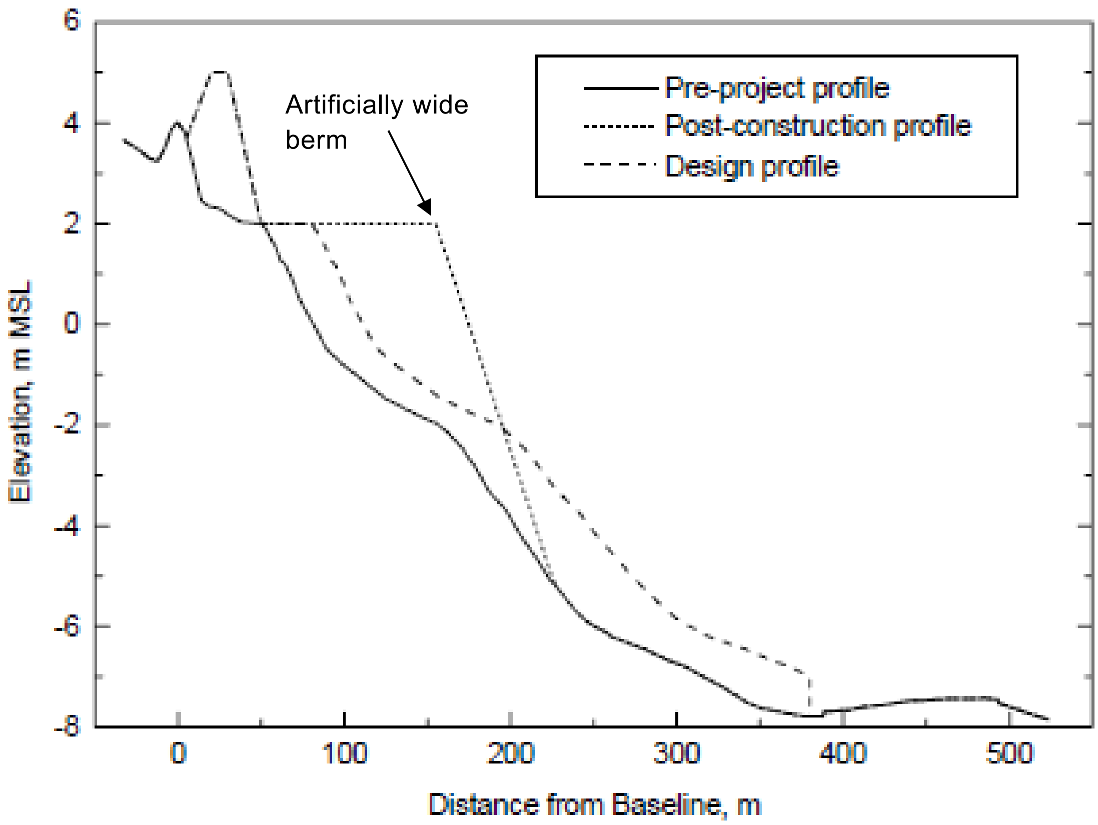

Figure 3.3 Schematic Illustration of Beach Nourishment

As noted in Section 2, MRA have previously estimated that for the period from 2000 to 2014, between 5,000 and 10,000 m^3 of sand has been lost per year for the shoreline between Batavia Coast Marina and the Chapman River. In light of this, the potential for longshore transport along the Bluff Point coastline is considered to be high. Hence sand placed onto the beach as nourishment, would be subject to longshore transport processes and hence, without additional measures, would be transported away from site relatively quickly.

In light of the above, sand nourishment as a standalone strategy, implemented solely at Bluff Point, is unlikely to have a significant effect in protecting the assets at risk from coastal erosion in the medium term, without significant ongoing placement of material. Hence, sand nourishment has not been included as a medium term adaption option. However, large scale sand nourishment implemented along the entire northern coastline at Geraldton may be more viable – potentially helping to alleviate erosion issues along the entire coastline. This is discussed further below.

Small scale sand nourishment has been included as a potential interim adaptation measure. Placement of sand onto critical areas will initially, locally widen the beach, increase the beach profile and provide a buffer against storm erosion. However, the placed sand will be lost from the nourished area relatively quickly, ie faster than historically observed erosion rates. This increased sand transport rate is due to a number of factors.

- If the placed material is finer than the native sediment, it will be lost very quickly and hence the ‘effective volume’ of the placed sand is lower than the actual volume. This is quantified as the overfill ratio, which accounts for sediment losses as a result of different characteristics between the borrowed and native sediment.

- The nourished area would be out of alignment with the downdrift shoreline (shoreline to the north), so losses from the end of the nourishment area would be increased.

Design of sand nourishment profiles requires recent survey profiles spanning from approximately the +2 mAHD contour (ie the vegetation line) extending out into the water, approximately to the -2 mAHD contour. Recent feature survey completed by HTD Surveys, on behalf of the City, only covers the area above approximately the 0 mAHD contour. However, the design profiles are expected to be comparable with the profile shown in Figure 3.3. If sand nourishment is implemented, it is envisaged that the design profile and scale of the works would be tailored to suit the available budget.

Options for placement of sand include hydraulic pumping (using a floating dredge or slurry pump) or using land based plant to transport, place and profile the beach area. Land based plant is the most practical and cost effective option for Bluff Point. Sand could be sourced either from terrestrial sources or extracted from Pages Beach and transported to Bluff Point as a sand bypassing operation.

Previous analyses of the median grain size (D_{50}) of sediment at Pages Beach suggests a D_{50} of 0.2 mm (Worley Parsons, 2010). This is comparable to the existing native material at Bluff Point. Hence, material sourced from Pages Beach may be suitable for use as sand nourishment at Bluff Point. Updated analyses of the material at Pages Beach would be required to confirm this

Based on the above, the overfill ratio for material from Pages Beach would be close to 1, ie the 'effective volume' would be similar to the placed volume. If material from terrestrial sources is used, well graded material with a median grain size slightly larger than the native material would be recommended. This material would be more resistant to longshore transport processes.

Sand Nourishment of Entire Northern Coastline

Though not included as a medium adaptation option for Bluff Point, it is noted that sand nourishment conducted on a much larger scale along the entire northern coastline at Geraldton, ie spanning from Beresford to Drummond Cove, may be a viable adaptation option for this entire area based on bypassing additional volumes of material from Pages Beach. This could be coupled with regular sand nourishment within each CMU in quantities comparable to the longshore sediment transport rates in each area to achieve stable beach widths in each of these areas. The adaptation options for Bluff Point assessed in this report could be combined with a larger scale sand nourishment campaign.

3.2.2 Dune Building & Dune Stabilisation

Dune building and dune stabilisation are coastal adaption measures typically undertaken to mitigate the impacts of wind blown loss from the rear of beaches and to provide resistance to beach overtopping and inundation impacts. Dune building can also be used to try to provide a reserviour of sand that can buffer storm erosion effects, however protection provided by dune systems that haven't been accompanied by a corresponding change in beach profile can be rapidly exhausted.

The function of dune stabilisation measures is to secure the surface of the sand to prevent it from blowing away under wind action. Examples of dunes stabilisation include coir matting and brush mattressing.

The function of dune building measures is to catch wind blown causing it to accumulate and form a dune. Examples of measures focussed on dune bulding include wind fencing and revegetation. Wind fencing can also provide the added benefit of controlling public access to vulnerable areas.

Wind fencing is currently in place in a number of areas at Bluff Point South and, as shown in Figures 3.4 and 3.5, appears to be providing some benefit.

Figure 3.4 Wind Fencing at Bluff Point South

Figure 3.5 Wind Fencing at Rundle Park

Dune building is not suitable to be implemented as a stand alone coastal adaption measure to protect against coastal erosion hazards. This is because the dune can simply be eroded during storms and high water levels. Even with highly successful revegatation campaigns, the vegetated dune cannot withstand the erosive forces storms.

It is noted that dune building and dune stabilisation measures can be effective in mitigatiging the risks of wind blown sand, both in terms of reducing erosion of the dune itself and, trapping wind blown sand from the beach area below, thus keeping the sand within the coastal system.

3.3 'Hard' Engineering Structures

In order to provide sufficient protection against coastal erosion, 'hard' engineering approaches to coastal adaptation need to address at least one of the following coastal erosion processes.

- Protect against erosion due to severe storms.
- Mitigate losses to longshore sediment transport.

In this regard, the following 'hard' engineering options have been assessed.

- Groynes.
- Revetments.
- Headlands.

The groyne and headland adaptation options have been considered in combination with sand nourishment.

Geotextile Sand Containers

Geotextile Sand Containers (GSCs) are a material which satisfies the "No Regret" approach for the structures in this assessment, and also have a low visual impact to beach amenity. Groynes, headlands and revetments comprised of geotextile sand containers (GSC) are considered below.

Structures comprised of alternative materials, such as fibre-reinforced plastic (FRP) or composite groynes, have also been considered. MRA has previously investigated other alternatives and 'left field' adaptation options, including revetments comprised of recycle tyres for example, for other projects. Thus far, in each case, alternative material options have not proven to be feasible for the considered application.

Downstream Effects

Each of the 'hard' engineering adaptation options are likely to result in some downstream effects further north along the shoreline. This is because the sediment supply to these areas will likely be reduced unless sand nourishment is placed regularly and in sufficient volumes.

Both the current erosion of the shoreline at Bluff Point and the ongoing longshore transport through this section of coast act as a source of sediment to the shoreline further north. A reduction of this supply through either reducing the longshore transport flux, or protecting the shoreline to prevent further erosion, can be expected to lead to at least some downstream effects.

3.3.1 GSC Groynes

Groynes are structures constructed perpendicular to the shoreline, aimed to block a portion of the longshore sediment transport and allow it to accumulate on the updrift shoreline of the groyne. Therefore, longshore sediment loss can be slowed down, allowing the beach to build up on the updrift side and therefore provide some resistance against potential future erosion. Groyne fields tend to result in the realignment of the contained beaches to an angle parallel to the incident wave approach.

Accumulation of sand on the updrift side of the groyne occurs until the updrift compartment is "filled," after which the sediment will bypass the groyne more readily. The sediment dynamics around each groyne is illustrated in the figure below.

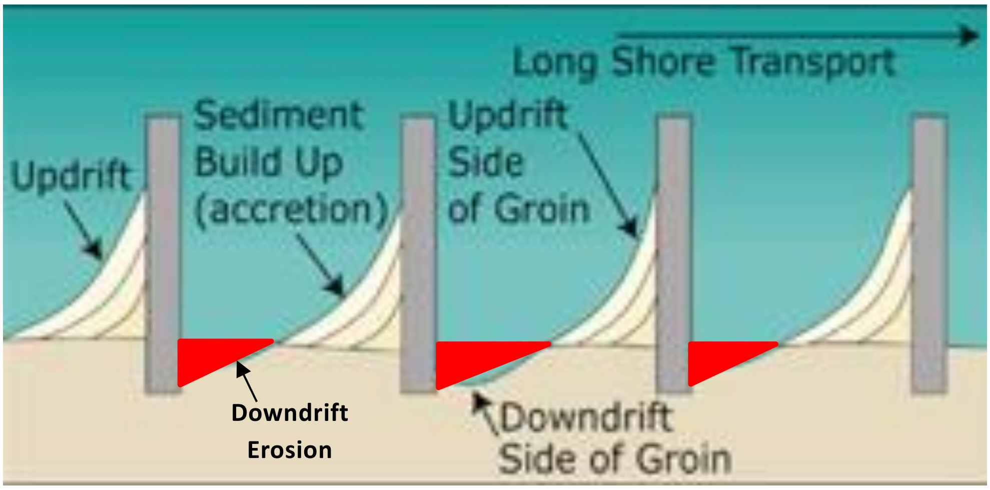

Figure 3.6 Groyne Adjusted Shoreline (Lumen Learning 2013)

The effectiveness of this option is enhanced by implementing GSC groynes into a groyne field. This approach is effective over a longer proportion of shoreline and serves to create multiple beach compartments which regulate erosion. This approach requires consideration to be given to the following factors.

- The angle of incidence between the predominate wind conditions and the Bluff Point shoreline.
- The supply of sediment from the south.
- The groyne crest height and length.

From these factors, an appropriate spacing to length ratio can be deduced. It should be noted that should a groyne option proceed to further design, the spacing to length ratio would need to be assessed in further detail.

Composite Groynes

An alternative option to GSC groynes is to install composite sheet pile groynes. In recent times, composite sheet piles have started to be more commonly used in the marine environment. Composite sheet piles are advantageous due to their resistance to corrosion and improved aesthetics when compared to traditional steel sheet piles. The recent use of composites has been backed by research into their durability and justification of their strength capacities.

An example of recently installed composite sheet piles for use as a shore perpendicular groyne is in Denham, Western Australia. Figures 3.7 and 3.8 show an aerial photograph and a site photograph of the composite groyne respectively. It is noted that this groyne does not include a capping beam to cover the top of the sheet piles and improve overall safety. If this option was to be progressed, MRA would recommend that a capping beam be included in the design.

Figure 3.7 Denham Foreshore Composite Sheet Pile Groyne Aerial Photograph (Supplied by Department of Transport, 2016)

Figure 3.8 Denham Foreshore Composite Sheet Pile Groyne Site Photograph (Supplied by Shire of Shark Bay, 2017)

The layout of composite sheet pile groynes would generally be interchangeable with that proposed for the GSC groyne field option.

Implementation of composite groynes at Bluff Point would require probing and/or geotechnical investigations to determine the level of rock beneath the beach. This would confirm the achievable embedment depth. Other investigations would also be required in the design of a composite groyne to ensure the structure would remain stable over its design life.

A key key benefit of composite groynes compared to GSC groynes are that they may be able to be removed and reused elsewhere. With this in mind, there may be some benefit to implementing composite groyne(s) as a trial. The following benefits are associated with implementing a composite groyne as a trial.

- To further advance the City's knowledge of the local sediment dynamics.

- The trial can be adaptable and guide design refinements and decision making when addressing the long-term adaptation plan for the shoreline.

- A removable, trial groyne is an innovative approach which may lead to positive public perception of City's response.

3.3.2 GSC Headlands

Headlands are detached, generally shore-parallel structures that reduce the amount of wave energy reaching a protected area. Several headlands are typically placed along a stretch of coast to form a field. Wave energy at the shoreline is reduced, due to breaking and reflection at the structures, with some of the incoming wave energy will arrive in the lee zone via the following phenomenon.

- Diffraction around tips and through gaps.

- Transmission through breakwater.

- Overtopping of the breakwater.

The diffracted waves in the lee zone break at angles to the shoreline causing sediment transport and a change in the alignment of the shoreline to form small embayments behind each headland. As shown in Figure 3.9, where the shoreline extends offshore and touches the headlands the resulting landform is known as a tombolo, whereas smaller shoreline features that don't touch the headland as referred to as a salient.

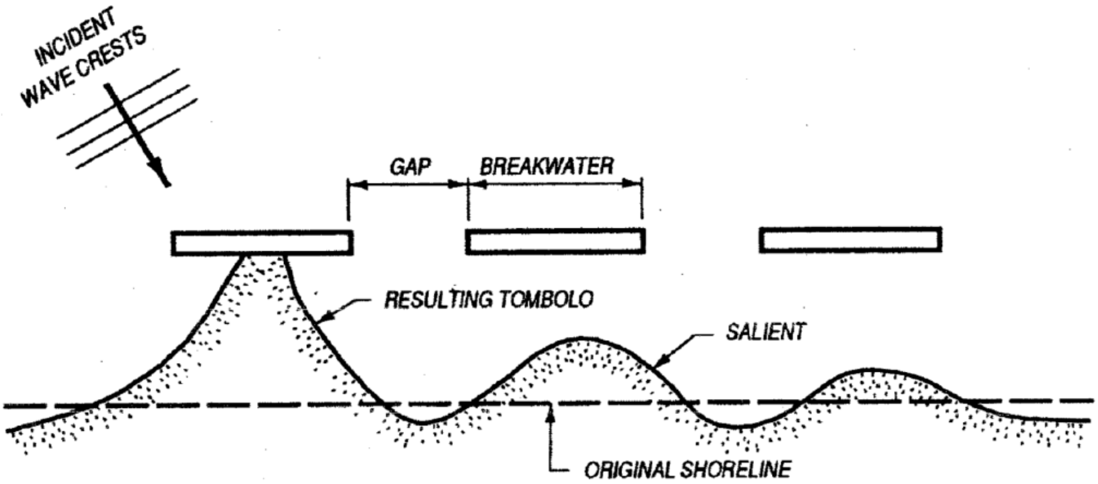

Figure 3.9 Function of Offshore Headlands (USACE 2002)

The resultant beach embayments act to reduce longshore sediment transport in the lee zone. Sand moving along the shore is trapped – to some extent – behind the structure resulting in local deposition of littoral sands within the protected lee of the breakwater, thus contributing to the seaward outbuilding of the beach (Van Rijn 2018).

A high crest level of the headlands is critical to the formation of tombolos and salients. Low crested headlands are susceptible to overtopping of storm waves and this can prevent tombolo formation or remove a tombolo once it has formed (Van Rijn 2018).

3.3.3 GSC Revetments

A revetment is a sloped structure built to protect against cross shore erosion by wave action, storm surge and currents. The aim of a revetment is to protect landward assets from coastal erosion.

These structures, have a limited effect on longshore sediment transport and cannot accumulate sand like the groyne and headland structures outlined previously. In this regard, with implementation of a revetment alone, the beach area in front of the revetment can be expected to erode over time. If the erosion reaches a point when the revetment is regularly exposed to wave action, the reflection of wave energy from the revetment can actually accelerate erosion of the adjacent shoreline. As a result, revetments are generally considered to provide a last line of defence against erosion and can either be built at the rear of a beach to provide an 'insurance policy' against the potential impacts of severe erosion events, or can be built at the water line accepting that the beach area seaward of the revetment may be lost, either from time to time or permanently depending on the sediment supply.

An example of a GSC revetment is shown in Figure 3.10.

Figure 3.10 GSC Revetment Example

4. Medium Term Adaptation Options

This section provides an assessment of potentially suitable medium term coastal adaptation options. The options outlined below are considered ultimate options to provide sufficient protection to the shorelines along the entire stretches of Bluff Point North and Bluff Point South. These options are intended to provide sufficient protection against coastal erosion hazards to 2030.

4.1 Bluff Point South

4.1.1 GSC Groynes

Preliminary Design

A preliminary sketch of a groyne field for Bluff Point South is presented in Figure 4.1.

Details of the preliminary design are as follows:

- 2.5 m^3 vandal resistant GSC bags are proposed, to withstand the incident wave climate.
- Five low profile groynes approximately 40 m long and spaced approximately 80 m apart are proposed to provide protection to this area. The southernmost groyne is to be placed to avoid the adjacent beach access track.
- Groynes are likely to be founded on rock in a number of locations.
- A GSC revetment may be added to the northern side of the existing GSC groyne to mitigate potential downdrift erosion effects and limit the potential for flanking erosion of the structure.
- Initial sand nourishment would be required to saturate each beach compartment and therefore minimise the extent of downdrift erosion north of the groyne field.
- Drainage outlets at the southern end of the site would be incorporated to ensure that they do not become clogged with accumulated sand.

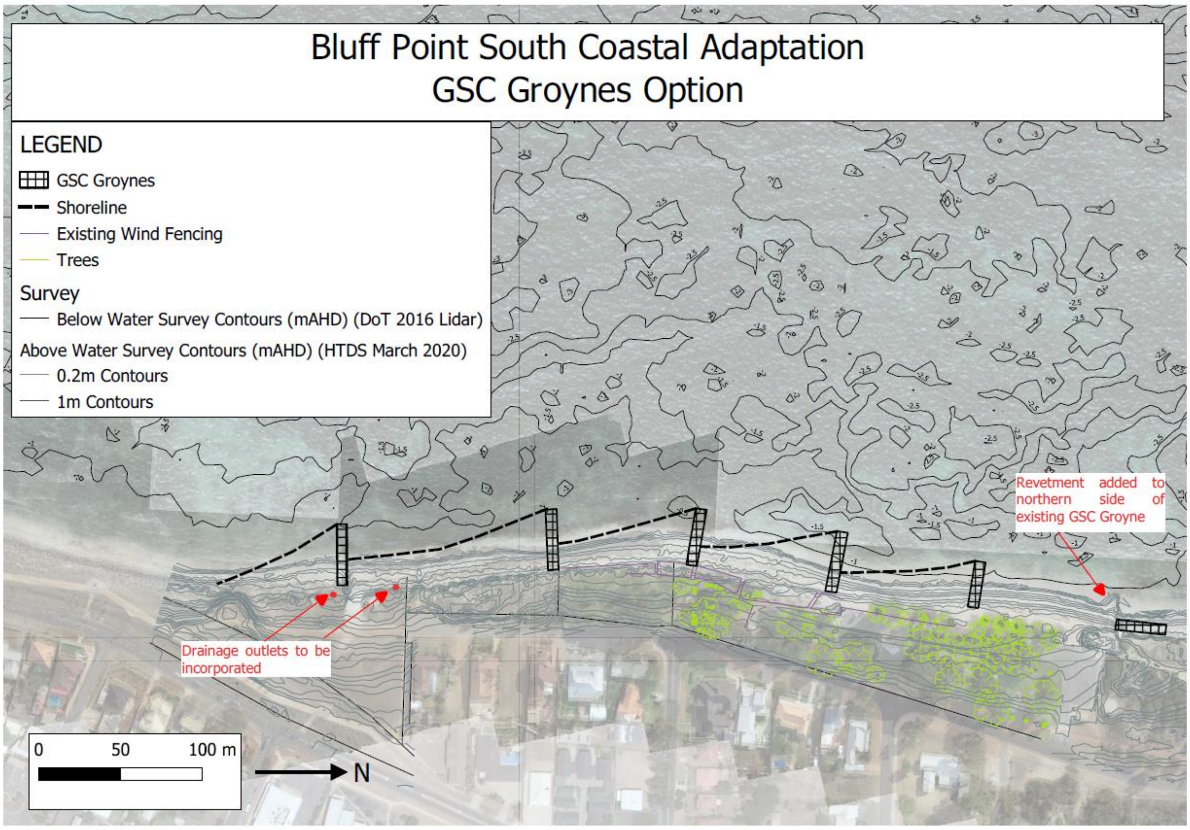

Figure 4.1 Bluff Point South – GSC Groynes Preliminary Sketch

The length, width and layout of the groynes will require further assessment and refinement should this option progress to more detailed concept design. In particular, the wave climate at the head of each groyne would need to be carefully considered to ensure that the 2.5 m^3 GSCs can withstand the incident wave conditions. The upper limit for stability of the 2.5 m^3 GSCs is a wave height of approximately 2.5 m. In this regard, some dislodgment of the GSCs and damage can be expected during larger storm events, hence the groynes will likely require some ongoing maintenance.

Vandal resistant GSCs would be required if the structures were to be built directly on a rocky reef platform. Inclusion of a layer of geotextile fabric between the GSCs and the rocky reef also is recommended as an additional precaution to protect the fabric. If the groynes are not founded on rock, scour protection is recommended for the heads of the groynes. This would involve embedment of the base layer off GSCs and inclusion of a scour flap. An example of this is shown in Figure 4.2.

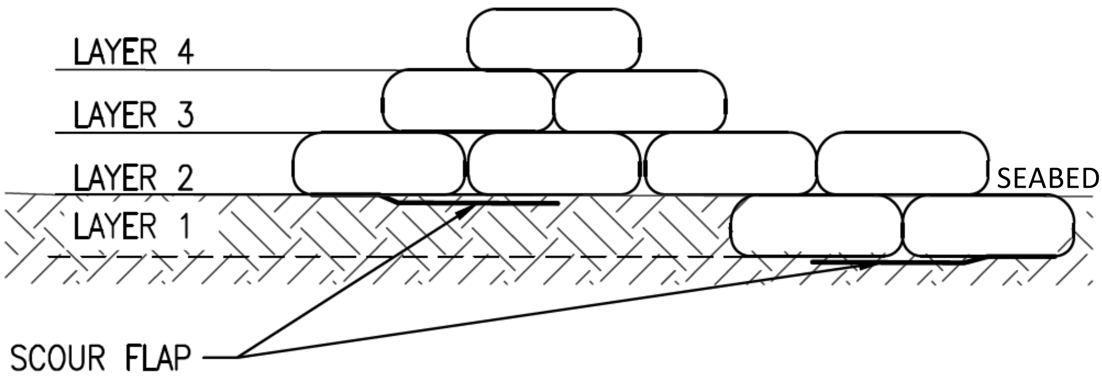

Figure 4.2 GSC Groyne Scour Protection Detail

While the low crest level of the low profile groynes may limit the sediment containment potential for each beach compartment, the impacts on beach amenity and access associated with high profile structures are minimised. Low profile structures also allow sand, and to some extent, wrack to pass over the groynes when the beach levels are high.

It is noted that there will be some potential for wrack to become trapped and potentially buried within each beach compartment. This would need to be considered in future design stages and may require ongoing management by the City.

The most severe downdrift erosion would be experienced at the northern end of the proposed groyne field, adjacent to the existing GSC groyne. At this location there is no beach compartment to hold sediment which has bypassed the groyne. In order to mitigate this risk, the adaption option includes the potential addition of a revetment to the northern side of the groyne. This revetment would help to prevent flanking erosion of the existing groyne.

It should also be noted that, over time, the City may need to increase the quantity of sand nourishment to ensure there is sufficient supply of sand to the area north of Bluff Point South. This would be required as if the groyne field were to prevent further erosion of the shoreline this would reduce the overall longshore sediment flux available to the shorelines further north, resulting in erosion.

If GSC groynes are implemented at Bluff Point South, erosion is initially expected to occur on the shoreline to the north of Rundle Park. This is likely to continue until at least the time when the beach compartments within the groyne field become saturated, or full, and sediment begins to bypass the northern most groyne. This impact can be minimised by completing a substantial initial sand nourishment campaign to fill each beach compartment. As noted above, ongoing sand nourishment will also be required to manage the supply of sand, and mitigate downstream effects, to areas to the north.

This adaptation option is not expected to adversely affect the shoreline and freehold coastal lot to the south. However, a sustained reversal in the net sediment transport direction, caused by persistent northerly winter conditions for example, may result in some shoreline loss. If this option were to be implemented it would be recommended that this is monitored and if required, a small groyne could be added to the south of the southernmost groyne to provide protection against a reversal in sediment transport direction. Additionally, the groyne field would provide no direct protection against cross shore erosion losses, though it is noted that if the groynes do increase the width of the beach then this would present an extra buffer against storm erosion.

As noted above, the potential accumulation of wrack within the beach compartments will need to be managed. There is some risk of large amounts of wrack accumulating. If large accumulations of wrack are left on the beach, they can begin to decompose which can lead to amenity loss and in the worst case, environmental issues due to odour. Regular removal of the accumulated wrack may be required, though it is noted that this does not appear to be an issue with the existing groyne.

The key advantages and disadvantages of the GSC groynes option at Bluff Point South are outlined in Table 4.1

Table 4.1 Bluff Point South GSC Groynes Option - Advantages & Disadvantages

Advantages	Disadvantages
Proven method for this site – the existing GSC groyne appears to be functioning well. Retains largely usable beach Relatively low impact to beach amenity. Relatively low cost to install, maintain and remove.	Ongoing sand nourishment required to prevent downdrift erosion. Some potential to trap wrack. May restrict beach access – more difficult to walk along the beach. Groynes will require ongoing monitoring and maintenance. No direct protection against cross shore erosion processes.

An estimate of the probable costs for construction of the GSC groynes option at Bluff Point South is provided in Table 4.2.

Table 4.2 Bluff Point South GSC Groyne Option – Estimate of Probable Costs

Item	Description	Quantity	Units	Unit Rate	Total ($ excluding GST)
1	40 m long GSC groynes	5	Number	$250,000	$1,250,000
2	30 m long GSC revetment	1	Number	$160,000	$160,000
3	Initial sand nourishment of beach compartment	5	Number	$50,000	$250,000
4	Extend drainage outlets	2	Number	$7,500	$15,000
				Sub Total	**$1,675,000**
				15% Contingency	**$251,250**
				Total	**$1,926,250**

Composite Sheet Pile Groynes

The considerations regarding composite groynes are largely similar to the above. The stability of the structure against fluctuating beach levels through the summer and winter seasons, would need to be carefully considered in future design stages if this option is progressed. Nevertheless, this would only be an issue if rock or reef limited the pile penetration depth to an extent that it caused overturning stability issues.

The finish of this option, as shown in Figure 3.8, could present somewhat of a hazard to beach users, with an exposed hard, thin edge along the top of the sheet pile. The design of would benefit from the inclusion of a capping element. This could be considered further in future design stages.

The construction cost of composite groynes is expected to be comparable with the GSC groynes option.

4.1.2 GSC Headlands

A preliminary sketch of the GSC headlands option for Bluff Point South is provided in Figure 4.3.

Details of the preliminary design are as follows:

- 2.5 m^3 vandal resistant GSC bags are proposed, to withstand the incident wave climate.
- Three GSC headlands are proposed, comprising of:
  - two 70 m long headlands located 60 m offsore; and
  - one 100 m long headland placed 80 m offshore. The larger headland would be placed centrally, offshore from the southern end of Rundle Park.
- Headlands to have sufficiently high crest level to reduce wave overtopping during high water level events.

- Headlands are likely to be founded on rock in a number of locations. Depending on the final layout and rock levels through the nearshore area, the structures may need to be partly founded on rock and partly on sand.

- Sand nourishment would be required to initiate formation of tombolos and salient without erosion of the adjoining coastline.

- Drainage outlets at the southern end of the site would be incorporated to ensure that they do not become clogged with accumulated sand.

The aim of the preliminary design shown in Figure 3.13 is to take advantage of the existing curve in the beach alignment located adjacent to the southern end of Rundle Park. With initial sand nourishment, the diffracted incoming waves would lead to the formation of a large tombolo inshore of the larger headland. Smaller tombolos are expected to form in the lee zone of the smaller headlands. These shoreline features would have a similar effect to groynes, in slowing the longshore transport.

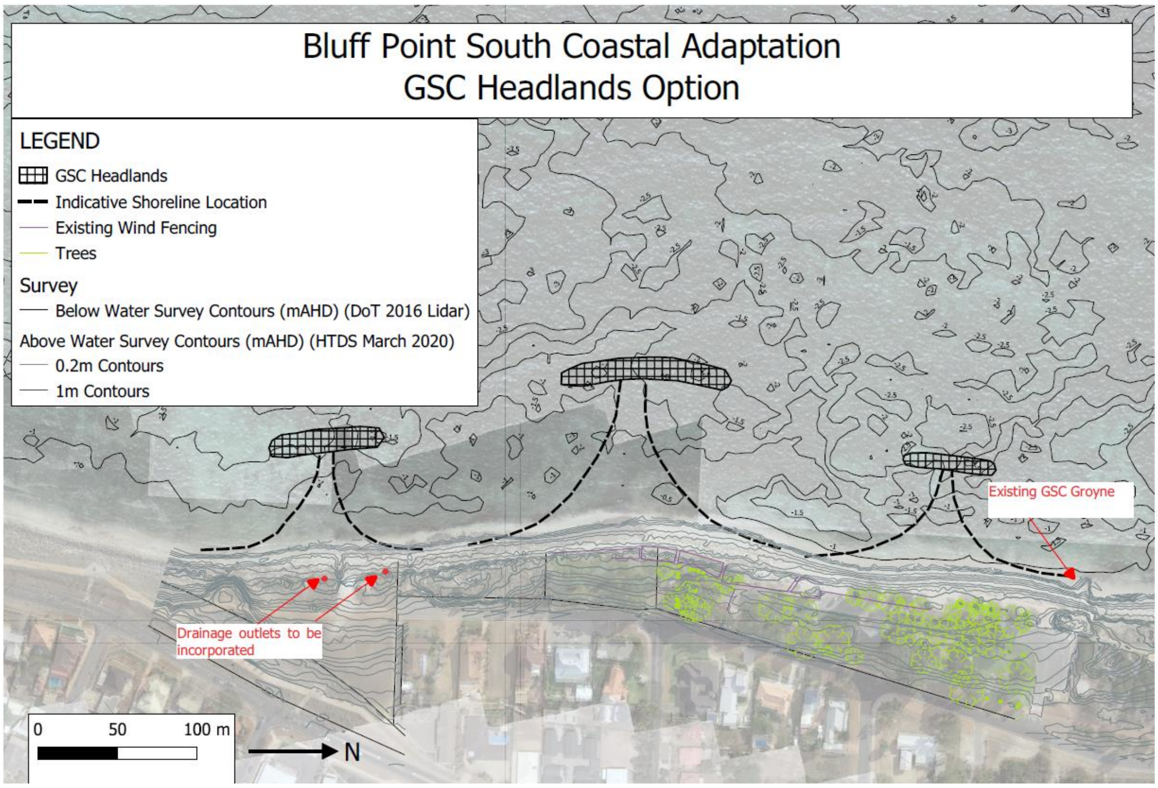

Figure 4.3 Bluff Point South – GSC Headlands Preliminary Sketch

A detailed assessment of wave climate would inform refinement of the layout of the headlands should this option progress beyond concept design. As noted previously, the upper limit for wave height for stability of the 2.5 m^3 GSCs is approximately 2.5 m. The structures may need to be located nearer to the shoreline to reduce the potential for damage to occur during storms. Given the relatively high maintenance costs associated with GSC headlands, due to their offshore location, it is recommended the structures are designed to be as robust as practicable to minimise maintenance. Additionally, the design guidelines for offshore headlands are based on recommended ratios of structure length spacing and distance offshore to the wavelength of incoming waves (CEM 2002, Garcia et al. 2018).

Similar to the GSC groynes option, inclusion of a layer of geotextile fabric between the GSCs and underlying rock is recommended as an additional precaution to protect the fabric. The final layout may require the headlands to be partly founded on rock and partly on sand. This is not expected to be a major issue, but will need to be considered to ensure that the structures will remain intact as the seabed level fluctuates. Geotechnical investigations such as jet-probing of the seabed, would be recommended to gather this information in later stages of design.

As the offshore breakwaters do not fully block the sand transport along the shoreline, they generally have a reduced effectiveness during more energetic events and higher water periods when sand transport rates can be high. Therefore, ongoing sand nourishment would be required to replenish the beaches.

The construction of the headlands would provide some direct protection against severe storm erosion, largely in the areas immediately behind the structures. Other areas between the structures would have no direct protection, but could benefit from an increased buffer against storm erosion associated with any increase in beach width.

It is noted that there is potential for wrack to become trapped and buried as sand accumulates in the lee zone of the headlands. This could need to be actively managed by the City through regularly removing accumulations of wrack before they become buried.

The key advantages and disadvantages of the GSC headlands are outlined in Table 4.3

Table 4.3 Bluff Point South GSC Headlands - Advantages & Disadvantages

Advantages	Disadvantages
Retains largely usable beach. Wave sheltering of some nearshore areas may improve beach amenity. No structures on the beach.	Visual impacts – high crest level. Ongoing sand nourishment required. High potential to trap wrack. Headlands will require ongoing monitoring and expensive maintenance. No direct protection of the shoreline against cross shore erosion effects in areas not directly behind the headlands.

An estimate of the probable costs for construction of the GSC headlands option at Bluff Point South is provided in Table 4.4.

Table 4.4 Bluff Point South GSC Headlands Option – Estimate of Probable Costs

Item	Description	Quantity	Units	Unit Rate	Total ($ excluding GST)
1	70 m long offshore GSC headland	2	Number	$750,000	$1,500,000
2	100 m long offshore GSC headland	1	Number	$1,000,000	$1,000,000
3	Initial sand nourishment	1	Number	$200,000	$200,000
4	Extend drainage outlets	2	Number	$7,500	$15,000
				Sub Total	**$2,715,000**
				15% Contingency	**$407,250**
				Total	**$3,122,250**

4.1.3 GSC Revetment

Preliminary Design

A preliminary sketch of a GSC revetment for Bluff Point South is presented in Figure 4.4.

Details of the preliminary design are as follows:

- 2.5 m^3 vandal resistant GSC bags are proposed, to withstand the incident wave climate.
- An approximately 570 m long GSC revetment would be constructed along the rear of the existing beach to provide protection against erosion events. The revetment would largely be buried initially.
- The GSC revetment would be founded at a toe level of approximately -1 mAHD, or onto existing rock levels, whichever is higher.
- The crest height of the revetment would need to be sufficiently high to withstand high water levels and wave overtopping during storms.
- A geotextile layer would be installed along the base and wrapped up the back of the revetment to prevent washout of sand from beneath and behind the structure.
- Existing drainage outlets would be extended through the revetment.
- Incorporation of existing beach access over the revetment.

As outlined previously, a GSC revetment along the southern shoreline would provide a protective barrier to coastal erosion. Since this structure cannot trap sediment, the beach would be expected to gradually erode back to the alignment of the revetment. However, the land area inshore of the revetment, including Rundle Park, would be protected and this space could be utilised.

For the GSC revetment to be effective, the structure would need to extend over the entire extent of Bluff Point South. It would be placed along the rear of the beach and would be largely buried. This option would initially have minimal visual impact, however as the beach erodes, the structure would become exposed. Exposure of the revetment to regular wave action would likely increase the erosion rate of the beach fronting the structure due to the effects of wave reflection off the structure.

The required depth of the revetment to prevent the structure becoming undermined as the beach erodes would need to be confirmed. In order to avoid the need for dewatering, an indicative toe depth of -1 mAHD has been included. The levels of rock beneath the beach may be higher than this level through some areas of the revetment alignment. In these areas, the structure would be founded on rock.

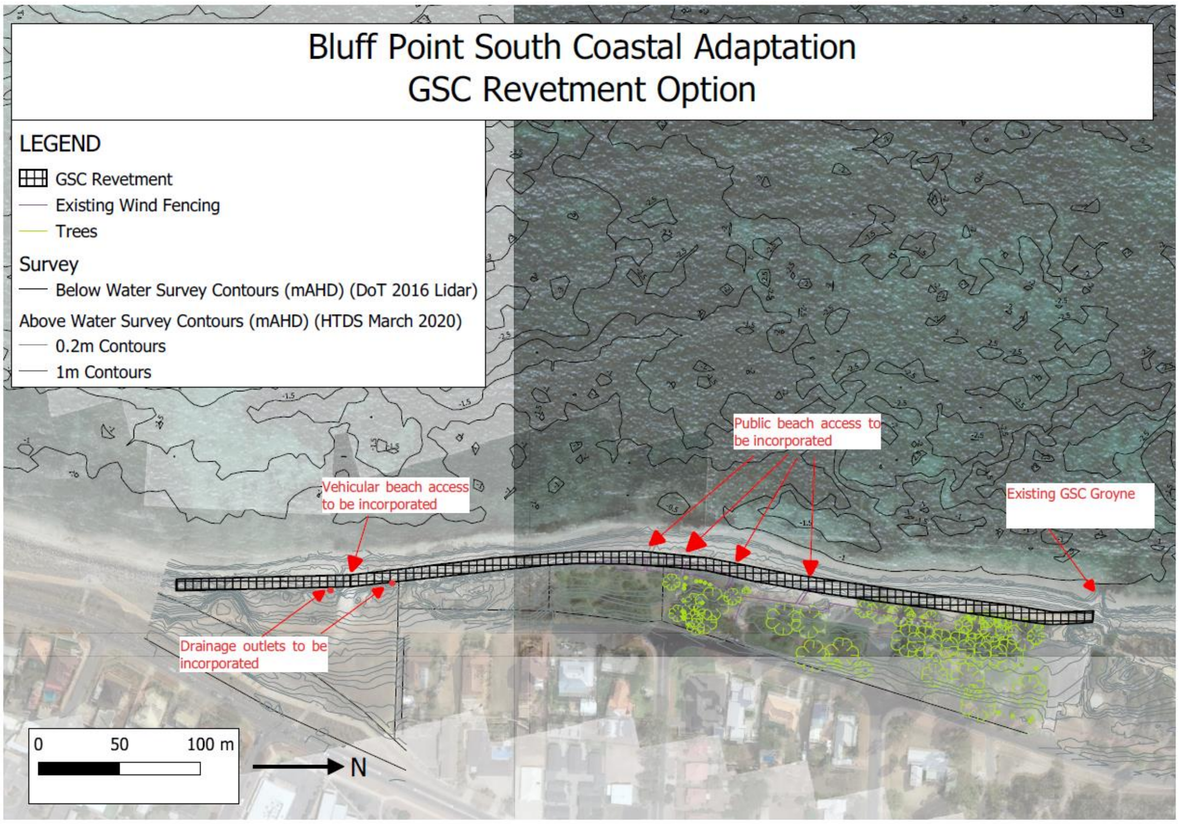

Figure 4.4 Bluff Point South – GSC Revetment Preliminary Sketch

Since the GSC revetment is proposed to span the entire extent of the southern shoreline, beach access would be interrupted. The revetment design would need to incorporate modifications to the existing beach access paths and drainage outlets. The beach access paths could pass over the revetment and the drainage outlets would need to be extended through the revetment. These details would need to be refined during future design stages.

Maintenance would likely not be required until the fronting beach has eroded and the structure becomes exposed.

The key advantages and disadvantages of the GSC revetment are outlined in Table 4.5.

Table 4.5 Bluff Point South GSC Revetment Option - Advantages & Disadvantages

Advantages	Disadvantages
Provides protection to landward assets from coastal erosion. Limited visual impact, with the revetment initially buried at the rear of the beach. Initially less monitoring and maintenance than groyne and headland options.	Beach will eventually erode back to either the existing rock levels, or the revetment. Requires considerably more GSC material than other adaptation options to span the length of the shoreline.

An estimate of the probable costs for construction of the GSC revetment option at Bluff Point South is provided in Table 4.6.

Table 4.6 Bluff Point South GSC Revetment Option – Estimate of Probable Costs

Item	Description	Quantity	Units	Unit Rate	Total ($ excluding GST)
1	570 m long GSC revetment	570	Lineal metre	$5,000	$2,850,800
2	Extend drainage outlets through revetment	2	Number	$10,000	$20,000
3	Incorporate existing beach access paths/vehicle tracks over revetment	5	Number	$5,000	$25,000
				Sub Total	**$2,895,000**
				15% Contingency	**$434,250**
				Total	**$3,329,250**

4.2 Northern Shoreline

The coast at Bluff Point North presents unique challenges in terms of coastal adaptation options and their suitability to provide adequate protection against coastal erosion hazards.

As outlined in Section 2, freehold development sits in a vulnerable location along the coastline, as does other infrastructure, including Water Corporation assets.

Each of the adaptation options outlined below have been developed to address the erosion issues in these areas.

4.2.1 Chapman River Estuary

It is recommended to avoid any disturbance to the Sub-Tropical and Temperate Coastal Salt-Marsh TEC. Each of the adaptation options considered below have been developed to avoid the mouth of the Chapman River. The aim of this is to categorically avoid any potential environmental impacts and avoid the lengthy federal environmental approvals processes that would otherwise likely be required.

As noted in Section 2.4, the mouth of the Chapman River is also noted as a High ASS risk area and falls within the Chapman River Mouth (Site #5561) Aboriginal Heritage site. Avoidance of the area should also dodge these issues.

It is recommended that the City seek advice from an environmental consultant to confirm the following.

- Footprint area of the TEC and area(s) to be avoided.
- Detail the measures and environmental requirements to be included to avoid the requirement for federal environmental approval.

There is some risk that coastal adaptation may have a secondary negative impact on the ecology of the river due to changes to the dynamics of the sand bar at the mouth and hence, seasonal flooding of the river through the sand bar and into the ocean.

Figure 4.5 Mouth of the Chapman River Estuary

4.2.2 GSC Groynes

A preliminary sketch of the GSC groyne adaptation option for Bluff Point North is presented in Figure 4.6.

Details of the preliminary design are as follows:

- 2.5 m^3 vandal resistant GSC bags are proposed, to withstand the incident wave climate.
- A field of 5 low profile groynes is proposed. This groyne field would comprise of:
    - a small 30 m long groyne positioned at the southern end of the site, to the south of the Fuller Street carpark;
    - a large 50 m long groyne positioned adjacent to the boundary between # 4 and # 3 Kempton Street; and

- three 40 m long groynes, positioned at 80 m intervals along the shoreline to the north of the 50 m long groyne.

- Initial sand nourishment as required to fill each beach compartment.

- Incorporation of the drainage outlet at the Fuller Street carpark to prevent it from being clogged with accumulated sand.

Similar to Bluff Point South, the layout of the groynes will require further assessment and refinement should this option progress to further concept design. The wave climate at the head of each groyne would need to be carefully considered to optimise the groyne lengths. The groynes, in particular the 50 m long groyne, will likely require ongoing maintenance.

Scour protection will likely be required for some sections. Embedment of the bottom layer of GSCs into the seabed and inclusion of a scour flap will likely be appropriate.

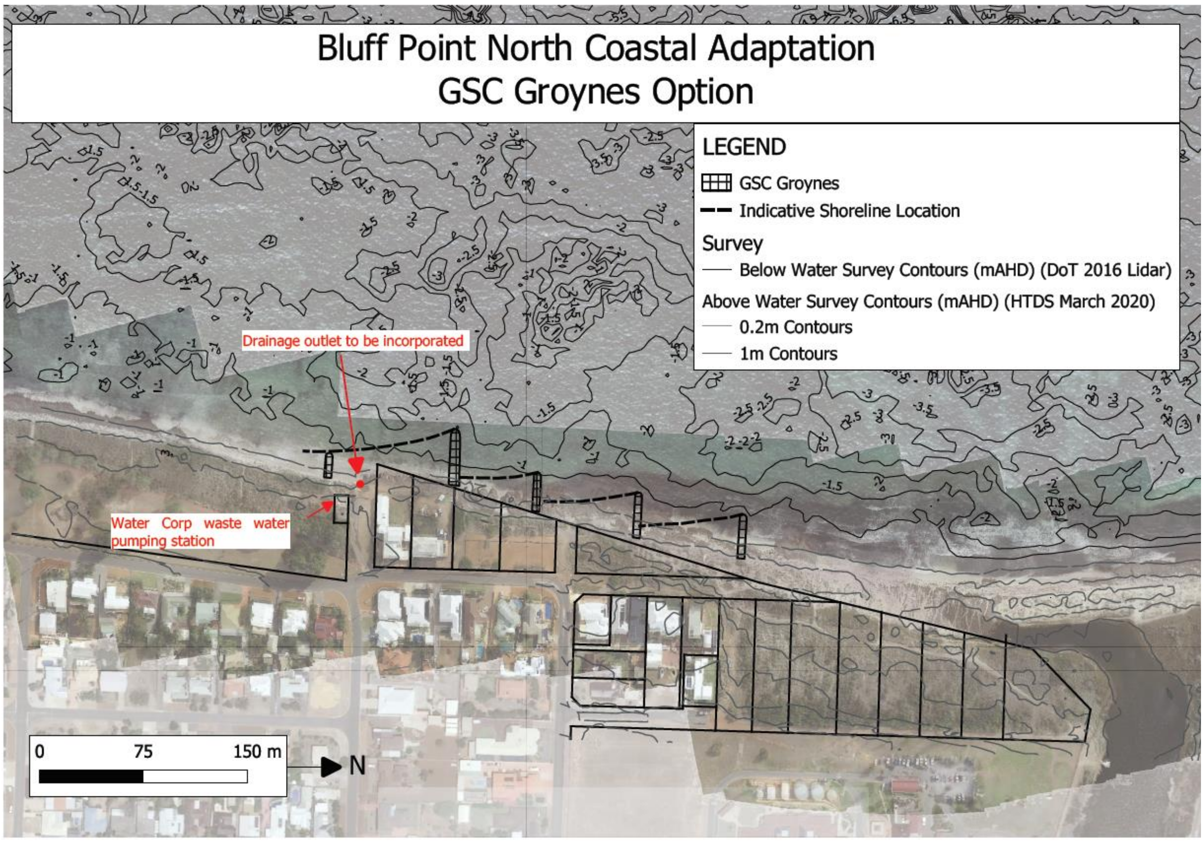

Figure 4.6 Bluff Point North– GSC Groynes Preliminary Sketch

As noted for Bluff Point South, low profile groynes are recommended due to the associated reduced impacts on beach amenity and the potential for sand and wrack to pass over the structures.

The small groyne to the south of the Fuller Street carpark will provide protection to assets in this area, including the Water Corporation waste water pump station. The small groyne will act to ensure a sufficiently wide beach is maintained during both summer and winter. In summer the groyne will be buried beneath the updrift accumulation associated with the 50 m long groyne. However, during winters with persistent north westerly conditions, the longshore sand transport can reverse, ie moving sediment southwards. In the event that this occurs, updrift accumulation will occur on the northern side of this small groyne.

The potential for accumulation of wrack is a key concern at Bluff Point North. Particularly for the area adjacent to #4 and #5 Kempton Street. Large volumes of wrack often accumulate on the beach in this area. An example of this is shown in Figure 4.7. If GSC groynes are implemented at Bluff Point North, considerable management effort may be required by the City to ensure that this wrack is removed in a timely manner.

Figure 4.7 Wrack Accumulation on the Beach at Bluff Point North

An estimate of probable cost for the implementation of this option is provided in Table 4.7.

Table 4.7 Bluff Point North GSC Groynes Option – Estimate of Probable Costs

Item	Description	Quantity	Units	Unit Rate	Total ($ excluding GST)
1	30 m long GSC groynes	1	Number	$190,000	$190,000
2	40 m long GSC groynes	3	Number	$250,000	$750,000
3	50 m long GSC groynes	1	Number	$310,000	$310,000
4	Initial sand nourishment of beach compartment	5	Number	$60,000	$300,000
5	Extend drainage outlet	1	Number	$7,500	$7,500
				Sub Total	**$1,557,500**
				15% Contingency	**$233,625**
				Total	**$1,791,125**

Key advantages and disadvantages associated with the GSC groynes options for Bluff Point North are presented in Table 4.8.

Table 4.8 Bluff Point North GSC Groynes Option – Advantages & Disadvantages

Advantages	Disadvantages
Retains largely usable beach Relatively low impact to beach amenity. Relatively low cost to install, maintain and remove.	Ongoing sand nourishment required. Significant potential to trap wrack. May restrict beach access – more difficult to walk along the beach. Groynes will require ongoing monitoring and maintenance. No direct protection against cross shore erosion processes.

Environmental Considerations

If GSC groynes are implemented at Bluff Point North, some downdrift erosion is initially expected to occur at the shoreline to the north of the northern most groyne. This is likely to continue until the beach compartments within the groyne field become saturated, or full, and sediment begins to bypass the northern most groyne. A robust sand nourishment campaign, in particular initial sand nourishment can mitigate this.

The design largely avoids any direct impact to the TEC at Chapman River. The aim of this is to avoid EPBC environmental approvals associated with the saltmarsh TEC, aboriginal heritage issues and ASS issues. However, indirect impact could occur and further investigation of this would likely be required.

4.2.3 GSC Headlands

A preliminary sketch of the GSC headlands option for Bluff Point North and is presented in Figure 4.8.

Details of the preliminary design are as follows:

- 2.5 m^3 vandal resistant GSC bags are proposed, to withstand the incident wave climate.
- Three GSC headlands are proposed, comprising of:
  - one 100 m long headland, located 70 m offshore from #4 / #5 Kempton Street;
  - one 50 m long headland located 65 m offshore; and
  - a small 35m long headland located, 50m offshore.
- Headlands to have sufficiently high crest level to reduce wave overtopping during high water level events.
- Sand nourishment would be required to initiate formation of tombolos and salient without erosion of the adjoining coastline.

- Drainage outlet at the Fuller Street carpark to be incorporated to ensure that it does not become clogged with accumulated sand.

The adaption option does not represent a field of headlands in the traditional sense. The layout of the headlands has been developed to for the following.

- Provide sufficient protection to the properties on the western side of the Kempton Street, in particular #4 and #5 and to the Fuller St carpark.

- Take advantage of the shallow reef area approximately between the 100 m and 60 m long headland. This reef provides some natural protection against erosion to areas in shore.

- Mitigate influence on the sediment dynamics associated with the sandbar at the mouth of the Chapman River.

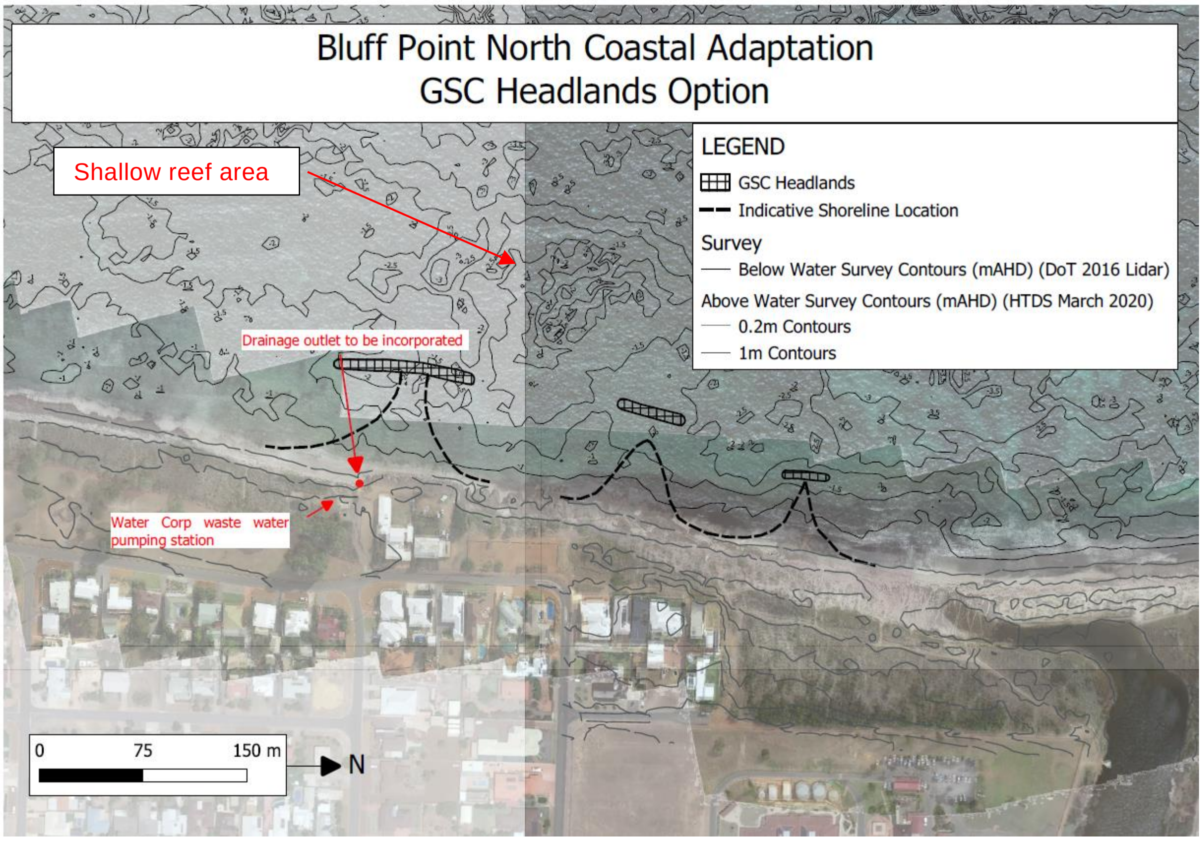

Figure 4.8 Bluff Point North– GSC Headlands Preliminary Sketch

Should this option progress beyond concept design, a detailed assessment of wave climate would need to inform refinement of the layout of the headlands. As noted previously, the stability of the 2.5 m^3 GSCs would need to be considered.

Scour protection will likely be required for some sections. Embedment of the bottom layer of GSCs into the seabed and inclusion of a scour flap will likely be appropriate unless they are founded on rock.

Initial sand nourishment will be required, to encourage the transformation of incoming wave energy to form a large tombolo inshore of the larger headland. The smaller headlands are expected to form smaller salients. These shoreline features would have a similar effect to groynes, in slowing the longshore transport, though the smaller salients are likely to have a lesser effect. As the headlands do not fully block the sand transport along the shoreline, they generally have a reduced effectiveness during more energetic events and higher water periods when sand transport rates can be high. Therefore, ongoing sand nourishment will be required to replenish the embayments and to maintain the longshore sediment transport.

A high crest level for the headlands is critical to the formation of tombolos and salients. Low crested headlands are susceptible to overtopping of storm waves and this can prevent tombolo formation or remove a tombolo once it has formed (Van Rijn 2018).

It is noted that there is potential for wrack to become trapped and buried as sand accumulates to form the tombolos in the lee one of the headlands. This would need to be managed by the City by regularly removing accumulations of wrack before they becoming buried.

Estimates of probable costs for the GSC headlands option for Bluff Point North is provided in Table 4.9.

Table 4.9 Bluff Point North GSC Headlands Option – Estimate of Probable Costs

Item	Description	Quantity	Units	Unit Rate	Total ($ excluding GST)
1	35 m long offshore GSC headland	1	Number	$370,000	$370,000
2	50m long offshore GSC headland	1	Number	$540,000	$540,000
3	100 m long offshore GSC headland	1	Number	$1,000,000	$1,000,000
4	Initial sand nourishment	1	Number	$275,000	$275,000
5	Extend drainage outlet	1	Number	$7,500	$7,500
				Sub Total	**$2,192,500**
				15% Contingency	**$328,875**
				Total	**$2,521,375**

The key advantages and disadvantages of the GSC headlands are outlined in Table 4.10.

Table 4.10 Buff Point North GSC Headlands Option - Advantages & Disadvantages

Advantages	Disadvantages
Retains largely usable beach. Wave sheltering of some nearshore areas may improve beach amenity. Only option to provide direct wave sheltering protection to vulnerable properties. No structures on the beach.	Visual impacts – high crest level. Ongoing sand nourishment required. High potential to trap wrack. Headlands will require ongoing monitoring and maintenance. To be more expensive than groynes. Limited protection to the northern area No direct protection of the shoreline against cross shore erosion effects in areas not directly behind the headlands.

Environmental Considerations

If GSC headlands are implemented at Bluff Point North, some downdrift erosion is initially expected occur at the shoreline to the north. This is likely to continue until the beach compartments within the groyne field become saturated, or full, and sediment begins to bypass the northern most groyne. A robust sand nourishment campaign, in particular initial sand nourishment can mitigate this.

The design largely avoids any direct impact to the TEC at Chapman River. The aim of this is to avoid EPBC environmental approvals associated with the saltmarsh TEC, aboriginal heritage issues and ASS issues. However, indirect impact could occur and further investigation of this would likely be required.

4.2.4 GSC Revetment

A preliminary sketch of a GSC revetment for Bluff Point North is presented in Figure 4.9.

Details of the preliminary design are as follows:

- 2.5 m^3 vandal resistant GSC bags are proposed, to withstand the incident wave climate.
- An approximately 460 m long GSC revetment would be constructed along the rear of the existing beach to provide protection against erosion events. The revetment would largely be buried initially.
- The GSC revetment would be founded at a toe level of approximately -1 mAHD, or onto existing rock levels, whichever is higher.
- The crest height of the revetment would need to be sufficiently high to withstand high water levels and wave overtopping during storms.
- A 5 m wide easement would need to be provided at the rear of revetment for maintenance access where adjacent to privately held property.
- A geotextile layer would be installed along the base and wrapped up the back of the revetment to prevent washout of sand from beneath and behind the structure.

- The existing drainage outlet at the Fuller Street carpark would need to be extended through the revetment.
- Incorporation of existing beach access over the revetment.
- Potential to stage construction at northern end of works.

Similar to the GSC revetment option proposed for the Bluff Point South, this structure is not able to trap sediment to stabilise the beach, but offers protection from coastal erosion and enables space at the rear of the structure to be utilised.

The revetment would need to span the entire northern shoreline, roughly following the alignment of the western boundary of the at-risk properties on the western side of Kempton St. The two 90 degree bends in the revetment alignment can be achieved with the geometry of the GSC bags.

The natural levels of the land behind the revetment will be considerably lower than the crest of the revetment. This area will need to be filled in and stabilised to some extent, with coir matting or similar. Failure to increase the elevation of the revetment crest above the land elevation would likely result in significant overtopping damage to the structure during severe events.

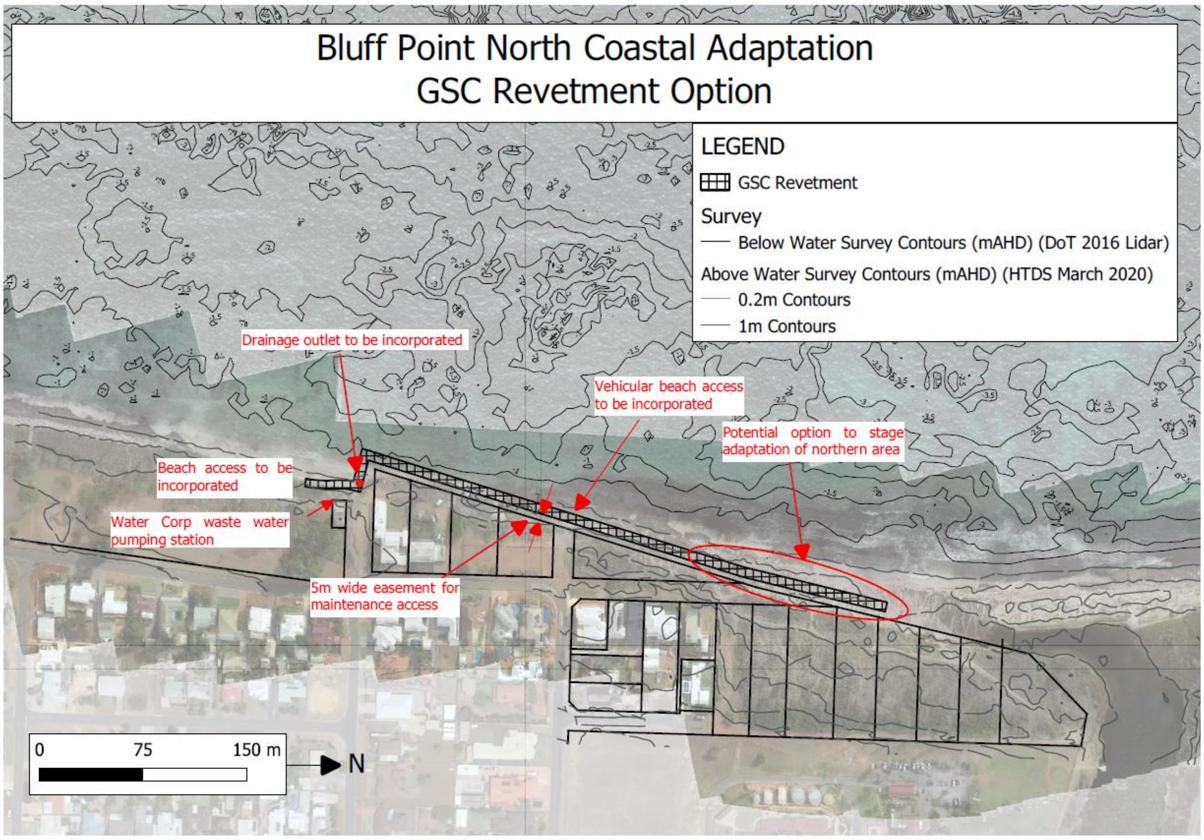

Figure 4.9 Bluff Point North– GSC Revetment Preliminary Sketch

With the narrow section of available beach between the properties on the western side of Kempton Street and the shoreline, construction of a proposed revetment would be challenging. Initial sand placement, to facilitate construction access, would likely be required.

In most areas, the indicative toe depth of -1 mAHD is likely to be sufficient, and would be achievable without the need for dewatering. Though this would need to be confirmed during future design stages.

There is also the potential to stage the construction of this adaptation option due to the wider beach at the northern end of this section of shoreline. Since landward assets in this section are afforded slightly more protection from coastal erosion due to the beach width, construction of the GSC revetment is not as critical in this section and could be staged at a later date.

Similar to the GSC revetment proposed for the southern shoreline, existing beach access paths would be required to be incorporated over the revetment. The existing drainage outlet at the Fuller Street carpark would need to be extended through the revetment.

The key advantages and disadvantages of the GSC revetment are outlined in Table 4.11.

Table 4.11 Bluff Point North GSC Revetment Option - Advantages & Disadvantages

Advantages	Disadvantages
Provides protection to landward assets from coastal erosion. Retains access along the beach. Access along the beach is retained in the short term. Does not require ongoing sand nourishment or frequent monitoring as the groyne and headland options.	Does not limit longshore erosion and therefore cannot retain beach in the medium to long term. Requires considerably more GSC material than other adaptation options to span the length of the shoreline. Some ongoing monitoring and maintenance will be required. Practical challenges in construction.

An estimate of the probable costs for construction of the GSC revetment option at Bluff Point North is provided in Table 4.12.

Table 4.12 Bluff Point North GSC Revetment Option – Estimate of Probable Costs

Item	Description	Quantity	Units	Unit Rate	Total ($ excluding GST)
1	460 m long GSC revetment	460	Lineal metre	$5,000	$2,300,000
2	Initial nourishment to facilitate construction access in narrow beach areas	1	Number	$50,000	$50,000
3	Infilling and stabilisation at rear of revetment	1	Number	$50,000	$50,000
4	Extend drainage outlet through revetment	1	Number	$10,000	$10,000
5	Incorporate existing beach access path/vehicle tracks over revetment	2	Number	$5,000	$10,000
				Sub Total	**$2,420,000**
				15% Contingency	**$363,000**
				Total	**$2,783,000**

Environmental Considerations

The GSC revetment option does not influence longshore sediment transport and therefore does not directly impact the shoreline to the north of, or the development to the south of the design location. However, as the shoreline erodes and the revetment becomes exposed, the supply of sediment to the north will decrease and hence erosion can be expected to occur eventually. This potential impact would likely necessitate a review of the environmental approval requirements for the works given the potential impact on the TEC at the Chapman River mouth.

4.3 Summary of Medium Term Adaptation Options

Estimated probable construction costs of each option for each section of coast are summarised in Tables 4.13 and 4.14. The advantages and disadvantages of each option for each section of coast are summarised in Tables 4.15 and 4.16.

It is recommended that the City consider the estimated construction costs and the non-financial aspects (advantages and disadvantages) summarised below to determine and appropriate adaptation option for the two stretches of coastline, Bluff Point North and Bluff Point South.

Table 4.13 Bluff Point South Adaptation Options – Summary of Probable Construction Costs

Option	Estimated Construction Cost (exc. GST)	Maintenance / On-going Requirements
GSC Groynes	$1,926,250	Ongoing sand nourishment. Removal of trapped wrack – considered to be minor. Ongoing monitoring and maintenance of structures
GSC Headlands	$3,122,250	Ongoing sand nourishment. Removal of trapped wrack – considered to be minor though worse than GSC groynes Ongoing monitoring and maintenance of structures – more expensive that groynes.
GSC Revetment	$3,329,250	Ongoing monitoring and maintenance – after structure becomes exposed.

Table 4.14 Bluff Point North Adaptation Options – Summary of Probable Construction Costs

Option	Estimated Construction Cost (exc. GST)	Maintenance / On-going Requirements
GSC Groynes	$1,791,125	Ongoing sand nourishment. Removal of trapped wrack – considerable. Ongoing monitoring and maintenance of structures
GSC Headlands	$2,521,375	Ongoing sand nourishment. Removal of trapped wrack – considered to be significant. Ongoing monitoring and maintenance of structures – more expensive that groynes.
GSC Revetment	$2,783,000	Ongoing monitoring and maintenance – after structure becomes exposed.

The advantages and disadvantages of each option for each section of coast are summarised in Tables 4.15 and 4.16.

Table 4.15 Bluff Point South Adaptation Options – Summary of Advantages & Disadvantages

Option	Advantages	Disadvantages
GSC Groynes	Proven method for this site – the existing GSC groyne appears to be functioning well. Retains largely usable beach Relatively low impact to beach amenity. Relatively low cost to install, maintain and remove.	Ongoing sand nourishment required to prevent downdrift erosion. Some potential to trap wrack. May restrict beach access – more difficult to walk along the beach. Groynes will require ongoing monitoring and maintenance. No direct protection against cross shore erosion processes.
GSC Headlands	Retains largely usable beach. Wave sheltering of some nearshore areas may improve beach amenity. No structures on the beach.	Visual impacts – high crest level. Ongoing sand nourishment required. High potential to trap wrack. Headlands will require ongoing monitoring and expensive maintenance. No direct protection of the shoreline against cross shore erosion effects in areas not directly behind the headlands.
GSC Revetment	Provides protection to landward assets from coastal erosion. Limited visual impact, with the revetment initially buried at the rear of the beach. Initially less monitoring and maintenance than groyne and headland options.	Beach will eventually erode back to either the existing rock levels, or the revetment. Requires considerably more GSC material than other adaptation options to span the length of the shoreline.

Table 4.16 Bluff Point North Adaptation Options – Summary of Advantages & Disadvantages

Option	Advantages	Disadvantages
GSC Groynes	Retains largely usable beach Relatively low impact to beach amenity. Relatively low cost to install, maintain and remove.	Ongoing sand nourishment required. Significant potential to trap wrack. May restrict beach access – more difficult to walk along the beach. Groynes will require ongoing monitoring and maintenance. No direct protection against cross shore erosion processes.
GSC Headlands	Retains largely usable beach. Wave sheltering of some nearshore areas may improve beach amenity. Only option to provide direct wave sheltering protection to vulnerable properties. No structures on the beach.	Visual impacts – high crest level. Ongoing sand nourishment required. High potential to trap wrack. Headlands will require ongoing monitoring and maintenance. To be more expensive than groynes. Limited protection to the northern area No direct protection of the shoreline against cross shore erosion effects in areas not directly behind the headlands.
GSC Revetment	Provides protection to landward assets from coastal erosion. Retains access along the beach. Access along the beach is retained in the short term. Does not require ongoing sand nourishment or frequent monitoring as the groyne and headland options.	Does not limit longshore erosion and therefore cannot retain beach in the medium to long term. Requires considerably more GSC material than other adaptation options to span the length of the shoreline. Some ongoing monitoring and maintenance will be required. Practical challenges in construction.

5. Interim Adaptation Options

MRA understands that the City have an available budget of $500-700K, for coastal adaptation measures at both Bluff Point North and Bluff Point South, with the potential for additional budget to become available over the coming years. Construction costs for all of the medium term adaptation options outlined in Section 4, exceed this available budget by a considerable margin.

Interim adaptation options to suit the available budget are outlined below. These measures are considered the first steps to provide protection to vulnerable assets at Bluff Point to 2030.

Due to the high unit cost, GSC headlands are not considered a viable option for the available budget. Similarly, GSC revetments have a relatively high unit cost and have only been considered as an option for localised protection at #4 and #5 Kempton Street.

5.1 Bluff Point South

Potentially suitable interim adaptation options at Bluff Point South include the following.

- A single GSC Groyne, with sand nourishment.
- Sand Nourishment.

5.1.1 Single GSC Groyne Option

A preliminary sketch of this interim adaptation option is presented in Figure 5.1.

Details of the preliminary design are as follows:

- 2.5 m^3 vandal resistant GSC bags are proposed, to withstand the incident wave climate.
- One approximately 30 m low profile groyne placed at the southern end of Rundle Park.
- Initial sand nourishment to saturate the beach areas on the updrift (south) side of both the proposed groyne and the existing groyne. This will promote natural bypassing of sediment at each groyne and will minimise downdrift erosion. This would require an estimated 6,000 to 7,000 m^3 of sand. Depending on the results of updated sediment size analyses, this material could be potentially sourced from Pages Beach.
- Option to extend the existing GSC groyne to locally increase the beach width and/or add a GSC revetment to the downdrift side (north) to mitigate downdrift erosion effects.

Figure 5.1 Bluff Point South Interim Adaptation – Single GSC Groyne Option

Key Considerations

Key considerations for this option are noted below.

- The location of the groyne has been selected to reduce the potential for beach loss due to downdrift erosion and associated impacts to amenity. This would be completed by creating a groyne compartment between the proposed groyne and the existing groyne. Some downdrift erosion and loss of beach may be expected to occur on the northern side of the proposed groyne from time to time, however the extent would be limited by the presence of the existing groyne. A wider beach area would form on the updrift (southern) side of the groyne. This is a popular area of beach and hence widening of the beach would provide some benefits in terms of amenity.

- Downdrift erosion may be experienced to the north of the existing GSC groyne. Inclusion of a revetment to the northern side of the groyne would help mitigate this and prevent flanking erosion. The City may wish to consider extending the existing GSC groyne. This would help to widen the beach area to the south. Though this may lead to increased down drift erosion. The balance of these two issues would need to be carefully considered.

- There will be some potential for wrack to become trapped and potentially buried on the updrift side of each groyne. The City will need to manage this.

- The construction of the additional groyne could be considered a first step towards the implementation of the overall groyne field discussed in Section 4.1.1.

An estimate of the probable costs for construction of the single GSC groyne option at Bluff Point South is provided in Table 5.1.

Table 5.1 Bluff Point South Single GSC Groyne Option – Estimate of Probable Costs

Item	Description	Quantity	Units	Unit Rate	Total ($ excluding GST)
1	30 m long GSC groyne	1	Number	$160,000	$160,000
2	Initial sand nourishment (6,000 - 7,000 m^3 from Pages Beach)	1	Number	$100,000	$100,000
				Sub Total	**$260,000**
				15% Contingency	**$39,000**
				Total	**$299,000**

The key advantages and disadvantages of the single GSC groyne option at Bluff Point South are outlined in Table 5.2.

Table 5.2 Bluff Point South Single Groyne Option - Advantages & Disadvantages

Advantages	Disadvantages
Proven method for this site – the existing GSC groyne appears to be functioning well. GSC groyne will reduce longshore transport of placed sand northwards along the beach. Relatively low impact to beach amenity. Relatively low cost to install, maintain and remove. Can be incorporated into larger GSC groyne field.	Ongoing sand nourishment required to prevent downdrift erosion. Some potential to trap wrack. May restrict beach access – more difficult to walk along the beach. Groynes will require ongoing monitoring and maintenance. No direct protection against cross shore erosion processes.

5.1.2 Sand Nourishment

Assuming an even split between Bluff Point North and Bluff Point South, the available budget for and sand nourishment at Bluff Point South is approximately $350K. The estimated unit costs, for terrestrial sand and sand sources from Pages Beach along with achievable nourishment volumes, within the $350K budget, are provided in Table 5.3.

Table 5.3 Estimated Achievable Sand Nourishment Volumes within Available Budget

Sand Source	Terrestrial	Pages Beach
Estimated unit cost (supply/extract & place)	\$35 / m^3	\$15 / m^3
Achievable nourishment volume within \$350K budget	10,000 m^3	23,000 m^3

As noted in Section 2.3, an estimated 5,000 to 10,000 m^3 is lost from the Bluff Point shoreline each year. With this in mind, 23,000 m^3 sand nourishment sourced from Pages Beach may remain in place for approximately 2 – 4 years, depending on weather patterns. If this process was completed over a number of years, the introduction of large volumes of sediment into the system would potentially help to alleviate the erosion issues being experienced along the northern beaches.

The lifespan of sand nourishment from a terrestrial source would depend on the quality and grain sizing of the material selected. Sand recently placed at Sunset Beach had a D_{50} of approximately 0.2 mm and was poorly graded. If 10,000 m^3 of this material was placed onto the beach at Bluff Point it may remain on the beach around 2 years depending on weather patterns.

The key advantages and disadvantages of the sand nourishment at Bluff Point South are outlined in Table 5.4.

Table 5.4 Bluff Point South Sand Nourishment - Advantages & Disadvantages

Advantages	Disadvantages
Longshore transport may nourish adjacent beaches. Potential to implement another adaptation option if required. No structures on the beach. Potential public perception benefits.	Ongoing sand nourishment required. No protection against cross shore erosion processes. Involves machinery on the beach for significant periods of time and requires management of scarps / drop offs. Sand nourishment will only remain in place for 2 – 4 years with the storm buffer width gradually decreasing over time.

5.2 Bluff Point North

Potentially suitable interim adaptation options at Bluff Point North include the following.

- A small GSC revetment, with sand nourishment.
- GSC Groyne Option 1, with sand nourishment.
- GSC Groyne Option 2, with sand nourishment.

- Sand Nourishment.

5.2.1 Small GSC Revetment Option

A preliminary sketch of this interim adaptation option is presented in Figure 5.2.

Details of the preliminary design are as follows:

- 2.5 m^3 vandal resistant GSC bags are proposed, to withstand the incident wave climate.
- An approximately 70 m long GSC revetment would be constructed along the rear of #4 and #5 Kempton Street. The revetment would largely be buried initially. A 5 m wide easement would need to be provided at the rear of revetment for maintenance access where adjacent to privately held property.
- The GSC revetment would be founded at a toe level of approximately -1 mAHD, or onto existing rock levels, whichever is higher.
- The revetment would be constructed with a low crest level. The crest could be raised in future stages.
- A geotextile layer would be installed along the base and wrapped up the back of the revetment to prevent washout of sand from beneath and behind the structure.
- Initial sand placement, to facilitate construction access, would be required. This would require an estimated 3,500 m^3 of material, which could be sourced from Pages Beach.
- Additional sand nourishment could be placed behind, in front of and on top of the structure to provide an additional storm erosion buffer to form a fronting beach and a dune. This would require an estimated 5,000 m^3 of material, which could be sourced from Pages Beach. The dune could be stabilised with coir matting or similar to mitigate windblown sand issues, however based on the alignment of the beach in this area, it is unlikely that any portion of the dune build seaward of the revetment would remain in place for long.
- The existing drainage outlet at the Fuller Street carpark would need to be extended to prevent it from becoming clogged with sand.

Figure 5.2 Bluff Point North Interim Adaptation – Small GSC Revetment Option

Flanking erosion at either end of the structure would need to be monitored. The revetment may need to be extended in future stages to mitigate this risk.

An estimate of the probable costs for construction of a small GSC revetment option at Bluff Point North is provided in Table 5.5.

Table 5.5 Bluff Point North GSC Revetment Option – Estimate of Probable Costs

Item	Description	Quantity	Units	Unit Rate	Total ($ excluding GST)
1	70 m long GSC low crest revetment	70	Lineal metre	$4,500	$315,000
2	Initial nourishment to facilitate construction access in narrow beach areas. (~ 3,500 m^3 from Pages Beach)	1	Number	$50,000	$50,000
3	Placement of sand in front of and on top of revetment to form beach and dune. (~5,000 m^3 from Pages Beach)	1	Number	$75,000	$75,000
4	Extend drainage outlet	1	Number	$7,500	$7,500
				Sub Total	**$447,500**
				15% Contingency	**$67,125**
				Total	**$514,625**

The key advantages and disadvantages of the small GSC revetment option at Bluff Point North are outlined in Table 5.6.

Table 5.6 Bluff Point North Small GSC Revetment Option - Advantages & Disadvantages

Advantages	Disadvantages
Provides protection to landward assets from coastal erosion. Does not require ongoing sand nourishment or frequent monitoring as the groyne and headland options.	Risk of overtopping of low crest level and flanking erosion. Some ongoing monitoring and maintenance will be required. Practical challenges in construction. Protection only offered to 50 m stretch of coast. High unit cost. Sets a precedent of the City providing direct protection for residential development.

5.2.2 GSC Groyne Option 1

A preliminary sketch of this interim adaptation option is presented in Figure 5.3.

Details of the preliminary design are as follows:

- 2.5 m^3 vandal resistant GSC bags are proposed, to withstand the incident wave climate.
- One approximately 40 m long low profile groyne placed to the north of #4 Kempton Street.
- Initial sand nourishment to saturate the beach areas on the updrift (south) side of both the proposed groyne. This would require an estimated 5,000 m^3 of material, which could be sourced from Pages Beach.
- The existing drainage outlet at the Fuller Street carpark would need to be extended to prevent it from becoming clogged with sand.

Figure 5.3 Bluff Point North Interim Adaptation – GSC Groyne Option 1

Key Considerations

Key considerations for this option are noted below.

- The location of the groyne has been selected to reduce the potential for downdrift erosion impacts at #4 and #5 Kempton Street. Downdrift erosion and loss of beach are expected to on the northern side of the however there are no critical assets in this area. Downdrift erosion can be mitigated by ongoing sand nourishment.
- A significant volume of sand would need to be placed to the south of the groyne to create a beach alignment conducive to sand naturally bypassing the groyne. This would require an estimated 5,000 m^3 of material, which could be sourced from Pages Beach.
- There will be some potential for wrack to become trapped and potentially buried on the updrift side of each groyne. The City will need to manage this.

An estimate of the probable costs for construction of the GSC groyne option 1 at Bluff Point North is provided in Table 5.7.

Table 5.7 Bluff Point North GSC Groyne Option 1 – Estimate of Probable Costs

Item	Description	Quantity	Units	Unit Rate	Total ($ excluding GST)
1	40 m long GSC groyne	1	Number	$250,000	$250,000
2	Initial sand nourishment (~5,000 m^3 from Pages Beach)	1	Number	$75,000	$75,000
3	Extend drainage outlet	1	Number	$7,500	$7,500
				Sub Total	**$335,000**
				15% Contingency	**$50,250**
				Total	**$385,250**

The key advantages and disadvantages of GSC groyne option 1 at Bluff Point North are outlined in Table 5.8.

Table 5.8 Bluff Point North GSC Groyne Option 1 - Advantages & Disadvantages

Advantages	Disadvantages
GSC groyne will reduce longshore transport of placed sand northwards along the beach. Relatively low impact to beach amenity. Relatively low cost to install, maintain and remove. Can be incorporated into larger GSC groyne field.	Ongoing sand nourishment required to prevent downdrift erosion. Significant potential to trap wrack. Groynes will require ongoing monitoring and maintenance. No direct protection against cross shore erosion processes. Sets a precedent of the City providing protection for residential development.

5.2.3 GSC Groyne Option 2

A preliminary sketch of this interim adaptation option is presented in Figure 5.4.

Details of the preliminary design are as follows:

- 2.5 m^3 vandal resistant GSC bags are proposed, to withstand the incident wave climate.
- One approximately 50 m long low profile groyne placed approximately 150 m to the north the Kempton St gravel carpark.
- Initial sand nourishment to saturate the beach areas on the updrift (south) side of the proposed groyne. This would require an estimated 5,000 m^3 of material, which could be sourced from Pages Beach.

Figure 5.4 Bluff Point North Interim Adaptation – GSC Groyne Option 2

Key Considerations

Key considerations for this option are noted below.

- The location of the groyne has been selected to avoid any direct impact to the TEC at Chapman River. The aim of this is to avoid EPBC environmental approvals associated with the saltmarsh TEC, aboriginal heritage issues and ASS issues. However, indirect impact could occur and further investigation of this would likely be required.
- The groyne would trap sand on the updrift side, which will provide a wider beach in the area to north of the Kempton St Carpark. The wider beach would provide an erosion buffer, mitigate long term retreat of the shoreline and hence provide some protection to properties on the western side of Fredrick St.
- A significant volume of sand would need to be placed to the south of the groyne to create a beach alignment conducive to sand naturally bypassing the groyne. This would require an estimated 5,000 m^3 of material, which could be sourced from Pages Beach.
- Wrack will likely become trapped and potentially buried on the updrift side of the groyne. The City will need to manage this.

An estimate of the probable costs for construction of the GSC groyne option 2 at Bluff Point North is provided in Table 5.9.

Table 5.9 Bluff Point North GSC Groyne Option 2 – Estimate of Probable Costs

Item	Description	Quantity	Units	Unit Rate	Total ($ excluding GST)
1	50 m long GSC groyne	1	Number	$310,000	$310,000
2	Initial sand nourishment (~5,000 m^3 from Pages Beach)	1	Number	$75,000	$75,000
				Sub Total	**$385,000**
				15% Contingency	**$57,750**
				Total	**$442,750**

The key advantages and disadvantages of GSC groyne option 2 at Bluff Point North are outlined in Table 5.10.

Table 5.10 Bluff Point North GSC Groyne Option 2 - Advantages & Disadvantages

Advantages	Disadvantages
GSC groyne will reduce longshore transport of placed sand northwards along the beach. Relatively low impact to beach amenity. Relatively low cost to install, maintain and remove. Can be incorporated into larger GSC groyne field. Low impact of potential downdrift erosion issues as land to the north of the proposed groyne is not occupied.	Ongoing sand nourishment required to prevent downdrift erosion. Trapping of wrack likely to occur. The City will need to manage this. Groynes will require ongoing monitoring and maintenance. No direct protection against cross shore erosion processes. Minimal protection offered to #4 and #5 Kempton Street.

5.2.4 Sand Nourishment

Considerations regarding sand nourishment as a stand-alone interim adaptation option at Bluff Point North are largely similar to Bluff Point South. These include the following.

- Assumed nourishment volume of approximately 23,000 m^3 of sand sourced from Pages Beach. Placed may remain in place for approximately 2 – 3 years, depending on weather patterns.
- Sand placed at Bluff Point North is likely to be transported away quicker than at Bluff Point South. This is because the shoreline at Bluff Point North is less protected from incoming waves by offshores reefs and shallows compared to Bluff Point South. Hence, the nearshore wave climate is more energetic and the longshore sediment transport potential is higher.

- Based on anecdotal evidence provided by the City, the existing large piles of wrack on the beach provide some protection against coastal erosion. This wrack could be placed onto the nourished beach profile to take advantage of this. To avoid burial, this wrack would need to be removed before sand is placed onto the beach. The wrack could then be placed back on top of the placed sand.
- The existing drainage outlet at the Fuller Street carpark would need to be extended to prevent it from becoming clogged with sand.
- Outside of the additional costs for handling of wrack (estimated at $2.5K) and extension of the drainage outlet (estimated at $7.5K), unit costs and achievable volumes of sand nourishment at Bluff Point North are congruent with Bluff Point South. The scale of the sand nourishment works could be tailored to meet the available budget.

The estimated cost for sand nourishment at Bluff Point North, assuming 23,000 m^3 of sand sourced from Pages Beach along with handling of wrack and extension of the drainage outlet, is $360K.

The key advantages and disadvantages of the sand nourishment option at Bluff Point North are outlined in Table 5.11.

Table 5.11 Bluff Point North Sand Nourishment - Advantages & Disadvantages

Advantages	Disadvantages
Longshore transport may nourish adjacent beaches. Potential to implement another adaptation option if required. No structures on the beach. Potential public perception benefits.	Ongoing sand nourishment required. No protection against cross shore erosion processes. Involves machinery on the beach for significant periods of time and requires management of scarps / drop offs. Sand nourishment will only remain in place for 2 – 4 years with the storm buffer width gradually decreasing over time.

5.3 Summary of Interim Adaptation Options

Estimates of construction costs for each interim adaption option outlined above are summarised Tables 5.12. The advantages and disadvantages of each option are summarised in Tables 5.13 and 5.14.

Selection of a preferred interim adaptation option will need to balance a number of priorities. It is recommended that the City consider the priorities outlined below.

- Potential to incorporate into medium term adaptation options above – ie the interim measures could form the first stage of works of ultimate strategy to protect vulnerable assets from coastal erosion 2030.
- Value for money – ie the amount of protection provided by the measure. Consideration of this should include requirements for ongoing works.

- Longevity – ie the life span, and or residual benefits provided over several years.

Table 5.12 Bluff Point Interim Adaptation Options - Summary of Probable Construction Costs

Option	Estimated Construction Cost (exc. GST)	Maintenance / On-going Requirements
Bluff Point South		
Single GSC Groyne	~$300K	Ongoing sand nourishment. Removal of trapped wrack – considered to be minor. Ongoing monitoring and maintenance of structures
Sand Nourishment	~$350K	Ongoing sand nourishment.
Bluff Point North		
Small GSC Revetment	~$515K	Ongoing sand nourishment. Removal of trapped wrack – considered to be minor. Ongoing monitoring and maintenance of structures
GSC Groyne Option 1	~$390K	Ongoing sand nourishment. Removal of trapped wrack – considered to be minor. Ongoing monitoring and maintenance of structures
GSC Groyne Option 2	~$440K	Ongoing sand nourishment. Removal of trapped wrack. Ongoing monitoring and maintenance of structures
Sand Nourishment	~$350K	Ongoing sand nourishment.

Table 5.13 Bluff Point South Interim Adaptation Options - Summary of Advantages & Disadvantages

Option	Advantages	Disadvantages
Single GSC Groyne	Proven method for this site – the existing GSC groyne appears to be functioning well. GSC groyne will reduce longshore transport of placed sand northwards along the beach. Relatively low impact to beach amenity. Relatively low cost to install, maintain and remove. Can be incorporated into larger GSC groyne field.	Ongoing sand nourishment required to prevent downdrift erosion. Some potential to trap wrack. May restrict beach access – more difficult to walk along the beach. Groynes will require ongoing monitoring and maintenance. No direct protection against cross shore erosion processes.
Sand Nourishment	Longshore transport may nourish adjacent beaches. Potential to implement another adaptation option if required. No structures on the beach. Potential public perception benefits.	Ongoing sand nourishment required. No protection against cross shore erosion processes. Involves machinery on the beach for significant periods of time and requires management of scarps / drop offs. Sand nourishment will only remain in place for 2 – 4 years with the storm buffer width gradually decreasing over time.

Table 5.14 Bluff Point North Interim Adaptation Options - Summary of Advantages & Disadvantages

Option	Advantages	Disadvantages
Small GSC Revetment	Provides protection to landward assets from coastal erosion. Does not require ongoing sand nourishment or frequent monitoring as the groyne and headland options.	Risk of overtopping of low crest level and potential for flanking erosion. Some ongoing monitoring and maintenance will be required. Practical challenges in construction. Protection only offered to 50 m stretch of coast. Sets a precedent of the City providing protection for certain residences
GSC Groyne Option 1	GSC groyne will reduce longshore transport of placed sand northwards along the beach. Relatively low impact to beach amenity. Relatively low cost to install, maintain and remove. Can be incorporated into larger GSC groyne field.	Ongoing sand nourishment required to prevent downdrift erosion. Significant potential to trap wrack. Groynes will require ongoing monitoring and maintenance. No direct protection against cross shore erosion processes. Sets a precedent of the City providing protection for certain residences
GSC Groyne Option 2	GSC groyne will reduce longshore transport of placed sand northwards along the beach. Relatively low impact to beach amenity. Relatively low cost to install, maintain and remove. Can be incorporated into larger GSC groyne field. Low impact of potential downdrift erosion issues as land to the north of the proposed groyne is not occupied.	Ongoing sand nourishment required to prevent downdrift erosion. Trapping of wrack likely to occur. The City will need to manage this. Groynes will require ongoing monitoring and maintenance. No direct protection against cross shore erosion processes. Minimal protection offered to #4 and #5 Kempton Street.
Sand Nourishment	Longshore transport may nourish adjacent beaches. Potential to implement another adaptation option if required. No structures on the beach. Potential public perception benefits.	Ongoing sand nourishment required. No protection against cross shore erosion processes. Involves machinery on the beach for significant periods of time and requires management of scarps / drop offs. Sand nourishment will only remain in place for 2 – 4 years with the storm buffer width gradually decreasing over time.

6. Recommendations

In discussion with the City, it has been determined that Bluff Point North is currently the priority area for interim coastal adaptation measures to be implemented. Part of the thinking behind this assignment of priority is that implementation of structural adaptation measures in the northern area may promote further stability on the shoreline to the south. There are also a number of other considerations relevant to Bluff Point South.

Of the interim adaptation options for Bluff Point North outlined in Section 5.2, the recommended option is GSC groyne option 2.

Key considerations relevant to this option are noted below.

- Initial sand nourishment, of an estimated 5,000 m^3 of material, would be required to saturate the beach areas on the updrift (south) side of the GSC groyne. The City may wish to carry out additional sand nourishment in other areas as required in addition to the GSC groyne construction works. The scale of the sand nourishment could be tailored to suit the available budget.

- Trapped wrack, on the updrift side of the groyne, will likely require active management from the City.

The next step in the design process for the implementation of this option is to complete a more detailed concept design. This more detailed concept design will enable a more detailed construction cost estimate to be prepared and will also allow for other important aspects of, and associated with, the design to be assessed. This includes items such as environmental and heritage requirements.

7. References

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