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R984 Rev 0

November 2017

City of Greater Geraldton

Sunset Beach
Adaptation Options Advice

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canals
breakwaters
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seawalls
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1. Introduction

The shoreline fronting the existing Sunset Beach development in Geraldton Western Australia has experienced recent erosion trends. This erosion has led to the City of Greater Geraldton (City) removing assets within close proximity to the vulnerable shoreline. Following the implementation of these emergency measures, the City engaged specialist coastal and port engineers' M P Rogers & Associates Pty Ltd (MRA) to provide advice on potential coastal adaptation options for Sunset Beach. In particular, MRA have been requested to provide advice on the following:

- Feasibility of low-crest Geotextile Sand Container (GSC) groynes along the Sunset Beach Foreshore (similar to that at St Georges Beach).
- An alternative no-regrets option.
- Recommendations on required data collection and further investigations to improve knowledge of the coastal processes and modelling for the immediate Sunset Beach area.

This report provides a high-level review of the sediment transport pathways along the northern Geraldton Beaches. This review was completed to provide advice regarding the feasibility of potential coastal adaptation options for the shoreline fronting the existing Sunset Beach development.

2. Local Sediment Dynamics

2.1 Background

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 2.1. 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.

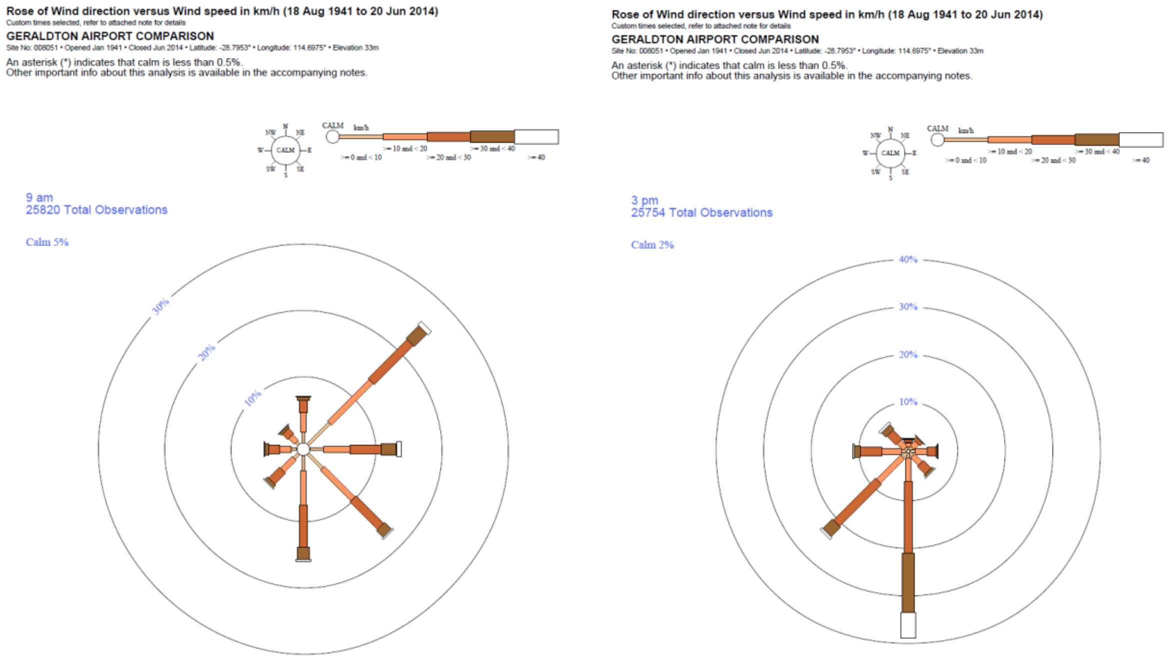

Figure 2.1 Geraldton average annual wind roses for 9am (left) and 3pm (right) (Source: Bureau of Meteorology, 2017)

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.

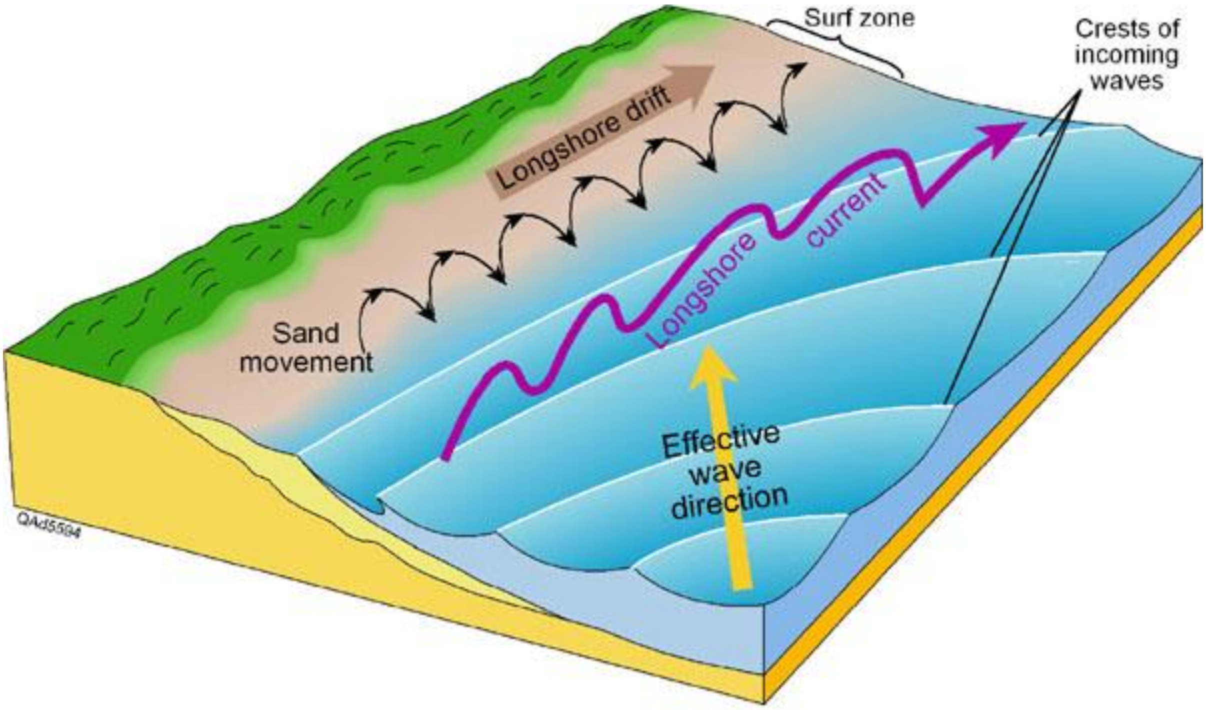

Figure 2.2 Northerly Longshore Drift during Afternoon Seabreeze Conditions (Revision World Networks Ltd. 2017)

Confirmation of this predominately northerly net sediment transport regime is provided by the Mid West Ports Authority's (MWPA) annual sand bypassing program. This program involves the extraction of sand from Pages Beach and the placement of this material as nourishment, generally on the northern side of the Batavia Coast Marina. Refer Figure 2.3 for locations.

Over the period since 2000, annual MWPA sand bypassing volumes have averaged around 11,000 m^3. Despite these volumes of sand bypassing, additional material continues to accrete at Pages Beach, while the shoreline to the north of Batavia Coast Marina has experienced significant erosive pressure.

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 informal seawall at the intersection of Kempton Street and Fuller Street and the Glenfield Beach reef system all experience accretion on their southern side and erosion on their northern side. The findings of Tecchiato et al. (2012) also suggest that there is net northerly sediment transport along the shoreline.

In recent times the erosive pressure on the section of coastline north of the Batavia Coast Marina, known locally as the Beresford and St Georges foreshore, has resulted in the requirement for beach management actions to preserve existing infrastructure. These management actions have included beach nourishment and a low crest GSC groyne at St Georges Beach and the implementation of a coastal protection scheme for the Beresford foreshore.

The Beresford and St Georges Beaches are located on shallow calcarenite reef with prominent sections of beach rock (refer Figure 2.4). In many locations along this section of coastline the erosion has exposed this beach rock, meaning that there is a reduction in sediment availability along the shoreline. This, combined with the absence of any significant dune system along the Beresford and St Georges Beaches, means that total sediment availability from this area is limited. Given that sediment is transported in a net northerly direction, the sediment from these beaches essentially provides a source of feed for the shoreline to the north, including Sunset Beach. Reduction in the available sediment supply from these beaches, through exhaustion or stabilisation as a result of the coastal protection works, may therefore reduce the available sediment supply to the northern shoreline, contributing to or exacerbating current erosion trends.

Figure 2.3 Location plan

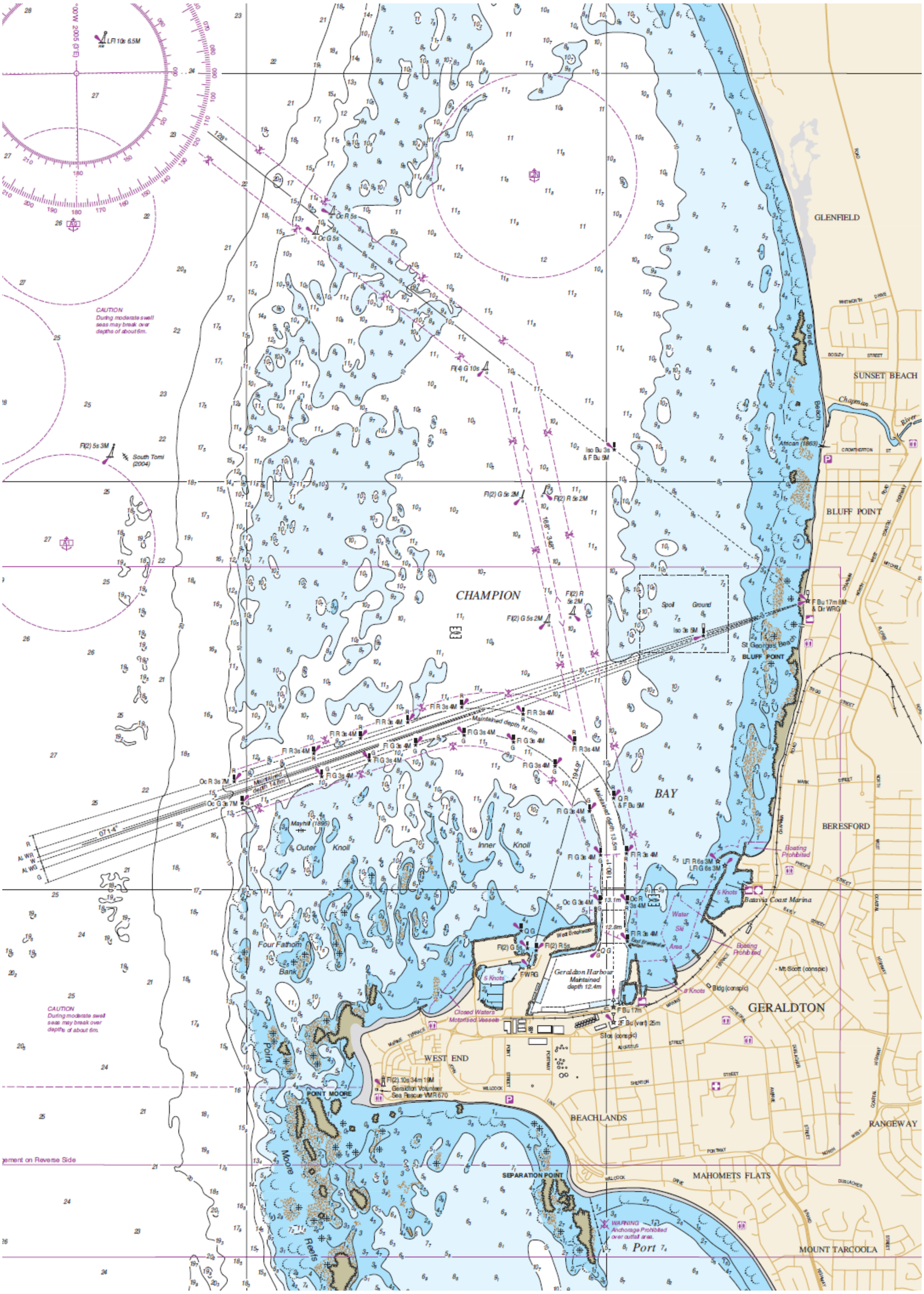

Figure 2.4 Extract from local nautical chart (Source: DPI Chart WA 939, 2005)

The extent of the erosion pressure on the Beresford and St Georges shoreline has increased over the last one to two decades. This corresponds with the period of increased shoreline erosion observed at Sunset Beach. It is possible that the reduction in sediment feed from the south may have contributed to the increased rate of shoreline erosion in this area.

A compounding factor for the Sunset Beach shoreline is the potential reduction in fluvial sediment supply from the Chapman River. Whilst the impacts of future climate change are difficult to predict, as rainfall in the southern portion of Western Australia continues to decrease the volume of sediment fed into the nearshore area during strong flows from the Chapman River may also decrease. This reduction in sediment supply below historical levels may have also contributed to the higher contemporary shoreline erosion rates compared to longer term averages.

2.2 Sediment Transport Pathway

Based on the information presented above, it is apparent that the feed of sediment from the shoreline south of the Chapman River (including from the river itself) may have decreased over the past one to two decades. This will have had some effect on the local sediment transport pathway, as the reduction in incoming sediment would cause an increase in the erosion rate of the shoreline.

Given the understanding of the sediment transport processes in the area, an outline of the expected net sediment transport pathway is presented in Figure 2.5. As indicated in this figure, 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 in front of the existing development. Given the apparent contributions from both these locations (as indicated by the persistent erosion trend) it is expected that the rate of northerly sediment transport increases with distance north. This is not unexpected given the corresponding increase in fetch length, and therefore wave energy, from Point Moore during southerly winds.

The sediment transport pathways presented in Figure 2.5 will provide the foundation for the high-level assessment of potential coastal adaptation options for the shoreline fronting the existing Sunset Beach development.

Figure 2.5 Indicative Net Sediment Transport Pathways

3. Adaptation Options

The are many adaptation options that could be considered to manage the eroding shoreline fronting the existing Sunset Beach development, including the following:

- Seawalls.
- Nearshore Headlands.
- Sand Nourishment only.

These options have their own advantages and disadvantages in regard to levels of protection they offer compared to overall aesthetic appearance. However, it has been assessed that these options would either be too costly over the design life or would not be considered as a “no regret” option.

On this basis, the City’s wanted to investigate the feasibility of Low-crest GSC Groynes and associated sand nourishment. Assessments of the feasibility of this option and an alternative “no regret” option are provided in the following Sections of this report.

3.1 Low-crest GSC Groynes

3.1.1 Feasibility Considerations

Groynes are structures constructed perpendicular to the shoreline to intercept the longshore transport of sediment and result in the realignment of the contained beaches to an angle parallel to the incident wave approach. A groyne field aims to reduce the longshore transport along the shoreline and provide protection to eroding coasts.

The City constructed a GSC groyne at St Georges Beach in 2016. The St Georges Beach GSC groyne is shown in the following figure.

Figure 3.1 St Georges Beach GSC Groyne (Nearmap, November 2016)

The St Georges Beach groyne is 25m long and is constructed from 2.5 m^3 GSCs.

The concept of a field of Low-crest GSC Groynes would be a feasible short-term option to mitigate the eroding shoreline in front of the existing Sunset Beach development. The feasibility of this option would be subject to following conditions:

- Construction of a sufficient number of groynes to protect an adequate length of shoreline.
- The individual groynes extending a sufficient length into the active zone of the shoreline to adequately trap the sand and enable shoreline realignment without significant erosion of the northern sides of the structures.
- Initial and potentially ongoing sand nourishment is undertaken to saturate the groynes and reduce the potential for erosion.
- Maintenance to the GSC groynes being undertaken approximately every 5 years or following damage from particularly severe storm events.

In order to reduce the impacts of downdrift erosion, sand nourishment between the constructed groyne field would need to be undertaken. The following figure presents the conceptual performance of a groyne field with and without sand nourishment.

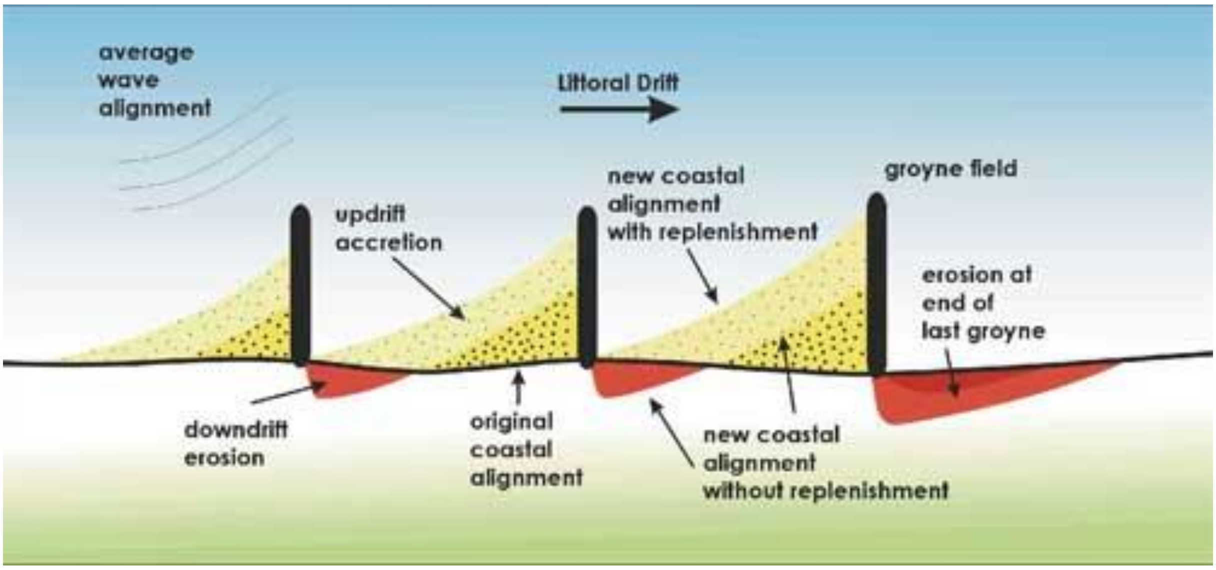

Figure 3.2 Conceptual Groyne Field Shoreline Response (Tes Teach 2017)

MRA has completed a high-level assessment of the potential groyne lengths, spacings, embedment depths and resultant shoreline alignments. Sunset Beach is exposed to more severe wave conditions when compared to the location of the St Georges Beach groyne. This can be seen in the wave modelling results from MRA (2016) presented in following figure.

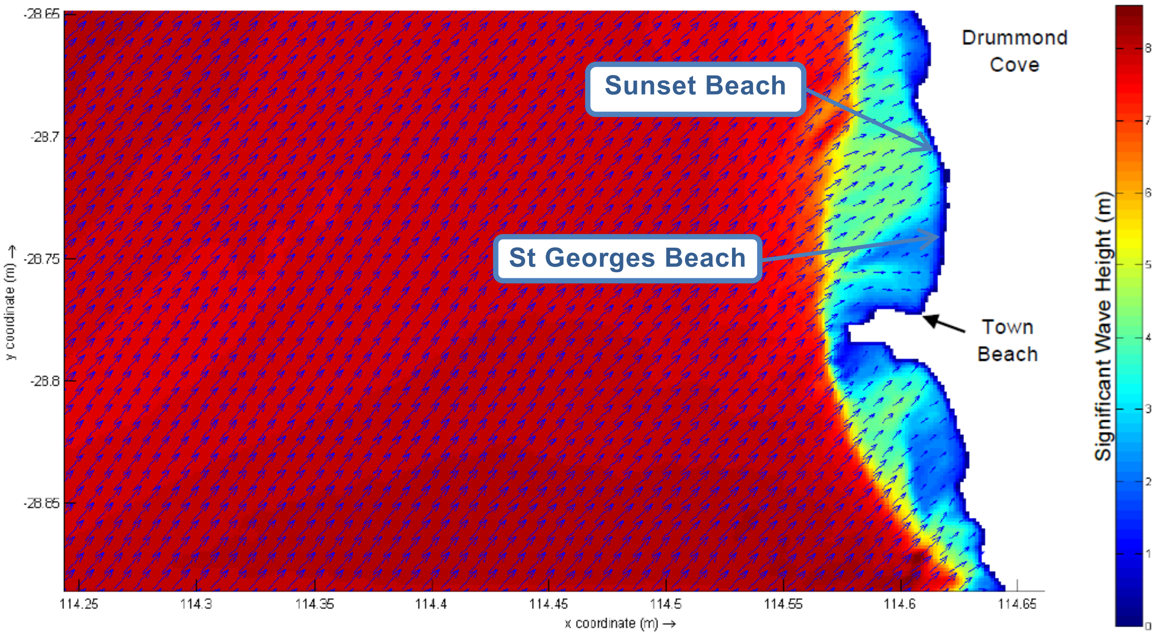

Figure 3.3 Wave Modelling for South Westly Direction 100 year Annual Recurrence Interval Storm Event (MRA 2016)

Given the increased exposure at Sunset Beach compared to St Georges Beach, and resulting changes in beach slope and dynamics, the Sunset Beach Groynes would require 3 layers of GSC's instead of 2. This will increase the construction cost associated with the GSC groynes from that experienced at St Georges beach. The conceptual layout of the proposed groyne field and indicative saturated groyne field shoreline alignments are shown in the following figure. These shoreline alignments will be subject to seasonal fluctuations. The appearance of the groynes would be similar to the groyne constructed at St Georges Beach.

Figure 3.4 Conceptual Groyne Field Layout

To provide an effective groyne field, the separation between the groynes needs to be relative to the overall length of the groynes. The Shore Protection Manual (USACE, 1984) suggests a spacing to length ratio of two to three, while Kraus et al (1994) and the Coastal Engineering

Manual (USACE, 2006) suggest a ratio of two to four. A spacing to length ratio of approximately 1.6 has been adopted on the basis of the following factors:

- The significant angle of incidence between the predominate afternoon sea breeze conditions and the current Sunset Beach shoreline.
- The reduced supply of sediment from the south discussed previously in Section 2.
- The proposed low-crest of the groynes.
- The high-level stage of this investigation.

The final two groynes shown on Figure 3.4 have been designed with reduced lengths to minimise the downdrift erosion of the shoreline further north based on the recommendations of USACE (2006).

The following key conceptual criteria would need to be met to minimise any additional erosion of the 500 m of shoreline fronting the existing Sunset Beach development as a result of longshore transport:

- The low-crest GSC groynes are to be constructed from 2.5 m^3 GSCs.
- Five approximately 50 m groynes and two approximately 30 m groynes constructed at spacings of approximately 80m.
- Initial sand nourishment volume of approximately 12,800 m^3 to saturate the groyne field and potential ongoing nourishment of approximately 10,000 m^3 approximately every 3 to 5 years.

It should be noted that the construction of a groyne field will not prevent recession of the shoreline caused by storm erosion, sea level rise and seasonal fluctuations. To minimise recession of the shoreline from these processes would require larger structures or significantly larger volumes of sand nourishment over the design life of the adaptation option.

If the City chooses to proceed with this adaptation option, the exact lengths and spacings of the groynes and quantities of sand nourishment would need to be further investigated. The investigations required to progress this adaptation option from feasibility to the latter design phases have been recommended in Section 4 of this report.

The groyne field is able to be constructed in stages to help reduce initial capital expenditure. Given the narrow buffer from the current face of the eroding dune system to the existing infrastructure south of the Bosley Street car park, the first stage of the groyne field would need to extend to the northern side of the car park (i.e. the 5 southern groynes on the current concept presented in Figure 3.4).

3.1.2 Impacts

It is likely that the construction of a groyne field in front of the existing Sunset Beach development would block some of the sediment transport from the southern beaches and reduce the supply of sediment to beaches north of the existing Sunset Beach development. However, given the proposed low-crest of the groynes, the containment of sediment on the southern side of the groynes would be limited by the elevation the crest. Provided the groynes are designed correctly and sufficient sand nourishment is undertaken, this option could be considered to minimise any significant impacts on the shorelines further south, north and between the groynes.

Provided the groyne field and associated sand nourishment programme is designed and implemented correctly, this adaptation option should not adversely impact the river month of the Chapman River.

From MRA's experience with shoreline management, the accumulation of wrack on beaches can be an issue in coastal communities (including Port Geographe and Two Rocks). The accumulations of detached macrophytes and seagrass in the surf zone and on beaches are commonly referred to as wrack (Kirkman & Kendrick 1997). From review of recent aerial imagery, there appears to be significant volumes of wrack that accumulate on the shorelines immediately south of the Chapmen River mouth. Although the proposed structures are significantly smaller than the breakwaters at Port Geographe and Two Rocks, there is the potential for wrack to accumulate in the beach compartments between the proposed groynes.

The proposed groynes could act as barriers that may prevent any wrack that has accumulated from leaving the beach compartment. During high water level events, there is the potential that wrack may become stranded on the upper reaches of the beach compartments. Once wrack has been accumulated for longer periods of time it can start to decompose which can result in pungent odours as it decays. This may be of concern to members of the public, including property owners, and local beach users. As a result the City could need to be manage any significant accumulations of wrack that result from the proposed groyne field.

3.1.3 Opinion of Probable Costs

The construction cost estimate for the groyne field is presented in the following table:

Table 3.1 Opinion of Probable Costs – GSC Groyne Field

Item	Description	Quantity	Units	Unit Rate	Total ($ excluding GST)
1	50 m long GSC groynes	5	Number	$300,000	$1,500,000
2	30 m long GSC groynes	2	Number	$180,000	$360,000
3	Initial sand nourishment	12,800	m^3	$30	$400,000
				Sub Total	**$2,260,000**
				15% Contingency	**$339,000**
				Total	**2,599,000**

Potential ongoing sand nourishment may cost in the order of $300,000 approximately every 3 to 5 years. However, this may vary significantly over time dependent on the met-ocean conditions and the response of the shoreline to sea level rise over the longer term.

Maintenance of the structures could be up to 5% of the capital construction costs per decade.

3.2 Alternative “No-Regrets” Option

An alternative option 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 on a section of shoreline exposed to longshore sediment transport is in Denham, Western Australia. Figures 3.5 and 3.6 show an aerial photograph and a site photograph of the composite groyne respectively.

Figure 3.5 Denham Foreshore Composite Sheet Pile Groyne Aerial Photograph (Supplied by Department of Transport, 2016)

Figure 3.6 Denham Foreshore Composite Sheet Pile Groyne Site Photograph (Supplied by Shire of Shark Bay, 2017)

It should be noted that this shoreline is typically exposed to less wave energy when compared to Sunset Beach and consideration of this would need to be further investigated in the latter design stages. It is likely that the groynes would need to be higher than the example shown in Figure 3.6 and would therefore have more of a visual impact on the shoreline at Sunset Beach.

The composite sheet pile groynes may be of benefit to the City as a no-regrets options for the following reasons:

- Implementation as a trial groyne could be used to further advance the City's knowledge of the local sediment dynamics (discussed later in Section 4).
- The composite sheet piles may be able to be removed and reused elsewhere for other coastal investigations/trials or on other projects.

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

- The trial could be seen by the community as a new innovative approach which results in the public perceiving the City was acting innovatively to address the current costal erosion issue.

The same investigations would be required to process this alternative no-regrets option to the latter design phases. However, there is the risk that rock is located below the surface of the beach which would prevent the composite sheet piles from reaching the desired elevations. This may prevent the design capacity of the groynes being met. Therefore, the geotechnical conditions at the proposed composite groyne locations would need to be investigated.

3.2.1 Opinion of Probable Costs

The construction cost estimate for the composite groyne field is presented in the following table.

Table 3.2 Opinion of Probable Costs – Composite Groyne Field

Item	Description	Quantity	Units	Unit Rate	Total ($ excluding GST)
1	50 m long composite groynes	5	Number	$300,000	$1,500,000
2	30 m long composite groynes	2	Number	$180,000	$360,000
3	Initial sand nourishment	12,800	m^3	$30	$400,000
				Sub Total	**$2,260,000**
				15% Contingency	**$339,000**
				Total	**2,599,000**

Potential ongoing sand nourishment may cost in the order of $300,000 approximately every 3 to 5 years. However, this may vary significantly over time dependent on the met-ocean conditions and the response of the shoreline to sea level rise over the longer term.

As seen in the table above, the costs associated with the composite groyne field are likely to be similar to the cost of the GSC groyne field. However, the construction timeframes for the composite groyne field would be significantly shorter than that of the GSC groyne field. This is likely to be perceived as a positive outcome for the community as there would be less interruption of beach use. Additionally, maintenance costs are expected to be less than those for the GSC groynes.

Removal of a trial 50 m composite groyne may cost in the order of $25,000. These materials could be stockpiled by the City for reuse elsewhere.

4. Recommendations for Further Work & Investigations

To confirm the feasibility of the proposed low-crest groyne field to protect the shoreline fronting the existing Sunset Beach development, the following investigations are recommended:

- Collection of wave data in the nearshore area in front of the existing Sunset Beach development for use in calibrating detailed wave and longshore sediment transport models. It is important to note that any data collected for use in design of shorter-term adaptation options will still be applicable for use in any future design of longer-term adaptation options. Collection of wave data could either be direction or non-directional given that directional data has been collected adjacent to the Beresford shoreline. However, if non-directional measurements are to be completed the monitoring should be collected at two locations concurrently.

- Establishment of a calibrated / validated site specific wave model using the recorded wave measurements.

- Establishment of a calibrated / validated longshore sediment transport model. The following information or investigations could be collected or completed to assist with the calibration / validation of this model.

    - Development of a refined local sediment budget. This would require an updated assessment of the regional shoreline movement using the latest available orthorectified aerial imagery, together with available survey information, to enable a local sediment budget to be developed. The sediment budget could be used to ensure that the longshore sediment transport model adequately reproduces the local sediment transport rates.

    - A cost effective way of calibrating a longshore sediment transport model can be to assess the shoreline response of similar shore perpendicular structures within the vicinity of the site. This method relies on similar shoreline alignments, wave exposure and relevant historic data being available. One structure's shoreline response that may be able to be used to calibrate a longshore sediment transport model for the site is the St Georges Beach groyne. However, given it has only recently installed, an accurate assessment of the shoreline response may not be possible until after a couple of years.

    - A more refined local calibration / validation could be achieved through installation and monitoring of a temporary shore perpendicular structure (such as a trial composite sheet pile groyne). Monitoring could be completed by surveying the nearshore area north and south of the temporary structure following installation. This method would enable a detailed and accurate assessment of the longshore transport mechanisms and may enable design refinements and associated cost savings.

- Longshore sediment transport modelling using the calibrated / validated model should be completed to simulate the impacts of the proposed adaptation option. The model could be used to simulate the impacts of the proposed "no regret" option, but could also be used to help guide further adaptation planning over the medium to longer term.

- To confirm the extent of potential wrack accumulation mechanisms and quantities, it is recommended that monitoring of wrack accumulation quantities is completed for the other sections of the shoreline north of Geraldton. This could enable estimates to be made for the anticipated quantities and accumulation durations of wrack between the proposed groynes for different typical events and periods of the year.

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