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R361 Rev 2

March 2015

City of Wanneroo

# Two Rocks
# Coastal Management

marinas
boat harbours
canals
breakwaters
jetties
seawalls
dredging
reclamation
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Form 035 17/01/13

## Limitations of this Document

# Executive Summary

The shoreline at Two Rocks has undergone substantial change since the construction of the Two Rocks Marina (Marina) in 1973. In particular, the sections of coast to the immediate north of the Marina have experienced substantial and long term erosion since its construction.

In 2006, the City of Wanneroo commissioned specialist coastal and port engineers, M P Rogers and Associates (MRA) to provide an assessment of this erosion and assess potential coastal management options. MRA (2006) recommended that over a 60 year assessment timeframe Staged Groynes were the most appropriate management option on a cost, social and environmental impact basis. MRA (2006) recommended that the assessment is re-evaluated in approximately 5 years.

In 2012, the City therefore engaged MRA to complete an updated assessment of the coastal processes in the area, investigate the erosion north of the Marina and evaluate potential coastal management options. This report covers a much larger area of coastline than the previous studies, stretching nearly 8 km from the Mallee Reef Salient in the north to the North Yanchep Headland in the south.

The work was completed in two separate stages. Stage 1 of the coastal management investigation involved:

- Reviewing the previous coastal erosion investigation (MRA, 2006);
- Assessing the impact of coastal processes on the Two Rocks coastline;
- Investigation of 6 conceptual options for the management of the coastline north of the Marina; and
- A preliminary evaluation of the coastal management options including assessment of Net Present Value and social, environmental and economic impacts.

The Stage 2 coastal investigations focused on refining the recommended coastal management options from the Stage 1 investigations. This included:

- Preliminary design of the recommend coastal management options;
- Estimating the effects of the coastal management options on the shoreline position and sediment transport patterns of the area; and
- Revising the estimated costs of the coastal management.

Past studies in the area suggested that prior to the construction of the Marina the coastline was generally stable, undergoing seasonal and inter-annual variations (Halpern Glick 1986). The construction of the Marina interrupted the longshore drift in the area, resulting in the accretion of sediment to the south and erosion of the shoreline to the north.

It was previously estimated that over the period of 1971 to 1996, approximately 14,000 $m^3$/yr of sediment was eroded from the 1.5 km stretch of coastline north of the Marina (MRA 2006). As part of this updated assessment, the estimated shoreline movement was updated for the period between 1981 and 2011. For this period, approximately 9,200 $m^3$/yr was being lost from the shoreline immediately to the north of the Marina. Overall, approximately 20,000 $m^3$/yr was estimated as being lost from the entire northern coastline of the study area.

The updated shoreline movement analysis conducted as part of this works established that the rate of shoreline recession immediately north of the Marina was approximately -0.7 m/yr for the period 1981 to 2011.

Severe storm erosion modeling was completed using the SBEACH computer model to simulate the extent of erosion experienced by the beach profile north of the Marina. It was estimated that approximately 20 m of erosion was likely to be experienced during a severe storm event.

An allowance for sea level rise based upon a potential rise of 0.9 m over the next 100 years was allowed for under the assessment. Based on a timeframe of 25 years, this resulted in a recession due to sea level rise of approximately 5 m.

The required allowances for coastal processes, including severe storm erosion, shoreline movement and sea level rise over the next 25 years was estimated to be approximately 43 m.

Several items of infrastructure were deemed to be vulnerable to coastal processes over the next 25 years, including the Sceptre Court stairs and viewing platform, northern Marina seawall and a DoT navigation marker.

Six conceptual coastal management options were investigated to manage the shoreline recession experienced north of the Marina and protect the vulnerable infrastructure. These options were Managed Retreat, Sand Nourishment, Sand Bypassing, Staged Seawall, Staged Groynes and Offshore Breakwaters.

These coastal management options were then compared on an economic, social and environmental impact basis to select a preferred coastal management option. This also included an assessment of the potential protection each option provided for timeframes longer than the 25 years selected for the investigation.

The outcomes of the initial Stage 1 assessment were presented to the City and Department of Transport (DoT) for review. Following this, the City requested that the Stage 2 works focus on the two most highly ranked coastal management options from the conceptual investigations.

The two highest ranked coastal management options that were recommended for further investigation as a result of the initial assessment, were the Managed Retreat and Staged Groyne options.

In Stage 2, these options were further investigated and refined. This included:

- Refining the layout, design and extents of the Staged Groyne option;
- Estimating the impact of the proposed management options on the sediment transport patterns of the area;
- Estimating the final position of the 2037 shoreline for the proposed management options;
- Estimating the timeframe in which the proposed management option is likely to impact Sovereign Drive;

- Assessment of the relative benefits and disadvantages of the two options;
- Assessing the environmental, social and economic impacts of the recommended management options; and
- Further refining the estimated cost and NPV analysis of the recommended management options.

Following the Stage 2 investigations, both the Managed Retreat and Staged Groyne options achieved the same rating. While the Staged Groynes had a higher economic cost than the Managed Retreat option over the 25 year planning timeframe, it was more successful in maintaining the shoreline position. The Managed Retreat option was therefore ranked first due its lower NPV over the 25 year timeframe considered. Over this assessment timeframe Managed Retreat is recommended as the most appropriate management option.

It was also noted that the Managed Retreat option was largely successful because of the timeframe considered. For an extended timeframe the Managed Retreat option would result in infrastructure such as Sovereign Drive and private development becoming vulnerable to coastal processes and would no longer be the higher ranked option.

The timeframes in which Sovereign Drive may be vulnerable to the coastal processes allowances were also investigated. It was assessed that under the Managed Retreat option, Sovereign Drive would be vulnerable to severe storm erosion in approximately 45 years (2057). For the Staged Groyne option, Sovereign Drive was likely to be vulnerable to severe storm erosion in approximately 80 years (2092).

Following recommendations from this study, the DoT commissioned a geotechnical survey of the foreshore which was completed in late 2014. The survey found limestone rock in the foreshore at levels between -0.5 and +6.3 mAHD. The location and presence of the rock should be reviewed with the outcomes and recommendations of this report.

The results of the investigations were presented to the Two Rocks community in March 2015 at a public information session. Representatives from the City, DoT and MRA attended, along with members of the public. Minutes from the meeting are attached to this report.

# Table of Contents

## Table of Figures

## Table of Tables

# 1. Introduction

Two Rocks is located on the Western Australian coastline, approximately 60 km north of Perth. Following construction of the Two Rocks Marina (Marina) in 1973, the sections of shoreline adjacent to the Marina have undergone significant changes. In particular, sections of the coastline immediately north of the Marina have experienced substantial and long term erosion while the coastline to the south of the Marina has undergone substantial accretion. Figure 1.1 shows the Marina and adjacent features.


**Figure 1.1 - Two Rocks Marina & Key Features (2011 Aerial)**

In 2005, an investigation into the erosion of the coastline north of the Marina was commissioned by the City of Wanneroo (City). One of the outcomes of that study was that the need for coastal management should be reviewed in a further 5 years (MRA 2006).

The City therefore commissioned specialist coastal and port engineers, M P Rogers and Associates (MRA) to provide an updated assessment of the coastal processes in the area, investigate the erosion north of the Marina and evaluate potential coastal management options for the area.

This work was completed in two separate stages. Stage 1 of the coastal management investigation included:

- A review of the previous coastal erosion investigation (MRA, 2006);
- Analysis of shoreline movement trends since the previous investigation;
- Estimating the likely severe storm erosion and impact of sea level rise;

- Investigation of 6 conceptual management options for the coastline north of the Marina; and

- Conducting a preliminary evaluation of the coastal management options including assessment of Net Present Value and social, environmental and economic impacts.

Following the Stage 1 investigations and presentation of the recommendations to the City, the City will agree on two management options to proceed with in Stage 2.

The Stage 2 works focus on refining the recommended coastal management options. This includes:

- Preliminary design of the two recommend coastal management options;

- Estimating the effects of the coastal management options on the shoreline position and sediment transport patterns of the area; and

- Revising the estimated costs of the coastal management.

These works are being completed as a 2012 Coastal Protection Grant awarded to the City by DoT.

This report presents the data, methodology and results of the Stage 1 and Stage 2 investigations.

# 2. Knowledge Summary & Coastal Processes

## 2.1 Previous Investigations

Several previous studies have investigated the coastal processes and shoreline movement around Two Rocks. The main outcomes of these reports are summarised and discussed below.

Halpern Glick (1986) carried out shoreline movement analysis for the periods between 1941 and 1973 and determined that prior to the construction of the Marina the Two Rocks coastline was generally stable, undergoing seasonal and inter-annual fluctuations (Halpern Glick 1986, Environmental Research Consultants 1972).

The construction of the Marina changed the local coastal dynamics of the area by interrupting the local longshore transport (Halpern Glick 1986). It was found that in the 10 years after the construction of the Marina, the vegetation line to the south of the Marina accreted between 10 and 30 m, while the vegetation line to the north of the Marina receded between 20 and 30 m (Halpern Glick 1986).

MRA (1997) confirmed that the shoreline to the south of the Marina experienced significant accretion, whilst the shoreline to the north experienced erosion. It was estimated that in the 10 year period following construction of the Marina, approximately 25,000 $m^3$/year eroded from a 3 km stretch of coastline to the north of the Marina (MRA 1997).

Further analysis of this section of shoreline north of the Marina over the period 1985 to 1996 indicated that the coastline was losing in the order of 15,000 $m^3$/year (MRA 1997). It was noted that this analysis included approximately twice the shoreline of the earlier Halpern Glick (1986) investigation.

MRA (2006) also investigated the coastal processes occurring for the coastline near Two Rocks. This investigation assessed the shoreline movement over a stretch of coastline extending 1 km to the south and approximately 1.5 km to the north of the Marina.

This assessment was conducted over the period 1965 to 2004 and further indicated that the erosion to the north of the Marina was attributable to the construction of the Marina. Over the period 1971 to 1996 it was estimated that approximately 14,000 $m^3$ had eroded from the 1.5 km stretch of coastline to the north of the Marina.

MRA (2006) investigated potential coastal management options to the north of the Marina. This assessment was initially conducted over a 30 year planning timeframe and extended to 60 years for the preliminary design. Following the extension of the planning timeframe to 60 years, the Managed Retreat option was shown to greatly impact both public and private infrastructure. Based on an economic, environmental and social impact assessment the recommended coastal management option was a Staged Groyne approach.

The current study has resulted from recommendations in MRA (2006) that the shoreline movement and recommended coastal management option be reviewed in 5 years.

## 2.2 Study Area

The study area extends from the Mallee Reef Salient in the north to the North Yanchep Headland approximately 1 km south of ‘The Spot’ in the south and covers approximately 8 km of coastline. This is a large extension to the study area that was previously investigated by MRA (2006) and provides greater information on the shoreline movement trends and alongshore sediment transport.  Figure 2.1 shows the extent of the study area considered as part of this report.

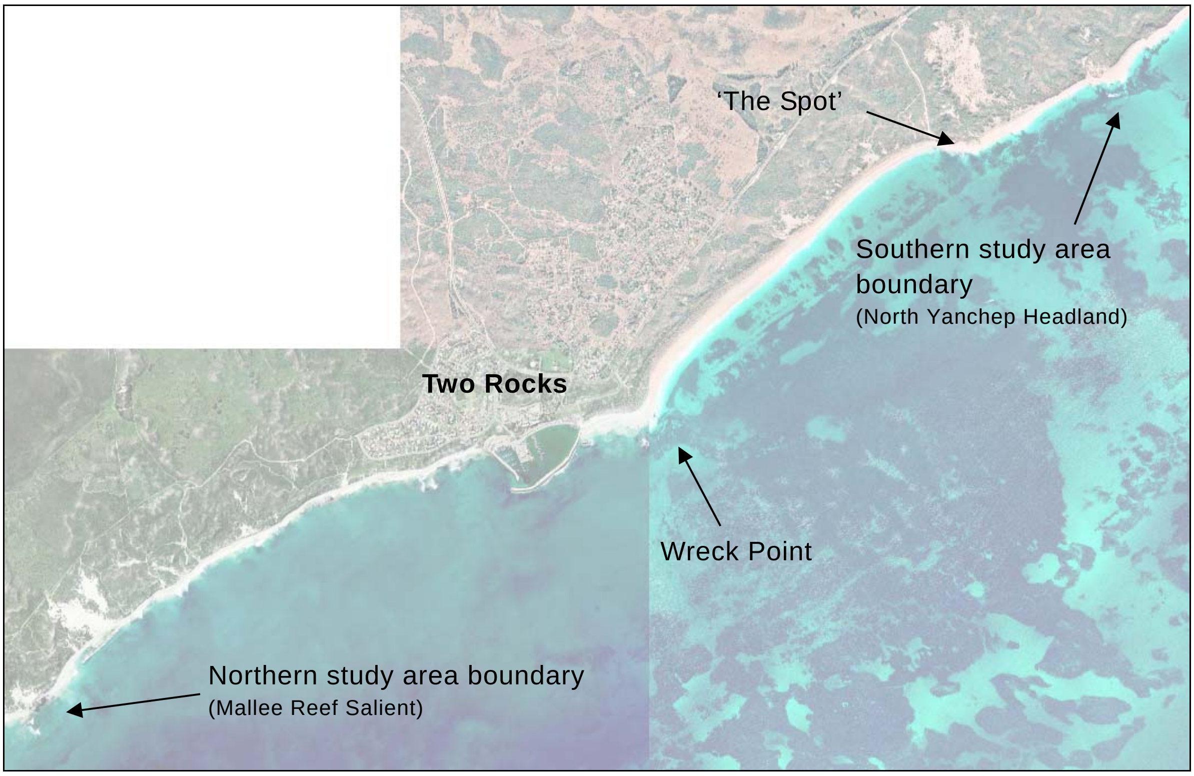



**Figure 2.1 - Study Area (2011 & 2004 Mosaic)**

The shoreline within the study area predominantly consists of a sandy beach, backed by dune systems of varying height, with isolated outcrops of limestone rock and nearshore reefs and rock platforms.

Investigations by Searle & Semeniuk (1985) and Eliot et al (2005) have classified the Mandurah to Two Rocks coastline in terms of primary and secondary sediment cells.  More recently a report prepared for DoT by Damara WA (2012a) classified the coastline between Cape Naturaliste and Moore River in terms of primary, secondary and tertiary level sediment cells.

The differences in cell hierarchy reflect the varying timescales for assessment of each sediment cell level.  Primary cells relate to geological processes and trends that may alter over geological timescales, but are considered to be relatively constant in the shorter developmental planning timeframes.  Secondary cells describe the contemporary sediment movement and inter-decadal trends and landform response (Damara WA, 2012a).  Tertiary cells generally cover the reworking and movement of sediment in the nearshore area with shoreline responses of the seasonal to inter-annual timescales.  Figure 2.2 shows an extract from Google Earth with the sediment cell boundaries from Damara (2012a) overlain.

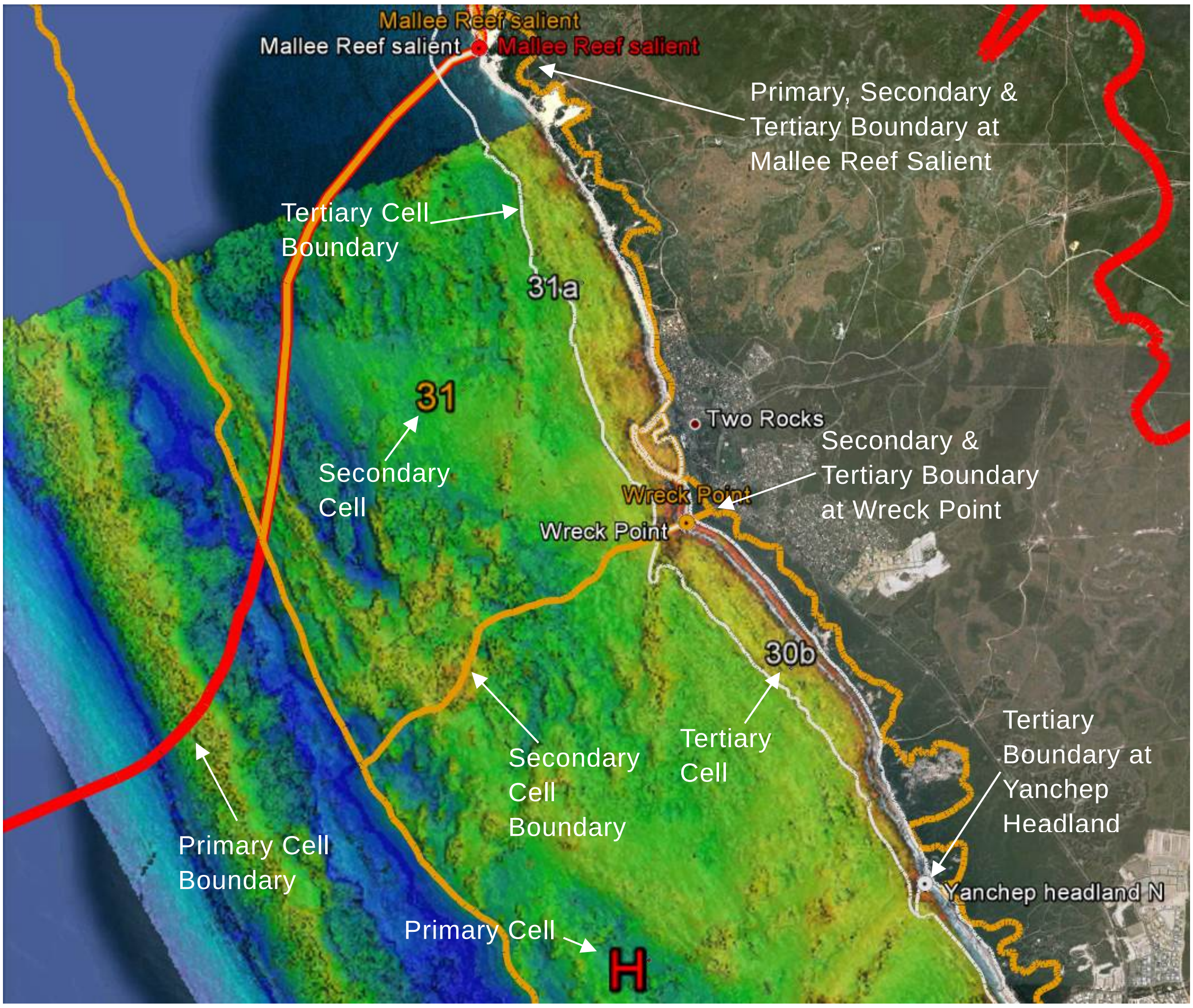



**Figure 2.2 - Damara (2012a) Sediment Cell Boundaries (Google Earth Image)**

The study area for this report falls within the primary sediment cell extending from Yanchep in the south to the Mallee Reef Salient in the north. This primary cell consists of two secondary sediment cells which extend from the primary cell boundaries to share a common boundary at Wreck Point to the south of the Marina.

At a tertiary level, the coastline is separated into three sediment cells. These tertiary cells cover the coastline as follows:

- Yanchep to North Yanchep Headland;
- North Yanchep Headland to Wreck Point; and
- Wreck Point to the Mallee Reef Salient.

The study area for this report covers the two tertiary cells from North Yanchep Headland to the Mallee Reef Salient and covers approximately two thirds of the primary sediment cell.

However, information for the remaining section of coastline within the primary sediment cell was able to be obtained from concurrent studies (MRA 2013a). Therefore, while the study area has been restricted to the coastline between the northern primary boundary and the southern tertiary boundary, it incorporates sediment movement information for the entire primary sediment cell.

This report will further estimate the sediment movements and pathways between North Yanchep Headland and the Mallee Reef Salient.

## 2.3 Site Setting

As part of the study MRA completed a site visit in December 2012 to inspect the area, ground truth coastal data and to map the position of exposed rock and reef.

As stated previously, the coastline within the study area is predominantly a sandy coastline, with isolated areas of limestone rock outcrops and nearshore reefs and rock platforms. An area of the shoreline near the southern end of the study area, known locally as 'The Spot', is shown in Figure 2.3.


**Figure 2.3 - Southern Study Area Coastline (6/12/12)**

Figure 2.3 shows that the coastline about The Spot consists of a series of limestone rock outcrops, backed by high dunes, with limited beach presence in front of the rock outcrops. Heading north from The Spot, the coastline becomes an increasingly wide sandy beach with low dunes. This trend of a wide beach with low dunes continues north towards Two Rocks as shown in Figure 2.4.

**Figure 2.4 - South of Marina - Looking South (6/12/12)**

North of the Marina, the coastline has a narrower sandy beach backed by high dunes with a steep erosion scarp. Immediately north of the Marina, the shoreline is receding past the current extents of the northern seawall. This has resulted in ad-hoc extensions to the seawall to protect the Marina from erosion as shown in Figure 2.5.

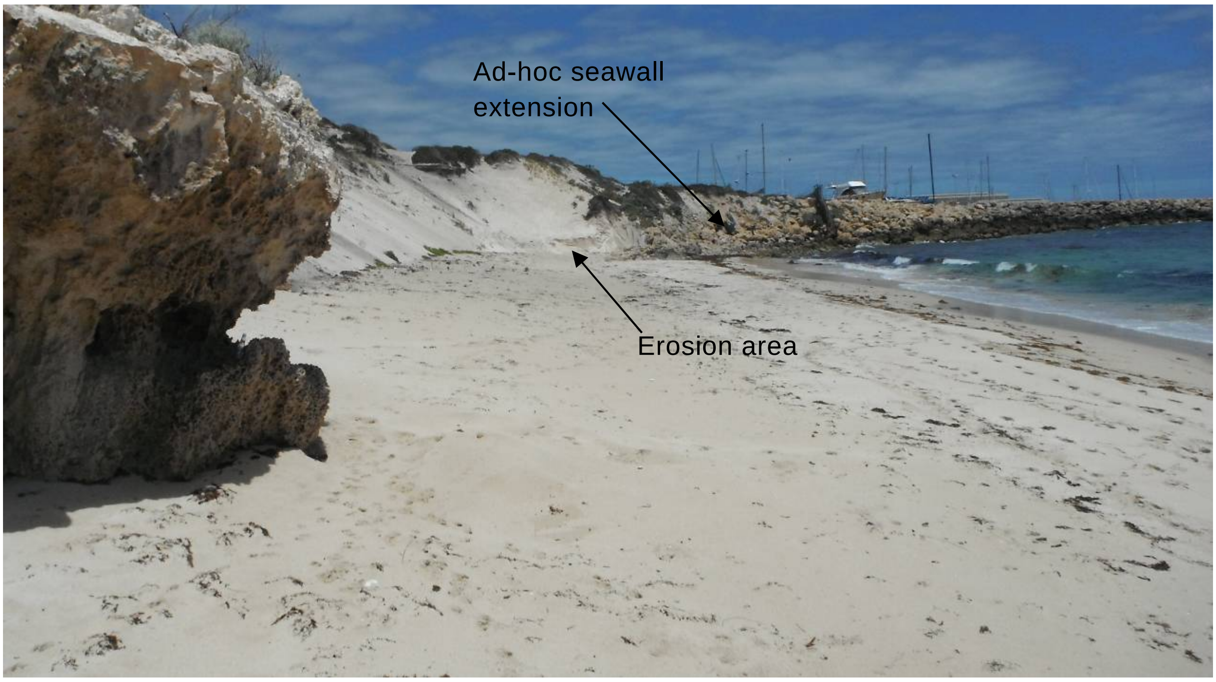



**Figure 2.5 - Erosion at the Northern End of the Marina (6/12/12)**

This area also includes a limestone rock outcrop located in the dune face that is currently exposed (Figure 2.5). The extent of this rock outcrop into the dunes is unknown.

Further north of the Marina the narrow beach continues with high dunes and a steep erosion scarp. At the small headland approximately 400 m to the north of the Marina, a series of rock platforms in the nearshore area have resulted in a wider beach forming. The dunes behind the nearshore rock platforms are still eroding (Figure 2.6).


**Figure 2.6 - Erosion North of the Marina (6/12/12)**

Approximately 600 m to the north of the Marina, beach access is provided in the form of the Sceptre Court stairs and viewing platform.  Continued shoreline recession in the area has now resulted in the stairs landing in the middle of the active beach (Figure 2.7).

**Figure 2.7 - Erosion Near the Sceptre Court Stairs & Viewing Platform (6/12/12)**

The overall trend of a narrow beach, steep eroding dune face and high elevation dunes continues to the northern end of the study area.  At a number of locations along the coastline, rock outcrops, nearshore rock platforms and reefs were noted.  The extent of limestone rock in the study area is discussed further in the following section.

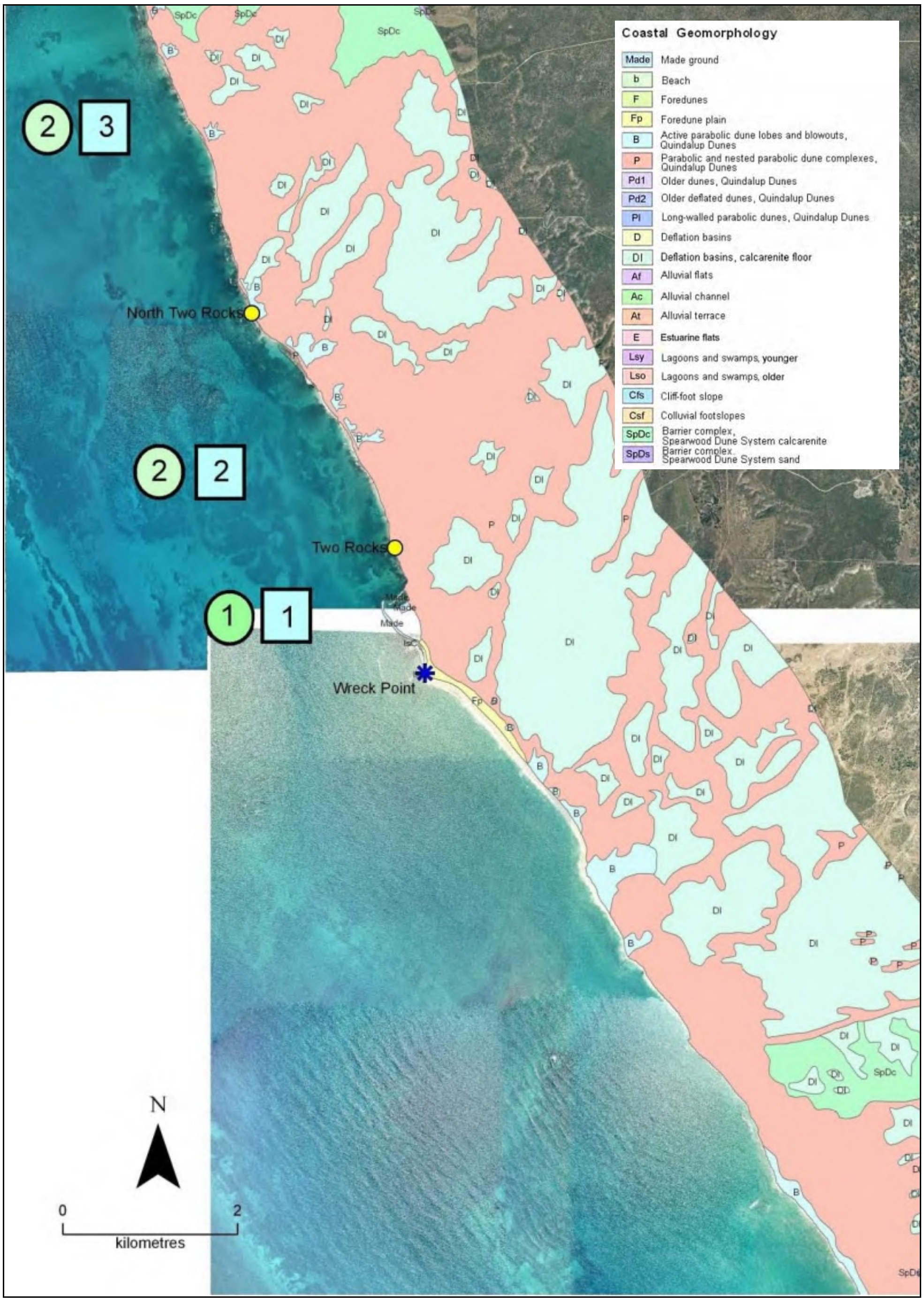
## 2.4 Geology & Geomorphology

The geology and geomorphology of the study area and greater Perth Metropolitan shoreline is described in detail by Searle & Semeniuk (1985).  The current shoreline lies on the Swan Coastal Plain, and generally comprises Holocene beach and dune sediment deposits overlying late Pleistocene, calcarenite limestone. These formations are the dominant, landforms along the coast (Searle & Semeniuk 1985).

Searle & Semeniuk (1985) broadly classified the coast into a number of sectors, with the study area falling in the Whitfords to Lancelin sector which the authors describe as a dominantly straight rocky shore with isolated accretionary cusps. The coast in this sector is generally characterised by rocky coasts and pocket beaches interspersed with straight sandy beaches (Searle & Semeniuk 1985).

This general characterisation of the sector is represented across the study area, with offshore reef platforms located to the north of the Marina, an accretionary cusp to the south of the Marina and sandy beaches and dune systems covering the majority of the study area. Limestone rock outcrops were also noted in several areas on site.

An assessment of the geology, geomorphology and vulnerability of the coastline for the Shires of Gingin and Dandaragan was undertaken in Damara (2012b). Figure 2.8 shows the results of the coastal geomorphology assessment for the Two Rocks area.




## Figure 2.8 - Two Rocks Coastal Geomorphology (Damara 2012b)

Overall, the geological assessment of the Two Rocks area in Damara (2012b) was sand overlying limestone. It was further determined that the area had a low to moderate landform vulnerability to coastal processes and potential sea level rise. This is a broad, regional scale assessment and does not apply equally to all sections of the coastline.

As part of this investigation, the extent of visible rock within the study area was assessed during the site inspection. Figure 2.9 shows a plan of the study area, indicating visible limestone rock outcrops, nearshore rock platforms and reefs.

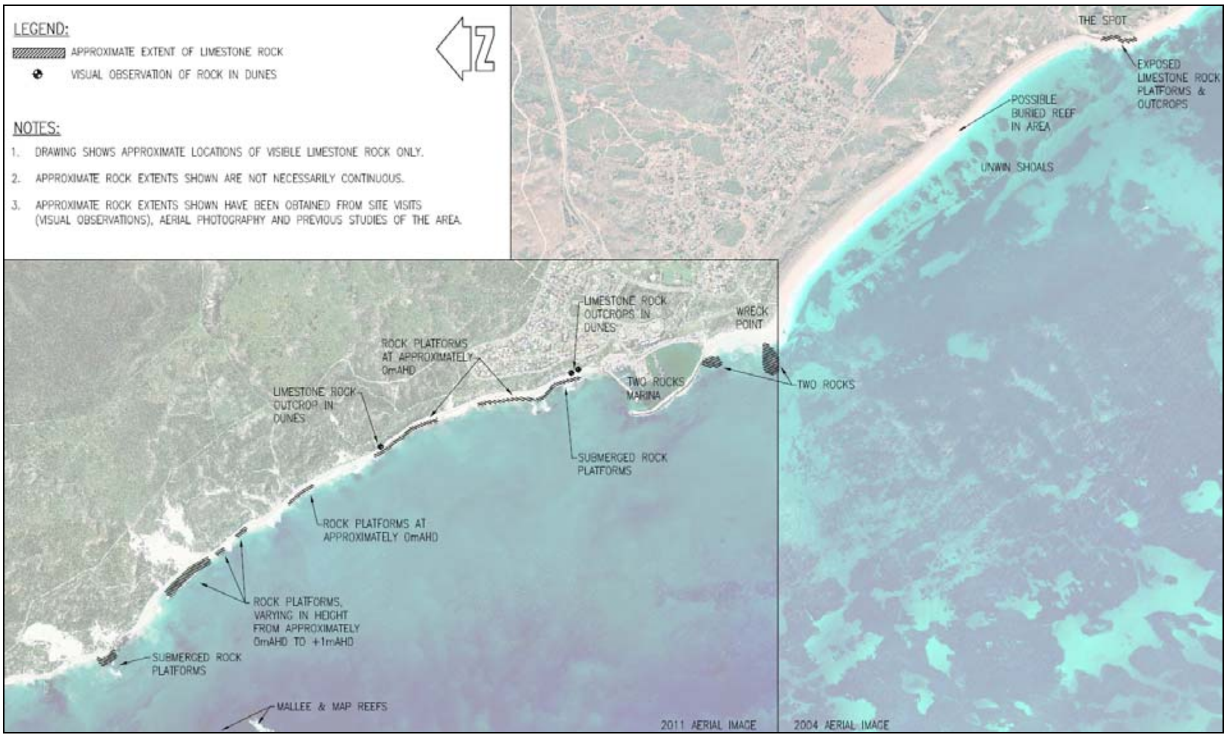



**Figure 2.9 - Extent of Visible Limestone Rock Outcrops, Platforms & Reefs**

At a meeting held between DoT, the City and MRA, DoT also noted that there were areas of limestone rock located in the dunes between Wreck Point and The Spot. It is recommended that the presence of rock in the dunes in the study area is investigated further.

## 2.5 Coastal Processes

From a coastal engineering perspective, the most important coastal processes are generally the interaction of waves, currents and beaches to transport sediment. There are three fundamental mechanisms that can transport sand towards or away from a point on the beach:

- Longshore sediment transport.
- Cross-shore sediment transport.
- Wind-blown sand transport.

The following sections discuss the fundamental mechanisms for the sandy shorelines which make up the majority of the study area.

### 2.5.1 Longshore Sediment Transport

A simplistic description of longshore sediment transport is that in the surf zone of sandy beaches, the breaking waves agitate the sand and place it into suspension. If the waves are approaching the beach at an angle, then a longshore current can form and this can transport the suspended sand along the beach. The suspended load transport is accompanied by a bed load transport where sand is rolled over the bottom by the shear of the water motion.

There can also be considerable variation in magnitude and direction of the longshore transport from season to season and year to year. In Perth, longshore sediment transport is typically north in summer and south in winter. The strong sea breezes blow from the south-west in summer, creating wind waves at an angle to the shoreline. This transports sediment to the north (Masselink and Pattiaratchi 2001). In winter, severe storms generate waves from the north, swinging to the south over their duration. This typically transports sediment to the south in winter storms (Masselink and Pattiaratchi 2001).

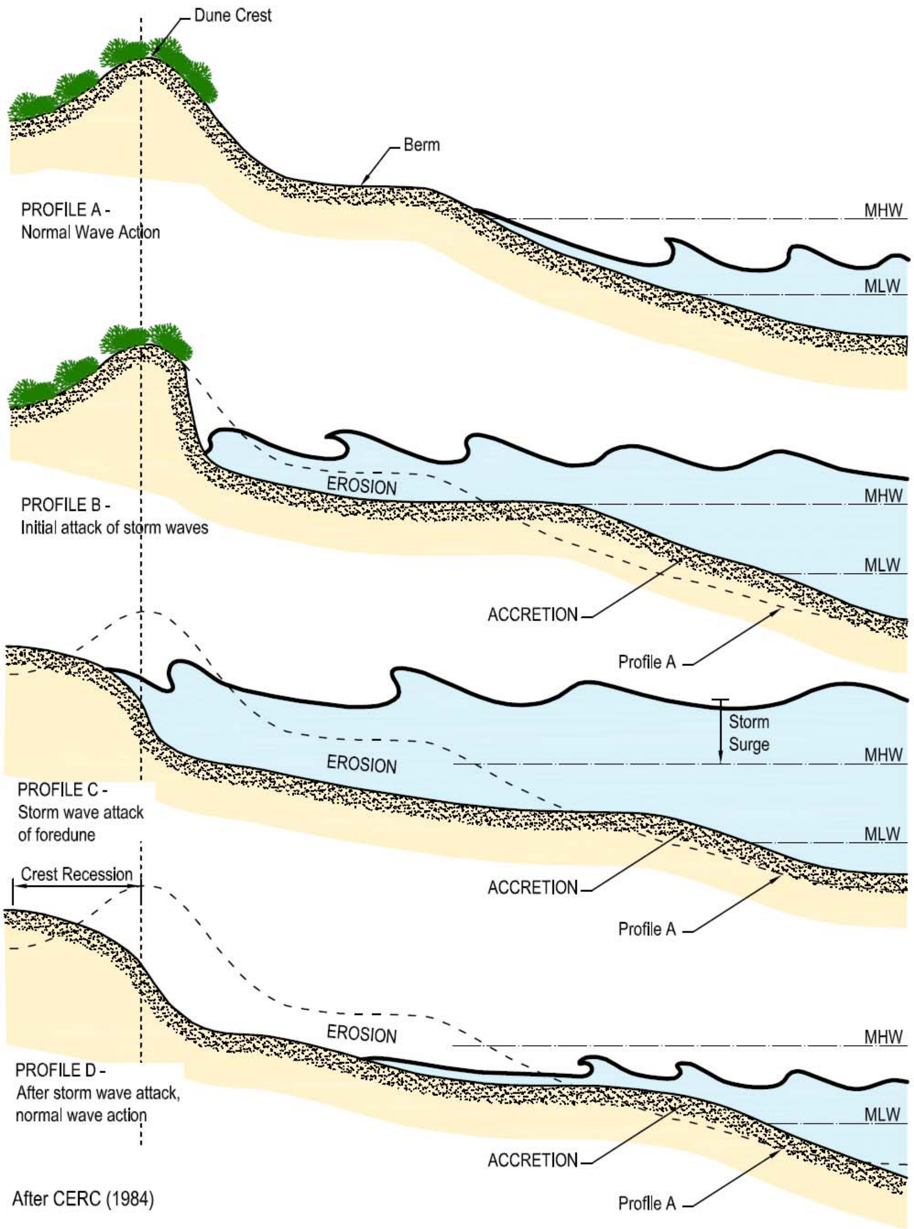
Previous studies on the local coastal processes have shown the overall sediment transport patterns for Two Rocks adhere to the patterns identified in Masselink and Pattiaratchi (2001) with an overall net movement of sediment from the south to the north.

This net movement pattern has resulted in the large accretions to the south of the Marina and erosion of the coastline to the north of the Marina since its construction.

### 2.5.2 Cross-Shore Sediment Transport

The second mechanism is the onshore/offshore movement of beach sand, commonly referred to as cross-shore sediment transport. During significant storm events, the strong winds generate high steep waves and an increase in water level known as storm surge. These factors, acting in concert, allow the waves to attack the higher portion of the beach that is not normally vulnerable.

For sandy beaches, the initial width of the surf zone is often insufficient to dissipate the increased wave energy of the storm waves. The residual energy is often spent in eroding the beach face, beach berm and sometimes the dunes. The eroded sand is carried offshore with return water flow where it is deposited and forms an offshore bar. Such bars can eventually grow large enough to break the incoming waves further offshore, causing the wave energy to be spent in a wider surf zone. This is shown diagrammatically in Figure 2.10.




### Figure 2.10 - Severe Storm Erosion Mechanism

Erosion of sandy beaches during storms can be quite rapid and significant changes can occur in a matter of hours. Subsequent to the storm, the swell activity may move sand from offshore to the shore. This onshore process is generally at a much, much slower rate than the storm erosion.

Site specific evidence of the loss of sediment to cross-shore sediment transport was shown previously in Figures 2.5 to 2.7. The high dunes to the north of the Marina show large erosion scarps resulting from large volumes of sediment being lost during high wave and water level events. This lost sediment is subsequently not being replenished through the onshore sediment processes, resulting in the loss of the dunes.

### 2.5.3 Wind-blown Sand

The final mechanism for the movement of sediment is wind-blown sediment transport. This can move sand from the beach into nearby dunes. This is the mechanism by which coastal dunes are formed and grow. There needs to be careful management of the public use and access through coastal dunes to prevent dune blowouts occurring due to lack of vegetation. The coastal dunes form a natural buffer to accommodate the erosion during severe storms.

## 2.6 Typical Metocean Conditions

Any comprehensive study of coastal processes must be done with knowledge of the fundamental driving forces. Consequently, an understanding of the magnitude and potential variation in the wind, waves and tide conditions are important in assessing the coastal processes.

### 2.6.1 Wave Climate

MRA (2006) investigated the wave climate near Two Rocks through substantial wave modelling of the study area using the 2GWave model. 2GWave is a finite difference model, and accounts for the following wave transformation processes:

- wave refraction and shoaling;
- atmospheric forcing causing wave generation;
- energy dissipation due to bottom friction and white capping;
- wave breaking in deep and shallow water;
- non-linear wave - wave interactions.

This modelling enabled the wave climate for approximately 16 km of coastline adjacent to the Marina to be simulated. The results were presented in MRA (2006) and will not be repeated in this report.

It should be noted that variability in wave conditions and the frequency of occurrence of key wave events of such as swell, sea breeze, moderate and severe storms occurs on an annual basis. These key events generally dominate the movement of sediment along the Perth metropolitan coastline and any changes in the relative occurrence can influence shoreline position (MRA 2012).

### 2.6.2 Water Level Conditions

DoT has measured water levels at the Two Rocks Marina since 1994. The tide is predominantly diurnal (one tidal cycle each day) and is relatively small in amplitude with a typical daily range of 0.5 m during spring tides.

An initial comparison between measurements at Two Rocks and Fremantle shows that recorded water levels are very similar between the two locations (Figure 2.11). This is expected due to their relative proximity. Due to the similarity of measurements, MRA have assessed the Fremantle measurements, where water levels have been recorded for more than a century. This provides a more comprehensive record of water levels for analysis and is believed to be applicable for the study area.

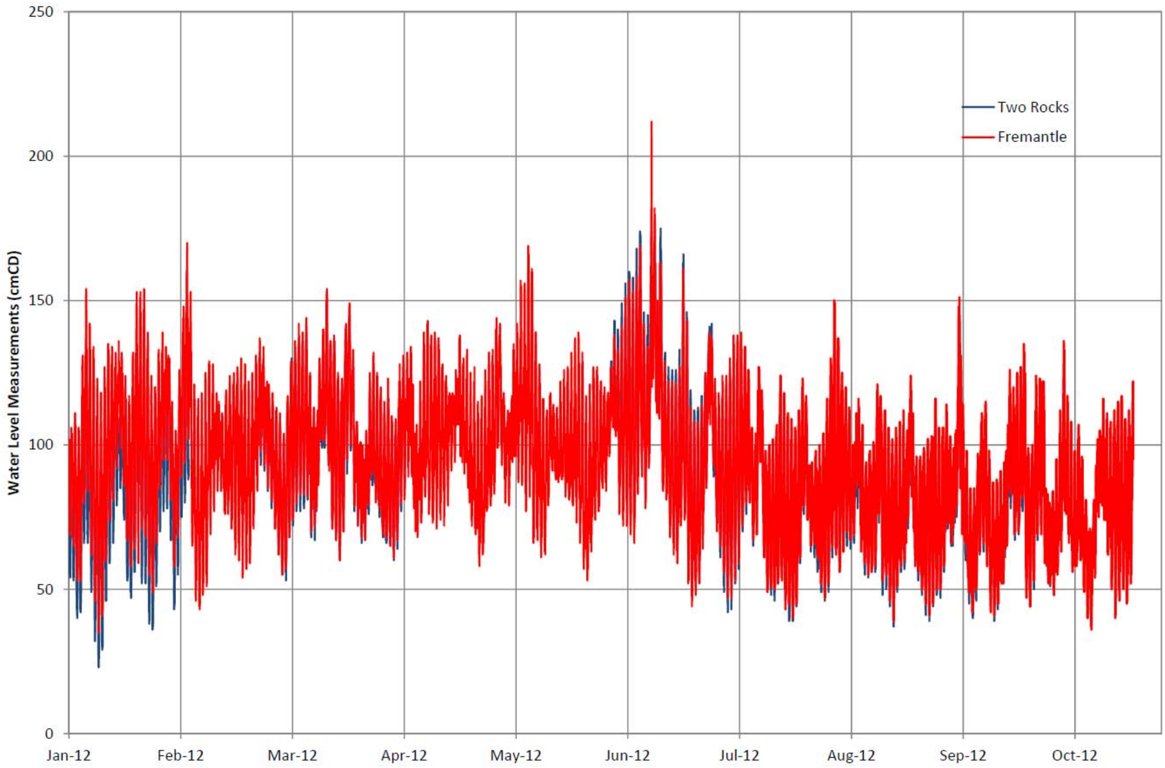



**Figure 2.11 - Comparison of 2012 Measured Water Levels at Fremantle and Two Rocks**

MRA has previously determined the most reliable data in this period has been measured since approximately 1950. Therefore only data since 1950 has been used in this investigation.

MRA (2013b) analysed the annual mean water levels between 1950 and 2012. Figure 2.11 presents the annual mean water level at Fremantle between 1950 and 2012, with the linear trend superimposed.

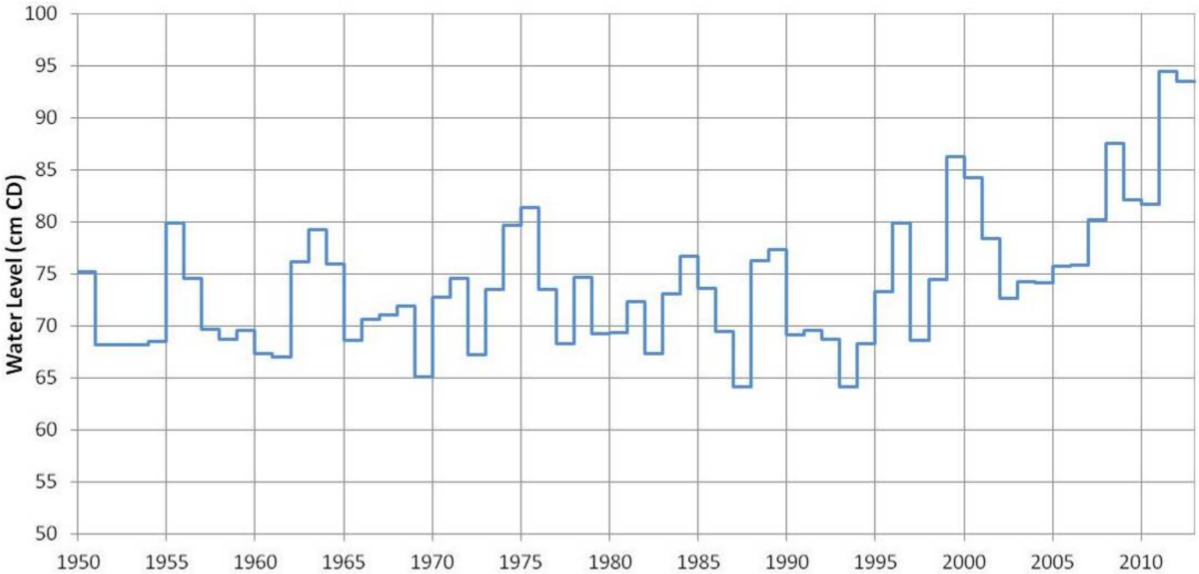



**Figure 2.12 - Annual Mean Water Level at Fremantle (1950 to 2012)**

Figure 2.11 shows that 2011 and 2012 have the highest average mean water levels in the entire data set. Higher water levels allow waves to attack the higher portion of the beach that is not normally vulnerable. Sustained high water levels may therefore contribute to increased beach erosion.

Total water level variability is due to a number of influences which vary at timescales of hours, days, years etc. The combination of peaks in these cycles can elevate the mean observed water level. Seasonal shifts in the sea level occur due to meteorological effects and the action of the Leeuwin Current. Typically, the mean sea level rises 0.1 m during winter and falls 0.1 m during summer. Eliot (2010) also states that the peak in an 18.6 year lunar nodical tidal cycle was in 2007, resulting in elevated mean water levels.

Figure 2.11 also shows that the rate of increase in sea level rise appears to have been greater over the past 15 years than the period prior, possibly as a result of the combination of inter-annual cycle peaks and increasing global sea levels.

In general the period between 2004 and 2012 is shown to have an elevated mean water level compared to the longer term record. This increases the potential for storm erosion. It is likely that future mean water levels will be higher than those in the recent past, increasing the erosion pressures on vulnerable shorelines.

### 2.6.3 Wind Climate

The wind regime influences coastal processes through the generation of ocean waves and currents as well as feeding dune systems with wind-blown beach sand.

The seasonal weather patterns along the Perth metropolitan shoreline are largely controlled by the position of the so called Subtropical High Pressure Belt. This is a series of discrete anticyclones that encircle the earth at the mid-latitudes (20° to 40°). These high pressure cells are continuously moving from west to east across the southern portion of the Australian continent. A notional line joining the centres of these cells is known as the High Pressure Ridge.

In winter this ridge is typically located between 25° to 30° S, to the north of Perth (located at 32° S). During summer, the ridge moves south and lies between 35° and 40° S. This latitudinal shift in the position of the High Pressure Ridge is fundamental to the seasonal wind patterns experienced in the region.

In addition to these regional scale effects that cause seasonal variations, the meso-scale phenomenon of a land-sea breeze system is commonly experienced along the Perth metropolitan shoreline, causing wind variations on a daily time scale. Offshore breezes are experienced in the morning, which swing around to the south-west and south in the afternoon. This is often referred to as the ‘sea breeze’ but is a land/sea breeze system.

## 2.7 Bathymetry

Any comprehensive study of coastal processes must be done with knowledge of the nearshore conditions. A critical part of this is determining the bathymetry that comprises the study area. Figure 2.12 shows the local bathymetry of the coastline around Two Rocks. The extent of the chart stops just north of the Spot.

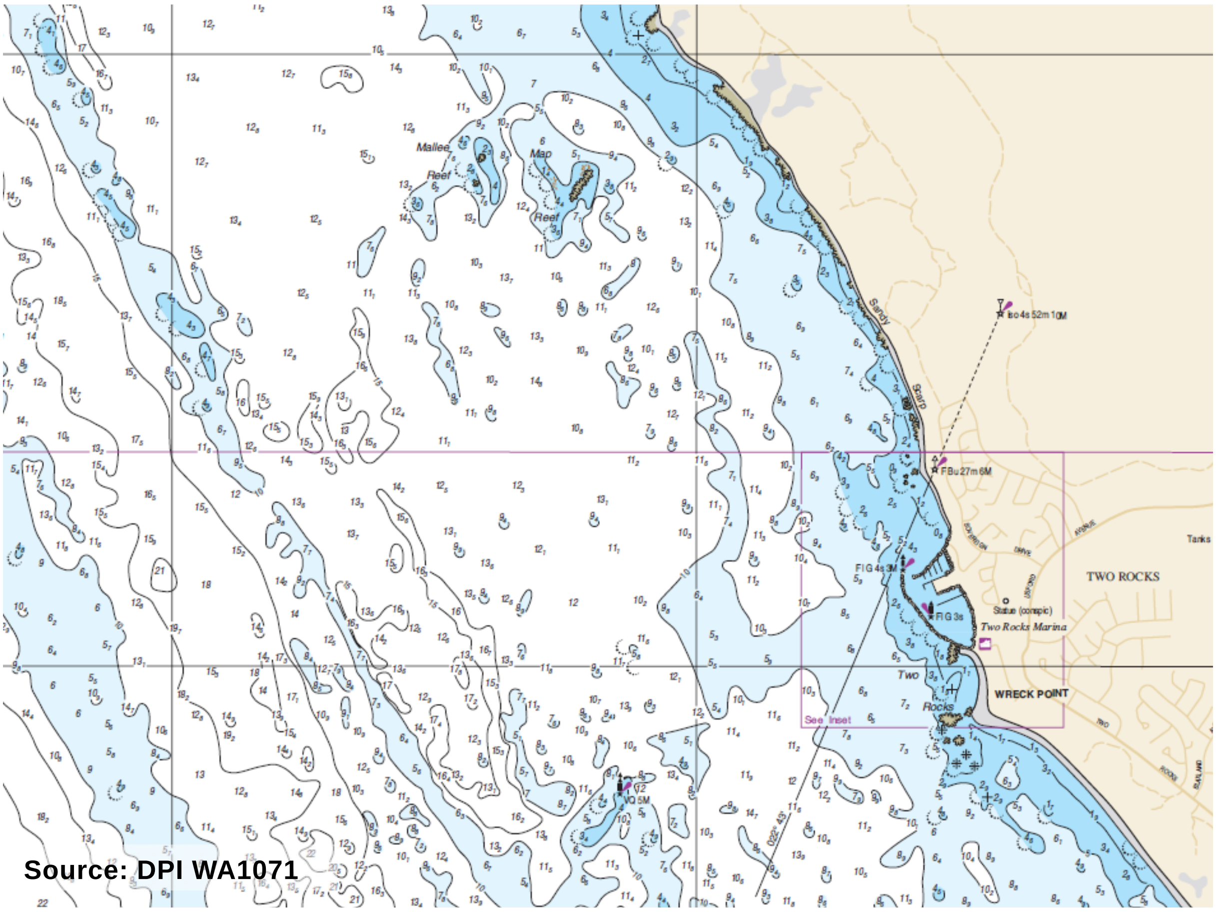



**Figure 2.13 - Two Rocks Bathymetry**

The extract of the nautical chart shows a number of reefs and submerged rock locations in the area surrounding the Marina. It can also be seen that the area immediately surrounding the Marina is shallower than the sections of shoreline further north and south.

In addition to nautical charts, DoT provided beach and hydrographic surveys for use in this assessment. The most recent surveys were taken in 2002 and 2012 and cover the area immediately surrounding the Marina and the coastline for several hundred metres to each side.

## 2.8 Coastal Data Availability

A summary of the available local coastal data for this assessment is given in Table 2.1. This list is not a comprehensive guide to all available data but details some of the more useful and readily available data.

### Table 2.1 – Coastal Data

| Available Data | | | |
|---|---|---|---|
| Type | Reference | Data Period | Comment |
| Nautical Chart | DPI WA 1071 | 2007 | Offshore and nearshore bathymetry |
| Wave Data | Directional Waverider Buoy RDW47 | From 1991 | DoT operated buoy in approximately 48 m of water, south west of Rottnest Island |
| Wave Data | AWAC | 2012/2013 | Installed by DoT in January 2013 in approximately 10m of water |
| Tidal Data | Two Rocks Tide Gauge | 1994 onwards | Fremantle tide gauge data also available |
| Survey Data | DoT – Drawing No. 594-3-1 to 594-3-3 | 2002 | Hydrographic & beach survey |
| | DoT – Drawing No. 594-21-1 to 594-21-3 | 2012 | Hydrographic & beach survey |
| | DoT – Drawing No. 594-23-1 | 2002 to 2012 | Difference Plot of 2002 and 2012 hydrographic surveys |
| | LiDAR | 2009 | Hydrographic survey from Two Rocks to Cape Naturaliste |
| Shoreline Movement Plans | DoT Drawing No. 351-22-04, 351-23-04, 351-24-02 | 1965 to 2011 | Shoreline movement plans showing vegetation lines and shoreline position |
| Sediment Cells | Moore River to Cape Naturaliste (Available from DoT website) | 2012 | Outlines primary, secondary and tertiary sediment cell boundaries |

Information that was not available but could assist future investigations in the area include:

- Beach, nearshore and offshore profiles that extend from behind the crest of the dune to several hundred metres offshore and are continuous and conducted at regular timeframes; and
- Hydrographic and beach surveys completed with greater capture of data and undertaken at more regular periods.
- Geotechnical surveys.

In addition, MRA have shoreline movement plans that have been prepared in-house and were used in the study.

# 3. Coastal Processes Investigations

## 3.1 Assessment of Coastal Processes

The Draft State Coastal Planning Policy (SPP) 2.6 (WAPC 2012) was used as a guideline for determining the required allowances for coastal processes over the planning period and the potential future vulnerability of the Two Rocks coastline. This is generally consistent with the approach undertaken in MRA (2006), which was conducted using the 2003 State Coastal Planning Policy (WAPC 2003).

As this study is not specifically concerned with determining the required setback to development, the Draft SPP 2.6 was only used as a guide. Schedule One of the Draft SPP 2.6 provides guidance on calculating the necessary width to allow for coastal processes (including erosion, accretion and inundation) by allowing for landform stability, natural variability and climate change over the proposed planning period.

The Draft SPP 2.6 states that the required allowances for coastal processes should be calculated based on the coastal classification and should consider each of the factors listed in the Draft SPP 2.6 for that coastal type. While Figure 2.1 showed that the coastline adjacent to the Marina includes areas of rock outcrops, reefs and rock platforms, the extent and elevations of these rock areas are unknown. Therefore, the study area will be classified as a Sandy Coast for the purposes of determining the evaluation criteria stated in the Draft SPP 2.6.

Based upon a Sandy Coast classification, the following criteria are to be used to assess the required allowances for coastal processes and climate change.

- S1 Severe Storm Erosion – An allowance for the current risk of storm erosion based upon a series of storms, with elevated water levels and an Average Recurrence Interval (ARI) of approximately 100 years in relation to beach erosion. There is also a requirement to consider potential longshore erosion during the severe storm event due to interruption in longshore sediment supplies as a result of adjacent structures such as the Marina.

- S2 Long Term Trends – An allowance for historic shoreline movement trends in order to provide an appropriate allowance for the planning period.

- S3 Climate Change – An allowance for erosion caused by potential sea level rise, with SPP 2.6 adopting a value of 0.9m for sea level rise in the coming 100 years.

The S1, S2 and S3 allowances will be combined to determine the estimated allowance for coastal processes for the coastline north of the Marina.

The allowances for coastal processes will be referenced to the Horizontal Setback Datum (HSD), which is defined as the toe of the erosion scarp on an eroding shoreline, and the extent of vegetation growth on an accreting shoreline in DoT (2009).

The City requested that timeframes of 10 and 25 years be used as the planning periods for this assessment in order to identify areas that are potentially at risk in the shorter term. These are shorter timeframes than recommended in the Draft SPP 2.6 or investigated in MRA (2006).

## 3.2 Severe Storm Erosion

Severe storm events have the potential to cause erosion to a shoreline through the combination of higher, steeper waves generated by sustained strong winds and increased water levels.

These two factors acting in concert allow waves to erode the upper parts of the beach not normally vulnerable to wave attack.

The Draft SPP 2.6 requires the use of a credible sediment transport model to calculate the maximum cross-shore storm erosion caused by a 100 year ARI storm event. The severe storm erosion component is also required to include consideration of the potential for additional erosion resulting from the interruption of available longshore sediment supply during a severe storm event.

MRA have completed sufficient validation to show the SBEACH computer model to be a credible model for cross-shore erosion modelling. The SBEACH computer model was developed by the Coastal Engineering Research Centre to simulate beach profile evolution in response to storm events. It is described in detail by Larson & Kraus (1989). Since then the model has been further developed, updated and verified based on field measurements (Wise et al, 1996). Primary input to the model includes time histories of wave height, period, water elevation, pre-storm beach profiles and median sediment grain size (Wise et al 1996).

### 3.2.1 SBEACH Profile

The SBEACH profile selected for the severe storm erosion modelling was located on the eroding shoreline north of the Marina. This profile extends out perpendicular from the shoreline in the approximate location shown in Figure 3.1.

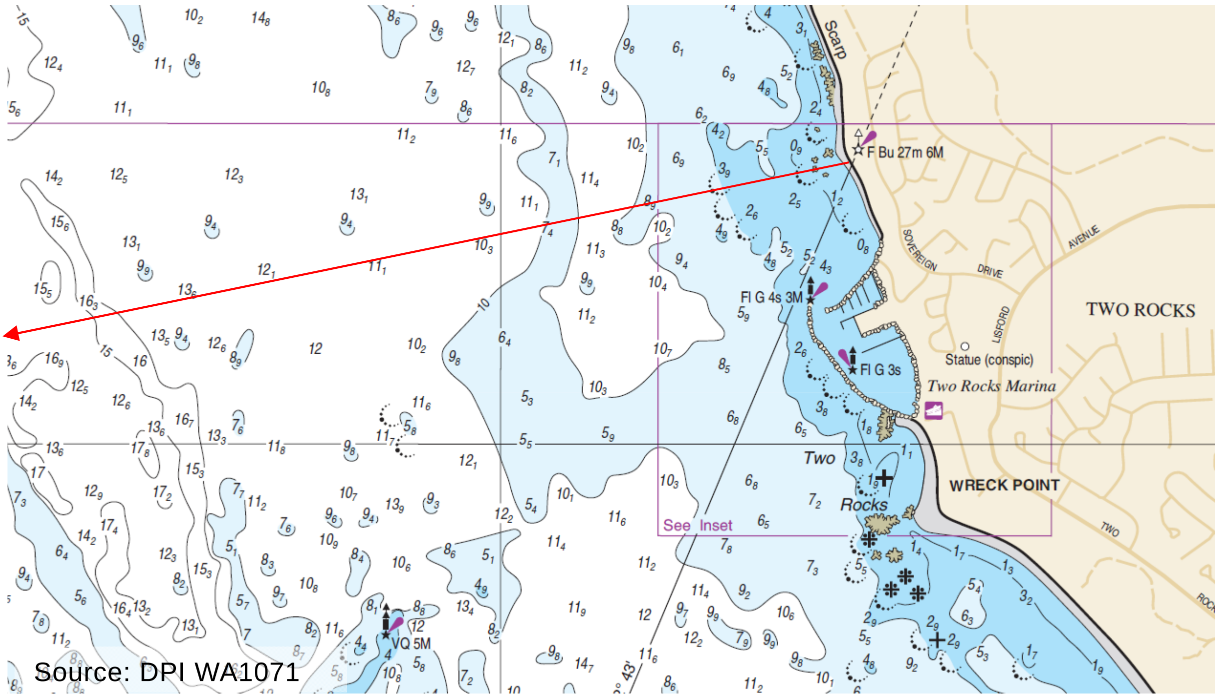



**Figure 3.1 - SBEACH Profile**

The beach profile was compiled using Department of Planning and Infrastructure (DPI) nautical charts (WA 1071, AUS 754), beach and nearshore water surveys conducted by MRA as well as 2012 beach and hydrographic surveys undertaken by DoT.

The sediment size used in the SBEACH analysis was obtained from on-site sampling performed by MRA. Composite samples from the waterline, beach berm and dune have been analysed for Particle Size Distribution (PSD) to obtain the median grain size ($d_{50}$) of 0.37 mm.

### 3.2.2 Storm Event

The Draft SPP 2.6 requires the use of a 100 year ARI event for erosion and accretion modelling of the study area. Previously DoT have recommended MRA model three repeats of a storm experienced in Western Australia in July 1996. Three repeats of this storm bring the duration to approximately 330 hours. The duration of this storm with elevated water levels and high waves is believed to conservatively represent the 100 year ARI event in relation to beach erosion.

The wave conditions experienced during the July 1996 event were recorded by DoT in approximately 48 m of water near Rottnest Island. The SBEACH model is not capable of accurately calculating the wave attenuation of these offshore conditions to the nearshore waters north of the Marina.

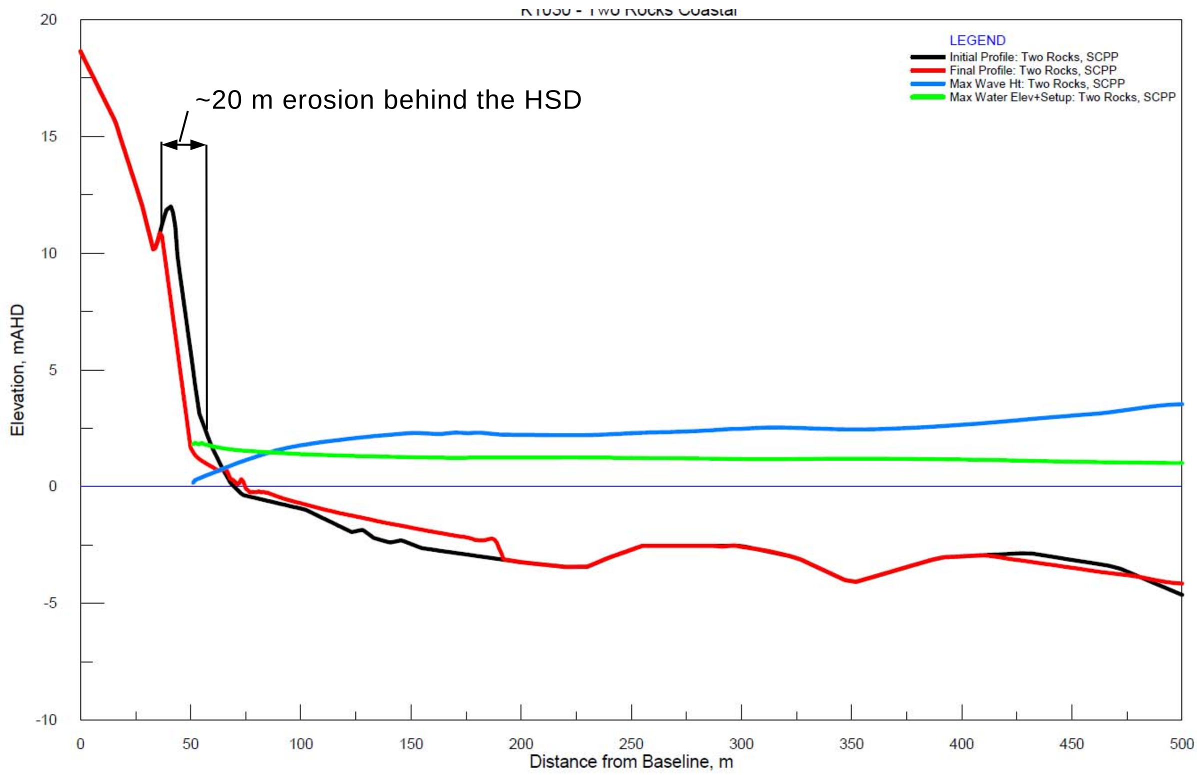
Therefore, the results of 2GWave modelling completed for MRA (2006) were used to transform the offshore wave conditions into the nearshore area. Using the modelling results, attenuated values for the inshore significant wave height ($H_s$) and wave period ($T_p$) were obtained for use in the severe storm erosion modelling.

The water levels during the July 1996 were also recorded by DoT in approximately 5 m of water at Fremantle. These water levels were input in SBEACH with a peak water level of +0.99 mAHD.

The results of the SBEACH storm erosion modelling are presented in the following section.

### 3.2.3 Modelling Results

Figure 3.2 shows the results of the SBEACH storm erosion modelling for the study area. The initial and final beach profiles, peak water levels and peak wave heights are also shown.




### Figure 3.2 - Severe Storm Erosion North of Marina

From on-site observations it was determined that the HSD for the coastline to the north of the Marina was the toe of the erosion scarp at +2.5 mAHD. As shown in Figure 3.2, the extent of erosion behind the HSD is approximately 20 m.

Due to the close proximity of the Marina, the potential impact of the structure on the available longshore sediment supply during a severe storm event was assessed. It was determined that the structure was only likely to restrict sediment supply for a south or south westerly event. Under these events, the Marina would act to shelter the shoreline immediately north of the Marina and the transport is likely to be reduced. Under a north, north westerly or westerly storm event, the Marina is not believed to restrict the available longshore sediment supply.

Therefore, no additional allowance has been made for erosion resulting from the interruption of available longshore sediment supply during a severe storm event.

The allowance for severe storm erosion (S1) will be 20 m. This is slightly more than the 17 m estimated in MRA (2006). The input and output data used in the SBEACH storm erosion modelling is included as Appendix 1.

### 3.2.4 Influence of Perched Beaches on the Modelled Erosion Extent

As noted in Section 2.4, rock outcrops and platforms were noted both above and below the water within the study area. This indicates that the area may consist of areas that have sand overlying a rocky underlayer, known as a perched beach.

Perched beaches can undergo rapid changes in beach width during storm events (MRA 2010). This is due to the following mechanisms:

- The low volumes of sediment available for erosion.  If a storm event has a capacity to move a fixed volume of sediment it will cut further landward on a perched beach than on a nearby sandy beach; and

- The influence of bed-rock on the groundwater conditions in the beach, as shown in Figure 3.3.  Outgoing water contains a larger amount of sediment than sandy beaches as the water cannot percolate through the bed-rock.

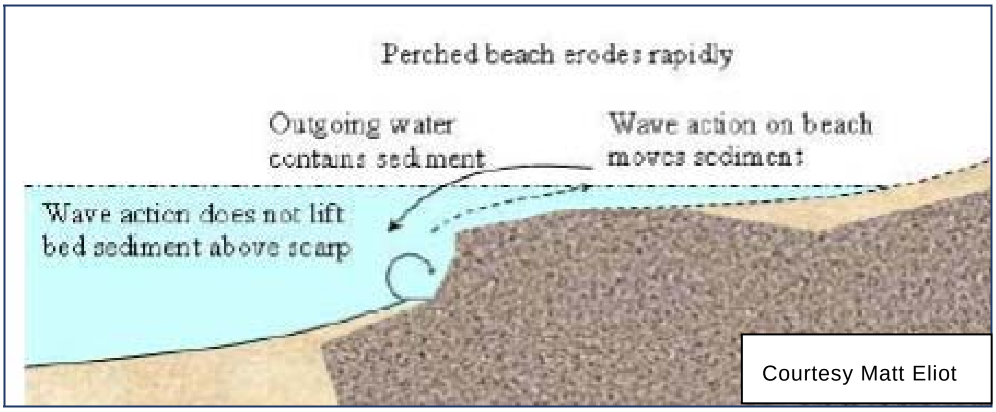



**Figure 3.3 - Process of Perched Beach Erosion (Ilich 2008)**

Therefore, perched beaches are expected to be more sensitive to extreme water levels and changes in wave energy than sandy beaches.  Perched beaches are also found to accrete more rapidly than sandy beaches due to the increased deposition of sand on the underlying reef (MRA 2010).  This process is shown in Figure 3.4.

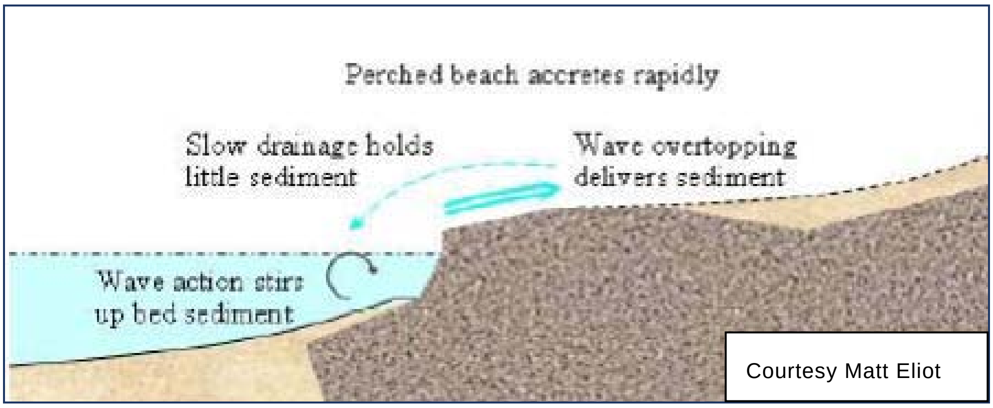



**Figure 3.4 - Process of Perched Beach Accretion (Ilich 2008)**

It is noted that the beach in front of the Two Rocks dunes is quite wide and may indicate that post storm recovery of the beach profile is able to occur in line with the accretion pattern shown in Figure 3.4.

The potential for perched beaches to alter the extent of erosion modelled through SBEACH was considered as part of the severe storm erosion modelling process.  During this analysis, it was noted that the inclusion of perched beaches did not have a noticeable impact of the extent of severe storm erosion modelled.  This may be in part due to the gaps in the nearshore survey data that do not allow the perched beach profile to be modelled accurately.  Should continuous beach profiles become available in the future, the potential impact of the perched beaches on the erosion extent could be further explored.

## 3.3 Historical Shoreline Movement Review

Changes in shoreline positions occur on varying timescales from storm to post storm, seasonal and longer term (Short 1999). The severe storm erosion allowance accounts for the short term storm induced component of beach change. The Historical Shoreline Movement (S2) Allowance accounts for the movement of the shoreline that may occur within the planning timeframes. To estimate the S2 Allowance, long term historical shoreline movement trends are examined and likely future shoreline movements predicted.

Previously, the shoreline movement assessment covered a section of coastline extending from approximately 1.0 km south of the Marina to 1.5 km to the north. For the current investigation, the extents of the shoreline considered have been extended to cover approximately 4 km either side of the Marina. Chainage 0 m is located at the south of the study area while Chainage 8,600 m is located at the northern end of the study area, at Mallee Reef Salient.

Typically, shoreline movement analysis uses the historical position of the vegetation line from aerial photographs to determine the movements of the shoreline over time. The vegetation line is often used as an indicator of the long term shoreline position, as it is less sensitive to changes in water levels such as tides and storm erosion than indicators like the water line.

The Draft SPP 2.6 recommends that shoreline movement analysis should be based on a review of available shoreline records carried out at roughly five yearly intervals. This should include historic beach and bathymetric surveys where available. MRA (2006) looked at the shoreline movement from 1965 to 2004. For this report, the shoreline movement trends were updated to cover the period 1965 to 2011 using the following information for the area:

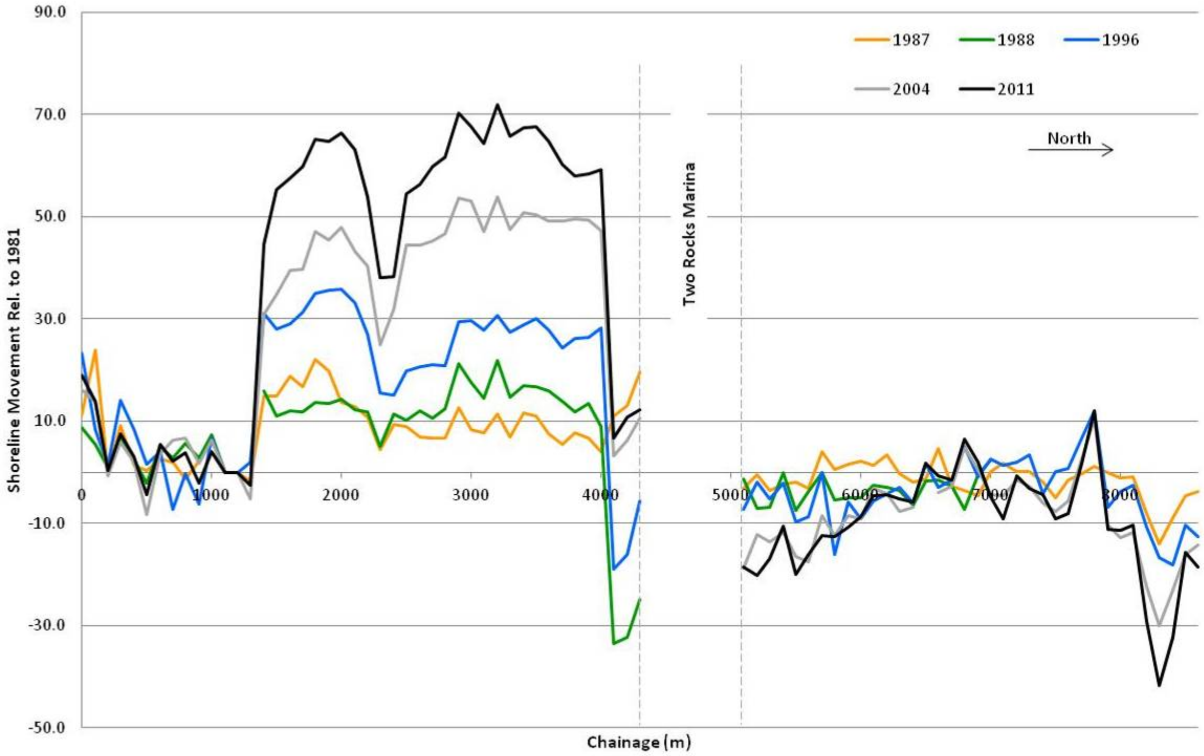
- Vegetation lines provided by DoT.
- Vegetation lines by MRA (MRA 2013a).

While MRA endeavoured to obtain shoreline movement data at roughly 5 year intervals, the availability and actual extents of reliable data has meant that this was not achieved for some periods. Specifically, the 1965 vegetation does not cover the full extent of the extended study area considered as part of this report. Therefore, the next full coverage vegetation line for the study area of 1981 was used as an alternative baseline.

The accuracy of the position of these vegetation lines is believed to be in the order of ±5 m, depending on the resolution of the aerial photographs and the rectification process.

It was also noted that the methods used by DoT to obtain the position of the vegetation lines in the most recent of DoT's lines has altered from the recommended methods of extraction identified in DoT (2009). This may have introduced errors into the most recent vegetation lines, which appear to overestimate shoreline recession and underestimate shoreline accretion.

From the vegetation lines, the position of the shoreline was determined at 100 m intervals for the study area. From these recorded shoreline positions, the relative shoreline movement was estimated and is shown in Figure 3.5.




## Figure 3.5 - Historical Shoreline Movement Relative to 1981 Baseline

Shoreline movement trends can be compared to changes in fundamental driving forces such as meteorological effects, climate change and coastal structures. This can help to identify potential contributors to the shoreline changes observed across the study area.

The shoreline movement analysis indicates that:

- For the shoreline between The Spot (~Chainage 1,000 m) and the southern side of Wreck Point, substantial long term accretion trends are noted.
- The area between Wreck Point (Chainage 4,000 m) and the Marina has continued to accrete, though at a slower rate than the majority of the southern coastline.
- For the shoreline north of the Marina, the trend of shoreline recession has continued. This effect is most prevalent for the 1,500 m of coastline north of the Marina.
- Substantial erosion is occurring at the northern most end of the study area, although this is several kilometres from the Two Rocks development.

The 1981 analysis used for the extended study area does not capture the shoreline movement for the period immediately after the construction of the Marina. This was previously assessed in MRA (2006) through the use of the 1965 shoreline position line. Therefore, the movement relative to 1965 was reassessed and is presented in Figure 3.6.

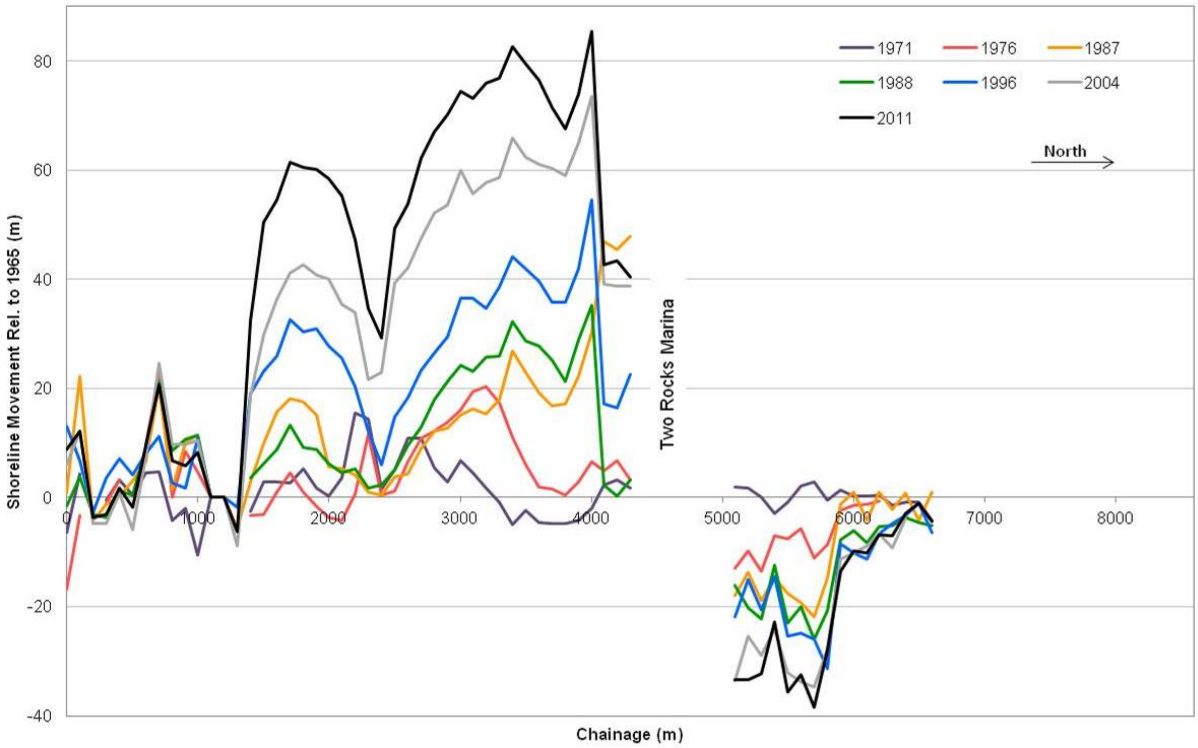



**Figure 3.6 - Historical Shoreline Movement Relative to 1965 Baseline**

The figure shows between 1965 and 1971 there was minimal change in shoreline position. From 1971 to 2011 there has been consistent and considerable accretion south of the Marina and erosion to the north. As previously noted by Halpern Glick (1986) and MRA (1997 & 2006) this suggests the construction of the Marina in 1973 caused significant changes to the sediment transport patterns of the area and is responsible for the erosion to the north of the Marina.

In order to estimate the potential future shoreline movement of the coastline north of the Marina, the shoreline movement rates were determined. Average shoreline movement rates for the periods spanning 1981 to 2004 and 1981 to 2011 were obtained for each chainage within the study area and are shown in Figure 3.7.

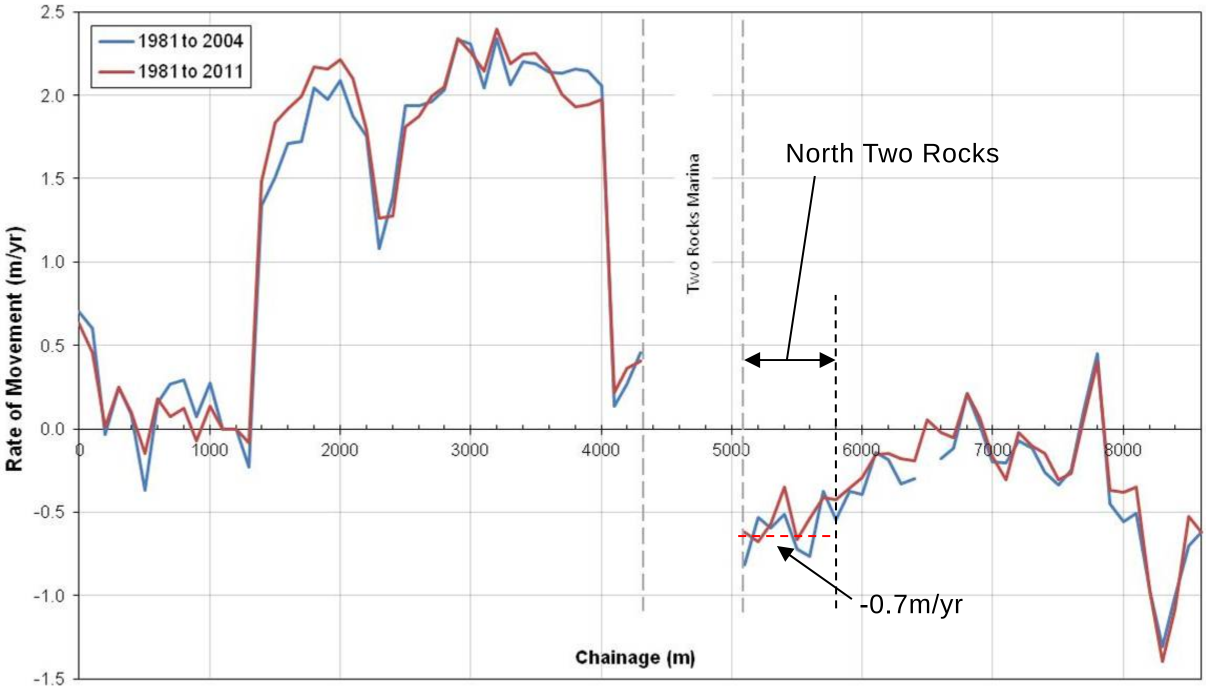



**Figure 3.7 - Shoreline Movement Rates Relative to 1981 Baseline**

The main area of development north of the Marina is located between Chainage 5,100 and 5,800 m. As shown in Figure 3.7, this section of coastline has a maximum erosion rate of approximately 0.7 m/yr for the period.

It can also be seen that over the two periods, the shoreline movement rates have remained relatively the same. For the area north of the Marina, sections of the shoreline have reduced erosion rates while others have increased erosion rates. Overall the trends are similar enough to suggest the historical trends are continuing.

For a sandy coastline, the Draft SPP 2.6 recommends the allowance for long term shoreline movement trends on an eroding coastline be calculated as 100 times the historic annual rate of erosion. This is for a planning period of 100 years and it is assumed that this is prorated for planning timeframes that are less than 100 years.

Therefore, when determining the S2 Allowance component of the coastal processes, a rate of -0.7 m/yr will be used. MRA also assessed the coastline for potential future changes in the nearshore conditions over the planning timeframes. It was determined that due to the short timeframes considered and the relative stability of the long term accretion and erosion trends identified that there was not likely to be any significant alteration to the existing trends.

## 3.4 Sediment Budget

A sediment budget was estimated for the full length of the Primary Sediment Cell that extends from Mallee Reef Salient in the north to Yanchep in the south and encompasses the entire study area. This sediment budget was further broken down to Tertiary Sediment Cells that fit the boundaries of the study area.

Using the identified horizontal movements of the vegetation line and beach profiles obtained from previous investigations in the area, the change in volume over the active zone (from the back of the dune to the estimated depth of closure) was estimated at each 100 m chainage.

Total volumes accreted or eroded for each shoreline sector were then estimated by summing the individual changes and are presented in the following section. During this process, it was assumed that each profile represents an area of shoreline to either side, equal to half the distance to the adjacent profile. This approach assumes that the entire profile accretes or erodes similarly for the entire active zone and that the shape of the profile does not change.

In preparing the sediment budget, MRA reviewed the 2002 and 2012 beach and hydrographic surveys of the area provided by DoT and note that while the vegetation line method used is not perfect, it does provide a reasonable method of developing an indicative sediment budget for the area. The commissioning of continuous beach, nearshore and offshore profiles that extend from behind the crest of the dune to several hundred metres offshore at regular timeframes would greatly assist in estimating future sediment budgets.

The construction of the Marina has changed the local sediment dynamics. Therefore, the sediment budget was analysed over the period 1981 to 2011, as this was the earliest period of continuous shoreline movement coverage following the construction of the Marina.

The compartments were identified using the sediment cell data determined in Damara (2012a) and an assessment of likely coastal compartments based on similar shoreline movement trends.

The sediment budget for the study area is shown in Figure 3.8. This sediment budget incorporates the Primary and Secondary level sediment movement as inputs at the southern boundary.

The sediment budget presented is indicative only and represents the average values across the measurement period. Inter-annual variations in sediment transport direction and quantity are likely to occur in response to prevailing weather conditions.

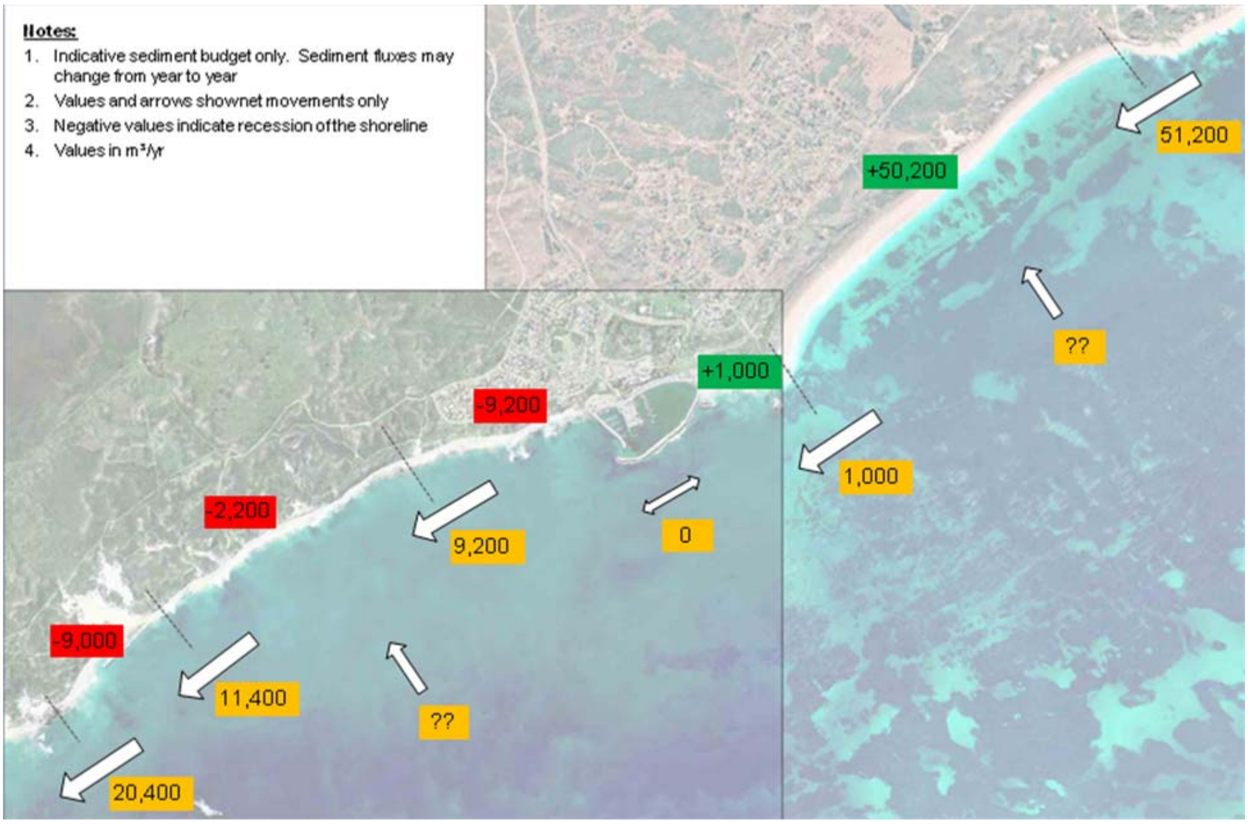



**Figure 3.8 - 1981 to 2011 Indicative Annual Sediment Budget ($m^3$/yr)**

In general the sediment budget shows:

- Substantial accretion of over 50,000 $m^3$/year on the shoreline to the south of Two Rocks due to a substantial sediment feed from the south.
- Accretion of 1,000 $m^3$/year on the beach immediately to the south of the Marina. It is noted the assessment of shoreline movement within this area may be affected by the accumulation of seaweed and wrack in the area.
- Limited sediment transport past the Marina was assumed due to the minimal need for dredging of the area.
- The northern sections of coastline showed substantial erosion totalling 20,400 $m^3$/year, of which approximately 9,200 $m^3$/year was lost from the sector encompassing the northern Two Rocks development.
- While onshore feeds were noted as being likely, the extent of these onshore feeds could not be ascertained from the available information.

Sediment movement analysis was also completed using the 2002 and 2012 hydrographic and beach surveys provided by DoT. While these surveys had a number of issues such as different survey methods and large gaps in the survey data, they provided another means of estimating the potential sediment movement of the areas immediately adjacent to the Marina.

Figure 3.9 shows the difference plot for the 2002 and 2012 survey data provided by DoT.

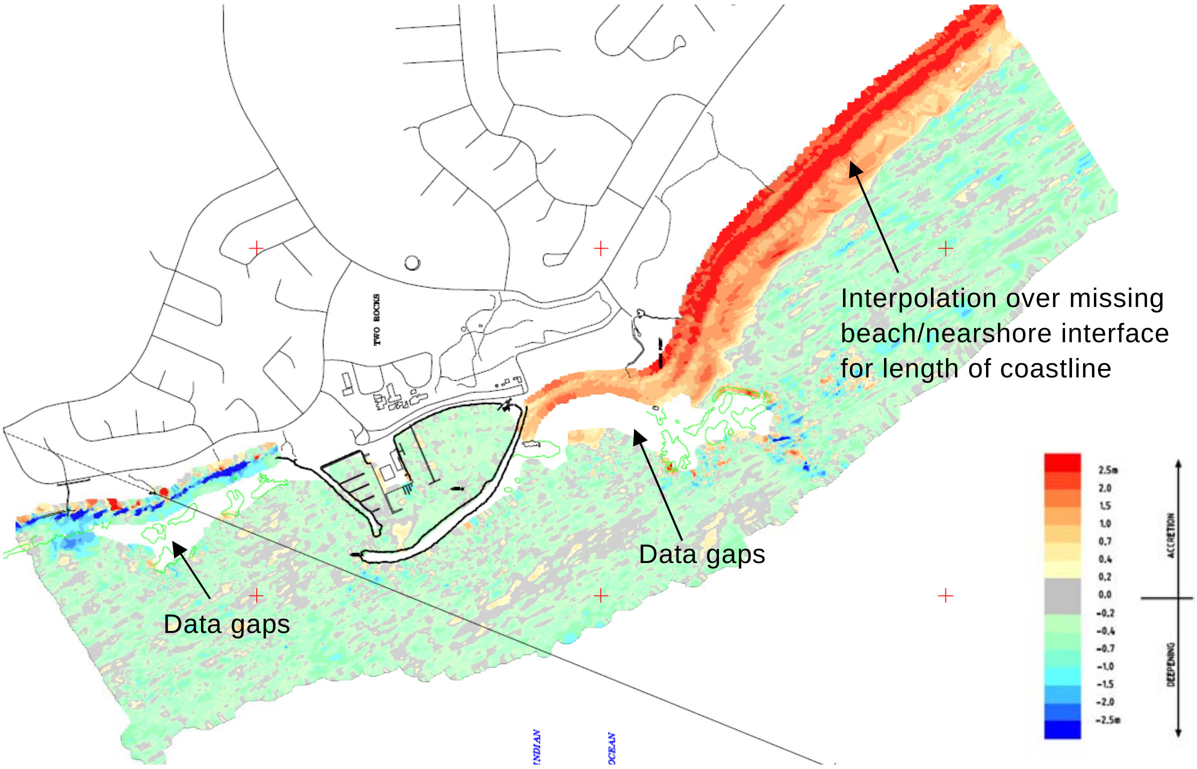



**Figure 3.9 - Difference Plot between 2002 & 2012 Survey Data**

Due to the large gaps in the survey data for key areas north of the Marina, there was no ability to determine changes in volume of the beach profile that extends from the waterline to the seaward side of the reefs and rock platforms. Therefore, the survey information located to the north of the Marina was not considered suitable for use in estimating the potential transport of sediment.

However, the survey information for the coastline south of the Marina had less missing data and was considered suitable for analysis. Using the 2002 and 2012 surveys, it was determined that:

- The coastline between Wreck Point and the Marina experienced accretion of approximately 5,200 $m^3$/year between 2002 and 2012.
- For approximately 1,400 m of coastline south of Wreck Point, there was accretion of approximately 33,500 $m^3$/year between 2002 and 2012.

It should be noted that the more complete southern surveys were still missing survey points for the key beach/nearshore water area interface.

A comparison of the difference plot and vegetation line methods of determining sediment movements and budget was then conducted for the shoreline south of the Marina. It should be noted that the two methods covered slightly separate timeframes of sediment movement. The vegetation line method covered the period 2004 to 2011, while the volumes obtained from the difference plot were for the period between 2002 and 2012.

For the section of coastline located between the Marina and Wreck Point, the difference plot shows an accretion of 5,200 $m^3$/year and the vegetation line method, an accretion of approximately 1,500 $m^3$/year. This area includes a large area of missing data, which may cause the difference in volume. This difference in volumes could also be influenced by factors such as the regular accumulation of large quantities of seagrass and wrack in the area, the small stretch of coastline being considered and differences in the timeframes used for the analysis.

For the section of coastline extending approximately 1,400 m south of Wreck Point, the difference plot method shows accretion of 33,500 $m^3$/year and the vegetation line method, accretion of approximately 29,000 $m^3$/year. Figure 3.9 shows that there was very good coverage of survey data in this area and therefore increased confidence in this comparison. This provides some confidence in the relative accuracy of the volumes determined for the remaining open sections of coastline through the vegetation line method.

The results of the sediment budget determined in the investigation were also compared to the results of MRA (2006) to check for any large scale changes in shoreline movement and sediment transport trends. MRA (2006) considered approximately 1 km of coastline to the south and 1.5 km to the north of the Marina over the period 1971 to 1996. From an analysis of this section of coastline, MRA (2006) estimated that:

- Over the 1971 to 1996 period, there was approximately 13,000 $m^3$/year of accretion south of the Marina and 14,000 $m^3$/year of erosion to the north of the Marina.

For the current 1981 to 2011 period over the same section of coastline, it was estimated that:

- There was approximately 18,000 $m^3$/year accretion for the shoreline to the south of the Marina and 10,000 $m^3$/year of erosion to the north.

Overall, the shoreline movement trends determined for the 1981 to 2011 period reasonably match the values presented in MRA (2006) for the 1971 to 1996 period. This indicates that there have been no large scale changes in the sediment transport dynamics. Some of the differences in the estimated quantities may be a result of the different baselines years and periods covered by the assessments.

## 3.5 Potential Recession Due to Sea Level Rise

The Intergovernmental Panel on Climate Change (IPCC) has presented various scenarios of possible climate change and the resultant Sea Level Rise (SLR) in the coming century, presented Figure 3.10 (IPCC 2001, 2007).

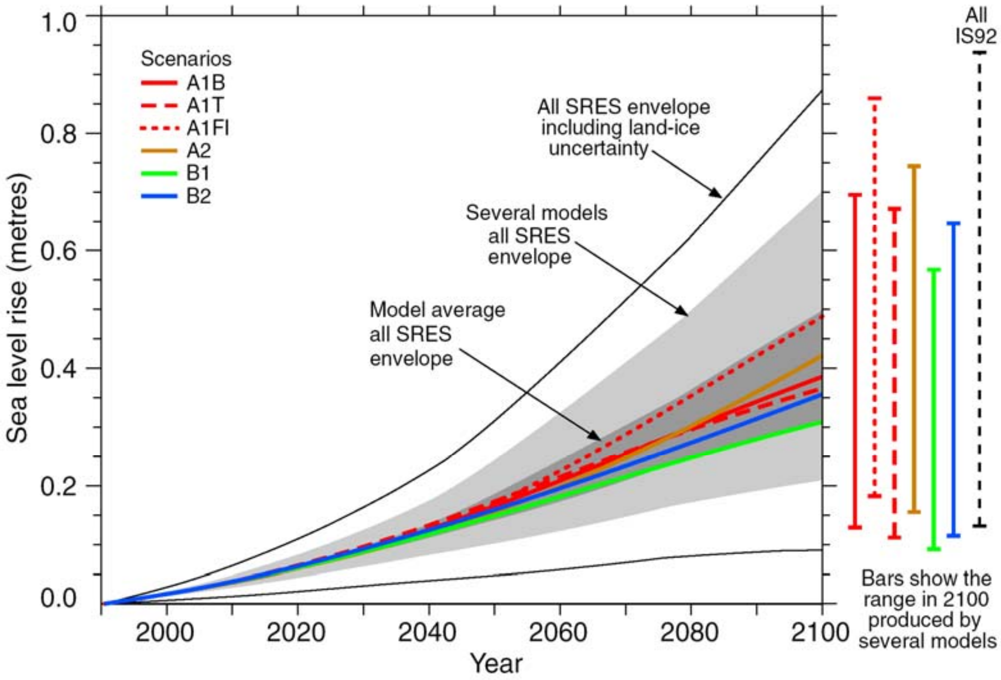



**Figure 3.10 - IPCC Scenarios for Sea Level Rise**

Previously, DoT (2010) had extrapolated work by Hunter (2009) to provide SLR values based on the IPCC (2007) A1F1 climate change scenario projections to the year 2110. Based on this, the WAPC released a position statement indicating that the allowance for SLR to 2110 be increased from 0.38 m to 0.9 m (WAPC, 2010). This was based upon the IPCC AR4 (scenario A1F1) and CSIRO (2008).

When determining the potential shoreline recession resulting from SLR (S3) Allowance, the Draft SPP 2.6 states that the allowance should be calculated as 100 times the adopted SLR of 0.9 m over the coming 100 year timeframe.

It is assumed that for timeframes less than 100 years, the SLR values proposed by DoT (2010) would be appropriate for calculating the shoreline recession allowance due to SLR. Figure 3.11 shows the planning period considered for this investigation and the DoT recommended allowance for SLR.

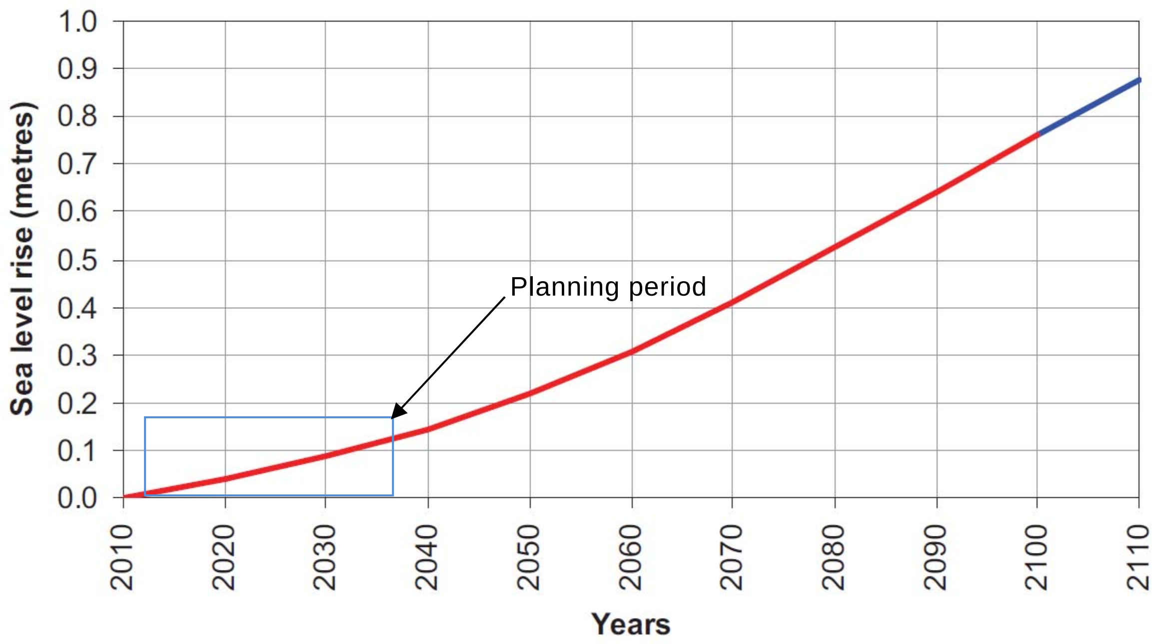



**Figure 3.11 - DoT Recommended Allowance for SLR (DoT 2010)**

From Figure 3.11, the SLR for use in the assessment to 2022 and 2037 is 0.05 and 0.12 m respectively

The effect of SLR on the coast is difficult to predict. Komar (1998) provides a reasonable treatment for sandy shores, including examination of the Bruun Rule (Bruun 1962). The Bruun Rule relates the recession of the shoreline to the SLR and slope of the nearshore sediment bed:

$$R = \frac{1}{\tan(\theta)} S$$

Where: *R* = recession of the shore;

$\theta$ = average slope of the nearshore sediment bed; and

*S* = SLR.

Komar (1998) suggests that the general range for a sandy shore is *R* = 50*S* – 100*S*. Under the Draft SPP 2.6, the allowance for recession of a sandy coast is required to be 100*S*, where the value for SLR to 2037 is 0.12 m.

It should be noted that the estimated impacts of SLR determined in line with the Draft SPP 2.6 are approximate only. They are based on a generic rough rule of thumb rather than a site specific analysis.

Therefore, MRA have calculated the potential recession due to SLR based on a site specific application of the Bruun Rule, using the beach profile obtained for the storm erosion modelling. Based on an allowance for SLR of 0.05 and 0.12 m to 2022 and 2037, the recession of the Two Rocks shoreline under the Bruun Rule was estimated to be 2 and 5 m respectively.

## 3.6 Summary of Coastal Processes Allowances

A summary of the allowances for severe storm erosion, historical shoreline movement and SLR on the coastline north of the Marina to 2022 and 2037 is presented in Table 3.1.

### Table 3.1 – Summary of Allowance for Coastal Processes

| Coastal Process | Estimated Allowance to 2022 (m) (10 year timeframe) | Estimated Allowance to 2037 (m) (25 year timeframe) |
|---|---|---|
| Severe Storm Erosion (S1) | 20 | 20 |
| Historical Shoreline Stability (S2) | 7 | 17.5 |
| Sea Level Rise (S3) | 2 | 5 |
| **Total Estimated Impact** | **25** | **42.5** |

The revised allowances calculated above are smaller than the 25, 40 and 65 m determined in MRA (2006) for 5, 15 and 30 year timeframes respectively.

Analysis of the shoreline north of the Marina was undertaken to identify areas that are potentially vulnerable to the coastal processes identified. It was determined that the key items of infrastructure vulnerable to 2037 are:

- The northern seawall of the Marina. This area is currently vulnerable to severe storm erosion and further shoreline recession due to sediment transport losses and sea level rise. These coastal processes are likely to result in the shoreline receding past the existing seawall extents and eroding the shoreline at the northern end of the Marina. The shoreline recession is also likely to result in substantial damage to the structure itself due to the unsecured end of the seawall being exposed to wave action.

- The navigation marker managed by DoT and located in the foreshore reserve to the north of the Marina. This item of infrastructure is located approximately 30 to 35 m from the 2011 HSD. Therefore, this item of infrastructure is likely to be vulnerable within 10 to 15 years.

- The Sceptre Court stairway and viewing platform. The site inspection conducted by MRA noted that the viewing platform and stairways are currently located on the eroding face of the dune. Therefore, they are currently vulnerable to severe storm erosion and future shoreline recession through coastal processes. These structures were noted as being piled structures, information on the depths of the piles would assist in determining the extent of the vulnerability of these structures.

- Sovereign Drive has a buffer of between 60 and 100 m from the 2011 HSD. The section of Sovereign Drive with the least buffer to coastal processes is located immediately north of the Marina. While this item of infrastructure is not currently vulnerable under the 25 year timeframe analysis, it is a highly valuable item of infrastructure and a proactive approach to its protection is recommended.

A number of items of infrastructure have been identified as vulnerable to severe storm erosion in the short term, while others are also vulnerable to longer term processes.

The items potentially at risk over the 25 year period are of varying importance and value. In order to assess the most appropriate method for managing the potential risks to this infrastructure, various coastal management options were investigated. These options are presented in the following section.

# 4. Conceptual Coastal Management Options

## 4.1 General

MRA were requested to consider and revise the coastal management options previously investigated in MRA (2006), as well as a specific sand bypassing management option. The conceptual options assessed in this report were:

- Managed Retreat (previously "Do-Nothing").
- Sand Nourishment.
- Sand Bypassing.
- Seawall.
- Staged Groynes.
- Offshore breakwaters.

The feasibility of these conceptual options was reviewed and the options were ranked to determine the two most appropriate coastal management options for the 25 year timeframe.

## 4.2 Managed Retreat

MRA (2006) investigated the Managed Retreat option, where it was assumed that the coastal processes will continue to erode the shoreline over the 60 year planning timeframe. Under this management option it was determined that a substantial amount of public and private infrastructure was at risk over the planning period and that mitigation works for the coastal infrastructure located within the foreshore would be required.

Under the revised Managed Retreat option for a planning period of 25 years, mitigation works are also recommended in order to accommodate the potentially vulnerable infrastructure in the foreshore reserve.

Over the coming 25 years the shoreline north of the Marina has an allowance for coastal processes of approximately 43 m. It is difficult to know the exact extent of shoreline recession in the coming years. However, based on the coastal processes identified, there are a number of items of infrastructure that are potentially vulnerable over the next 25 years.

Under this management option, mitigation works would have to be undertaken for:

- The Sceptre Court stairway, viewing platform and access path.
- The navigation marker.
- The northern seawall of the Marina.

The Sceptre Court stairway, viewing platform and access path are currently assessed to be vulnerable to severe storm erosion. Additionally, the shoreline is receding around the structure, causing scouring of the piles used to support the viewing platform. As the shoreline continues to recede, the structure will continue to project further out into the beach and will not provide suitable beach access. The structure may also become isolated if the access path to the viewing platform is undermined during future shoreline recession.

Therefore, mitigation works for this item of infrastructure are likely to be required in order to maintain access to the beach north of the Marina. It is recommended that mitigation works allow for the relocation of the structure to a position further back in the foreshore reserve.

If this beach access point is to be maintained, works to relocate the stairs and viewing platform should be undertaken in the near future as the structure appears to be vulnerable to severe storm erosion. An estimated cost for the relocation/replacement of the stairs and viewing platform was estimated to be in the order of $340,000 plus GST.

The navigation marker was previously identified in MRA (2006) as requiring relocation in approximately 10 years' time. Under the revised allowances for coastal processes it is estimated that the navigation marker is likely to be vulnerable in 10 to 15 years. This indicates that the rate of shoreline recession in that area may have slightly slowed from that determined in MRA (2006), potentially as a result of the nearshore reefs and rock platforms in the area.

It is estimated that the relocation of the navigation marker to an area set further back in the foreshore would cost approximately $50,000 plus GST. MRA have been advised that the navigation marker is owned, managed and maintained by DoT.

The current shoreline position north of the Marina is located at the end of an ad-hoc and un-engineered section of seawall. If the shoreline is allowed to continue to recede, the shoreline in this area will end up behind the existing structure. This exposes the northern sections of the Marina to erosion and is likely to result in increased damage of the seawall structure itself.

It is therefore recommended that an extension of the seawall be undertaken as part of the Managed Retreat option. This seawall would be an extension of the existing seawall and would continue in a similar orientation to the existing structure back towards Sovereign Drive. It is estimated that an 80 m extension of the seawall is required to account for the coastal processes allowances over the 25 year period. This is expected to cost in the order of $456,000 plus GST.

Based on a shoreline recession allowance of approximately 43 m to 2037, there is only estimated to be a 17 m buffer to the most vulnerable section of Sovereign Drive at the end of the planning period. Future shoreline recession due to coastal processes could therefore be impact Sovereign Drive.

It is also recommended that a beach monitoring program be implemented to monitor the shoreline recession over the proposed planning timeframe. This would allow for the management option to be adapted to any changes in coastal processes. A beach monitoring program would involve the surveying of several beach, nearshore and offshore profiles to track shoreline movement over a number of years. For the purposes of tracking shoreline recession at Two Rocks, a beach monitoring program would only be likely to be needed every two years following the establishment of a baseline data set. The likely cost of a beach monitoring program managed by the City is in the order of $10,000 plus GST per annum.

The estimated cost of the Managed Retreat option is presented in Table 4.1.

### Table 4.1 – Managed Retreat Cost Estimate

| Item | Description | Estimated Cost |
|---|---|---|
| 1 | Relocation of Navigation Marker | $50,000 |
| 2 | Relocation of Sceptre Court Stairs & Platform | $340,000 |
| 3 | Complete 80 m extension of northern Marina seawall | $455,600 |
| 4 | Shoreline Monitoring (per annum) | $10,000 |
| **5** | **Subtotal for Managed Retreat Option** | **$855,600** |
| 5.1 | Contingencies (15%) | $128,340 |
| **5.2** | **Total Estimated Cost (Excl GST)** | **$983,940** |

Notes:
1. Costs do not include allowances for the revegetation of disturbed areas resulting from the works.
2. All costs are exclusive of GST and are indicative only.
3. Costs are for the managed retreat of the coastline to 2037. Additional infrastructure is at risk for timeframes greater than this.
4. Costs for the relocation of Sceptre Court stairs are on the basis of replacement.

A conceptual plan, showing the allowances for coastal processes to 2022 and 2037 for the Managed Retreat Option is attached as Appendix 2. This plan also highlights the steps required to be undertaken for the proposed management option.

## 4.3 Sand Nourishment

Sand nourishment has been used to manage eroding beaches in WA since the 1970's, and is a common management option utilised in coastal areas throughout the world (DPI 2004). The artificially placed sand is worked along the beach by wave action, and could be used to protect the eroding shoreline. As the City specifically requested a separate Sand Bypassing option to assess potential uses for the sand accumulation to the south of the Marina, this management option will not consider the availability of the sand to the south of the Marina and is based upon the importation of sand from off-site.

From the analysis conducted in Section 3.4, the coastline to the north of the Marina was shown to be losing approximately 20,000 $m^3$ of sediment per year. When considering the potential amount of sediment to be included for sand nourishment works, it is best to allow for a greater volume of sand than that required to meet the existing erosion requirements. This is to allow for relative accuracies of the methods used to determine the sediment transport rates and for changes in the local dynamics following the sand nourishment works.

The sand nourishment option has therefore been assessed on the basis of placing 25,000 $m^3$ of sediment. The sand would be placed in a bank on the shoreline to the north of the Marina, and allow wave action to rework the sediment north along the shoreline, and distribute it over the active profile. Initially there may appear to be a rapid loss of sand from the land part of the beach profile as the sediment moves offshore and is redistributed over the entire profile.

For the purposes of financial comparison, it is assumed that 25,000 $m^3$ of sand nourishment will be required every year. It should be noted that the actual quantity of sand required would depend on the wave conditions experienced during the year. Therefore beach monitoring and careful management would be required to ensure that sufficient quantities of sand are placed on the beach if significant erosion occurs in any one year.

As sand nourishment works only act to reduce the shoreline recession resulting from alongshore sediment transport, there is still infrastructure remaining that is vulnerable to the coastal processes of severe storm erosion and sea level rise. Therefore, additional mitigation works will have to be undertaken. Alternatively, a larger quantity of sand nourishment could be placed each year in order to increase the buffer to infrastructure and sand available for coastal processes.

Similar to the Managed Retreat option, the Sceptre Court stairs and viewing platform remain vulnerable to coastal processes, as does the northern seawall of the Marina. The navigation marker was not assessed to be vulnerable to coastal processes over the 25 year planning timeframe due to the reduced shoreline recession expected to result from the Sand Nourishment works.

Therefore, only mitigation works for the Sceptre Court stairs and viewing platform and the northern seawall of the Marina are required under this management option. The extent of these works is the same as those needed for the Managed Retreat option, except that the extent of the seawall extension required is only 50 m. This is due to reduced shoreline recession resulting from eliminating the alongshore sediment transport losses.

The estimated costs of conducting the Sand Nourishment option and associated mitigation works are given in Table 4.2.

### Table 4.2 – Sand Nourishment Cost Estimate

| Item | Description | Estimated Cost |
|---|---|---|
| 1 | Relocation of Sceptre Court Stairs & Platform | $340,000 |
| 2 | Complete 50 m extension of northern Marina seawall | $301,000 |
| 3 | Annual Sand Nourishment Works of 25,000 $m^3$ | $905,000 |
| 4 | Shoreline Monitoring (per annum) | $10,000 |
| **5** | **Subtotal for Sand Nourishment Option** | **$1,556,000** |
| 5.1 | Contingencies (15%) | $233,400 |
| **5.2** | **Total Estimated Cost (Excl GST)** | **$1,789,400** |

Notes: 1. Costs do not include allowances for the revegetation of disturbed areas resulting from the works.
2. All costs are exclusive of GST and are indicative only.
3. Sand nourishment is required to be undertaken annually.
4. Costs for the relocation of Sceptre Court stairs are on the basis of replacement.

Therefore, the estimated annual ongoing cost of completing the Sand Nourishment works is in the order of $905,000 plus GST. For budgeting purposes we would recommend a contingency is allowed.

There may also be the potential to obtain reduced sand nourishment costs over time by placing the required quantities at intervals of two or three years. This would reduce the number of mobilisations required but would result in greater quantities being required for each occurrence of the nourishment works.

It is proposed to commence the sand nourishment as soon as possible, in order to obtain the greatest benefit from the sand nourishment program by retaining a wider foreshore reserve area and ensuring an adequate buffer to Sovereign Drive is achieved at the end of the 25 year planning timeframe.

During the course of the works, it was also determined that the quantity of external sediment required may not be sustainable over the long term due to supplier constraints.

A conceptual plan, showing the allowances for coastal processes to 2022 and 2037 for the Sand Nourishment option is attached as Appendix 3. This plan also highlights the steps required to be undertaken for the proposed management option.

## 4.4 Sand Bypassing

In addition to the Sand Nourishment option, the City requested that a specific investigation into the potential for a Sand Bypassing management option be undertaken. This is due to the large accumulation of sand that is forming on the southern side of the Marina due to the interruption of the sediment transport pathways. Both sand nourishment and sand bypassing were covered under "Sand Nourishment" in MRA (2006).

Under the Sand Bypassing option, sediment would be transported from the southern side of the Marina to the northern side as for the Sand Nourishment option. A number of different sand bypassing options were investigated, including:

- Using trucks and heavy machinery to load sediment from the southern side of the Marina and transport it via road to the northern side.
- A mobile plant setup that would pump the material as a slurry mixture of sand and salt water through temporary pipelines to the beach north of the Marina.
- Semi Mobile/fixed plant bypassing. This type of sand bypassing system uses a fixed or semi mobile system to extract sand from a specific location and transport it through pipelines to the outfall location.

A summary of some of the Sand Bypassing options considered for this management option are given in Table 4.3.

**Table 4.3 – Sand Bypassing Systems**

| Type | Example & Bypassing Quantity | Description of Sand Bypassing System | System Components | Approximate Cost of Example System |
|---|---|---|---|---|
| **Fixed Structure** | • Nerang, QLD<br>• ~500,000 $m^3$ | • Jetty extending from the shoreline with jet pumps to intercept sediment movement and bypass sand around inlet entrance. | • Jetty with 10 jet pumps along its length.<br>• Permanent sand bypassing pipelines to bypass sediment around inlet entrance. | • Construction cost in 1986 of $8,134,000.<br>• Operating costs in 1996/97 of $735,289. |
| **Mobile Pumping** (Land) | • WA, (Perth, Busselton, Mandurah)<br>• ~15,000 $m^3$ | • A semi-mobile system of pumps, pipelines and heavy earth moving machinery used to bypass a slurry mixture of sand and water. | • Pumping equipment, intake pipes, outlet pipes, excavators, dozer, trucks.<br>• Pipes can be permanently installed or temporary for the duration of the works. | • Cost in 2012 of $290,000. Estimated cost of approximately $14/$m^3$ plus mobilisation, preliminaries and insurances |
| **Semi Permanent Pumping** | • Noosa, QLD<br>• ~40,000 $m^3$ | • A self burying submarine sand extractor is installed in an area of sand accumulation. Onshore pumping facilities transport the sand through pipelines to selected outlet areas. | • Self burying submarine sand extractor with jet pumps<br>• Onshore pumping and control station<br>• Permanent or temporary pipelines and outlets. | • Capital cost in 2009 of $2,500,000.<br>• Operational costs of approximately $200,000 per annum budgeted. |
| **Trucking** | • World Wide<br>• Any quantity | • Transportation of sand from the sand source to the disposal area via trucks. | • Heavy earth machinery including excavators, graders and loaders.<br>• Potentially includes the use of off-road dump trucks and road trucks. | • Varies. For short hauls, estimate a rate of $16/ $m^3$ plus mobilisation, preliminaries and insurances |
| **Trap & Dredging** | • Delaware, USA<br>• 76,000 $m^3$ | • Fixed or temporary (mobile) dredge system located near the accretionary trap area. | • Dredge, pipelines, pumping equipment and boosters as needed. | • Capital purchase costs of US$1.7 million in 1990<br>• US$4/$m^3$ per annum operating costs in 1996. |

The potential Sand Bypassing systems were also assessed for their suitability for the Two Rocks area and the requirements of the Sand Bypassing option. This assessment is summarised in Table 4.4.

**Table 4.4 – Suitability of Sand Bypassing Options for Two Rocks**

| Type | Benefits | Disadvantages | Comment on Suitability for Two Rocks |
|---|---|---|---|
| **Fixed Structure** | • Once constructed, low $/m$^3$ rate can be achieved<br>• Low social impact after construction | • Large capital investment with ongoing maintenance costs<br>• Structure is immobile and cannot adapt to changes in longshore transport | • Generally large scale structures more suited to coastlines with substantial sediment bypassing requirements<br>• System is not appropriate for Two Rocks |
| **Mobile Pumping** (Land) | • No large scale capital investment in infrastructure or machinery<br>• Relatively independent of weather<br>• Can tailor bypassing quantities as required | • Substantial mobilisation costs to conduct annual bypassing<br>• Increased setup time to lay approximately 1,400m of pipeline<br>• Ongoing commitment to hire a contractor | • No capital costs, but ongoing annual expenditure required<br>• Operational capabilities suit the required sediment bypassing quantities for Two Rocks<br>• System is appropriate for Two Rocks |
| **Semi Permanent Pumping** | • Low $/m$^3$ rate possible<br>• Can conduct works at low use beach times to minimise social impact<br>• Available for use all year | • Sand is required to accumulate at extraction point<br>• Large upfront investment<br>• Seawrack may foul extraction area, reducing efficiency | • Large capital investment with smaller ongoing annual costs<br>• Can be tailored to suit the bypassing requirements for Two Rocks<br>• System may be appropriate for Two Rocks |
| **Trucking** | • No large capital investment required<br>• Largely independent of weather<br>• Extraction area can be readily shifted | • Access to beaches may be an issue<br>• May require double handling between off-road and on-road trucks<br>• Large increase in truck traffic | • System suits the required sediment quantity to be bypassed<br>• System is appropriate for Two Rocks |
| **Trap & Dredging** | • Required quantity can be bypassed relatively quickly<br>• Proximity to marina will allow for quick mobilisation of equipment | • High capital cost for purchase of equipment or expensive mobilisation costs each year<br>• Operations are restricted to fine weather due to exposed location | • Ability to operate is likely to be restricted by weather, open coastline and lack of sheltered mooring<br>• Not suitable for Two Rocks |

Based on the assessments above and the relatively low quantity of sediment being bypassed, it was determined that the most cost effective and appropriate sand bypassing system for use at the Two Rocks site would be a mobile pumping plant system. This involves the use of pumps, pipelines, excavators and other heavy machinery to load sediment and water into a central hopper which creates a slurry mixture that is then pumped through the temporary pipelines to the northern side of the Marina. There, wave action would distribute the sediment north along the shoreline over the active profile.

For the purposes of financial comparison, it is assumed that 25,000 m$^3$ of sand bypassing will be required every year. It should be noted that the actual quantity of sand required would depend on the wave conditions experienced during the year. Therefore beach monitoring and careful management would be required to ensure that sufficient quantities of sand are placed on the beach if significant erosion occurs in any one year.

As for sand nourishment, the Sand Bypassing option will only prevent the recession due to alongshore sediment transport processes and infrastructure will remain vulnerable to severe storm erosion and sea level rise recession. The extent of mitigation works required for the Sand Bypassing option is the same as that for the Sand Nourishment option.

The estimated costs of conducting the Sand Bypassing option and associated mitigation works are given in Table 4.5.

### Table 4.5 – Sand Bypassing Cost Estimate

| Item | Description | Estimated Cost |
|---|---|---|
| 1 | Relocation of Sceptre Court Stairs & Platform | $340,000 |
| 2 | Complete 50 m extension of northern Marina seawall | $301,000 |
| 3 | Annual Sand Bypassing Works of 25,000 $m^3$ | $387,500 |
| 4 | Shoreline Monitoring (per annum) | $10,000 |
| **5** | **Subtotal for Sand Bypassing Option** | **$1,038,500** |
| 5.1 | Contingencies (15%) | $155,775 |
| **5.2** | **Total Estimated Cost (Excl GST)** | **$1,194,275** |

Notes: 1. Costs do not include allowances for the revegetation of disturbed areas resulting from the works.
2. All costs are exclusive of GST and are indicative only.
3. Sand bypassing is required to be undertaken annually.
4. Costs for the relocation of Sceptre Court stairs are on the basis of replacement.

The estimated annual ongoing cost of conducting the Sand Bypassing works is in the order of $387,500 plus GST. For budgeting purposes we would recommend a contingency is allowed.

There may also be the potential to obtain reduced Sand Bypassing costs over time by bypassing the required quantities at intervals of two or three years. This would reduce the number of mobilisations required but would result in greater quantities being required for the bypassing works.

To retain a wider foreshore reserve area and ensure that adequate buffer to Sovereign Drive is achieved at the end of the 25 year planning timeframe, it would be proposed to commence the Sand Bypassing as soon as possible.

A conceptual plan, showing the allowances for coastal processes to 2022 and 2037 for the Sand Bypassing option is attached as Appendix 4. This plan also highlights the steps required to be undertaken for the proposed management option.

While this option does not replicate the coastal processes that were occurring prior to the construction of the Marina, it is likely to limit the recession of the shoreline north of the Marina.

## 4.5 Seawall

Shore parallel seawalls are generally constructed to provide protection to land behind the wall. Typically, they are constructed as a last line of defence to protect assets such as roads, car parks and buildings. This option involves the construction of a seawall along the eroding shoreline to provide protection to the existing Two Rocks development.

The Seawall option has been developed to provide a minimum buffer of 40 m between the seawall and the road reserve at Sovereign Drive. The 40 m buffer has been used to provide a stable slope from the rear of the seawall to the height of the existing road.

Under this option, the shoreline would be allowed to recede until it approached the trigger distance for the construction of the seawall to protect Sovereign Drive. Therefore, under this option the navigation marker, Sceptre Court stairs and platform and northern Marina seawall would all be impacted prior to construction of the Seawall and require mitigation measures to be undertaken.

Under the proposed Seawall option, the seawall is to be constructed in stages as the shoreline recedes to within the trigger distance for protection. This has the effect of reducing the initial works required and allowing for further monitoring of the rate of shoreline recession prior to additional construction works.

The construction of the northern Marina seawall extension has been incorporated into the initial Stage A Seawall construction works. It has been estimated that the initial stage of the seawall should be built in approximately 5 years to maintain the required buffer to Sovereign Drive and minimise the potential damage resulting from the existing exposed northern Marina seawall.

Approximately half of the remaining seawall stages will be constructed by 2020 with the remaining stages built by 2032. It is important to note that while the construction of a seawall will protect the land behind it, a useable sandy beach is unlikely to exist in front of the structure.

By protecting only Sovereign Drive, the estimated length of the seawall was able to be reduced from the 920 m estimated for MRA (2006) to 860 m. After construction of each stage of the seawall, the erosion is likely to extend to the north, as the available longshore sediment supply to each area is effectively lost following construction.

A conceptual plan, showing a conceptual seawall section and the allowances for coastal process to 2022 and 2037 for the Seawall option is attached as Appendix 5. This plan also highlights the steps required to be undertaken for the proposed management option.

No geotechnical investigations of the area have been carried out, and the extent of rock beneath the sandy beach is unclear. The toe of the seawall has therefore been shown to -1.5 mAHD, to prevent undermining due to scouring. This may be revised based on the presence of rock.

The crest of the seawall was set at +5 mAHD, based on calculations of wave overtopping in an extreme event. In an extreme event of approximately 20 to 50 years ARI, the wall will not experience damage to the crest due to wave overtopping, but it would be dangerous for pedestrians standing on the crest. Appropriate signage warning of the dangers may therefore be required.

During extreme storm events, there may be some erosion of the slope behind the seawall. However, the provision of a minimum of 40 m buffer between development and the seawall means this damage will not affect the existing infrastructure.

The estimated costs of completing the Seawall option and associated mitigation works are given in Table 4.6.

### Table 4.6 – Seawall Option Cost Estimate

| Item | Description | Estimated Cost |
|---|---|---|
| 1 | Relocation of Navigation Marker | $50,000 |
| 2 | Relocation of Sceptre Court Stairs & Platform | $340,000 |
| 3 | Seawall – Stage A Construction (Including northern Marina seawall extension) | $857,300 |
| 4 | Construction of Remaining Seawall Stages | $3,852,400 |
| 5 | Shoreline Monitoring (per annum) | $10,000 |
| **6** | **Subtotal for Seawall Option** | **$5,109,700** |
| 6.1 | Contingencies (15%) | $766,455 |
| **6.2** | **Total Estimated Cost (Excl GST)** | **$5,876,155** |

Notes: 1. Costs do not include allowances for the revegetation of disturbed areas resulting from the works.
2. All costs are exclusive of GST and are indicative only.
3. Costs for the relocation of Sceptre Court stairs are on the basis of replacement.

It should be noted that the construction stages identified for the Seawall option are preliminary in nature and should be reviewed in any future detailed design. Further investigations should determine the specific timing and extents of each Seawall stage as well as determining the tie-ins required for each stage of Seawall in order to protect the ends of the structures from coastal processes.

An allowance for beach monitoring has been included in the Seawall option as it will provide increased confidence in the need for and timing of the construction works.

## 4.6 Staged Groynes

Groynes are structures constructed perpendicular to the shoreline to intercept the longshore transport of sediment and result in the realignment of the contained beach to an angle parallel to the incident wave approach. The construction of groyne structures north of the Marina will reduce the longshore transport along the shoreline and provide protection to the eroding coast.

As the structures are only preventing the recession of shoreline due to longshore sediment transport, the shoreline can still recede from SLR and be vulnerable to severe storm erosion.

As a result, mitigation measures will be required to be undertaken in conjunction with this management option. This includes:

- Relocating/modifying the Sceptre Court stairs and platform.
- Extending the northern Marina seawall by approximately 50 m.

Under the Staged Groyne option, it is proposed to construct two groynes north of the Marina. The southernmost groyne will be constructed approximately 400 m to the north of the Marina and the second will be an additional 400 m north. The groynes will be initially constructed to be approximately 100 m long, with a final proposed length of approximately 160 m. This staged approach will allow for reduced initial construction costs and monitoring of the shoreline to fine tune the Staged Groyne option prior to completing the groyne extensions.

A conceptual plan, showing the proposed groyne cross sections, lengths and positioning of the groynes is attached as Appendix 6. This plan also shows the allowances for coastal processes to 2022 and 2037 under the Staged Groyne option and highlights the steps required to be undertaken for the proposed management option.

The groynes have been developed to contain sediment within the constructed compartments, and prevent further sediment loss from the eroding shoreline. To do this they have been extended landward into the primary dune, to prevent erosion behind the structure during severe storm events, and extended seaward past the lower limit of sediment movement, to prevent sediment movement past the head of the structure.

Based on the allowances for coastal processes summarised in Table 3.1, the initial stage will be required by 2017. This will provide sufficient buffer to Sovereign Drive over the planning period, when taking into account allowances such as fluctuations in shoreline position due to beach rotation and interruption of sediment supply during severe storm events.

The groynes were designed for a design event with an ARI of approximately 50 years. During the design storm, the maximum significant wave height at the head of the structure is unlikely to exceed 2.4 m. Using the methods of Van der Meer and Hudson (CIRIA 2007), two layers of 6 tonne limestone armour are likely to be appropriate for this wave climate. Landward of the waterline, the structure is not likely to be exposed to large wave action and two layers of 3 tonne limestone armour are appropriate.

The locations of the groynes shown in Appendix 6 indicate that the southern groyne is likely to be founded on a low reef. As the levels of rock in this area were not picked up in the survey data provided for the study, the preliminary designs do not specifically account for the presence of this rock.

The estimated costs of conducting the Staged Groyne option and associated mitigation works are given in Table 4.7.

### Table 4.7 – Staged Groyne Option Cost Estimate

| Item | Description | Estimated Cost |
|---|---|---|
| 1 | Relocation of Sceptre Court Stairs & Platform | $340,000 |
| 2 | Complete 50 m extension of northern Marina seawall | $301,000 |
| 3 | Stage 1 Groyne Construction | $2,159,500 |
| 4 | Stage 2 Groyne Construction | $1,278,000 |
| 5 | Shoreline Monitoring (per annum) | $10,000 |
| **6** | **Subtotal for Staged Groyne Option** | **$4,088,000** |
| 6.1 | Contingencies (15%) | $613,200 |
| **6.2** | **Total Estimated Cost (Excl GST)** | **$4,701,200** |

Notes: 1. Costs do not include allowances for the revegetation of disturbed areas resulting from the works.
2. All costs are exclusive of GST and are indicative only.
3. Costs for the relocation of Sceptre Court stairs are on the basis of replacement.

## 4.7 Offshore Breakwaters

Offshore breakwaters function by reducing the nearshore wave energy in the lee of the structure and creating a shadow zone where sediment transported alongshore can accumulate (CERC 1984b). The Offshore Breakwater Option involves the construction of two offshore breakwaters along the coastline to the north of the Marina.

The breakwaters are designed to form tombolos in the lee of the structures in order to prevent longshore transport to the north from occurring between the structure and the shoreline. The structures were also designed to be placed an appropriate distance offshore to stop longshore transport on their seaward side. This has made the overall length of 240 m longer than many other offshore breakwaters along the Perth coastline.

The breakwaters were designed based on an estimated 50 year ARI design storm. At the peak of this storm, a significant wave height of 2.4 m would be experienced. The structure has therefore been designed with two layers of 6 tonne armour

To construct the breakwaters, a sand bund could be built out to the structure. The bund could make use of a filter fabric, to restrict the loss of sand from wave action. Following the construction of the breakwaters, the sand could be placed to assist in the formation of a tombolo, encourage sediment deposition in the lee of the structure and to prevent longshore transport. The sand used for the construction works could be sourced from the beaches to the south of the Marina.

The overall layout, sections and extents of the Offshore Breakwaters are shown on the conceptual plan, attached as Appendix 7. The plan shows the estimated allowances for coastal processes to 2022 and 2037 for the Offshore Breakwater option. This plan also highlights the steps required to be undertaken for the proposed management option.

As shown on the concept plan in Appendix 7, mitigation measures would have to be undertaken for:

- Relocating/modifying the Sceptre Court stairs and platform; and
- Extending the northern Marina seawall by approximately 50 m.

The estimated costs of conducting the Offshore Breakwater option and associated mitigation works are given in Table 4.8.

### Table 4.8 – Offshore Breakwater Option Cost Estimate

| Item | Description | Estimated Cost |
|---|---|---|
| 1 | Relocation of Sceptre Court Stairs & Platform | $340,000 |
| 2 | Complete 50 m extension of northern Marina seawall | $301,000 |
| 3 | Construct the Offshore Breakwaters | $5,632,000 |
| 4 | Shoreline Monitoring (per annum) | $10,000 |
| **5** | **Subtotal for Offshore Breakwater Option** | **$6,283,000** |
| 5.1 | Contingencies (15%) | $942,450 |
| **5.2** | **Total Estimated Cost (Excl GST)** | **$7,225,450** |

Notes: 1. Costs do not include allowances for the revegetation of disturbed areas resulting from the works.
2. All costs are exclusive of GST and are indicative only.
3. Costs for the relocation of Sceptre Court stairs are on the basis of replacement.

Shoreline monitoring has been included to monitor the shoreline positions following construction of the offshore breakwaters. This will help to identify if the structures are successfully blocking the alongshore sediment transport.

# 5. Evaluation of Coastal Management Options

The objective of the coastal management options at Two Rocks is to effectively manage the coastline north of the Marina for shoreline recession over the 25 year planning period.

In comparing the management options, the cost, performance and impact of each of the coastal structures needs to be considered.  A table summarising the estimated impacts that each management option may have is included in Appendix 8.  This table includes an assessment of each management options:

- Feasibility and practicality.
- Environmental and social impacts.
- Capital and annual ongoing costs.
- Long Term effectiveness.
- Response to climate change.

Additionally, as each of the proposed options will have a different impact on the area, community consultation will be undertaken to assess the responses to each option.

Using the estimated capital costs of the management options outlined in the previous sections, a discounted cash flow analysis has been used to determine the Net Present Value (NPV) of the options for a range of discount rates.

Although the conceptual options have been designed for low maintenance, an allowance for some maintenance has been made every 5 years for issues such as structural damage in severe storm events.  In addition to allowances for regular maintenance, beach monitoring prior to implementation of the selected coastal management option has been allowed.  Regular and careful monitoring will ensure that the appropriate management option can be put in place at the correct time.

The timing of construction of the various coastal protective structures was estimated based on the estimated rates of shoreline recession and to ensure an adequate buffer to existing development was provided where required.  The NPV's for each option, assuming a discount rate of 6%, are summarised in Table 5.1.

### Table 5.1 – Summary of Coastal Management Option Costs

| Item | Management Option | Net Present Value at 6% for 25 years |
|---|---|---|
| 1 | Managed Retreat | $861,612 |
| 2 | Sand Nourishment (Annual) | $14,789,286 |
| 3 | Sand Bypassing (Annual) | $6,725,129 |
| 4 | Staged Seawall Construction | $3,671,288 |
| 5 | Staged Groyne Construction | $3,359,141 |
| 6 | Offshore Breakwater Construction | $6,265,015 |

The NPV analysis for each management option is included in Appendix 9.

In addition to comparing the options on a NPV basis, the potential environmental and social impacts of the proposed management option and potential long term risk to infrastructure under the management options were also assessed. Table 5.2 shows the subjective ratings that each management option received for these categories and the overall ranking of the coastal management options for the Two Rocks coastline.

### Table 5.2 – Summary Ranking Table of Conceptual Coastal Management Options

| Management Option | Impacts over 25 years | | | Long Term Risk to Infrastructure (Over 100 years) | Overall Ranking (Rating Value) |
|---|---|---|---|---|---|
| | Environmental | Social | NPV over 25 years | | |
| Managed Retreat | Medium | Low | Low | High | 1 (9) |
| Sand Nourishment | Low/Medium | Low/Medium | High | Medium | 6 (8) |
| Sand Bypassing | Low/Medium | Low/Medium | Medium/High | Medium | 5 (8.5) |
| Seawall | Medium | Medium/High | Medium | Low | 3 (8.5) |
| Groynes | Medium | Low/Medium | Medium | Low/Medium | 2 (9) |
| Offshore Breakwaters | Medium | Low/Medium | Medium/High | Low/Medium | 4 (8.5) |

Notes: 1. High Risk and Impacts are rated as 1, Medium Risks and Impacts are rated as 2, Low Risks and Impacts are rated as 3.

2. Where two options tie for a ranking, the lower NPV option is ranked higher.

Table 5.2 shows that the two highest ranking coastal management options for Two Rocks over the next 25 year planning period are Managed Retreat and Staged Groynes.  This is consistent with the previous MRA (2006) findings of “Do Nothing” and Groynes.

It is noted that the Managed Retreat option has a high long term risk to infrastructure, as no steps are undertaken to resolve the issue of shoreline recession for the area.

# 6. Preliminary Design of Recommended Options

## 6.1 General

Following the completion of the Stage 1 investigations and a presentation of the results to the City and DoT, the City requested that the Managed Retreat and Staged Groynes be further investigated and refined as the Stage 2 works. In particular, it was agreed that in the Stage 2 investigations MRA would:

- Maintain the 25 year planning timeframe and NPV.
- Examine potential options to complement the Managed Retreat Option such as sand nourishment/bypassing.
- Assess the timeframe in which the shoreline under each option is estimated to threaten Sovereign Drive.

The decision to maintain the planning timeframe of 25 years, knowing that a longer timeframe would substantially affect the viability of the Managed Retreat option, was made on the basis that the results of the Stage 1 investigations have closely conformed to the predictions made in MRA (2006).

Further refinement and investigation of the two recommended conceptual coastal management options is reported in the following sections.

## 6.2 Managed Retreat

The Managed Retreat option was previously discussed in Section 4.2. Under this option of allowing the shoreline to continue to erode, the following mitigation works will have to be undertaken:

- Relocation of the Sceptre Court stairway, viewing platform and access path.
- Relocation of the navigation marker.
- Extension of the northern seawall of the Marina by 80 m.

Based on the shoreline recession rates previously estimated in Section 2, the allowance for shoreline recession from historical shoreline movement and sea level rise to 2037 is shown in Figure 6.1. The allowance for severe storm erosion is also highlighted.

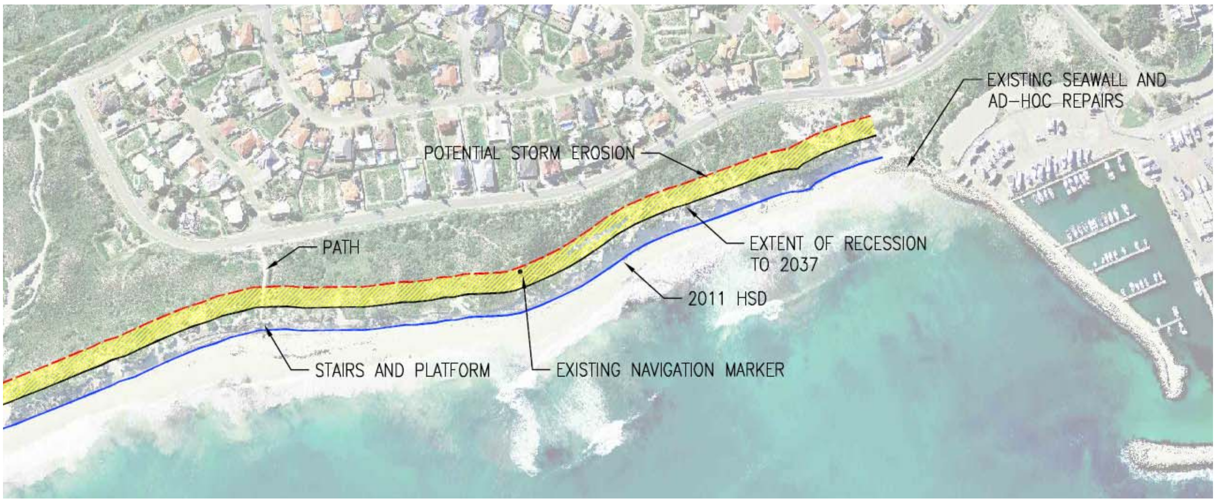



**Figure 6.1 - Shoreline Recession & Potential Severe Storm Erosion to 2037**

Under the proposed Managed Retreat option, there would be no significant alteration to the existing coastal processes. Therefore, the shoreline is likely to recede in line with the estimated extents noted in Section 3. It should be noted that no allowance has been made for the presence of rock in the dunes. This is due to uncertainty regarding the extents, elevations and composition of the rock. Therefore, the extent of shoreline recession experienced in the future may differ from that shown above.

Geotechnical investigations in the area could be undertaken to confirm the location and extent of the rock. One option for determining the extents of the visible rock is through the use of Ground Penetrating Rader (GPR). Focusing on the area north of the Marina, investigations using GPR could be expected to cost in the order of $40,000 plus GST.

It is expected that the shoreline will continue to recede substantially in the area immediately north of the Marina, between the Marina and the reef in front of the navigation marker, until the available sediment supply is lost or the shoreline achieves an angle of equilibrium. Following this, the shoreline recession will extend further north to the next sediment supply.

Due to the recession of the shoreline, the navigation marker is likely to require relocation to a position further landward in the foreshore reserve. If this resulted in the navigation marker being located in an area of lower elevation, the structure will have to be extended to maintain the same sight lines. The estimated cost of extending and relocating the navigation marker, when conducted in conjunction with the other mitigation works, is approximately $50,000 plus GST.

As noted previously, the Sceptre Court stairs are currently landing in the middle of the beach due to shoreline recession, while the platform is undergoing scouring of the piles supporting the structure. With further shoreline recession the stairs may not provide access to the beach as designed and the viewing platform may become unsafe. With continued shoreline recession, the access path to viewing platform may be undermined, isolating the viewing platform and stairs. As a priority, the depths and design conditions for the piles supporting the viewing platform should be investigated.

Following this, planning can be undertaken for the relocation or modification of the existing platform and stairs as needed. For the purposes of the cost estimate it has been assumed that the demolition and replacement of the structure at a more landward location will be required. Based on this assessment, the estimated cost for the mitigation works for the Sceptre Court stairs and platform is approximately $340,000 plus GST.

Under the proposed Managed Retreat Option, the northern Marina seawall is required to be extended in order to prevent damage to the structure and to prevent erosion of the land behind the seawall. The extent of shoreline recession to 2037 has been assessed as requiring a seawall extension of approximately 80 m. This includes an allowance to replace the ad-hoc seawall section that is not sufficient to resist the coastal processes in the area.

The seawall extension has been designed to resist an extreme event in the order of approximately a 50 year ARI and has a median armour size of 2 tonnes. The toe of the seawall has been founded at -1.5 mAHD to prevent undermining due to scouring. This could be revised in the detailed design stage based on the presence of any rock in the area. Figure 6.2 shows the preliminary design of the northern Marina seawall extension.

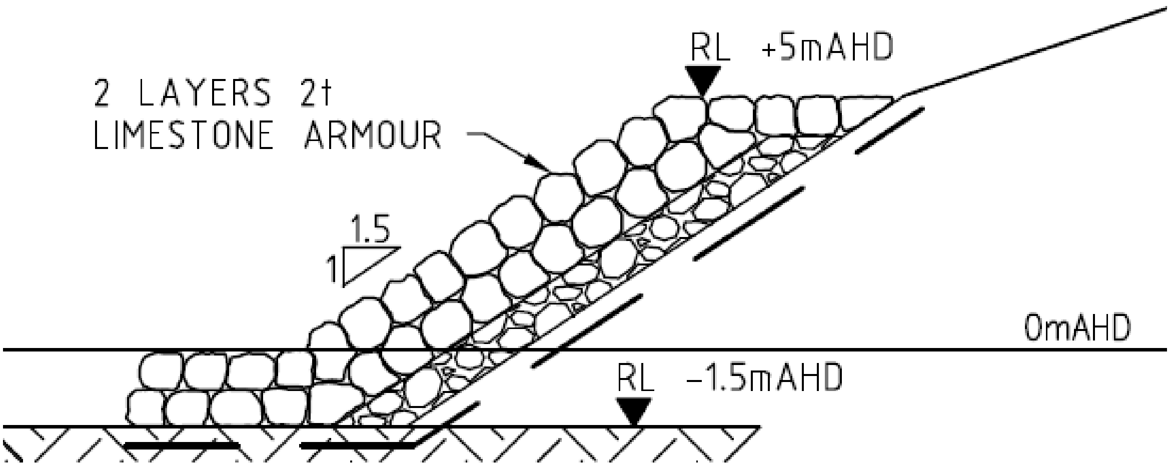
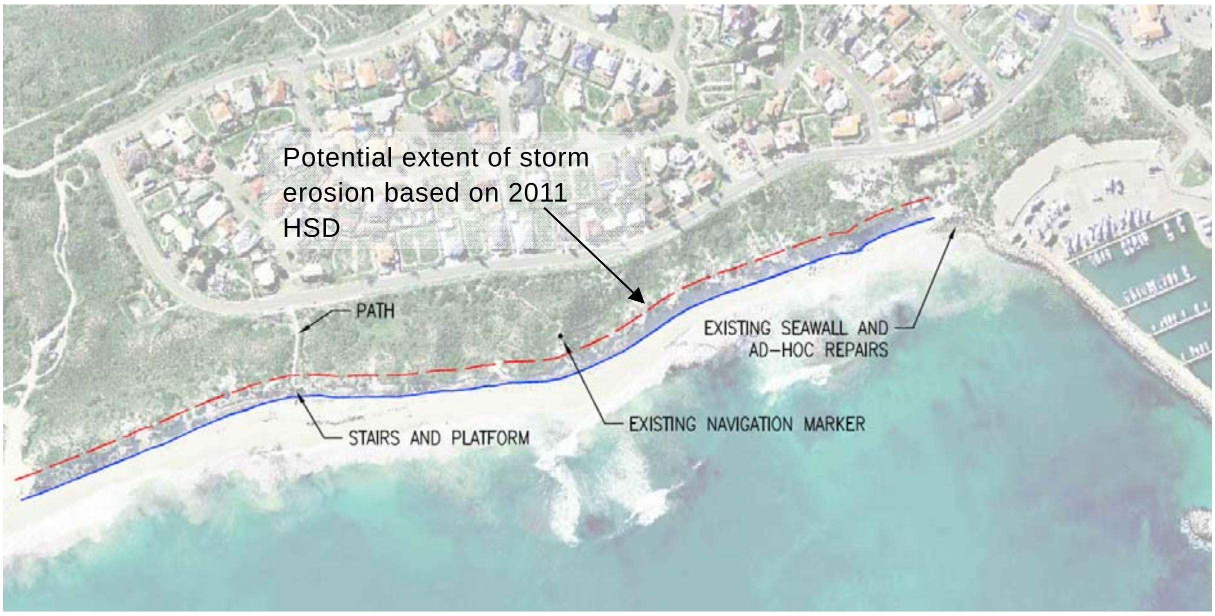



**Figure 6.2 - Indicative Northern Marina Seawall Extension Section**

The crest of the seawall was set at +5 mAHD, based on calculations of wave overtopping in an extreme event. In an extreme event of approximately 20 to 50 years ARI, the wall will not experience damage to the crest due to wave overtopping, but it would be dangerous for pedestrians standing on the crest. Appropriate signage warning of the dangers may therefore be required. During extreme storm events, there may also be some erosion of the slope behind the seawall.

The estimated cost for extending the northern Marina seawall by 80 m is approximately $455,600 plus GST.

Both the northern Marina seawall extension and the Sceptre Court stairs and viewing platform mitigation works are recommended as soon as possible. This will enable these works to be prevent potential severe storm erosion from damaging these structures. Figure 6.3 shows the potential extent of severe storm erosion (red dashed line) based on the 2011 HSD (blue line). It can be seen that both fall within the extent of severe storm erosion while the navigation marker is not subject to the same immediate risk.




### Figure 6.3 - Present Day Potential Vulnerability to Severe Storm Erosion

Therefore, based on the shoreline recession rates determined previously, the timeframes for completion of the works are as follows:

- Navigation marker. Required within approximately 10 to 15 years based on current rates of shoreline recession.
- Sceptre Court stairs and platform. Currently at risk of damage, works to be conducted as soon as possible.
- Northern Marina seawall extension. Currently in poor condition and at risk of damage, works to be conducted as soon as possible.

These timeframes have been used when conducting the Net Present Value (NPV) analysis of the Stage 2 management options.

Based on the current shoreline recession rates and potential for severe storm erosion, the remaining buffer to Sovereign Drive at the end of the planning period is estimated at 17 m.

Therefore, in addition to estimating the required allowances for coastal processes over the 25 year planning timeframe, consideration was also given to assessing the timeframe in which the Sovereign Drive was likely to be vulnerable.

It was determined that the road reserve of Sovereign Drive, with a current buffer of approximately 60 m, would be vulnerable to severe storm erosion events in approximately 45 years (2057).

It is therefore recommended that a beach monitoring program be implemented to monitor the shoreline recession over the proposed planning timeframe. This would allow for the management option to be adapted to changes in the coastal processes and monitor the remaining buffer to infrastructure. For the purposes of tracking shoreline recession at Two Rocks, a beach monitoring program would only be likely to be needed every two years.

The likely cost of a beach monitoring program is in the order of $20,000/per assessment plus GST. This cost has been revised as part of the Stage 2 works and allows for a brief analysis of the beach monitoring results by coastal engineering consultants. The cost of this monitoring program has been included in the NPV assessment of this management option.

Overall, the capital cost of the Managed Retreat under a 25 year planning period, including mitigation works, is in the order of $995,500 plus GST

A preliminary plan, outlining the management steps to be undertaken for the Managed Retreat option and the allowances for coastal processes to 2037 is also included in Appendix 10.

## 6.3 Staged Groynes

As an alternative to the Managed Retreat option, the construction of two groynes to the north of the Marina as part of a Staged Groyne option was also investigated. This management option has the benefits of retaining a much greater portion of the foreshore reserve and useable beach than the Managed Retreat option.

As noted in the Stage 1 investigations, the proposed groyne system is based upon the construction of two groynes approximately 400 m apart, with the objective of preventing longshore transport past the groynes and therefore retaining sand that would otherwise be lost to northward sediment transport. The southernmost groyne is proposed to be approximately 400 m to the north of the Marina, in line with the navigation marker. Figure 6.4 shows the approximate locations and layouts of the groynes.

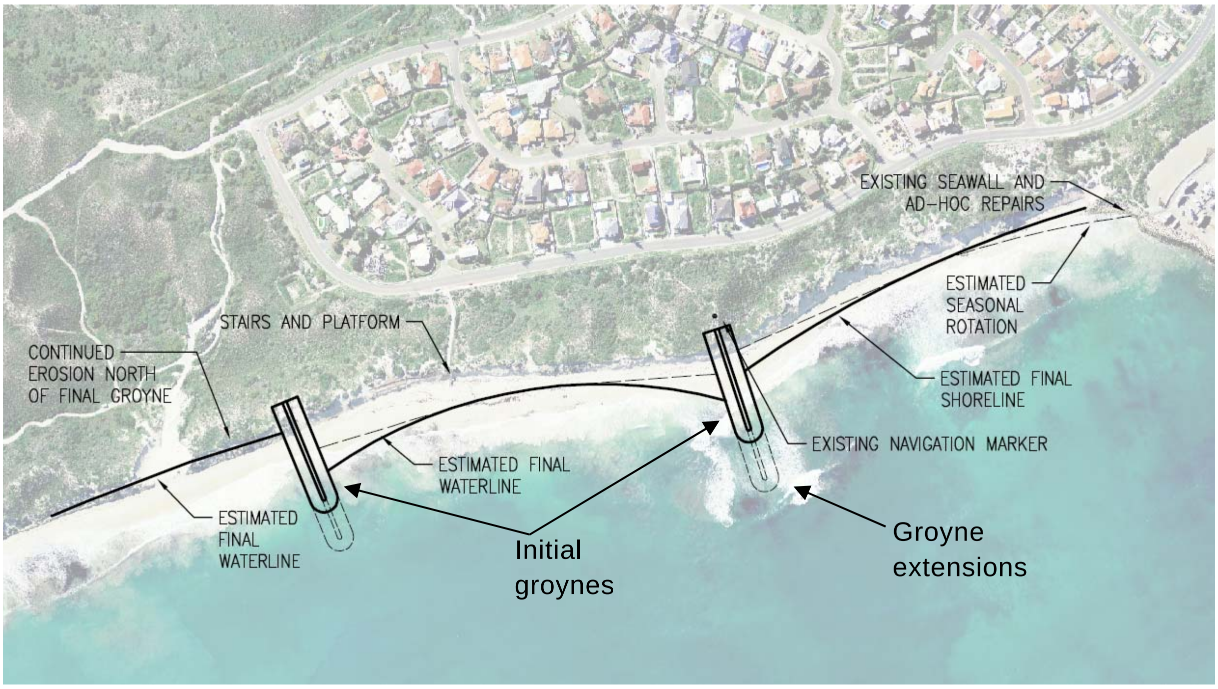



**Figure 6.4 - Preliminary Staged Groyne Layout**

The construction of the groynes is proposed to occur in two stages. An initial 'partial length' construction stage will occur first, followed by a future extension of the groynes. This has the benefit of enabling a less expensive initial stage to be constructed to immediately reduce the rate of shoreline recession from alongshore sediment transport.

In order to maximise the effectiveness of the Staged Groyne approach, the layout and proposed lengths of the groynes were investigated. This included:

- Assessment of the estimated active sediment transport depths for the proposed locations.
- Reviewing the lengths of groyne constructed for each stage, extent of tie-ins required to prevent scouring and the expected head depth for each structure.
- Estimating the impact of the groyne constructions on future sediment transport.
- Estimating the final predicted shoreline positions under the staged approach.

Using bathymetry available from DoT's 2012 hydrographic and beach survey of the area, the active depth for the transport of sediment was determined using Birkemier (1985) to be in the order of -3.5 to -4 mAHD. By constructing groynes that reach or exceed this depth, the vast majority of sediment transport will be prevented. Therefore, the heads of the final groynes were designed to reach this depth. Although the initial groyne constructions will not achieve this depth they are still expected to trap a substantial amount of sediment and reduce the shoreline recession for the coastline between the groynes and the Marina.

The design of the Staged Groyne Option has been slightly revised from the Stage 1 investigations to extend further into the dunes and ensure that during stormy periods the rear of the groyne is not eroded. Additionally, as the northernmost groyne reaches the required depth of -4 mAHD closer to shore, the length of this groyne is approximately 10 m shorter than the southern groyne. Overall the lengths of the northern and southern groynes are approximately 150 and 160 m respectively. This includes tie-ins to the existing dunes of approximately 30 m to account for future shoreline recession, an initial construction length of 100 m (including tie-in) and extensions of 50 m for the northern groyne and 60 m for the southern groyne.

The 50 year ARI design event used in the Stage 1 investigations to determine the required armour crest levels and armour size has been carried through to the preliminary design. Therefore, the previously determined 2 layers of limestone armour of 6 tonne for the groyne heads and trunks are applied. For the tie-in section of 30 m, it is proposed that an armour size of 3 tonne be used in 2 layers as the wave climate this area is likely to be exposed to is much less than that for the rest of the structure.

Typical trunk and head sections for the groynes are shown in Figure 6.5a and 6.5b.

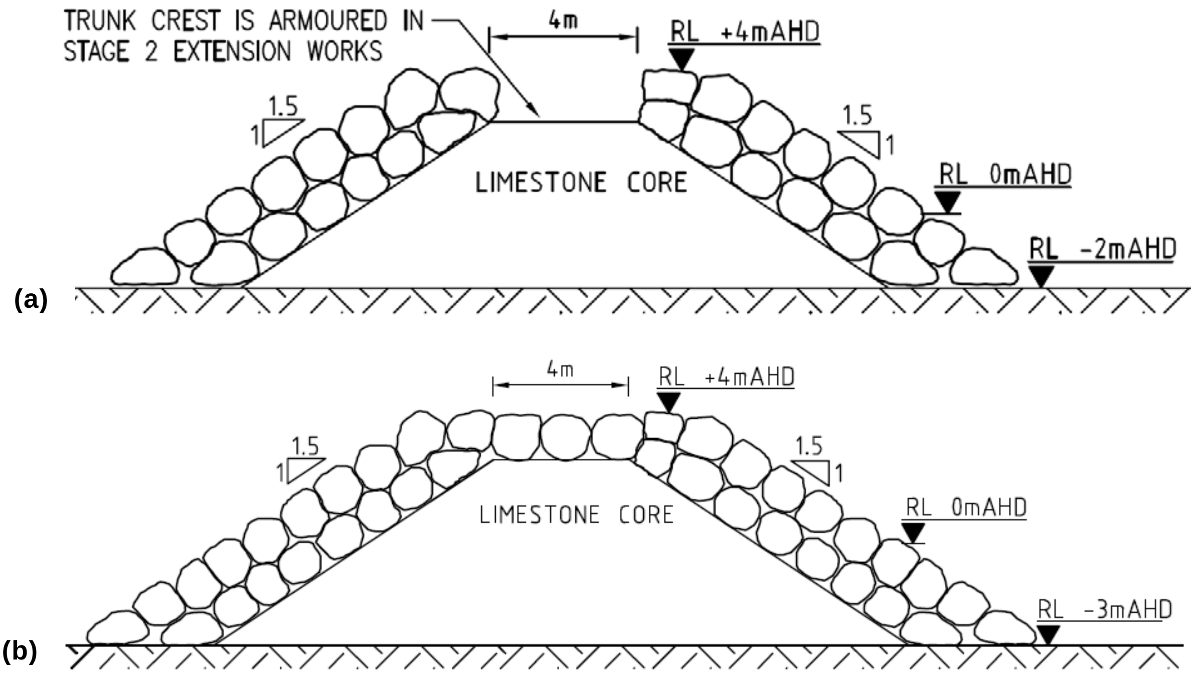



**Figure 6.5 - (a) Initial Stage - Trunk Section & (b) Groyne Extension - Head**

As shown in the Figure 6.5(a) above, it is proposed to leave the crest of the trunk unarmoured until after the groyne extensions have been completed. This will prevent double handing of the crest armour as it would have to be removed to allow access for machinery to conduct the extension stage of the works. The head of the groyne for the initial stage will remain fully armoured however, this will reduce overtopping damage for the most exposed section of the structure.

The crest level of +4 mAHD for the structure has been selected to reduce the impact of the groyne visually as well as reducing the construction costs. Therefore, under the proposed 50 year ARI event the structure would be subject to overtopping rates that make it unsafe for pedestrian use during the event. Appropriate signage should be installed as part of the works make the public aware of these limitations.

The potential impact of the construction of the groynes on the longshore sediment transport was investigated as part of the Stage 2 works. It was determined that when complete, the structures would act to transfer the shoreline recession to the north of the final structure. This area would then likely recede at the estimated 9,200 $m^3$ that the current area between the groynes is undergoing. Figure 6.6 shows the likely changes to the existing sediment transport under the Staged Groyne Option.

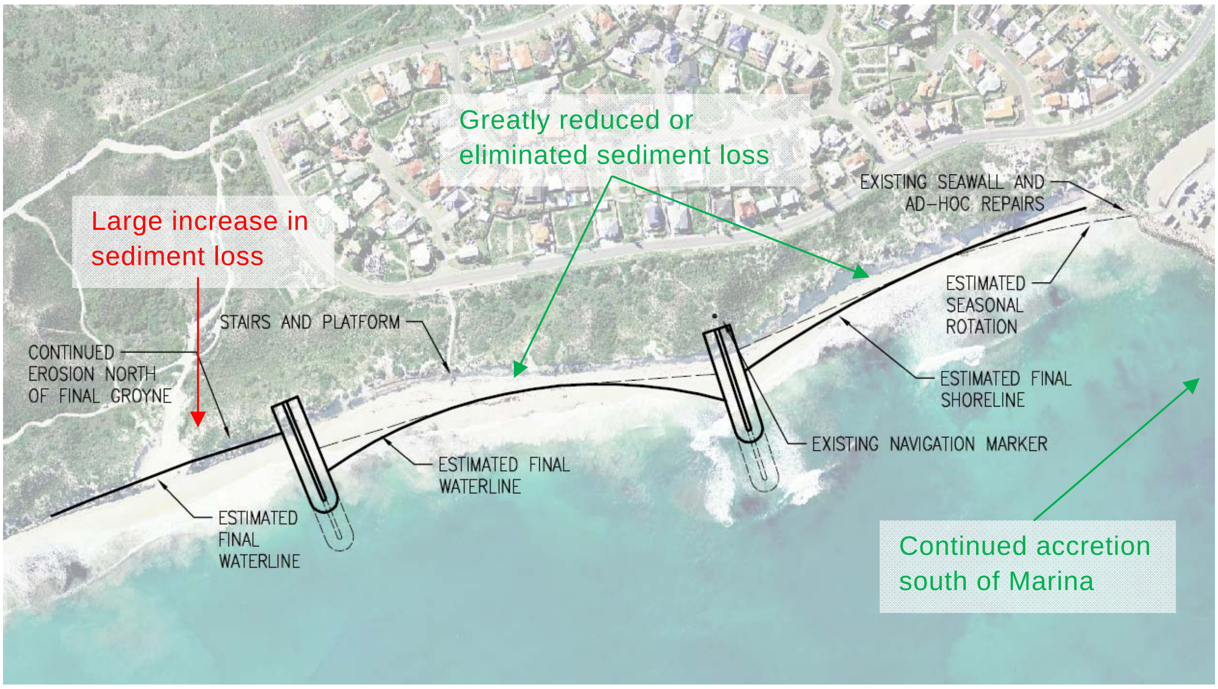



**Figure 6.6 - Estimated Impact of Structures on Sediment Transport**

The Staged Groynes management option does not solve the existing issue of erosion due to longshore sediment transport (Figure 6.6). The loss of sediment transport is simply shifted to a location further north. Should this area be developed in the future, additional steps such as additional groyne construction or substantial setbacks may be required.

The estimated final shoreline (waterline) positions shown in Figure 6.6 were determined as part of the Stage 2 works. This was done through analysis of previous investigations into shoreline orientation and stability that were conducted as part of MRA (2006) as well as through revised analytical and desktop level analysis.

MRA (2006) determined that due to the wave approach angles, a stable shoreline orientation would be achieved for the shoreline between the southern groyne and the Marina once the shoreline had rotated approximately 4° counter-clockwise from its 2004 alignment. Under the Stage 2 investigations, it was estimated that the shoreline has undergone approximately 2° rotation since the previous assessment. Therefore, an additional 2° of shoreline rotation has been allowed for when determining the final shoreline orientation between the Marina and the southernmost groyne.

The shoreline orientation between the two groynes was determined through an assessment of the likely wave incident angles based upon refraction of waves by nearshore features such as reefs and rock platforms, previous wave modelling conducted by MRA in the area and engineering experience and analysis of similar groyne systems. It should be noted that this is an indicative shoreline position only, as the final shoreline orientation can be affected by a large number of factors.

The shoreline to the north of the final groyne was estimated using analytical methods included those in Kamphuis (2000). This was done using the assumption that the area to the north of the groyne would be required to supply the 9,200 $m^3$/year sediment that the groynes would be retaining. This volume is in addition to the existing sediment loss experienced by the sector.

Overall, the shorelines shown in Figure 6.6 have been determined to an appropriate level for preliminary investigations. However, should detailed design of the structures be undertaken, detailed shoreline movement modelling using nearshore wave conditions should be completed. This could be done through a computer model such as Delft 3D.

To estimate the timing required for the construction of the groynes, the position of the shoreline was determined at a number of intervals of the 25 year planning period and compared to the available buffer to infrastructure.

It was determined that to maintain a suitable buffer to Sovereign Drive over the 25 year planning period, construction of the initial stage of the groynes would have to be undertaken in the next 5 years. Following construction of the initial stage, the groynes would be required to be extended to full length within approximately 10 years, i.e approximately 15 years from Year 0 (2012). If these construction timeframes are not achieved, additional actions such as sand nourishment may be required to maintain the preferred buffer.

In reality, the actual timing of the implementation of the Staged Groyne option will be dependent on the rates of recession experienced in the coming years. Changes to the rate of recession of the shoreline will change the timing of the works. Regular beach monitoring should therefore be undertaken prior to the construction of the groynes.

As for the Managed Retreat option, no allowance has been made for the presence of rock within the study area due to the unknown extent within the dune system. Geotechnical investigations to confirm the presence of rock and the implementation of a regular beach monitoring program to track shoreline recession and guide the requirements of the works is again recommended.

Based on the extent of shoreline recession rates estimated in Section 3, the extent of shoreline recession expected under the Staged Groyne option to 2037 is shown in Figure 6.7. The extent of severe storm erosion that may occur is also highlighted.

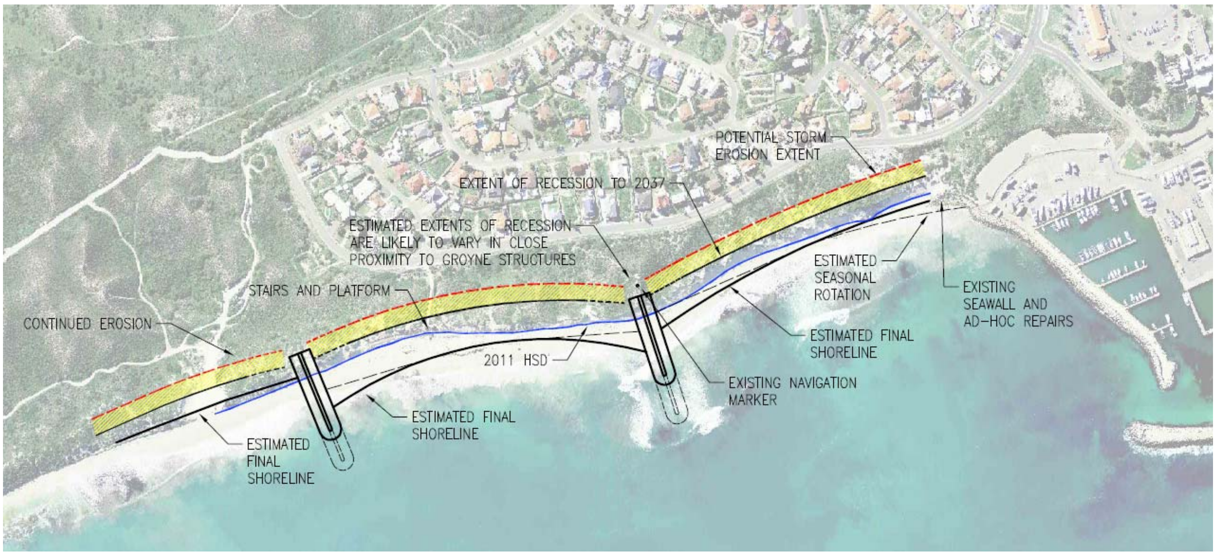



**Figure 6.7 - Shoreline Recession & Potential Severe Storm Erosion to 2037**

In addition to the allowances for long term shoreline erosion trends, sea level rise and severe storm erosion, allowances have been included for seasonal rotation of the beaches between the structures.

The groynes are much more effective than the Managed Retreat option at maintaining the overall shoreline position in the long term. However, there is still the potential for future coastal processes to affect Sovereign Drive to the immediate north of the Marina. The benefit of the Staged Groyne approach is that further shoreline recession following the 25 year planning period is greatly restricted.

Whereas the Managed Retreat Option resulted in Sovereign Drive being vulnerable to severe storm erosion in approximately 45 years, under the Staged Groyne option Sovereign Drive is estimated to be vulnerable to severe storm erosion in approximately 80 years (2092).

As shown in Figure 6.3, the Sceptre Court stairways and platforms and northern Marina seawall are vulnerable to potential severe storm erosion. As the Staged Groyne option is not planned to commence for 5 years, mitigation works for these structures are recommended. The estimated cost of the conducting these mitigation works is approximately $641,000 plus GST.

Under the proposed Staged Groyne option, no mitigation works are required for the navigation marker, as the southernmost groyne is proposed to be located directly seaward of the structure.

A summary cost estimate to construct the Staged Groyne option is presented in Table 6.1

### Table 6.1 – Staged Groyne Option Cost Estimate

| Item | Description | Estimated Cost |
|---|---|---|
| 1 | Relocation of Sceptre Court Stairs & Platform | $340,000 |
| 2 | Complete 50 m extension of northern Marina seawall | $301,000 |
| 3 | Stage 1 Groyne Construction | $2,131,000 |
| 4 | Stage 2 Groyne Construction | $1,254,000 |
| 5 | Shoreline Monitoring (per annum) | $20,000 |
| **6** | **Subtotal for Staged Groyne Option** | **$4,046,000** |
| 6.1 | Contingencies (15%) | $606,900 |
| **6.2** | **Total Estimated Cost (Excl GST)** | **$4,652,900** |

Notes: 1. Costs do not include allowances for the revegetation of disturbed areas resulting from the works.
2. All costs are exclusive of GST and are indicative only.
3. Costs for the relocation of Sceptre Court stairs are on the basis of replacement.

In addition to the capital cost assessment of the Staged Groyne works, a NPV assessment over 25 years was conducted. Under this assessment an allowance for maintenance of the groynes every 5 years has been made in the financial analysis.

A preliminary plan, outlining the management steps to be undertaken for the Staged Groyne option and showing the coastal processes allowances to 2037 is included in Appendix 11.

## 6.4 Stage 2 Evaluation of Coastal Management Option

### 6.4.1 Net Present Value Assessment

The capital costs of the two coastal management options examined in the Stage 2 investigations were presented in the previous sections and are summarised in Table 6.2. In order to establish the NPV of the management options, the likely maintenance, monitoring and various other costs have also been estimated. An allowance for some maintenance of the groyne structures has been made every 5 years, to account for issues such as storm damage. Provisional allowances for the planning and detailed designs of the mitigation and coastal management options have also been included as appropriate.

Similarly to the Stage 1 analysis, a discounted cash flow analysis has been used to determine the Net Present Value (NPV) of the options for a range of discount rates. The undiscounted net cost over the 25 year analysis period and the NPV of the Stage 2 options, assuming a discount rate of 6%, are summarised in Table 6.2.

**Table 6.2 – Stage 2 Cost Summary for Coastal Management Options**

| Item | Management Option | Capital Cost | Undiscounted Net Cost over 25 years | Net Present Value at 6% for 25 years |
|---|---|---|---|---|
| 1 | Managed Retreat | $995,440 | $1,286,440 | $1,045,718 |
| 2 | Staged Groyne Construction | $4,652,900 | $5,684,900 | $3,742,668 |

Full NPV analysis for a range of rates for the Managed Retreat and Staged Groyne options are included as Appendix 12.

As noted previously, the assessment is purely based on the next 25 years, prior to the Managed Retreat option impacting any substantial infrastructure. Therefore, any analysis of a longer period is unlikely to favour the Managed Retreat option.

### 6.4.2 Further Considerations

In comparing the management options, the cost, performance and impact of each of the options needs to be considered. Each of the proposed coastal management options will have a different impact on the area, and community consultation will be undertaken to assess the responses to each option.

In addition to an economic comparison of the two management options, consideration was also given to the benefits and disadvantages of each option. These are shown in Table 6.3.

### Table 6.3 – Benefits & Disadvantages for Coastal Management Options

| Management Option | Benefits to 2037 | Disadvantages to 2037 |
|---|---|---|
| Managed Retreat | • Beach amenity is retained<br>• No additional interference with coastal processes<br>• Low cost to 2037<br>• Low social impact over the planning period | • Unlikely to be a viable long term option<br>• Large erosion scarp and reduced public safety and beach access<br>• Loss of foreshore asset<br>• Would still require management of stairs, platform and navigation aid |
| Groynes | • Beach access is maintained<br>• Works can be constructed in stages<br>• Maintenance costs are periodic and relatively low<br>• Allows refinement of scheme through monitoring | • Moderate capital cost<br>• Requires management of stairs, platform and seawall extension<br>• Environmental impact on nearshore reefs<br>• Visual impact<br>• Erosion likely to continue north of the groynes |

It is noted that there may be other impacts, either direct or indirect resulting from the management options. The impacts presented above are believed to be the most important is assessing the appropriate coastal management option.

As for the Stage 1 investigations, a subjective comparison of each options likely environmental, social and economic impacts and long term risk to infrastructure under the proposed coastal management plan was conducted. This assessment and overall ranking for each coastal management option is shown in Table 6.4.

### Table 6.4 – Assessment of Preliminary Coastal Management Options

| Management Option | Impacts over 25 years | | | Long Term Risk to Infrastructure (Over 100 years) | Overall Ranking (Rating Value) |
|---|---|---|---|---|---|
| | Environmental | Social | NPV over 25 years | | |
| Managed Retreat | Medium | Low | Low | High | 1 (9) |
| Groynes | Medium | Low/Medium | Medium | Low/Medium | 2 (9) |

Notes: 1. High Risk and Impacts are rated as 1, Medium Risks and Impacts are rated as 2, Low Risks and Impacts are rated as 3.
2. Where two options tie for a ranking, the lower NPV option is ranked higher.

It can be seen that both coastal management options are awarded an equal overall ranking, with the increased cost and social impact of the Staged Groyne option counteracted by the high long term risk of the Managed Retreat option. The table above is based on a subjective assessment of the impacts of each option and is for comparative purposes only. The potential impacts of the preferred option should be assessed in more detail during the detailed design phase. However the Managed Retreat option was ranked first due its lower NPV over the 25 year timeframe considered. Over this assessment timeframe Managed Retreat is therefore recommended as the most appropriate management option.

It is recommended that a minimum buffer of approximately 25 m to the Sovereign Drive road reserve be used as the trigger for commencing immediate supplementary coastal management works to the preferred option. This trigger value is based upon a severe storm erosion allowance of 20 m and an additional 5 m as a factor of safety and working area.

Should this trigger be reached, additional coastal management options would be required. Ongoing sand nourishment or bypassing could be commenced, or a last line of defence protection such as a seawall could be implemented. It is noted that if the trigger is reached, it is recommended that coastal management works are commenced immediately. It is also noted that at that stage some of the options presented in this report may no longer be possible.

# 7. Recommended Future Actions

In the process of conducting this investigation, a number of areas were identified where additional information would benefit future investigations into the Two Rocks area and assist in the implementation of coastal management options. A summary of these recommended actions is listed in Table 7.1.

### Table 7.1 – Summary of Recommended Actions

| Recommended Action | Extents | Recommended Frequency | Comment |
|---|---|---|---|
| Beach Monitoring | Profiles should extend from behind the crest of the dune to several hundred meters offshore | Surveys at 2 year intervals following establishment of baseline dataset | Beach profile surveys to monitor shoreline movement and assist future investigations and implementation of coastal management options |
| Photo Monitoring | North Yanchep Headland to Mallee Reef Salient | Seasonally and following severe storm events | Coverage covers the sediment cells adjacent to Two Rocks, a more targeted program could capture movements immediately north and south of the Marina |
| Hydrographic & Beach surveys | Coverage should include the Marina and adjacent sections of coastline. | Conduct in conjunction with beach monitoring profiles | Hydrographic surveys need to have continuous data coverage from the beach to offshore. Data gaps reduce the usefulness of the surveys |
| Geotechnical Investigations | Shoreline north of the Marina | Single occurrence | Ground penetrating radar or similar should be used to determine the location and extent of rock in the beach and dunes north of the Marina |

Since earlier versions of this report, the DoT has completed geophysical investigations at the site. This confirmed the presence of limestone rock in the foreshore at elevations of between -0.5 and +6.3 mAHD. The presence of rock may influence:

- Rates and areas of shoreline movement.
- Protection to infrastructure.
- Cost of mitigation measures.

The location and presence of the rock should be reviewed with the outcomes and recommendations of this report.

# 8. Review & Public Presentation

The DoT and the City reviewed and provided comments on a draft version of this report. DoT comments and MRA's responses are provided in Appendix 13. No further comments were received from DoT following MRA's response.

In March 2015 a summary of the works completed and the outcomes from this study were presented in a public information session in Two Rocks. The session was attended by representatives from the City, DoT and MRA as well as members of the public. Minutes from the session are included in Appendix 14.

# 9. Summary & Recommendations

The City of Wanneroo commissioned specialist coastal and port engineers, M P Rogers and Associates to investigate the erosion north of the Two Rocks Marina and re-evaluate potential coastal management options for the area. This was completed in two stages.

In Stage 1, MRA investigated the required allowances for coastal processes north of the Marina for a timeframe of 25 years and re-assessed the previously determined conceptual coastal management options for the updated assessment findings.

Following a presentation of the Stage 1 results to the City and DoT, Stage 2 involved further detailed investigation and refinement of the two preferred coastal management options.

The required allowances for coastal processes over a 25 year period were assessed using the Draft State Coastal Planning Policy (SPP) 2.6 as a framework. The following key conclusions and recommendations have been made as a result of the investigations.

It was established in MRA (2006) that between 1965 and 1996 in the order of 14,000 $m^3$/yr was eroding from the 1.5 km of coastline to the north of the Marina. It was further determined that the cause of this erosion was the construction of the Marina, interrupting the alongshore sediment transport of the area.

This assessment updated the shoreline movement and sediment budget analysis and estimated that the erosion experienced north of the Marina was in the order of 20,000 $m^3$/yr over approximately 4 km of coastline for the period 1981 to 2011. This larger estimate of sediment loss is the result of a larger length of coastline being considered. Overall, it was found that the rate of erosion may be slightly decreasing for the area immediately north of the Marina, as the shoreline movement recession rates decreased from -1.2 m/yr in MRA (2006) to -0.7 m/yr for the current assessment.

Severe storm erosion modelling was completed using the SBEACH computer model to simulate the extent of erosion experienced north of the Marina. It was estimated that approximately 20 m of erosion behind the HSD may be experienced during a severe storm event.

An allowance for sea level rise based upon a potential rise of 0.9 m over the next 100 years was allowed for under the assessment. Based on a timeframe of 25 years, this resulted in a recession due to sea level rise of approximately 5 m.

The required allowance for coastal processes over the next 25 years was estimated to be approximately 43 m.

Several items of infrastructure were deemed to be vulnerable to coastal processes over the next 25 years, including the Sceptre Court stairs and viewing platform, northern Marina seawall and a DoT navigation marker.

Six conceptual coastal management options were investigated to manage the shoreline recession experienced north of the Marina and protect the vulnerable infrastructure. These options were Managed Retreat, Sand Nourishment, Sand Bypassing, Seawall, Staged Groynes and Offshore breakwaters.

These coastal management options were compared on an economic, social and environmental impact basis to select two preferred coastal management options. This also included an assessment of the potential protection each option provided for timeframes longer than the 25 years selected for the investigation.

The two highest ranked coastal management options from the Stage 1 works were the Managed Retreat and Staged Groyne options. These were recommended for further investigation in Stage 2.

In Stage 2, these options were further investigated and refined. This included:

- Refining the layout, design and extents of the Staged Groyne option;
- Estimating the impact of the proposed management options on the sediment transport patterns of the area;
- Estimating the final position of the 2037 shoreline for the proposed management options;
- Estimating the timeframe in which the proposed management option is likely to impact Sovereign Drive;
- Assessment of the relative benefits and disadvantages of the two options;
- Assessing the environmental, social and economic impacts of the recommended management options; and
- Further refining the estimated cost and NPV analysis of the recommended management options.

Following the Stage 2 investigations, both the Managed Retreat and Staged Groyne options achieved the same rating. Therefore, the Managed Retreat option was ranked first due its lower NPV over the 25 year timeframe considered.

It was also noted that the Managed Retreat option was largely successful because of the timeframe considered. For an extended timeframe the Managed Retreat option would result in infrastructure such as Sovereign Drive and private development becoming vulnerable to coastal processes and would no longer be the higher ranked option.

The timeframes in which Sovereign Drive may be vulnerable to the coastal processes allowances were also investigated. It was assessed that under the Managed Retreat option, Sovereign Drive would be vulnerable to severe storm erosion in approximately 45 years (2057). For the Staged Groyne option, Sovereign Drive was likely to be vulnerable to severe storm erosion in approximately 80 years (2092).

Following recommendations from this study, the DoT has completed a geophysical investigation of the foreshore in the study area. This found limestone rock at levels of between -0.5 and +6.3 mAHD. The location and presence of the rock should be reviewed with the outcomes and recommendations of this report.

The results of the investigations were presented to the Two Rocks community in March 2015 at a public information session. Representatives from the City, DoT and MRA attended, along with members of the public. Minutes from the meeting are attached to this report.

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# 11. Appendices

**Appendix 1 SBEACH Storm Erosion Model – Input & Output Data**

**Appendix 2 Conceptual Managed Retreat Option - Plan**

**Appendix 3 Conceptual Sand Nourishment Option - Plan**

**Appendix 4 Conceptual Sand Bypassing Option - Plan**

**Appendix 5 Conceptual Staged Seawall Option - Plan**

**Appendix 6 Conceptual Staged Groyne Option - Plan**

**Appendix 7 Conceptual Offshore Breakwater Option - Plan**

**Appendix 8 Assessment Summary of Management Options**

**Appendix 9 Stage 1 Net Present Value Analysis**

**Appendix 10 Preliminary Managed Retreat Option – Plan**

**Appendix 11 Preliminary Staged Groyne Option – Plan**

**Appendix 12 Stage 2 Net Present Value Analysis**

**Appendix 13 DoT Comments & MRA Response**

**Appendix 14 Public Information Session Minutes**

# Appendix 1 SBEACH Storm Erosion Model – Input & Output Data

# K1030 - Two Rocks Coastal

## Reach: Two Rocks Storm: SCPP

Report

Project: K1030 - Two Rocks Coastal
Reach: Two Rocks
Storm: SCPP

MODEL CONFIGURATION

INPUT UNITS (SI=1, AMERICAN CUST.=2): 1
NUMBER OF CALCULATION CELLS: 1000
GRID TYPE (CONSTANT=0, VARIABLE=1): 1
NUMBER OF GRID CELL REGIONS: 4
NUMBER CELLS AND CELL WIDTH IN REGION 1: 300, 1.0
NUMBER CELLS AND CELL WIDTH IN REGION 2: 200, 5.0
NUMBER CELLS AND CELL WIDTH IN REGION 3: 200, 20.0
NUMBER CELLS AND CELL WIDTH IN REGION 4: 300,109.0
NUMBER OF TIME STEPS AND VALUE OF TIME STEP IN MINUTES: 4008, 5.0
TIME STEP(S) OF INTERMEDIATE OUTPUT 1: 1336
TIME STEP(S) OF INTERMEDIATE OUTPUT 2: 2772
NO COMPARSION WITH MEASURED PROFILE.
PROFILE ELEVATION CONTOUR 1: 5.00
PROFILE ELEVATION CONTOUR 2: 0.00
PROFILE ELEVATION CONTOUR 3: -5.00
PROFILE EROSION DEPTH 1: 0.00
PROFILE EROSION DEPTH 2: 1.00
PROFILE EROSION DEPTH 3: 1.50
REFERENCE ELEVATION: 2.50
TRANSPORT RATE COEFFICIENT (m^4/N): 1.75E-6
COEFFICIENT FOR SLOPE DEPENDENT TERM (m^2/s): 0.0020
TRANSPORT RATE DECAY COEFFICIENT MULTIPLIER: 0.50
WATER TEMPERATURE IN DEGREES C : 16.0

WAVE TYPE (MONOCHROMATIC=1, IRREGULAR=2): 2
WAVE HEIGHT AND PERIOD INPUT (CONSTANT=0, VARIABLE=1): 1
TIME STEP OF VARIABLE WAVE HEIGHT AND PERIOD INPUT IN MINUTES: 120.0
WAVE ANGLE INPUT (CONSTANT=0, VARIABLE=1): 0
CONSTANT WAVE ANGLE: 0.0
WATER DEPTH OF INPUT WAVES (DEEP WATER = 0.0): 10.0
SEED VALUE FOR WAVE HEIGHT RANDOMIZER AND % VARIABILITY: 4567, 20.0
TOTAL WATER ELEVATION INPUT (CONSTANT=0, VARIABLE=1): 1
TIME STEP OF VARIABLE TOTAL WATER ELEVATION INPUT IN MINUTES: 120.0
WIND SPEED AND ANGLE INPUT (CONSTANT=0, VARIABLE=1): 0
CONSTANT WIND SPEED AND ANGLE: 20.0, 0.0

TYPE OF INPUT PROFILE (ARBITRARY=1, SCHEMATIZED=2): 1
DEPTH CORRESPONDING TO LANDWARD END OF SURF ZONE: 0.30
EFFECTIVE GRAIN SIZE DIAMETER IN MILLIMETERS: 0.36
MAXIMUM PROFILE SLOPE PRIOR TO AVALANCHING IN DEGREES: 45.0

NO BEACH FILL IS PRESENT.

NO SEAWALL IS PRESENT.

HARD BOTTOM IS PRESENT.

---

COMPUTED RESULTS

DIFFERENCE IN TOTAL VOLUME BETWEEN FINAL AND INITIAL PROFILES:
-1.0 m^3/m

# K1030 - Two Rocks Coastal

## Reach: Two Rocks Storm: SCPP

MAXIMUM VALUE OF WATER ELEVATION + SETUP FOR SIMULATION
1.89 m

TIME STEP AND POSITION ON PROFILE AT WHICH MAXIMUM VALUE
OF WATER ELEVATION + SETUP OCCURRED
1792, 52.0 m
MAXIMUM ESTIMATED RUNUP ELEVATION: 3.26 m
(REFERENCED TO VERTICAL DATUM)

POSITION OF LANDWARD MOST OCCURRENCE OF A 0.00 m EROSION DEPTH:
37.0 m

DISTANCE FROM POSITION OF REFERENCE ELEVATION ON INITIAL PROFILE
TO POSITION OF LANDWARD MOST OCCURRENCE OF A 0.00 m EROSION DEPTH:
19.4 m

POSITION OF LANDWARD MOST OCCURRENCE OF A 1.00 m EROSION DEPTH:
38.0 m

DISTANCE FROM POSITION OF REFERENCE ELEVATION ON INITIAL PROFILE
TO POSITION OF LANDWARD MOST OCCURRENCE OF A 1.00 m EROSION DEPTH:
18.4 m

POSITION OF LANDWARD MOST OCCURRENCE OF A 1.50 m EROSION DEPTH:
39.0 m

DISTANCE FROM POSITION OF REFERENCE ELEVATION ON INITIAL PROFILE
TO POSITION OF LANDWARD MOST OCCURRENCE OF A 1.50 m EROSION DEPTH:
17.4 m

MAXIMUM RECESSION OF THE 5.00 m ELEVATION CONTOUR:
5.87 m

MAXIMUM RECESSION OF THE 0.00 m ELEVATION CONTOUR:
0.01 m

MAXIMUM RECESSION OF THE -5.00 m ELEVATION CONTOUR:
0.00 m

## Appendix 2 Conceptual Managed Retreat Option – Plan


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MANAGED RETREAT OPTION

CITY OF WANNEROO – TWO ROCKS COASTAL REVIEW

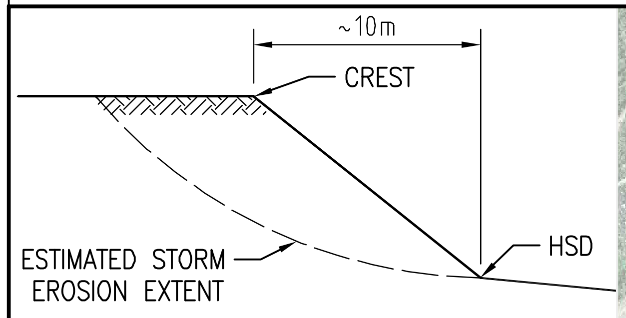
SCALE AT A3 1:5,000

FEBRUARY 2013

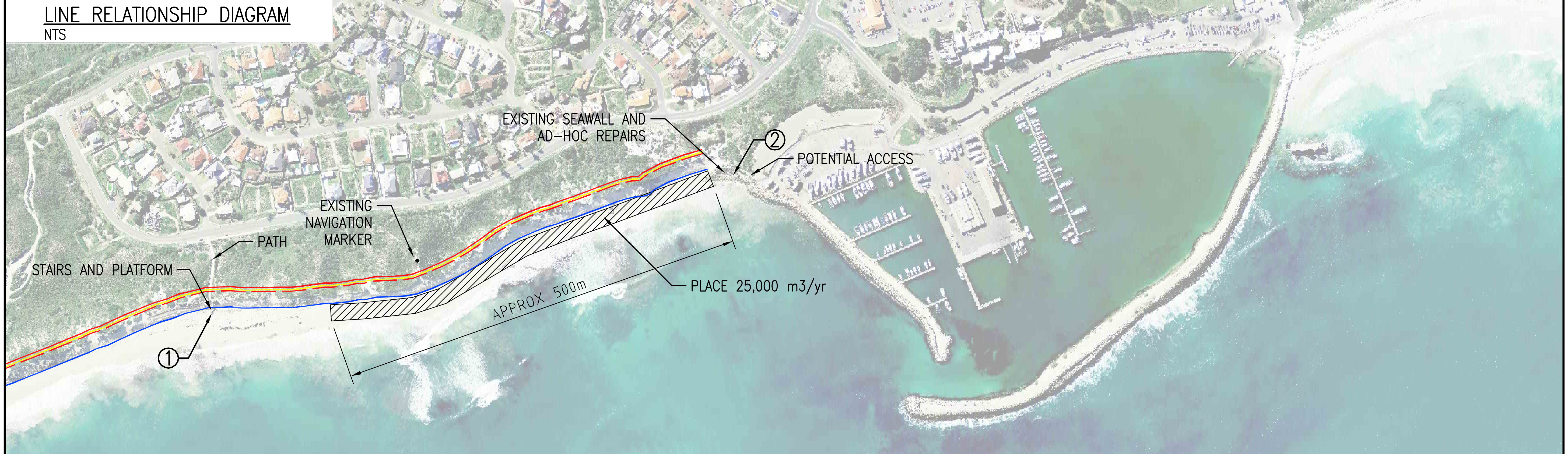
SK1030-25/07/2013-1

## Appendix 3 Conceptual Sand Nourishment Option – Plan

AT CORRECT SCALE THIS IS 100 mm




## LINE RELATIONSHIP DIAGRAM
NTS




## LEGEND:

- 2037 CREST LINE
- 2022 CREST LINE
- EXTENT OF STORM EROSION
- 2011 HSD (TOE OF SCARP)

## NOTES:

1. 2022, 2037 LINES DO NOT INCLUDE AN ALLOWANCE FOR SHORELINE RECESSION DUE TO LONGSHORE TRANSPORT
2. POTENTIAL SEDIMENT SOURCES INCLUDE ROCLA GIN GIN QUARRY AND CARRAMAR RESOURCE INDUSTRIES
3. A MONITORING PROGRAM SHOULD BE CONDUCTED WITH SAND NOURISHMENT PROGRAM
4. ESTIMATED CREST LINES ARE BASED ON RECESSIONS DUE TO STORM EROSION AND SEA LEVEL RISE

## MANAGEMENT NOTES

① RELOCATE OR MODIFY STAIRS AND PLATFORM

② EXTEND SEAWALL BY APPROXIMATELY 50m

③ SAND NOURISHMENT OF 25,000 m3/yr TO BE CONDUCTED ANNUALLY

AT CORRECT SCALE THIS IS 100 mm

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SAND NOURISHMENT OPTION

CITY OF WANNEROO – TWO ROCKS COASTAL EROSION REVIEW

FEBRUARY 2013

SCALE AT A3 1:5,000

SK1030–25/07/2013–2

## Appendix 4 Conceptual Sand Bypassing Option – Plan

AT CORRECT SCALE THIS IS 100 mm


## LEGEND:

- 2037 CREST LINE
- 2022 CREST LINE
- EXTENT OF STORM EROSION
- 2011 HSD (TOE OF SCARP)

## NOTES:

1. 2022, 2037 LINES DO NOT INCLUDE AN ALLOWANCE FOR SHORELINE RECESSION DUE TO LONGSHORE TRANSPORT.
2. MONITORING OF SHORELINE SHOULD BE UNDERTAKEN TO TRACK SHORELINE RECESSION & EFFECTIVENESS OF BYPASSING.
3. ESTIMATED CREST LINES ARE BASED ON RECESSIONS DUE TO STORM EROSION AND SEA LEVEL RISE.

## MANAGEMENT NOTES

① RELOCATE OR MODIFY STAIRS AND PLATFORM

② EXTEND SEAWALL BY APPROXIMATELY 50m

③ SAND BYPASSING OF 25,000 m3/yr TO BE COMPLETED ANNUALLY

AT CORRECT SCALE THIS IS 100 mm


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SAND BYPASSING OPTION

CITY OF WANNEROO – TWO ROCKS COASTAL EROSION REVIEW

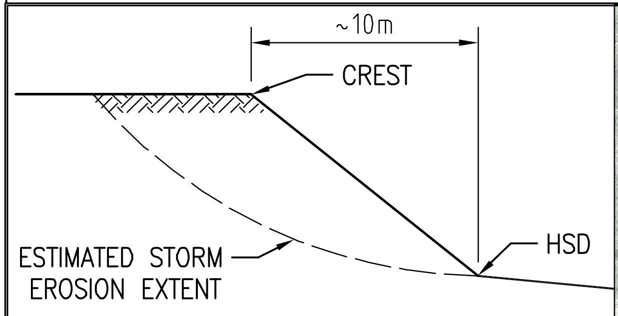
FEBRUARY 2013

SCALE AT A3 1:5,000

SK1030–25/07/2013–6

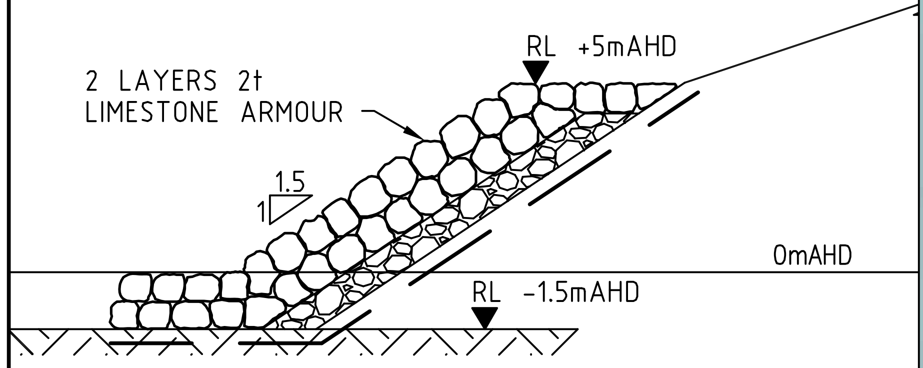
## Appendix 5 Conceptual Staged Seawall Option – Plan

AT CORRECT SCALE THIS IS 100 mm




## LINE RELATIONSHIP DIAGRAM
NTS


AT CORRECT SCALE THIS IS 100 mm




## TYP SECTION
1:20

## LEGEND:

| | |
|---|---|
| red line | 2037 CREST LINE |
| yellow line | 2022 CREST LINE |
| red dashed line | EXTENT OF STORM EROSION |
| blue line | 2011 HSD (TOE OF SCARP) |

## NOTES:

1. ESTIMATED CREST LINES ARE BASED ON RECESSIONS DUE TO STORM EROSION, SHORELINE MOVEMENT AND SEA LEVEL RISE IF SEAWALL NOT CONSTRUCTED
2. MONITORING OF SHORELINE SHOULD BE UNDERTAKEN TO TRACK SHORELINE RECESSION

## MANAGEMENT NOTES

① STAGE A IS PRIORITY FOR WORKS. SEAWALL IS CONSTRUCTED TO MAINTAIN MINIMUM BUFFER OF 40m FROM THE ROAD RESERVE TO ALLOW FOR DUNE SLOPE AND USEABLE FORESHORE RESERVE

② REMAINDER OF SEAWALL TO BE COMPLETED IN STAGES AS EROSION PROGRESSES

③ RELOCATE NAVIGATION MARKER TO BEHIND PROPOSED SEAWALL LOCATION AS NEEDED

④ RELOCATE OR MODIFY STAIRS AND PLATFORM

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**SEAWALL OPTION**
CITY OF WANNEROO – TWO ROCKS COASTAL EROSION REVIEW

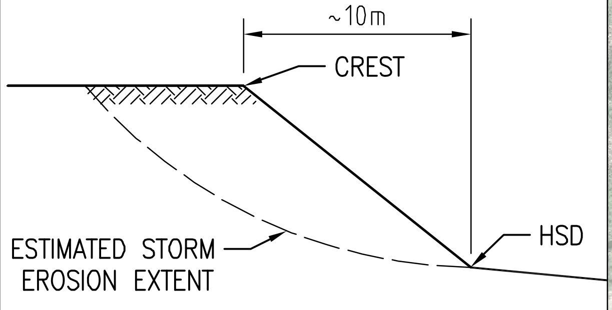
FEBRUARY 2013

SCALE AT A3 1:5,000

SK1030-25/07/2013-3

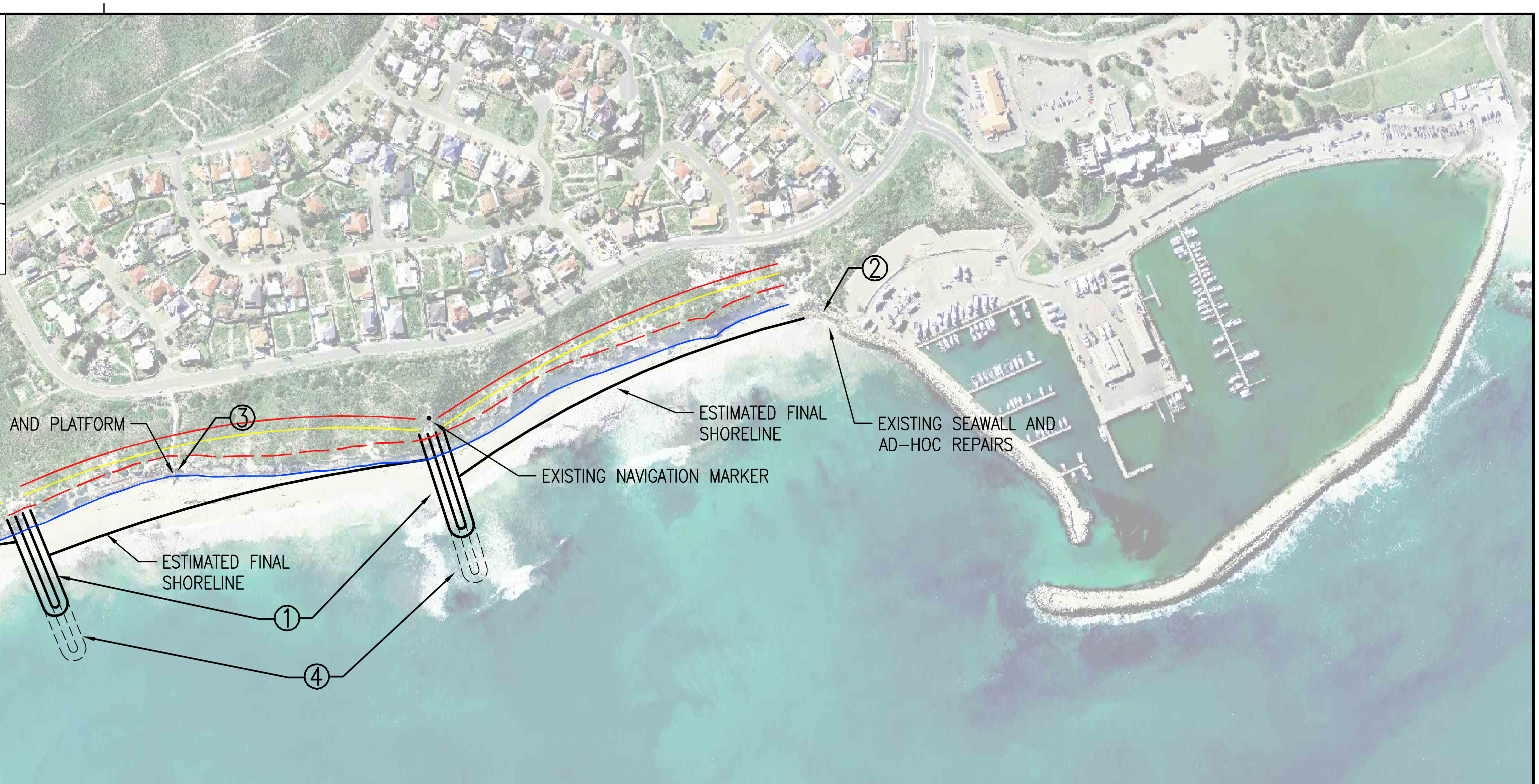
## Appendix 6 Conceptual Staged Groyne Option – Plan

AT CORRECT SCALE THIS IS 100 mm




LINE RELATIONSHIP DIAGRAM

NTS




## LEGEND:

- 2037 CREST LINE
- 2022 CREST LINE
- EXTENT OF STORM EROSION
- 2011 HSD (TOE OF SCARP)

## NOTES:

1. TO MAINTAIN APPROPRIATE BUFFER, GROYNES HAVE TO BE BUILT WITHIN ~5 YEARS
2. IF CONSTRUCTION IS DELAYED, NOURISHMENT MAY BE REQUIRED
3. ESTIMATED CREST LINES ARE BASED ON RECESSIONS DUE TO STORM EROSION AND SEA LEVEL RISE
4. MONITORING OF SHORELINE SHOULD BE UNDERTAKEN TO TRACK SHORELINE RECESSION
5. 2022, 2037 LINES DO NOT INCLUDE AN ALLOWANCE FOR SHORELINE RECESSION DUE TO LONGSHORE TRANSPORT

## MANAGEMENT NOTES

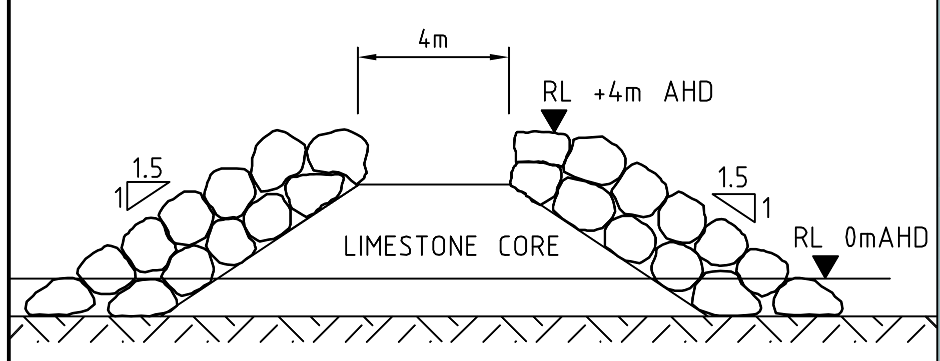
① CONSTRUCTION OF STAGE 1 GROYNES

② EXTEND SEAWALL BY APPROXIMATELY 50m

③ STAIRS AND PLATFORM TO BE RELOCATED OR MODIFIED

④ CONSTRUCT STAGE 2 GROYNES PRIOR TO 2037

AT CORRECT SCALE THIS IS 100 mm




TYP SECTION

SCALE 1:250

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GROYNES OPTION

CITY OF WANNEROO – TWO ROCKS COASTAL EROSION REVIEW

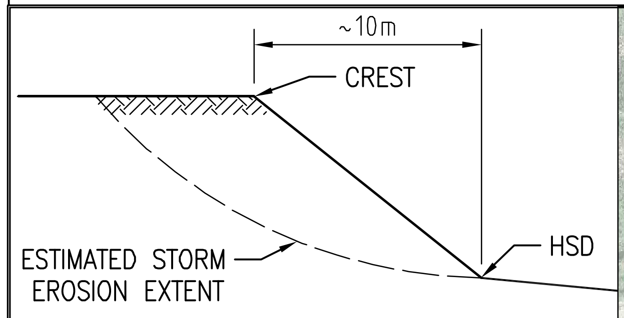
SCALE AT A3 1:5,000

FEBRUARY 2013

SK1030-25/07/2013-4

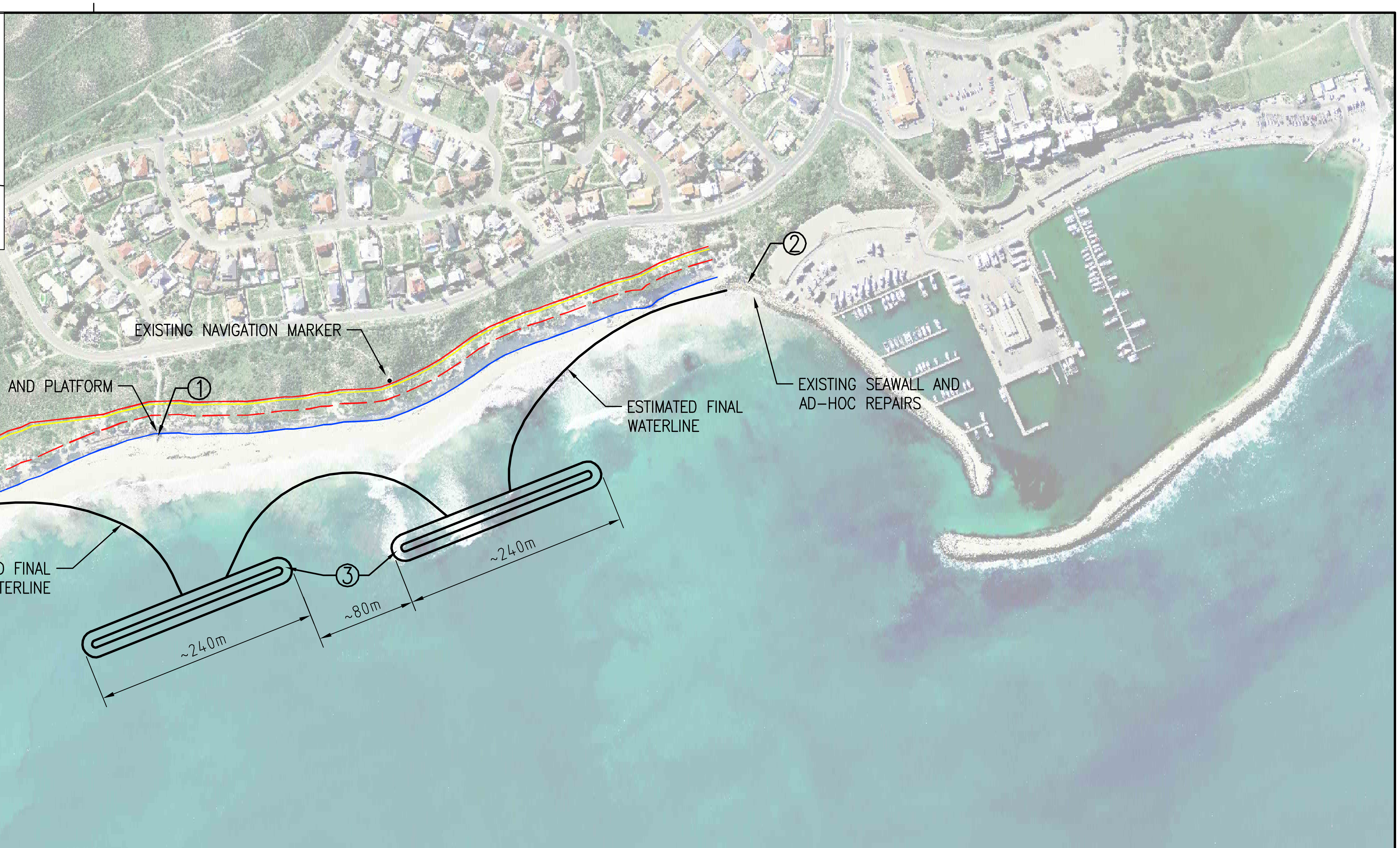
## Appendix 7 Conceptual Offshore Breakwater Option – Plan

AT CORRECT SCALE THIS IS 100 mm




## LINE RELATIONSHIP DIAGRAM

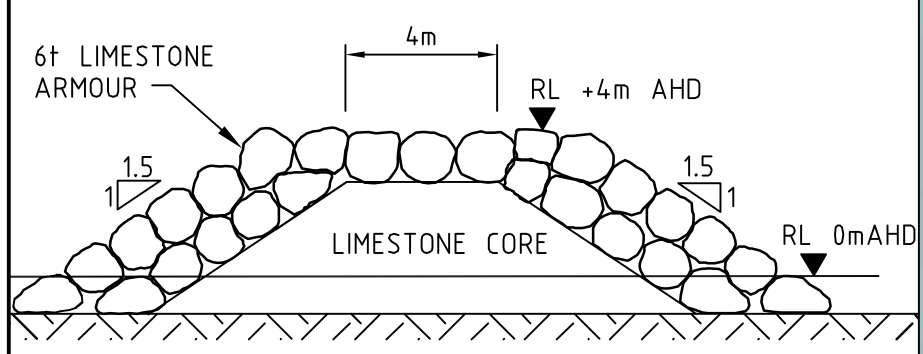
NTS




## LEGEND:

- 2037 CREST LINE
- 2022 CREST LINE
- EXTENT OF STORM EROSION
- 2011 HSD (TOE OF SCARP)

AT CORRECT SCALE THIS IS 100 mm




## TYP SECTION

SCALE 1:250

## NOTES:

1. 2022, 2037 LINES DO NOT INCLUDE AN ALLOWANCE FOR SHORELINE RECESSION DUE TO LONGSHORE TRANSPORT.
2. MONITORING OF SHORELINE SHOULD BE UNDERTAKEN TO TRACK SHORELINE RECESSION
3. ESTIMATED CREST LINES ARE BASED ON RECESSIONS DUE TO STORM EROSION AND SEA LEVEL RISE.

## MANAGEMENT NOTES

① RELOCATE OR MODIFY STAIRS DUE TO STORM EROSION RISK

② EXTEND SEAWALL LENGTH BY APPROXIMATELY 50m

③ CONSTRUCT OFFSHORE BREAKWATER, LEAVE SAND BUNDS AS NOURISHMENT FOR TOMBOLO FORMATION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# OFFSHORE BREAKWATERS OPTION

CITY OF WANNEROO – TWO ROCKS COASTAL EROSION REVIEW

FEBRUARY 2013

SCALE AT A3 1:5,000

SK1030-25/07/2013-5

## Appendix 8 Assessment Summary of Management Options

| Management Option | Feasibility & Practicality | Environmental Impacts | Social Impacts | Capital & Ongoing Costs | Long Term Effectiveness | Response to Climate Change |
|---|---|---|---|---|---|---|
| **Managed Retreat** | • Practical method of managing the coastal erosion in the short term.<br>• Mitigation works for existing coastal infrastructure are relatively minor.<br>• Infrastructure remains at risk in the long term. | • Minor. Some impact due to mitigation works to modify/relocate vulnerable coastal infrastructure.<br>• No additional interference with coastal processes.<br>• Sand continues to accrete south of the marina. | • Low social impact over the planning period.<br>• Beach amenity is retained in the short term.<br>• Continued loss of beach and steep beach scarps.<br>• Potential loss of beach access infrastructure. | • Lowest capital investment in the short term. Mitigation costs are ~$980,000.<br>• Potential ongoing costs include a beach monitoring programme. | • Unlikely to be viable due to the high value infrastructure that will be vulnerable in the long term. | • Subject to potential changes in rate of shoreline recession as a result of climate change and sea level rise. |
| **Sand Nourishment** | • Purchase cost of sand is prohibitive given available source nearby.<br>• Substantial undertaking required each year.<br>• Existing coastal infrastructure remains at risk and will require mitigation. | • Shoreline recession due to longshore sediment transport is reduced.<br>• Partial replication of the natural coastal processes. Sand continues to accumulate south of the marina. | • Beach amenity is maintained through nourishment.<br>• Impact associated with bypassing operations.<br>• Potential loss of beach access infrastructure. | • Capital cost of mitigation works is ~ $740,000.<br>• Ongoing annual cost of ~$1.05 million for sand nourishment.<br>• Potential ongoing costs include a beach monitoring programme. | • Effective management of longshore erosion requires a long term commitment to an annual nourishment program.<br>• Does not prevent shoreline recession due to storm damage or sea level rise. | • Subject to changes in the longshore transport of sediment.<br>• Option does not protect infrastructure from the effects of climate change or sea level rise. |
| **Sand Bypassing** | • Large source of sediment available nearby.<br>• Variety of sand bypassing methods available for use.<br>• Existing coastal infrastructure remains at risk and will require mitigation. | • Shoreline recession due to longshore sediment transport is reduced.<br>• Partial replication of the natural coastal processes.<br>• Bypassing sediment around a man-made obstruction. | • Beach amenity is retained.<br>• Bypassing methods are available to minimise social impacts.<br>• Potential loss of beach access infrastructure. | • Capital cost of mitigation works is ~$740,000.<br>• Likely annual bypassing costs through temporary onshore pumping system is ~$450,000. | • Effective management of longshore erosion requires a long term commitment to an annual nourishment program.<br>• Does not prevent shoreline recession due to storm damage or sea level rise. | • Subject to changes in the longshore transport of sediment.<br>• Option does not protect infrastructure from the effects of climate change or sea level rise. |
| **Seawall** | • Can be conducted in stages.<br>• Substantial undertaking required to protect potentially vulnerable infrastructure in the long term.<br>• Existing coastal infrastructure remains at risk and will require mitigation. | • Potential impacts associated with the seawall construction.<br>• Erosion likely to continue north of the structures | • Loss of beach amenity likely over the long term.<br>• Continued loss of beach and steep beach scarps prior to seawall being built.<br>• Potential loss of beach access infrastructure.<br>• Visual impact of structure. | • Capital cost of mitigation works is ~$450,000.<br>• High capital works investment of ~$5.5 million.<br>• Can be conducted in stages to reduce initial investment.<br>• Maintenance required approximately every 5 years. | • Very effective for long term protection of valuable infrastructure.<br>• Does not protect existing vulnerable coastal infrastructure. | • Structure will be designed for expected increases in sea level rise.<br>• Climate change may alter the shoreline recession rate and effect the construction timeframes. |
| **Groynes** | • Can be conducted in stages.<br>• Some existing coastal infrastructure remains at risk and will require mitigation.<br>• Can account for changes in vulnerability in future stages of construction. | • Potential impacts associated with the groyne construction.<br>• Alters the coastal processes in the area.<br>• Erosion likely to continue north of structures. | • Beach amenity is retained.<br>• Visual impact of structure.<br>• Potential loss of beach access infrastructure through storm erosion. | • Capital cost of mitigation works is ~$740,000.<br>• High capital works investment of ~$4.00 million.<br>• Can be conducted in stages to reduce initial investment.<br>• Maintenance required approximately every 5 years. | • Does not protect all existing vulnerable coastal infrastructure.<br>• Very effective management of longshore erosion.<br>• Does not prevent shoreline recession due to storm damage or sea level rise. | • Shoreline remains vulnerable to severe storm erosion and sea level rise.<br>• Climate change may alter the shoreline recession rate and effect the construction timeframes. |
| **Offshore Breakwaters** | • Expensive offshore construction<br>• Existing coastal infrastructure remains at risk and will require mitigation. | • Potential impacts associated with the offshore breakwaters construction.<br>• Alters the coastal processes in the area.<br>• Erosion will continue north of structures. | • Beach amenity is retained.<br>• Visual impact of structure.<br>• Potential loss of beach access infrastructure through storm erosion. | • Capital cost of mitigation works is ~$740,000.<br>• Highest capital works investment of ~$6.5 million.<br>• Maintenance is more expensive than other structures. | • Effective management of longshore erosion.<br>• Does not prevent shoreline recession due to storm damage or sea level rise. | • Shoreline remains vulnerable to severe storm erosion and sea level rise.<br>• No protection to infrastructure from the effects of climate change or sea level rise. |

# Appendix 9 Stage 1 Net Present Value Analysis

## K1030 - Two Rocks Coastal Erosion Review

**Net Present Value Analysis**

**1 - Managed Retreat**

| Year | Item | Cost in 2012 | NPV of Cost for a Range of Discount Rates | | | | |
|---|---|---|---|---|---|---|---|
| | | (excl GST) | 0.02 | 0.04 | 0.06 | 0.08 | 0.1 |
| | **Totals** | **$1,092,440** | **$1,003,476** | **$927,496** | **$861,612** | **$803,764** | **$752,447** |
| 1 | | | $0 | $0 | $0 | $0 | $0 |
| 2 | Beach monitoring | $10,000 | $9,804 | $9,615 | $9,434 | $9,259 | $9,091 |
| 3 | Modify/replace Sceptre Court Stairs & Platform | $391,000 | $375,817 | $361,501 | $347,989 | $335,219 | $323,140 |
| 4 | Beach monitoring | $10,000 | $9,423 | $8,890 | $8,396 | $7,938 | $7,513 |
| 5 | Extend Northern Marina Seawall (80m) | $523,940 | $484,040 | $447,866 | $415,010 | $385,112 | $357,858 |
| 6 | Beach monitoring | $10,000 | $9,057 | $8,219 | $7,473 | $6,806 | $6,209 |
| 7 | | | $0 | $0 | $0 | $0 | $0 |
| 8 | Beach monitoring | $10,000 | $8,706 | $7,599 | $6,651 | $5,835 | $5,132 |
| 9 | | | $0 | $0 | $0 | $0 | $0 |
| 10 | Beach monitoring, relocate Nav Marker | $67,500 | $56,481 | $47,425 | $39,953 | $33,767 | $28,627 |
| 11 | | | $0 | $0 | $0 | $0 | $0 |
| 12 | Beach monitoring | $10,000 | $8,043 | $6,496 | $5,268 | $4,289 | $3,505 |
| 13 | | | $0 | $0 | $0 | $0 | $0 |
| 14 | Beach monitoring | $10,000 | $7,730 | $6,006 | $4,688 | $3,677 | $2,897 |
| 15 | | | $0 | $0 | $0 | $0 | $0 |
| 16 | Beach monitoring | $10,000 | $7,430 | $5,553 | $4,173 | $3,152 | $2,394 |
| 17 | | | $0 | $0 | $0 | $0 | $0 |
| 18 | Beach monitoring | $10,000 | $7,142 | $5,134 | $3,714 | $2,703 | $1,978 |
| 19 | | | $0 | $0 | $0 | $0 | $0 |
| 20 | Beach monitoring | $10,000 | $6,864 | $4,746 | $3,305 | $2,317 | $1,635 |
| 21 | | | $0 | $0 | $0 | $0 | $0 |
| 22 | Beach monitoring | $10,000 | $6,598 | $4,388 | $2,942 | $1,987 | $1,351 |
| 23 | | | $0 | $0 | $0 | $0 | $0 |
| 24 | Beach monitoring | $10,000 | $6,342 | $4,057 | $2,618 | $1,703 | $1,117 |
| 25 | | | $0 | $0 | $0 | $0 | $0 |

## K1030 - Two Rocks Coastal Erosion Review

**Net Present Value Analysis**

**2 - Sand Nourishment**

| Year | Item | Cost in 2012 (excl GST) | NPV of Cost for a Range of Discount Rates 0.02 | 0.04 | 0.06 | 0.08 | 0.1 |
|---|---|---|---|---|---|---|---|
| | **Totals** | **$26,875,900** | **$21,516,530** | **$17,644,148** | **$14,789,286** | **$12,642,874** | **$10,998,251** |
| 1 | Sand nourishment | $1,040,750 | $1,040,750 | $1,040,750 | $1,040,750 | $1,040,750 | $1,040,750 |
| 2 | Sand nourishment & beach monitoring | $1,050,750 | $1,030,147 | $1,010,337 | $991,274 | $972,917 | $955,227 |
| 3 | Sand nourishment & modify/replace Sceptre Court Stairs & Platform | $1,431,750 | $1,376,153 | $1,323,733 | $1,274,252 | $1,227,495 | $1,183,264 |
| 4 | Sand nourishment & beach monitoring | $1,050,750 | $990,145 | $934,113 | $882,230 | $834,119 | $789,444 |
| 5 | Sand nourishment & extend Northern Marina Seawall (50m) | $1,386,900 | $1,281,281 | $1,185,528 | $1,098,555 | $1,019,413 | $947,271 |
| 6 | Sand nourishment & beach monitoring | $1,050,750 | $951,697 | $863,640 | $785,182 | $715,123 | $652,433 |
| 7 | Sand nourishment | $1,040,750 | $924,156 | $822,520 | $733,688 | $655,849 | $587,476 |
| 8 | Sand nourishment & beach monitoring | $1,050,750 | $914,741 | $798,484 | $698,809 | $613,103 | $539,201 |
| 9 | Sand nourishment | $1,040,750 | $888,270 | $760,466 | $652,979 | $562,285 | $485,518 |
| 10 | Sand nourishment & beach monitoring | $1,050,750 | $879,221 | $738,243 | $621,937 | $525,637 | $445,621 |
| 11 | Sand nourishment | $1,040,750 | $853,777 | $703,093 | $581,149 | $482,069 | $401,254 |
| 12 | Sand nourishment & beach monitoring | $1,050,750 | $845,079 | $682,547 | $553,522 | $450,649 | $368,281 |
| 13 | Sand nourishment | $1,040,750 | $820,624 | $650,049 | $517,221 | $413,296 | $331,615 |
| 14 | Sand nourishment & beach monitoring | $1,050,750 | $812,264 | $631,053 | $492,633 | $386,359 | $304,365 |
| 15 | Sand nourishment | $1,040,750 | $788,758 | $601,007 | $460,325 | $354,335 | $274,062 |
| 16 | Sand nourishment & beach monitoring | $1,050,750 | $780,723 | $583,444 | $438,441 | $331,240 | $251,541 |
| 17 | Sand nourishment | $1,040,750 | $758,130 | $555,665 | $409,687 | $303,785 | $226,498 |
| 18 | Sand nourishment & beach monitoring | $1,050,750 | $750,406 | $539,427 | $390,211 | $283,985 | $207,885 |
| 19 | Sand nourishment | $1,040,750 | $728,691 | $513,743 | $364,620 | $260,447 | $187,188 |
| 20 | Sand nourishment & beach monitoring | $1,050,750 | $721,267 | $498,731 | $347,287 | $243,471 | $171,806 |
| 21 | Sand nourishment | $1,040,750 | $700,395 | $474,985 | $324,511 | $223,291 | $154,701 |
| 22 | Sand nourishment & beach monitoring | $1,050,750 | $693,259 | $461,104 | $309,084 | $208,738 | $141,988 |
| 23 | Sand nourishment | $1,040,750 | $673,198 | $439,150 | $288,813 | $191,436 | $127,852 |
| 24 | Sand nourishment & beach monitoring | $1,050,750 | $666,339 | $426,317 | $275,083 | $178,959 | $117,346 |
| 25 | Sand nourishment | $1,040,750 | $647,057 | $406,019 | $257,043 | $164,126 | $105,663 |

## K1030 - Two Rocks Coastal Erosion Review

**Net Present Value Analysis**

**3 - Sand Bypassing**

| Year | Item | Cost in 2012 (excl GST) | NPV of Cost for a Range of Discount Rates | | | | |
|---|---|---|---|---|---|---|---|
| | | | 0.02 | 0.04 | 0.06 | 0.08 | 0.1 |
| | **Totals** | **$11,997,775** | **$9,665,255** | **$7,975,175** | **$6,725,129** | **$5,781,822** | **$5,056,080** |
| 1 | Sand bypassing | $445,625 | $445,625 | $445,625 | $445,625 | $445,625 | $445,625 |
| 2 | Sand bypassing & beach monitoring | $455,625 | $446,691 | $438,101 | $429,835 | $421,875 | $414,205 |
| 3 | Sand bypassing & modify/replace Sceptre Court Stairs & Platform | $836,625 | $804,138 | $773,507 | $744,593 | $717,271 | $691,426 |
| 4 | Sand bypassing & beach monitoring | $455,625 | $429,346 | $405,049 | $382,552 | $361,690 | $342,318 |
| 5 | Sand bypassing & extend Northern Marina Seawall (50m) | $791,775 | $731,478 | $676,813 | $627,160 | $581,978 | $540,793 |
| 6 | Sand bypassing & beach monitoring | $455,625 | $412,674 | $374,491 | $340,470 | $310,091 | $282,907 |
| 7 | Sand bypassing | $445,625 | $395,702 | $352,184 | $314,148 | $280,819 | $251,544 |
| 8 | Sand bypassing & beach monitoring | $455,625 | $396,649 | $346,238 | $303,017 | $265,853 | $233,808 |
| 9 | Sand bypassing | $445,625 | $380,337 | $325,614 | $279,591 | $240,757 | $207,887 |
| 10 | Sand bypassing & beach monitoring | $455,625 | $381,247 | $320,116 | $269,684 | $227,926 | $193,229 |
| 11 | Sand bypassing | $445,625 | $365,568 | $301,048 | $248,835 | $206,411 | $171,808 |
| 12 | Sand bypassing & beach monitoring | $455,625 | $366,442 | $295,965 | $240,018 | $195,410 | $159,694 |
| 13 | Sand bypassing | $445,625 | $351,372 | $278,336 | $221,462 | $176,964 | $141,990 |
| 14 | Sand bypassing & beach monitoring | $455,625 | $352,213 | $273,637 | $213,615 | $167,532 | $131,978 |
| 15 | Sand bypassing | $445,625 | $337,728 | $257,337 | $197,100 | $151,718 | $117,347 |
| 16 | Sand bypassing & beach monitoring | $455,625 | $338,536 | $252,992 | $190,116 | $143,632 | $109,073 |
| 17 | Sand bypassing | $445,625 | $324,614 | $237,923 | $175,419 | $130,074 | $96,981 |
| 18 | Sand bypassing & beach monitoring | $455,625 | $325,390 | $233,906 | $169,203 | $123,141 | $90,143 |
| 19 | Sand bypassing | $445,625 | $312,009 | $219,973 | $156,122 | $111,517 | $80,150 |
| 20 | Sand bypassing & beach monitoring | $455,625 | $312,755 | $216,259 | $150,590 | $105,574 | $74,498 |
| 21 | Sand bypassing | $445,625 | $299,893 | $203,377 | $138,948 | $95,608 | $66,239 |
| 22 | Sand bypassing & beach monitoring | $455,625 | $300,610 | $199,944 | $134,025 | $90,513 | $61,569 |
| 23 | Sand bypassing | $445,625 | $288,248 | $188,034 | $123,663 | $81,968 | $54,743 |
| 24 | Sand bypassing & beach monitoring | $455,625 | $288,937 | $184,859 | $119,281 | $77,600 | $50,883 |
| 25 | Sand bypassing | $445,625 | $277,055 | $173,848 | $110,060 | $70,275 | $45,242 |

## K1030 - Two Rocks Coastal Erosion Review

**Net Present Value Analysis**

**4 - Staged Seawall**

| Year | Item | Cost in 2012 (excl GST) | NPV of Cost for a Range of Discount Rates | | | | |
|---|---|---|---|---|---|---|---|
| | | | 0.02 | 0.04 | 0.06 | 0.08 | 0.1 |
| | **Totals** | **$6,632,155** | **$5,334,185** | **$4,383,287** | **$3,671,288** | **$3,126,678** | **$2,701,495** |
| 1 | | | $0 | $0 | $0 | $0 | $0 |
| 2 | Beach monitoring | $10,000 | $9,804 | $9,615 | $9,434 | $9,259 | $9,091 |
| 3 | Modify/replace Sceptre Court Stairs & Platform | $391,000 | $375,817 | $361,501 | $347,989 | $335,219 | $323,140 |
| 4 | Beach monitoring | $10,000 | $9,423 | $8,890 | $8,396 | $7,938 | $7,513 |
| 5 | Construct Stage A of the seawall, including the extension of the Northern Marina Seawall (50m) | $985,895 | $910,815 | $842,747 | $780,921 | $724,662 | $673,380 |
| 6 | Beach monitoring | $10,000 | $9,057 | $8,219 | $7,473 | $6,806 | $6,209 |
| 7 | | | $0 | $0 | $0 | $0 | $0 |
| 8 | Construct half of the remaining seawall stages, relocate navigation aid & beach monitoring | $2,311,380 | $2,012,195 | $1,756,459 | $1,537,200 | $1,348,668 | $1,186,103 |
| 9 | | | $0 | $0 | $0 | $0 | $0 |
| 10 | Beach monitoring | $10,000 | $8,368 | $7,026 | $5,919 | $5,002 | $4,241 |
| 11 | | | $0 | $0 | $0 | $0 | $0 |
| 12 | Beach monitoring | $10,000 | $8,043 | $6,496 | $5,268 | $4,289 | $3,505 |
| 13 | Seawall maintenance | $160,000 | $126,159 | $99,936 | $79,515 | $63,538 | $50,981 |
| 14 | Beach monitoring | $10,000 | $7,730 | $6,006 | $4,688 | $3,677 | $2,897 |
| 15 | | | $0 | $0 | $0 | $0 | $0 |
| 16 | Beach monitoring | $10,000 | $7,430 | $5,553 | $4,173 | $3,152 | $2,394 |
| 17 | | | $0 | $0 | $0 | $0 | $0 |
| 18 | Beach monitoring & seawall maintenance | $170,000 | $121,408 | $87,273 | $63,132 | $45,946 | $33,634 |
| 19 | | | $0 | $0 | $0 | $0 | $0 |
| 20 | Construct remaining stages of seawall & beach monitoring | $2,253,880 | $1,547,133 | $1,069,787 | $744,937 | $522,251 | $368,527 |
| 21 | | | $0 | $0 | $0 | $0 | $0 |
| 22 | Beach monitoring | $10,000 | $6,598 | $4,388 | $2,942 | $1,987 | $1,351 |
| 23 | | | $0 | $0 | $0 | $0 | $0 |
| 24 | Beach monitoring | $10,000 | $6,342 | $4,057 | $2,618 | $1,703 | $1,117 |
| 25 | Seawall maintenance | $270,000 | $167,865 | $105,333 | $66,684 | $42,579 | $27,412 |

## K1030 - Two Rocks Coastal Erosion Review

**Net Present Value Analysis**

**5 - Groynes**

| Year | Item | Cost in 2012 | NPV of Cost for a Range of Discount Rates | | | | |
|---|---|---|---|---|---|---|---|
| | | (excl GST) | 0.02 | 0.04 | 0.06 | 0.08 | 0.1 |
| | **Totals** | **$5,384,700** | **$4,503,206** | **$3,852,416** | **$3,359,141** | **$2,975,427** | **$2,669,428** |
| 1 | | | $0 | $0 | $0 | $0 | $0 |
| 2 | Beach monitoring | $10,000 | $9,804 | $9,615 | $9,434 | $9,259 | $9,091 |
| 3 | Modify/replace Sceptre Court Stairs & Platform | $391,000 | $375,817 | $361,501 | $347,989 | $335,219 | $323,140 |
| 4 | Beach monitoring | $10,000 | $9,423 | $8,890 | $8,396 | $7,938 | $7,513 |
| 5 | Construct Stage 1 Groynes & extend Northern Marina Seawall (50m) | $2,829,000 | $2,613,559 | $2,418,241 | $2,240,833 | $2,079,399 | $1,932,245 |
| 6 | Beach monitoring | $10,000 | $9,057 | $8,219 | $7,473 | $6,806 | $6,209 |
| 7 | | | $0 | $0 | $0 | $0 | $0 |
| 8 | Beach monitoring | $10,000 | $8,706 | $7,599 | $6,651 | $5,835 | $5,132 |
| 9 | | | $0 | $0 | $0 | $0 | $0 |
| 10 | Beach monitoring & groyne maintenance | $135,000 | $112,962 | $94,849 | $79,906 | $67,534 | $57,253 |
| 11 | | | $0 | $0 | $0 | $0 | $0 |
| 12 | Beach monitoring | $10,000 | $8,043 | $6,496 | $5,268 | $4,289 | $3,505 |
| 13 | | | $0 | $0 | $0 | $0 | $0 |
| 14 | Beach monitoring | $10,000 | $7,730 | $6,006 | $4,688 | $3,677 | $2,897 |
| 15 | Groyne maintenance | $125,000 | $94,734 | $72,184 | $55,288 | $42,558 | $32,916 |
| 16 | Beach monitoring | $10,000 | $7,430 | $5,553 | $4,173 | $3,152 | $2,394 |
| 17 | | | $0 | $0 | $0 | $0 | $0 |
| 18 | Beach monitoring | $10,000 | $7,142 | $5,134 | $3,714 | $2,703 | $1,978 |
| 19 | | | $0 | $0 | $0 | $0 | $0 |
| 20 | Construct Stage 2 Groynes, groyne maintenance & beach monitoring | $1,604,700 | $1,101,515 | $761,659 | $530,374 | $371,828 | $262,381 |
| 21 | | | $0 | $0 | $0 | $0 | $0 |
| 22 | Beach monitoring | $10,000 | $6,598 | $4,388 | $2,942 | $1,987 | $1,351 |
| 23 | | | $0 | $0 | $0 | $0 | $0 |
| 24 | Beach monitoring | $10,000 | $6,342 | $4,057 | $2,618 | $1,703 | $1,117 |
| 25 | Groyne maintenance | $200,000 | $124,344 | $78,024 | $49,396 | $31,540 | $20,305 |

## K1030 - Two Rocks Coastal Erosion Review

**Net Present Value Analysis**

**6 - Offshore Breakwaters**

| Year | Item | Cost in 2012 (excl GST) | NPV of Cost for a Range of Discount Rates | | | | |
|---|---|---|---|---|---|---|---|
| | | | 0.02 | 0.04 | 0.06 | 0.08 | 0.1 |
| | **Totals** | **$8,633,950** | **$7,671,412** | **$6,900,455** | **$6,265,015** | **$5,728,764** | **$5,267,527** |
| 1 | | | $0 | $0 | $0 | $0 | $0 |
| 2 | Beach monitoring | $10,000 | $9,804 | $9,615 | $9,434 | $9,259 | $9,091 |
| 3 | Modify/replace Sceptre Court Stairs & Platform | $391,000 | $375,817 | $361,501 | $347,989 | $335,219 | $323,140 |
| 4 | Beach monitoring | $10,000 | $9,423 | $8,890 | $8,396 | $7,938 | $7,513 |
| 5 | Construct Offshore Breakwaters & extend Northern Marina Seawall (50m) | $6,822,950 | $6,303,351 | $5,832,286 | $5,404,415 | $5,015,072 | $4,660,167 |
| 6 | Beach monitoring | $10,000 | $9,057 | $8,219 | $7,473 | $6,806 | $6,209 |
| 7 | | | $0 | $0 | $0 | $0 | $0 |
| 8 | Beach monitoring | $10,000 | $8,706 | $7,599 | $6,651 | $5,835 | $5,132 |
| 9 | | | $0 | $0 | $0 | $0 | $0 |
| 10 | Beach monitoring | $10,000 | $8,368 | $7,026 | $5,919 | $5,002 | $4,241 |
| 11 | | | $0 | $0 | $0 | $0 | $0 |
| 12 | Beach monitoring | $10,000 | $8,043 | $6,496 | $5,268 | $4,289 | $3,505 |
| 13 | | | $0 | $0 | $0 | $0 | $0 |
| 14 | Beach monitoring | $10,000 | $7,730 | $6,006 | $4,688 | $3,677 | $2,897 |
| 15 | Offshore Breakwater maintenance | $650,000 | $492,619 | $375,359 | $287,496 | $221,300 | $171,165 |
| 16 | Beach monitoring | $10,000 | $7,430 | $5,553 | $4,173 | $3,152 | $2,394 |
| 17 | | | $0 | $0 | $0 | $0 | $0 |
| 18 | Beach monitoring | $10,000 | $7,142 | $5,134 | $3,714 | $2,703 | $1,978 |
| 19 | | | $0 | $0 | $0 | $0 | $0 |
| 20 | Beach monitoring | $10,000 | $6,864 | $4,746 | $3,305 | $2,317 | $1,635 |
| 21 | | | $0 | $0 | $0 | $0 | $0 |
| 22 | Beach monitoring | $10,000 | $6,598 | $4,388 | $2,942 | $1,987 | $1,351 |
| 23 | | | $0 | $0 | $0 | $0 | $0 |
| 24 | Beach monitoring | $10,000 | $6,342 | $4,057 | $2,618 | $1,703 | $1,117 |
| 25 | Offshore Breakwater maintenance | $650,000 | $404,119 | $253,579 | $160,536 | $102,505 | $65,992 |

## Appendix 10 Preliminary Managed Retreat Option – Plan

AT CORRECT SCALE THIS IS 100 mm


## LEGEND:

- 2037 CREST LINE (INCLUDING STORM EROSION) (red line)
- 2022 CREST LINE (INCLUDING STORM EROSION) (yellow line)
- POTENTIAL STORM EROSION AT 2012 (red dashed line)
- 2011 HSD (TOE OF SCARP) (blue line)

## MANAGEMENT NOTES

① RELOCATE OR MODIFY STAIRS AND PLATFORM

② RELOCATE NAVIGATION MARKER

③ EXTEND SEAWALL BY APPROXIMATELY 80m

## NOTES:

1. MONITORING OF SHORELINE SHOULD BE UNDERTAKEN TO TRACK SHORELINE RECESSION
2. ESTIMATED CREST LINES ARE BASED ON RECESSIONS DUE TO STORM EROSION, SHORELINE MOVEMENT AND SEA LEVEL RISE
3. DOES NOT ACCOUNT FOR ROCK IN DUNES DUE TO UNKNOWN EXTENTS AND ELEVATIONS

D103001010

AT CORRECT SCALE THIS IS 100 mm

| REV | DATE | APP'D | DESCRIPTION |
|---|---|---|---|
| 0 | 25.7.13 | TSH | ISSUED FOR REPORT |
| A | 22.4.13 | TSH | PRELIMINARY ISSUE |

CLIENT: CITY OF WANNEROO

DESIGNED: DSH | CHECKED: TSH | APPROVED:

DRAWN: DSH | CHECKED: TSH



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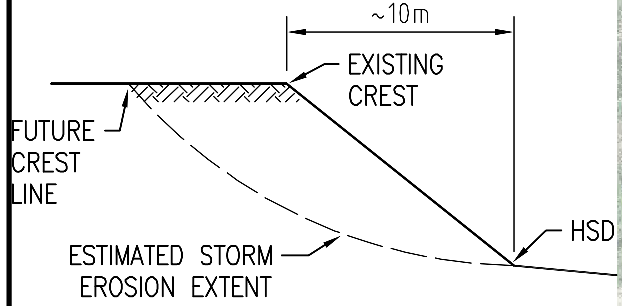
PROJECT: TWO ROCKS COASTAL MANAGEMENT

TITLE: MANAGED RETREAT

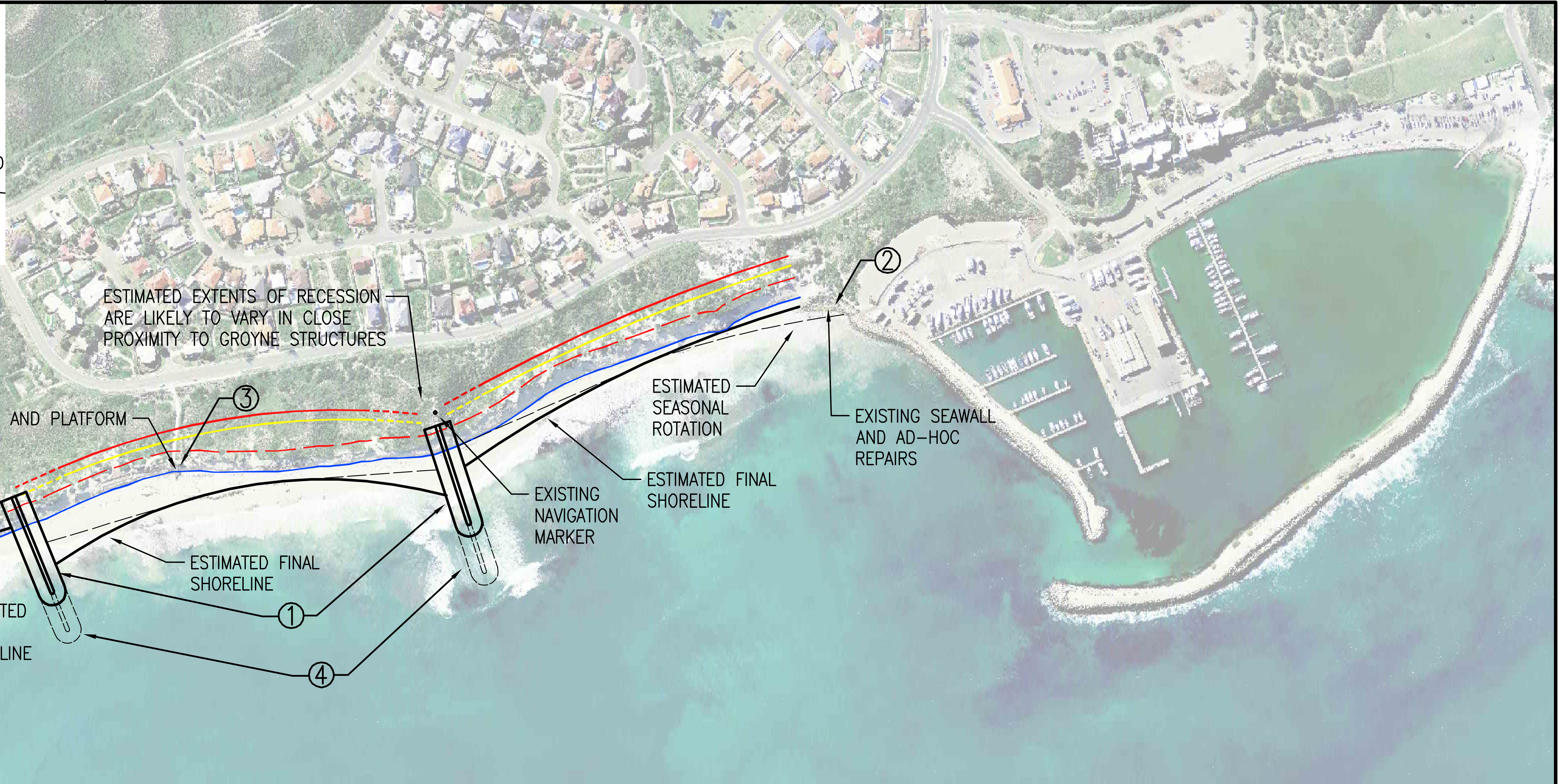
SCALE AT A3: 1:5,000 | DRAWING NUMBER: D1030-01-01 | REV: 0

## Appendix 11 Preliminary Staged Groyne Option – Plan

AT CORRECT SCALE THIS IS 100 mm




LINE RELATIONSHIP DIAGRAM
NTS




## LEGEND:

- 2037 CREST LINE (INCLUDING STORM EROSION)
- 2022 CREST LINE (INCLUDING STORM EROSION)
- POTENTIAL STORM EROSION AT 2012
- 2011 HSD (TOE OF SCARP)

## MANAGEMENT NOTES

① CONSTRUCTION OF STAGE 1 GROYNES

② EXTEND SEAWALL BY APPROXIMATELY 50m

③ STAIRS AND PLATFORM TO BE RELOCATED OR MODIFIED

④ CONSTRUCT STAGE 2 GROYNES PRIOR TO 2037

## NOTES:

1. TO MAINTAIN APPROPRIATE BUFFER, GROYNES HAVE TO BE BUILT WITHIN ~5 YEARS
2. IF CONSTRUCTION IS DELAYED, NOURISHMENT MAY BE REQUIRED
3. ESTIMATED CREST LINES ARE BASED ON RECESSIONS DUE TO STORM EROSION AND SEA LEVEL RISE
4. MONITORING OF SHORELINE SHOULD BE UNDERTAKEN TO TRACK SHORELINE RECESSION
5. 2022, 2037 LINES DO NOT INCLUDE AN ALLOWANCE FOR SHORELINE RECESSION DUE TO LONGSHORE TRANSPORT

3. DOES NOT ACCOUNT FOR ROCK IN DUNES DUE TO UNKNOWN EXTENTS AND ELEVATIONS

D103002010

AT CORRECT SCALE THIS IS 100 mm

| REV | DATE | APP'D | DESCRIPTION |
|---|---|---|---|
| 0 | 25.7.13 | TSH | ISSUED FOR REPORT |
| A | 22.4.13 | TSH | PRELIMINARY ISSUE |

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|---|---|---|
| DSH | TSH | |
| DRAWN: DSH | CHECKED: TSH | |



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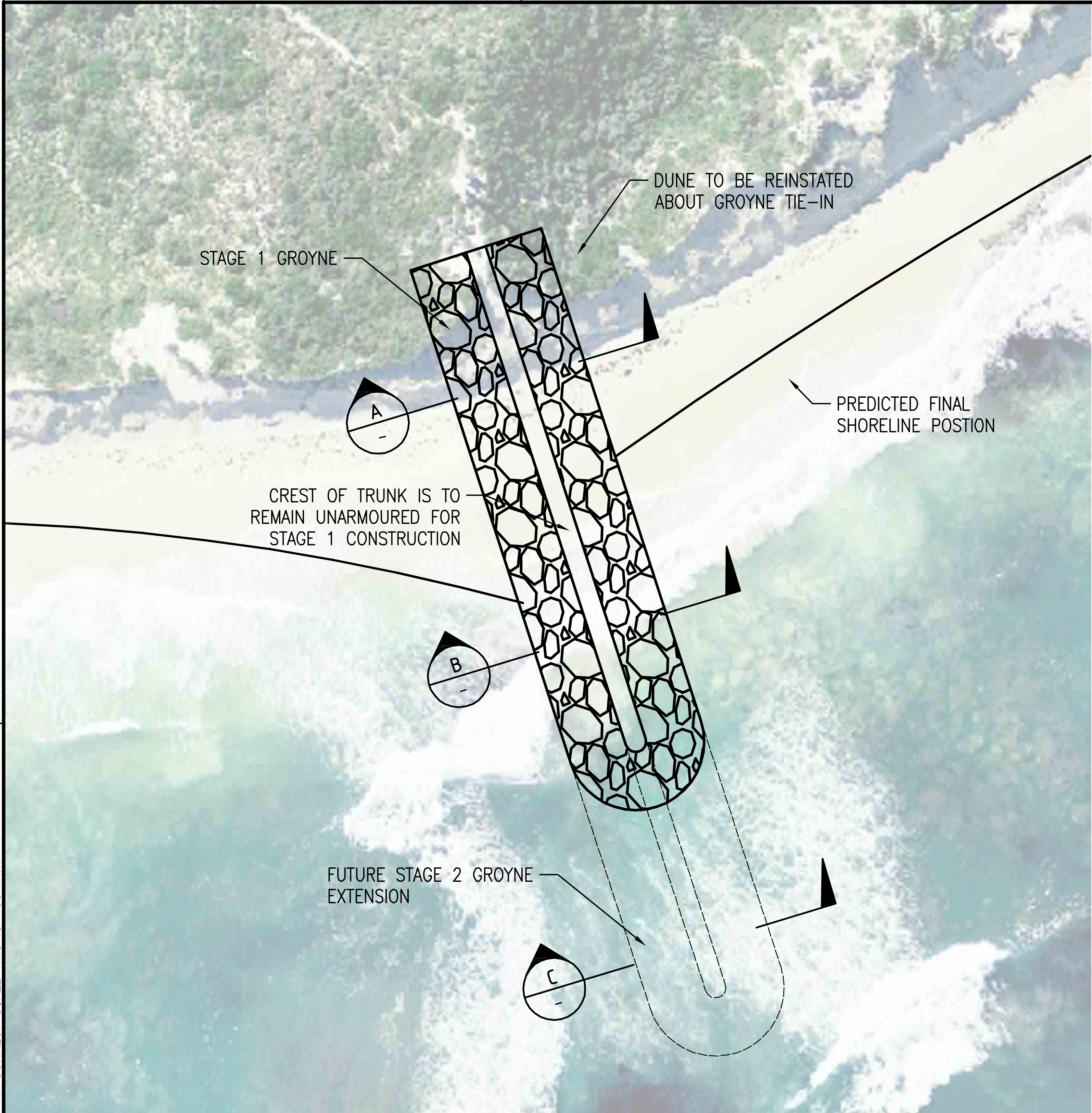
PROJECT: TWO ROCKS COASTAL MANAGEMENT

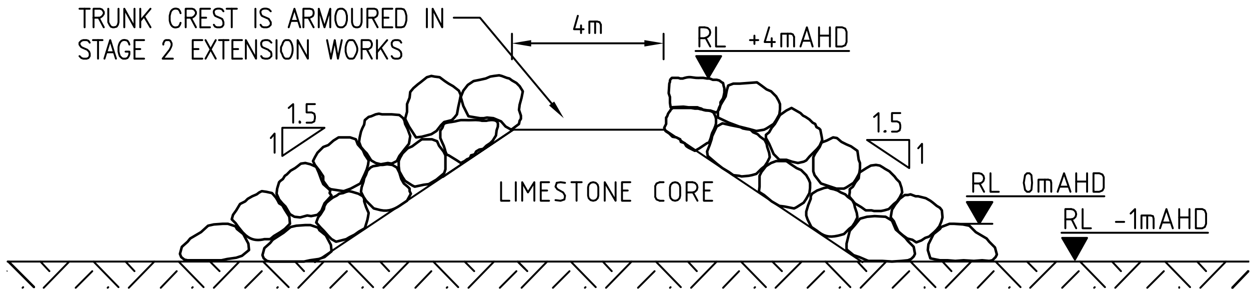
TITLE: STAGED GROYNES GENERAL LAYOUT

| SCALE AT A3 | DRAWING NUMBER | REV |
|---|---|---|
| 1:5,000 | D1030-02-01 | 0 |

AT CORRECT SCALE THIS IS 100 mm




TYPICAL STAGED GROYNE
SCALE 1:1,000




SCALE 1:250

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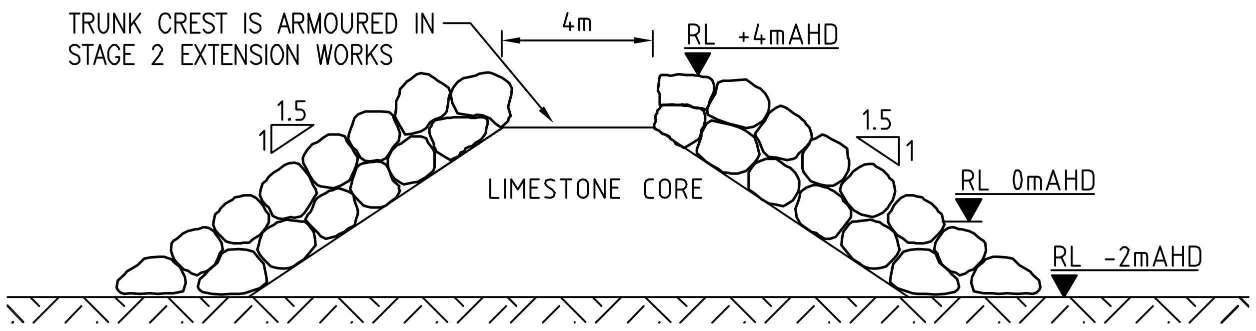
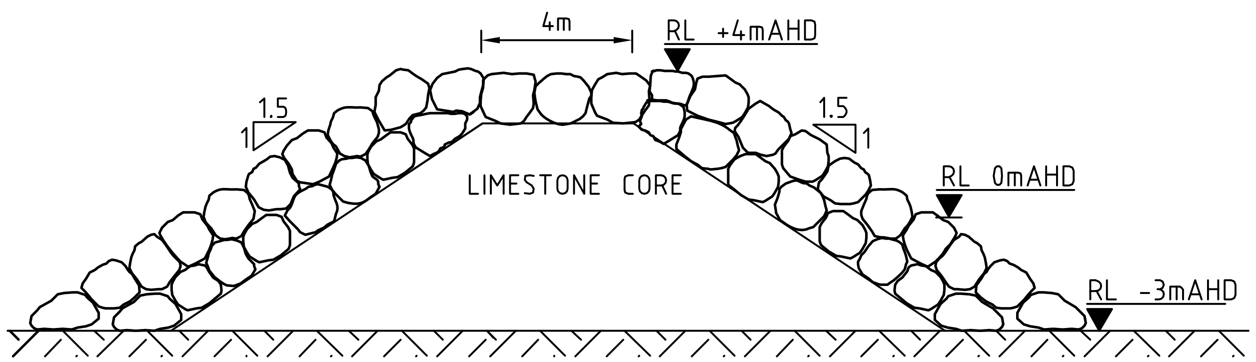
1:20




SCALE 1:250

SECTION B
1:20




SCALE 1:250

SECTION C
1:20

D103002020

AT CORRECT SCALE THIS IS 100 mm

| REV | DATE | APP'D | DESCRIPTION |
|---|---|---|---|
| 0 | 25.7.13 | TSH | ISSUED FOR REPORT |
| A | 22.4.13 | TSH | PRELIMINARY ISSUE |

CLIENT: CITY OF WANNEROO

DESIGNED: DSH | CHECKED: TSH | APPROVED:
DRAWN: DSH | CHECKED: TSH



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PROJECT: TWO ROCKS COASTAL MANAGEMENT
TITLE: STAGED GROYNES TYPICAL SECTIONS
SCALE AT A3: AS SHOWN
DRAWING NUMBER: D1030-02-02
REV: 0

## Appendix 12 Stage 2 Net Present Value Analysis

## K1030 - Two Rocks Coastal Erosion Review

**Net Present Value Analysis**

**1 - Managed Retreat**

| Year | Item | Cost in 2012 | NPV of Cost for a Range of Discount Rates | | | | |
|---|---|---|---|---|---|---|---|
| | | (excl GST) | 0.02 | 0.04 | 0.06 | 0.08 | 0.1 |
| | **Totals** | **$1,286,440** | **$1,190,452** | **$1,111,771** | **$1,045,718** | **$989,105** | **$939,720** |
| 1 | | | $0 | $0 | $0 | $0 | $0 |
| 2 | Beach monitoring, planning & design for Mitigation Works | $89,000 | $87,255 | $85,577 | $83,962 | $82,407 | $80,909 |
| 3 | Modify/replace Sceptre Court Stairs & Platform, extend Northern Marina Seawall (80m) | $914,940 | $879,412 | $845,913 | $814,293 | $784,414 | $756,149 |
| 4 | Beach monitoring | $20,000 | $18,846 | $17,780 | $16,792 | $15,877 | $15,026 |
| 5 | | | $0 | $0 | $0 | $0 | $0 |
| 6 | Beach monitoring | $20,000 | $18,115 | $16,439 | $14,945 | $13,612 | $12,418 |
| 7 | | | $0 | $0 | $0 | $0 | $0 |
| 8 | Beach monitoring | $20,000 | $17,411 | $15,198 | $13,301 | $11,670 | $10,263 |
| 9 | Planning & design for relocation of Nav Marker | $5,000 | $4,267 | $3,653 | $3,137 | $2,701 | $2,333 |
| 10 | Beach monitoring, relocate Nav Marker | $77,500 | $64,849 | $54,450 | $45,872 | $38,769 | $32,868 |
| 11 | | | $0 | $0 | $0 | $0 | $0 |
| 12 | Beach monitoring | $20,000 | $16,085 | $12,992 | $10,536 | $8,578 | $7,010 |
| 13 | | | $0 | $0 | $0 | $0 | $0 |
| 14 | Beach monitoring | $20,000 | $15,461 | $12,011 | $9,377 | $7,354 | $5,793 |
| 15 | | | $0 | $0 | $0 | $0 | $0 |
| 16 | Beach monitoring | $20,000 | $14,860 | $11,105 | $8,345 | $6,305 | $4,788 |
| 17 | | | $0 | $0 | $0 | $0 | $0 |
| 18 | Beach monitoring | $20,000 | $14,283 | $10,267 | $7,427 | $5,405 | $3,957 |
| 19 | | | $0 | $0 | $0 | $0 | $0 |
| 20 | Beach monitoring | $20,000 | $13,729 | $9,493 | $6,610 | $4,634 | $3,270 |
| 21 | | | $0 | $0 | $0 | $0 | $0 |
| 22 | Beach monitoring | $20,000 | $13,196 | $8,777 | $5,883 | $3,973 | $2,703 |
| 23 | | | $0 | $0 | $0 | $0 | $0 |
| 24 | Beach monitoring | $20,000 | $12,683 | $8,115 | $5,236 | $3,406 | $2,234 |
| 25 | | | $0 | $0 | $0 | $0 | $0 |

## K1030 - Two Rocks Coastal Erosion Review

**Net Present Value Analysis**

**5 - Groynes**

| Year | Item | Cost in 2012 (excl GST) | NPV of Cost for a Range of Discount Rates | | | | |
|---|---|---|---|---|---|---|---|
| | | | 0.02 | 0.04 | 0.06 | 0.08 | 0.1 |
| | **Totals** | **$5,684,900** | **$4,870,349** | **$4,240,123** | **$3,742,668** | **$3,342,589** | **$3,015,179** |
| 1 | | | $0 | $0 | $0 | $0 | $0 |
| 2 | Beach monitoring, planning & detailed design for Mitigation Works | $85,000 | $83,333 | $81,731 | $80,189 | $78,704 | $77,273 |
| 3 | Modify/replace Sceptre Court Stairs & Platform, extend Northern Marina Seawall (50m) | $737,150 | $708,526 | $681,537 | $656,061 | $631,987 | $609,215 |
| 4 | Beach monitoring, planning & detailed design for Stage 1 Groyne works | $85,000 | $80,097 | $75,565 | $71,368 | $67,476 | $63,862 |
| 5 | Construct Stage 1 Groynes | $2,450,650 | $2,264,022 | $2,094,826 | $1,941,144 | $1,801,301 | $1,673,827 |
| 6 | Beach monitoring | $20,000 | $18,115 | $16,439 | $14,945 | $13,612 | $12,418 |
| 7 | | | $0 | $0 | $0 | $0 | $0 |
| 8 | Beach monitoring | $20,000 | $17,411 | $15,198 | $13,301 | $11,670 | $10,263 |
| 9 | | | $0 | $0 | $0 | $0 | $0 |
| 10 | Beach monitoring & groyne maintenance | $145,000 | $121,330 | $101,875 | $85,825 | $72,536 | $61,494 |
| 11 | | | $0 | $0 | $0 | $0 | $0 |
| 12 | Beach monitoring | $20,000 | $16,085 | $12,992 | $10,536 | $8,578 | $7,010 |
| 13 | | | $0 | $0 | $0 | $0 | $0 |
| 14 | Beach monitoring & planning for Stage 2 Groyne works | $65,000 | $50,247 | $39,037 | $30,475 | $23,900 | $18,828 |
| 15 | Construct Stage 2 Groynes and Groyne maintenance | $1,567,100 | $1,187,666 | $904,961 | $693,130 | $533,536 | $412,666 |
| 16 | Beach monitoring | $20,000 | $14,860 | $11,105 | $8,345 | $6,305 | $4,788 |
| 17 | | | $0 | $0 | $0 | $0 | $0 |
| 18 | Beach monitoring | $20,000 | $14,283 | $10,267 | $7,427 | $5,405 | $3,957 |
| 19 | | | $0 | $0 | $0 | $0 | $0 |
| 20 | Groyne maintenance & beach monitoring | $210,000 | $144,150 | $99,675 | $69,408 | $48,660 | $34,337 |
| 21 | | | $0 | $0 | $0 | $0 | $0 |
| 22 | Beach monitoring | $20,000 | $13,196 | $8,777 | $5,883 | $3,973 | $2,703 |
| 23 | | | $0 | $0 | $0 | $0 | $0 |
| 24 | Beach monitoring | $20,000 | $12,683 | $8,115 | $5,236 | $3,406 | $2,234 |
| 25 | Groyne maintenance | $200,000 | $124,344 | $78,024 | $49,396 | $31,540 | $20,305 |

## Appendix 13 DoT Comments & MRA Responses

# Report Comments Register

| Item | Date | DoT Comment | Date | MRA Response | Status |
|---|---|---|---|---|---|
| **Strategic Comments** | | | | | |
| 1 | 11/06/13 | The general approach adopted has aimed to align with the details in SPP2.6. This is often not appropriate for these types of investigations. This is not a land development project/application and hence the investigation of coastal processes should not have been constrained to a general planning method to determine foreshore reserve allowances. This work was to inform coastal management activities by the City and should have been more flexible in its methods. | 25/06/13 | The SPP2.6 approach used as a guideline for this report was selected to maintain consistency with the previous study. It was recommended by DoT as appropriate in the previous study. This approach covers key factors that are likely to influence the shoreline recession and accretion over the selected planning timeframe of 25 years. | OPEN |
| 2 | 11/06/13 | The City must carefully consider the method used to evaluate coastal management options – both the initial assessment in Stage One and the subsequent comparison of groynes and managed retreat. The consultant has considered the technical and cost aspects of the work but the City needs to consider what do they want to do/have on these sections of coast and are there any other recreational/amenity issues affecting the choice of options. Is a beach required? Is visual amenity (e.g. groynes interrupting ocean view) a key issue for this community? | 25/06/13 | As noted in the report, each management option will impact the area differently in terms of social, recreational and amenity impacts. This is expected to be addressed in the community consultation period.<br>The query is noted and is to be addressed by the City | OPEN |
| 5 | 11/06/13 | An important management issue for the city is that for both recommended preliminary options (groyne field and managed retreat) and several of the other concept options (not sand bypassing and sand nourishment) stabilise a short section of coast (at most) and then the next section of coast to the north (where active management stops) will continue to experience erosion long-term. The City must consider this with any development planning of the large area of land to the north. | 25/06/13 | This is noted in the analysis and report and highlighted in the past study and outcomes. | OPEN |
| 6 | 11/06/13 | We recommend the City have a Coastal Monitoring Program in place for this section of coast so that all relevant information is available for detailed design, and following any construction works that the behaviour of the study area and relevant beaches can be monitored more effectively into the future. | 25/06/13 | This is also a recommendation of the report. | CLOSED |
| **Suggested Changes** | | | | | |
| 1 | 11/06/13 | Photos in text need dates in the captions. | 25/06/13 | Will be included. | CLOSED |
| 2 | 11/06/13 | There is no discussion of metocean conditions (waves, water levels, winds and currents). This is highly unusual for a coastal process investigation, as this information sets the context of the study area, and is a key omission of the report. These must be at least initially considered and then if there are grounds to ignore the datasets they must be clearly stated. | 25/06/13 | This is a review and update of past work, which considered metocean conditions. It is also in a study area in which several metocean studies have been completed and not new. The Consultants Brief stated that the report should describe the governing coastal processes in the area and be succinct. This was done and we felt that there was no benefit in repeating information provided in previous work. We will review this approach and see if any additional information should be included. No datasets were ignored in the work. | OPEN |

| Item | Date | DoT Comment | Date | MRA Response | Status |
|---|---|---|---|---|---|
| 3 | 11/06/13 | Provide SBEACH input and output data for the storm erosion modelling – at the moment this reads like it is just a repeat of 2005/6 work. What information has been used to run the model? How relevant are the SBEACH results given the model assumes no longshore transport? | 25/06/13 | Additional information on the SBEACH modelling will be included. As noted in the report, an assessment of the impact of longshore sediment transport during storm events was conducted and was not believed to substantially impact the outcome. | OPEN |
| 4 | 11/06/13 | Specifically consider Perched beaches – it is their relevance to the coastal processes which is important – is the presence of the beach rock/reef platforms likely to increase the speed/extent of erosion beyond that predicted on a simple sandy coast by the SBEACH model. | 25/06/13 | Our initial assessment was that the presence of reef and rock platforms in this location would not increase the extent of erosion. However we will specifically consider and include in the report. | OPEN |
| 5 | 11/06/13 | We understand the estimated volumes in the sediment budget are indicative. Is an estimate of their accuracy able to be provided? E.g. +/-50%? | 25/06/13 | Will be investigated to see if a confidence band can be provided. | OPEN |
| 6 | 11/06/13 | Inferring net alongshore sediment transport rates purely from vegetation line movement is highly susceptible to uncertainty. It seems the coast was split into sections and the volume change rate estimated based on an estimation of the shoreline movement. Insufficient detail of this analysis has been provided and it is not clear whether this assumes a beach profile at one or more sites/reaches or uses measured profile information (What year? What dataset? What season?) and if the horizontal distance is from shoreline movement plots or another source? | 25/06/13 | The estimated net sediment transport was assessed using vegetation line movement and surveyed beach profiles at several locations. This was the best method available given the data sets for the area. The need for regular survey profiles was a recommendation of the report. Additional details on the methods used will be included. | OPEN |
| 7 | 11/06/13 | More discussion on the results of the difference plot between the 2002 and 2012 surveys should be included. The report states that the data for the area north of the harbour cannot be used due to gaps in the nearshore. We understand there will always be gaps in the wave breaking zone for hydrographic surveys, but the beach profiles from both years can be used to determine the net changes for the northern coastline. | 25/06/13 | This would only show the sand lost from the above water portion of the beach. There was no ability to determine changes in volume of the beach profile that extended from the waterline to the seaward side of the rock platforms/reefs. Therefore, this approach was felt to be too inaccurate. It is also important to note that we would not necessarily expect there to be gaps in hydrographic surveys in the wave breaking zones, but there was in these surveys. | OPEN |
| | 11/06/13 | The discussion around the comparison of the “shoreline movement method” with the results of the difference plot needs to be improved. The figure needs to be legible and volume change analysis clearly summarised. Similarly for the “shoreline movement method” it should be clear what the results were for what section of coast. | 25/06/13 | Section will be revisited. | CLOSED |
| 8 | 11/06/13 | A relatively regular ongoing set of coastal processes is assumed, the report does not discuss seasonal changes and episodic/event-scale changes such as particular severe storms. The storm erosion calculation considered a rare “worst case” event, but more frequently occurring events were not discussed. | 25/06/13 | Inter-annual variations in the coastal processes were investigated and reported in the previous study. For succinctness we did not want to repeat this information. Additionally, such inter-annual variations are considered to be encompassed within the overall net changes that are used in the assessment. Episodic andmore frequently occurring events are likely to be within the bands of shoreline movement trends and severe storm erosion. | OPEN |

| Item | Date | DoT Comment | Date | MRA Response | Status |
|---|---|---|---|---|---|
| | 11/06/13 | Most importantly the processes for post-storm "recovery" of the beaches were not covered and this is where the local-scale geomorphology including perched beaches and rock outcrops become very important. One profile for the whole section of coast north of the harbour is unlikely to be appropriate. | 25/06/13 | It is believed that without substantial modelling and much more frequent monitoring it would be difficult to establish the rate at which the beach is recovering in the close proximity to a marina, rock platforms and reef outcrops. This was proposed by MRA at tender stage but not accepted for this study. The coastline north of the marina uses several profiles, but the report is focused on the area immediately north of the marina that fronts the Two Rocks development | OPEN |
| | 11/06/13 | How have the identified rock features (both platforms and outcrops) been incorporated into estimating potential erosion hazard – which sections of coast are more/less susceptible? Does this affect any infrastructure/assets? | 25/06/13 | The presence of rock has been considered in the assessment and treated in a conservative manner to provide what we believe is a conservative assessment. Allowances for the the full extent of rock present in the study area can't be made without further detailed investigation of the scale of the rock. This is a recommendation of the report. | OPEN |
| 9 | 11/06/13 | Further explanation on the decision for spacing two groynes 400m apart – or clarification that detailed design of the groyne field would be determined following selection of this option (e.g. number of groynes, length, height, spacing, overtopping limits and consider (re)location of beach access etc.). We would expect the compartmentalised beach pockets created by the groynes to rotate anti-clockwise, eroding significantly on the northern side of the structures, more so than is depicted in the report's figures. | 25/06/13 | The spacing was based on an assessment of the potential beach alignment and location of vulnerable infrastructure and adepth of closure to limit transport. The report notes that this a design suitable for the preliminary stage. An assessment of the potential shoreline position was made that is appropriate for the current stage of the management option. Sediment modelling was initially proposed but is outside the brief and should be completed with the detailed design. Detailed design would incorporate all appropriate aspects of groyne design. It is also noted that the shoreline shown was attempting to show an average position. At times of the year it is very likely the pockets would rotate further anti-clockwise (and possibly further clockwise at other times). | OPEN |
| 10 | 11/06/13 | A summary of data gaps and recommended monitoring should be included as a stand-alone item if possible. Several notes are made throughout the report about the need for hydrographic, beach profile, geotechnical, and photo monitoring. The recommended extents, resolution, frequency etc. would be very useful summarised in a table or similar. | 25/06/13 | A stand alone table was provided. A summary of recommended future actions will be included. | OPEN |
| **For Consideration** | | | | | |
| 1 | 11/06/13 | Executive Summary - Typo on page two referring to a seawall | 25/06/13 | Noted | CLOSED |
| 2 | 11/06/13 | A series of references are made to erosion volumes and areas analysed to determine erosion and accretion distances, however, it does not clearly indicate the area/extent of coastline the analysis was applied to. Could more information be provided about the extent the studies were conducted for. | 25/06/13 | Noted | CLOSED |
| 3 | 11/06/13 | May be good to include a figure with the sediment cell boundaries for the reader in section 2.2. | 25/06/13 | We will look at including an image with overlaying sediment boundaries. | OPEN |
| 4 | 11/06/13 | Damara WA (2012a) is wrong citation for that document | 25/06/13 | Noted | CLOSED |

| Item | Date | DoT Comment | Date | MRA Response | Status |
|---|---|---|---|---|---|
| 5 | 11/06/13 | This section needs to be linked back to its relevance to the study area (Two Rocks). | 25/06/13 | We will review this section to see if it can be further related to the Two Rocks area. | OPEN |
| 6 | 11/06/13 | Refers to seasonal sediment transport processes creating situation of northern erosion and southern accretion adjacent to the harbour – whereas the report generally attributes these features to an interruption of net inter-annual longshore sediment transport processes. | 25/06/13 | We will clarify this statement to refer to net movements. | OPEN |
| 7 | 11/06/13 | Separates longshore and cross-shore erosion, but it seems likely that these connected processes act in concert to create local sediment transport processes and affects. | 25/06/13 | Correct. | CLOSED |
| 8 | 11/06/13 | Bathymetry figure should show the entire study area south to The Spot, the current figure cuts off the southern section of coast. | 25/06/13 | Figure will be changed. | CLOSED |
| 9 | 11/06/13 | Table 2.1 instrument in the water now is an "AWAC" measuring waves, water levels, and currents magnitude and directions in ~10m water depth. | 25/06/13 | Updated info will be included. | CLOSED |
| 10 | 11/06/13 | What beach and nearshore water survey does MPRA hold? Has it been provided to the City? DoT can archive it also, upon request. | 25/06/13 | Survey of the beach profile was undertaken during the site inspection by MRA through the use of a tripod mounted level. This was a small section of beach profile that extended from the toe of the scarp to approximately 50m offshore. It was specific to our work in this study and we don't believe it would offer great benefit for others | OPEN |
| 11 | 11/06/13 | Figure 3.2 is too small to read any results – it appears both the before and after lines are the same? | 25/06/13 | We will look at incorporating a larger figure. As the figure extends to several hundred metres offshore, the erosion results can appear to be in close proximity to the original beach profile. | OPEN |
| 12 | 11/06/13 | p31- in the first paragraph state that a review of two DoT beach and hydrographic surveys was done – which surveys? | 25/06/13 | The provided 2002 and 2012 beach and hydrographic surveys, outlined earlier in report. Will make clearer. | CLOSED |
| 13 | 11/06/13 | The estimates of erosion and accretion provided are difficult to understand. Different values are provided, we are not sure which ones to use as the final estimate. It is difficult to review the approach used to determine the sediment budget as little information is provided on how estimates were derived. | 25/06/13 | We will review this section to clarify and incorporate additional detail | OPEN |
| 14 | 11/06/13 | The navigation marker is owned and managed/maintained by DoT and the Department is responsible for it. | 25/06/13 | Noted | CLOSED |
| 15 | 11/06/13 | For the staged groynes approach it has not been indicated that nourishment will occur in combination with construction of the groynes, is this something that needs to be considered? | 25/06/13 | The Stage 2 investigations include a proviso for delayed construction with beach nourishment | OPEN |
| 16 | 11/06/13 | Staging of construction – are there economies of scale building the groynes to full length at the beginning? | 25/06/13 | This was previously investigated in detail via the NPV assessment. There was little difference in constructing the groynes as one works. | OPEN |
| 17 | 11/06/13 | Is the City willing to accept the erosion that will occur north of the second groyne as the erosion problem will be transferred further north? This needs to be stated very clearly for almost all the options – wherever management activities cease, ongoing erosion is likely to be experienced. | 25/06/13 | This is noted on a number of drawings, and within the text of the report. This issue was also noted at the presentation of the Stage 1 findings. | OPEN |
| 18 | 11/06/13 | The southern beach within each compartment created by the groynes will still be narrow, is this considered acceptable or will ongoing nourishment of the groyne compartments need to be considered. | 25/06/13 | Question for the City. Ongoing nourishment in the groyne option was not believed necessary for the comparison purposes. | OPEN |

| Item | Date | DoT Comment | Date | MRA Response | Status |
|---|---|---|---|---|---|
| 19 | 11/06/13 | Would it be useful to undertake initial or ongoing bypassing if groynes are chosen as the management option. | 25/06/13 | The groynes are designed to stabilise the shoreline in front of the Two Rocks development. Erosion north of the groyne field could be mitigated through bypassing. Timing of the groyne construction to maximise sand contained within the area can also prevent the need for sand nourishment. | OPEN |
| 20 | 11/06/13 | P58 – Birkemier (1985) reference not in reference list. | 25/06/13 | Noted | CLOSED |
| 21 | 11/06/13 | The nearshore bathymetry is very rocky, has this been given consideration when designing the offshore breakwaters and groynes. | 25/06/13 | The presence of nearshore rock and reef was considered and is noted in the report. It was anticipated this would be considered in detail in the detailed design phase. | OPEN |
| 22 | 11/06/13 | Strong consideration should be given to undertaking geotechnical investigations, this will better inform coastal management and the design and construction process of management options. | 25/06/13 | This was a recommendation of the report. | OPEN |
| 23 | 11/06/13 | Has site access been adequately considered during the identification and evaluation of options? It seems that with the high dunes system it could be quite difficult to access the beach for the different options. | 25/06/13 | Site access was considered during the works and noted as likely via a temporary access track constructed over the northern marina seawall. This is noted on the sand bypassing and sand nourishment drawings. This was considered to be appropriate for the current stage of the assessment. | OPEN |
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## Appendix 14 Public Information Session Minutes

City of Wanneroo

15/93798

# MEETING MINUTES

## COMMUNITY INFORMATION SESSION – TWO ROCKS COASTAL MANAGEMENT

## 18 MARCH 2015, PHIL RENKIN CENTRE

**ATTENDEES**

Mayor Tracey Roberts (City of Wanneroo)

Harminder Singh (City of Wanneroo)

Rory Ellyard (City of Wanneroo)

Brian Gee (City of Wanneroo)

Councillor Winton (City of Wanneroo)

Councillor Aitken (City of Wanneroo)

Trent Hunt (M P Rogers & Associates)

Fangjun Li (Department of Transport)

Rose Murphy (Department of Transport)

Two Rocks Community (29 Registered Attendees)

**MEETING OPENING**

Mayor Roberts opened the meeting at 7:15PM and introduced Elected Members, City of Wanneroo staff members, Department of Transport representatives and M P Rogers & Associates Representative. Mayor then invited Trent Hunt to present the outcomes of the M P Rogers study on Two Rocks Coastal Management and Fangjun Li to present the findings of the Two Rocks Geotechnical Study.

**PRESENTATION OF COASTAL STUDIES**

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| Trent Hunt<br>(M P Rogers & Associates) | Coastal Engineer from M P Rogers & Associates presented power point slides summarising the recently completed coastal management study including:<br>• Recap of 2006 study and outcomes;<br>• Summary of coastal processes;<br>• Summary of conceptual coastal management options; and<br>• Summary of the preferred preliminary design options including managed retreat and stage groynes. |
| Fangjun Li<br>(Department of Transport) | Department of Transport's Manager Coastal Infrastructure presented a summary of the geotechnical study along the Two Rocks coast, explaining that buried limestone rock beneath the existing sand dunes is now expected, which will minimise the extent of erosion and provide some protection to adjacent infrastructure. |

**QUESTIONS FROM THE FLOOR**

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| Resident | Can a section of the marina wall be removed to allow sand to pass through the marina? |
| Trent Hunt | Trent explained that this would not be a viable option as it would lead to sediment deposition inside the marina. |
| Resident | Managed retreat is not an acceptable option. It appears that rock is only 0.5mAHD in front of my house. |
| Trent Hunt | Trent ran through the slides showing estimate limestone levels beneath the sand dunes and explained that the presence of rock will slow rates of erosion landward of the rock. |
| Rory Ellyard | Rory explained that the City has implemented an ongoing coastal monitoring programme including quarterly photographic beach monitoring and quarterly beach profile surveys. This will allow the City to track rates of erosion and compare with predictions and identify when additional coastal management measures will be required. |
| Resident | Has wind erosion been considered? |
| Trent Hunt | Trent explained that the main factors driving coastal erosion north of the marina are water levels and waves. There is no specific allowance for wind erosion. |
| Resident | Is the rate of erosion increasing? |
| Trent Hunt | Trent explained that the rate of erosion is likely to slow over time as the coastline reaches a new equilibrium. |
| Resident | Is cost the biggest factor supporting managed retreat? Why not construct the groynes now? |
| Trent Hunt | Trent explained the multi-criteria analysis and net present value analysis undertaken to assess the options to show that construction of the groynes in the future is a better option. |
| Resident | What can prevent erosion of the berm area? Has a seawall option been considered? |
| Trent Hunt | Trent explained the beach erosion processes where erosion is initially focussed on the beach berm which then results in collapse of dune batter as the coast retreats. Details of the seawall option was also further discussed. |
| Resident | Will the groynes act as a seaweed trap increasing the problem of rotting and smelly seaweed? |
| Trent Hunt | Trent explained that the trapping of seaweed along two rocks is a complex process which is increased to the south of the marina due to the presence of the large rock. Some seaweed may be trapped between groynes; however the shoreline between the two groynes would be exposed to direct wave action which should act to disperse the seaweed. |

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| Resident | If we wait before building anything we might lose too much foreshore. Build the seawall now. |
| Trent Hunt | Trent explained that construction should commence at the appropriate time and that by building a seawall now, the loss of foreshore up to the location of the seawall would not occur any slower. Additionally, the rock encountered in the geotech survey sits at +4 or 5mAHD in most locations which is comparable with the proposed crest of the seawall and will act as a seawall when uncovered by erosion. |
| Resident | Will offshore breakwater be a better option to stop erosion to the north and trapping of seaweed? |
| Trent Hunt | Offshore breakwaters result in the build up of sand on the landside of the structure (tombolo formation) which will then result in erosion to the north of the structure, similar to a groyne field. Trapping of seaweed is also likely to occur to a similar extent with offshore breakwaters, plus with additional wave protection of the breakwaters, wave action may not be sufficient to disperse the trapped seaweed. Offshore breakwaters are also more costly to construct and maintain. |
| Resident | What about submerged breakwaters? |
| Trent Hunt | This was not considered for this site due to the exposure to storm waves and they would not provide protection to the coast during significant storms. |
| Councillor Winton | Is the marina design a main factor contributing to erosion? Can we modify the marina to reduce the problems? |
| Trent Hunt | Trent explained that changes to marina design to improve bypassing of sand is likely to result in the deposition of sediment in the deeper areas of the marina entrance which would then require costly maintenance dredging to enable continued use of the marina. |
| Resident | What is the timeframe for a decision? |
| Harminder Singh | Harminder explained that the plan is to report to Council in May 2015 and once a decision is made, the City will be approaching State government for funding and management of the site since the construction of the marina is the clear cause of erosion. |
| Resident | If funding was not an issue, what is the best option? |
| Trent Hunt | Due to the presence of rock beneath the sand dunes, the best option moving forward is still ongoing monitoring and managed retreat with the intention for additional works (groynes) in the future as and when required.<br><br>Trent also explained that in every coastal management option, relocation of the stairs will be required at some point in time. |
| Resident | Has sand nourishment been included? |
| Trent Hunt | No, sand nourishment has not been included and is not anticipated to be required in any of the options (excluding sand re-nourishment and |

bypassing). Groynes are designed to lock up sediment in between the structures and minimise transport.

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| Resident | Why not construct full length groynes straight away? |
| Trent Hunt | By constructing partial length groynes and monitoring, in addition to a cost saving, the City can be surer of the outcome of the groynes and then make an informed decision in the future to extend them if required. |
| Councillor Winton | Has dredging been considered for nourishment? |
| Trent Hunt | This option would be more costly than transporting sand from the southern side of the marina, plus requirements for environmental approvals for dredging works introduces another complication. |
| Resident | Is the only option to completely stop erosion a seawall? |
| Trent Hunt | Yes, but if a seawall is put in, over time there will be no beach left in front of the structure at this location. |
| Resident | Put in a "retreating line" at the back of the beach in the form of buried rocks or sandbags? |
| Trent Hunt | A retreating line is the same idea as a buried seawall and costs would be similar to the seawall option as ultimately the structure would need to be large enough to withstand waves once exposed from continued erosion. |
| Resident | It will be devastating to lose the beach. |
| Trent Hunt | Trent explained that the managed retreat option will still result in a beach area, however the beach and dune would simply retreat back as erosion continues. |
| Resident | Is the decision dependent on State Government? |
| Fangjun Li | Department of Transport support the coastal management investigation and are optimistic of a long term plan for two rocks including expansion of boat harbour and management of the coast. The City and State are working close together to ensure there is a usable beach and harbour into the future. |
| Harminder Singh | The City and State are continuing to work closely together on coastal management issues and Department of Transport have contributed 50% funding for the coastal management consultancy study. |
| Mayor Roberts | The City is taking this issue very seriously and will leave no stone unturned regarding funding for coastal management of Two Rocks in discussion with State government. Mayor Roberts then explained that works at Quinns Beach could not wait due to immediate risks to private and public infrastructure and as a result the City copped the full cost and acted quickly to protect the coast without delay. |
| Resident | All options push the problem north, what about extending the marina breakwater? |

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| Trent Hunt | Extending the marina breakwater will have significantly higher costs due to the construction in deeper water and there would also be issues with environmental approvals and impacts on marina operations. |

**MEETING CLOSURE**

Harminder Singh reiterated that the final outcomes of the coastal management study and preferred coastal management approach will be presented to Council at its meeting in May 2015 and that funding and management responsibilities will be sought from State government to allow for the implementation of any coastal management measures. He then thanked The Mayor, Cr Winton, Cr Aitken, all meeting attendees and representatives from the City of Wanneroo, Department of Transport and M P Rogers & Associates.

Mayor reiterated that coastal erosion at Two Rocks is taken very seriously by the City and funding will be sought from State government and that the City and State will continue to work together to ensure continued protection of the coast.

Mayor closed the meeting at 9:00PM.

m p rogers & associates pl

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