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R1782 Rev 0

December 2023

City of Albany

Frenchman Bay Public Infrastructure Coastal Hazard Risk Management & Adaptation Plan

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1. Introduction

The City of Albany (City) manages the popular Frenchman Bay area (Site), located south-east of Albany, Western Australia. The site is a popular destination for both tourists and locals alike and with a high-end holiday accommodation development planned for the area an increase in use of the public assets is likely. The locality of the site is shown in Figure 1.1.

The Site has numerus public assets and the City is responsible for their management. As part of the management process, there is a requirement to assess the risks to the public assets from coastal hazards. The City has therefore engaged specialist coastal engineers M P Rogers & Associates Pty Ltd (MRA) to produce a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) for the public assets within the Site.

A Coastal Hazard Assessment (CHA) has recently been completed for Frenchman Bay. This work was commissioned by the City, though was partly funded by the developer of the holiday accommodation. The results of the coastal hazard assessment are outlined in MRA (2022) and will be used as the basis for this CHRMAP. The CHA identified some localised erosion that was affecting the foreshore area and detailed some stabilisation works completed by the city.

The requirements and framework for a CHRMAP are outlined in State Planning Policy No. 2.6 - State Coastal Planning Policy (SPP2.6) and more specifically in the CHRMAP Guidelines (WAPC 2019). The CHRMAP for the public assets within the Frenchman Bay area has been completed in accordance with those documents.

Figure 1.1 Location of Site

1.1 State Planning Policy 2.6

Within Western Australia, SPP2.6 provides guidance for land use and development decision-making within the coastal zone, including the establishment of coastal foreshore reserves to protect, conserve and enhance coastal values. SPP2.6 also provides guidance on the assessment of coastal hazard risks for assets located in close proximity to the coast.

The objectives of SPP2.6 are wide ranging, however a key component of the policy is the identification of appropriate areas for the sustainable use of the coast. This includes maintaining public access to the foreshore and provision of appropriate foreshore amenities. Table 1.1 provides details of how the City is addressing the stated objectives of SPP2.6.

Table 1.1 Alignment of asset management with SPP2.6 Objectives

SPP2.6 Policy Objective		Description of Proposed Public Asset
1	Ensure that development and the location of coastal facilities takes into account coastal processes, landform stability, coastal hazards, climate change and biophysical criteria.	The identification of Coastal Hazards is addressed within Section 3 of this CHRMAP. This section assesses the coastal processes at Frenchman Bay, within the context of the coastal geomorphology and geology as recommended by SPP2.6. This CHRMAP aims to inform and provide appropriate guidance to key stakeholders with respect to future management of the aforementioned factors.
2	Ensure the identification of appropriate areas for the sustainable use of the coast for housing, tourism, recreation, ocean access, maritime industry, commercial and other activities.	The foreshore area and associated public assets facilitate access to the coast for locals and tourists alike. In addition, the Site has historic whaling station ruins accessible as tourist attractions encouraging engagement with the region's rich maritime history. This CHRMAP aims to inform the current and future uses to ensure sustainability with regard to the identified coastal hazards.
3	Provide for public coastal foreshore reserves and access to them on the coast.	The existing public foreshore reserve 21337 includes a grassed picnic area with BBQs and tables behind the sandy beach. The adaptation and management plan aims to provide public access to the beach and foreshore area for the longest timeframe.
4	Protect, conserve and enhance coastal zone values, particularly in areas of landscape, biodiversity and ecosystem integrity, indigenous and cultural significance.	The City recognises the strong support for retaining public access to the beaches and foreshore reserve as well as preserving the surrounding natural environment for future generations. The foreshore reserve also conserves and enhances engagement with the significant cultural heritage of the area, particularly the historic Norwegian whaling station.

The key requirement of a CHRMAP is to develop a risk based adaptation framework for assets that could be at risk of impact by coastal hazards over the relevant planning timeframe. Importantly, the balance of these risks needs to be considered with reference to the expected lifetime of the relevant assets.

This CHRMAP report has been prepared to provide guidance regarding the risks posed by coastal hazards. Specifically, it covers the following items:

- Establishment of the context.
- Coastal hazard assessment and identification.
- Risk/vulnerability analysis and evaluation.
- Risk management and adaptation planning.
- Implementation planning.
- Monitoring and review.

Details regarding each of these items will be provided in this report.

2. Context

2.1 Purpose

The potential vulnerability of the coastline and the subsequent risk to the community, economy and environment needs to be considered for any coastal infrastructure.

SPP2.6 requires that the responsible management authority prepares a CHRMAP where existing or proposed assets or infrastructure may be at risk from coastal hazards over the planning timeframe. The main purpose of the CHRMAP is to define areas of the coastline which could be vulnerable to coastal hazards and to outline the preferred approach to the monitoring and management of these hazards where required.

A CHRMAP can be a powerful planning tool to help provide clarity to existing and future developers, users, managers or custodians of the coastline. This is done by defining levels of risk exposure, management practices and adaptation techniques that the management authority considers acceptable in response to the present and future risks posed by coastal hazards.

Specifically, the purpose of this CHRMAP is as follows.

- Determine the specific extent of coastal hazards in relation to the City's public assets.
- Determine the coastal hazard risks associated with the City's public assets and how these risks may change over time.
- Establish the basis for present and future risk management and adaptation.
- Provide guidance on appropriate management and adaptation planning for the future, including monitoring.

2.2 Objectives

The key objectives of this CHRMAP are as follows:

- Ensure that the City and key stakeholders understand the potential likelihood of assets and infrastructure being impacted by coastal hazards over a range of planning horizons.
- Identify vulnerability trigger points and respective timeframes for risk management and adaptation actions.
- Present management and adaptation measures that are informed by, and are acceptable to, the City and key stakeholders.
- Outline the coastal adaptation approach in an Implementation Plan that is acceptable to the City and key stakeholders.
- Incorporate management and adaptation measures into short and long term decision making documentation.

2.3 Scope

The *CHRMAP Guidelines* (WAPC 2019) provide a specific framework for the preparation of a CHRMAP. This is outlined in the flowchart presented in Figure 2.1 which shows the risk management process adapted to coastal planning.

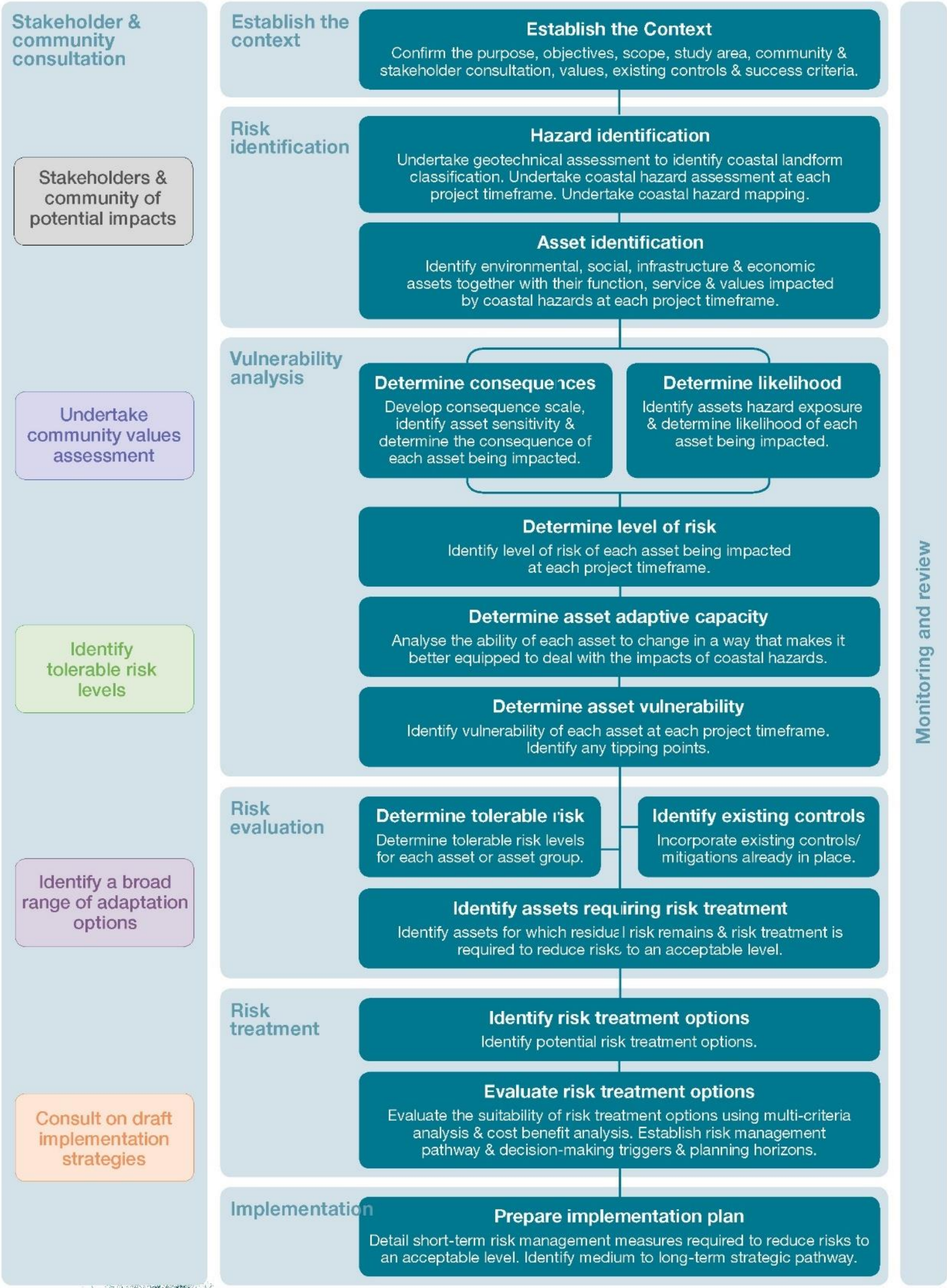

Figure 2.1 Risk Management & Adaptation Process Flow Chart (WAPC 2019)

As presented in the flowchart, the process for the development of a meaningful CHRMAP process requires a number of fundamental inputs. These inputs enable the assessment and analysis of risk, which should ultimately be informed by input received from key stakeholders, to help shape the subsequent adaptation strategies.

The management of coastal hazard risk associated with the City's public assets will be required to present a proposed adaptation plan that is acceptable to the stakeholders. As a result, the approach that has been taken for this plan is to develop a management methodology that allows for flexibility into the future.

The development of the adaptation plan will be informed by the coastal hazard assessment completed for the site. The identification of the coastal erosion and inundation hazards for the Site is discussed within Section 3 of this report.

This CHRMAP will consider the potential risks and vulnerability to coastal assets and infrastructure over a range of horizons covering the 100 year planning timeframe. This planning timeframe is required by SPP2.6.

Intermediate planning horizons will also be considered to assess how risk profiles may change in the future and to inform the requirement for adaptation strategies. The intermediate planning horizons that will be considered in this CHRMAP are listed below, with present day taken as 2021 (the time when this CHRMAP process was initiated).

- Present day (2021).
- 20 years to 2041.
- 40 years to 2061.
- 60 years to 2081.
- 80 years to 2101.
- 100 years to 2121.

Based on the results of the risk and vulnerability assessments, risk mitigation strategies will be developed, where required, in order to provide a framework for future management. However, it is important to realise that the risk and vulnerability assessments will be based on the outcomes of the coastal hazard assessment, which, by their nature, are justifiably conservative. This is due to the uncertainty around coastal dynamics when predicting impacts over long timeframes. As a result, the framework for future risk management strategies should be considered to be a guide of future requirements.

The actual requirement for implementation of these management actions should ultimately be informed by a coastal monitoring regime. The purpose of this coastal monitoring regime is to identify changes in the shoreline or sea level that could alter, either positively or negatively, the risk exposure and vulnerability of the proposed assets and infrastructure. A recommended coastal monitoring regime is included within the implementation plan, presented within Section 7 of this report.

2.4 The Site

This site setting which forms the basis of the CHRMAP has been discussed in detail in the CHA. This report includes details of the erosion to the foreshore area and the adaptation works conducted by the City. Since the CHA further remediation works have been conducted to the foreshore, including the regrading and revegetation to areas affected by erosion. The extent of the area being considered within this CHRMAP extends from Vancouver Point to Waterbay Point, as shown in Figure 1.1.

2.5 Stakeholder Engagement

The City is planning on consulting with the relevant stakeholders including the general public and the Frenchman Bay Association to understand their concerns and be able to address them when implementing the adaptation plan.

2.6 Key Assets

Key assets within the study area and surrounds have been summarised in Table 2.1 and their location shown in Figures 2.2 and 2.3. The risk assessment will focus on these assets to identify their vulnerability and consequently the requirement for risk management. These assets have been broken down into their key components and further refinement would not be beneficial to the CHRMAP. For this type of assessment, it is the vulnerability of the overall assets that is the important factor.

Figure 2.2 Public Assets within the Frenchman Bay Area

Figure 2.3 Public Assets within the Frenchman Bay Recreational Area

Table 2.1 Key Assets Identified for Analysis

Type	Key Assets	Elevation (mAHD)
Public	Gravel Access Road	1.9 – 3.2
	Lower Gravel Parking	1.8 – 2.7
	Boat Access Point	0.8 – 1.9
	Beach Access Stairs	0.8 – 2.1
	Lower Bitumen Parking	2.6 – 3.2
	Bitumen Access Road	2.7 – 14.8
	Concrete Stairs	3.6 – 13.1
	Top Parking Area	14.9 – 16.3
	Eastern Picnic Area	1.8 – 3.5
	Eastern BBQ, tables and Associated Structures	1.8 – 3.5
	Central Picnic Area	2.8 – 3.1
	Central BBQ, tables and Associated Structures	2.8 – 3.1
	Western Picnic Area	2.5 – 3.5
	Western BBQs, tables and Associated Structures	2.5 – 3.5
	Toilet Block	15.1
	Lookout	>20

It is noted that the list of assets considered in this report relates solely to the public assets that are of social or economic value that are located within the Frenchman Bay area. Some assets have been grouped together such as the BBQ, tables and associated structures, these include any picnic tables, gazebos or shelters within each respective picnic area. The picnic areas represent the area itself as an asset and include the smaller items such as bins, fences, bollards and signs.

Many small assets such as signage, bollards, fencing and bins are considered part of other larger assets such as roads or picnic areas and have been left off the vulnerability assessment aspect of this CHRMAP. The rationale for this is because these small assets would typically only be impacted by coastal hazards when the larger asset are also effected. An example is the bollards on the gravel access road, which are considered to be part of the road and would be impacted at the same time that the road would be impacted.

2.7 Heritage Assets

It is important to note that the area in question has significant heritage assets such as the remains of a historical Norwegian whaling station and a spring that used to supply Albany with water. The Norwegian whaling station was in use for three years between 1913 and 1915. There is very few remnants of this station left, with most already being affected by coastal erosion. The Vancouver Spring was used for fresh water supply over many years with the first dam being built in the 1850s. The use of this spring continued up until the late 1980s when a bore was sunk (Frenchman Bay Association, 2021).

These sites, while of cultural significance, have been excluded from the CHRMAP. The management of these assets into the future is governed by the City through their Archaeological Management Plan (AMP). This document provides management and adaption planning into the future, considering the ongoing effects of social connection as well as any environmental change, this includes the effects of coastal hazards. The recommendations outlined in the AMP are that the heritage assets are maintained in-situ to allow for arrested decay (Archae-Aus, 2022).

2.8 Success Criteria

The success criteria for the CHRMAP will ultimately be as follows:

- Demonstrated understanding by the key stakeholders regarding the likelihood, consequence and subsequent risk of coastal hazards impacting identified assets over each planning horizon.
- Evidence of stakeholder engagement outcomes being incorporated throughout the development of risk management and adaptation measures.
- Acceptance of a risk management and adaptation plan for the 100 year planning timeframe by key stakeholders.
- Adoption of the Implementation Plan by key stakeholders going forward.

The outcomes of the success criteria listed above are presented in later sections of this report.

3. Coastal Hazard Assessment

The CHA aspect of the CHRMAP process was completed by MRA in January 2022. The CHA was competed following SPP2.6 guidelines and provides the inundation and coastal hazard risks for the future planning timeframes. The reader is referred to Appendix A to view this section of the CHRMAP.

Figure 3.1 demonstrates an important outcome of the Coastal Hazard Assessment the coastal hazard lines. This figure shows the locations of the Coastal Erosion Hazard lines, which represent the worst possible erosion scenario for the planning timeframes. A copy of this coastal erosion hazard map is also included in Appendix B.

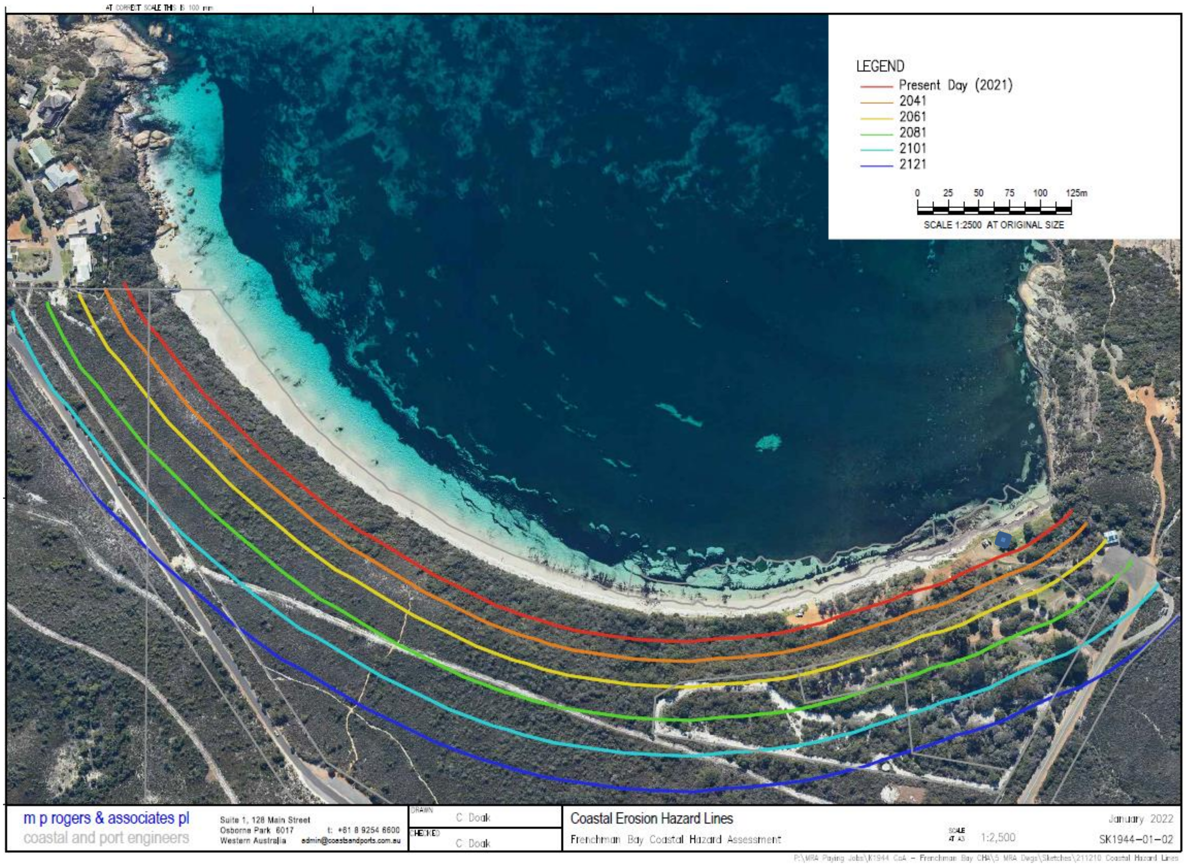

Figure 3.1 Coastal Hazard Map (MRA, 2022)

Table 3.1 shows the relevant inundation levels for the area over various planning timeframes as determined within the Coastal Hazard Assessment. It is noted that these inundation levels are likely to be conservative given that the shoreline has a northerly aspect yet the majority of the conditions that cause elevated water levels along the south coast will have a southerly component to the incident event directions.

Table 3.1 S4 Inundation Levels

Component	Planning Timeframe					
	Present Day (2021)	2041	2061	2081	2101	2121
500 year ARI peak steady water level at tide gauge (mAHD)	1.13					
Allowance for nearshore setup - wind and wave (m)	0.80					
Allowance for sea level rise (m)	0.00	0.11	0.27	0.49	0.73	0.97
Total Inundation Level (mAHD)	**1.93**	**2.04**	**2.20**	**2.42**	**2.66**	**2.90**

4. Risk Analysis

In accordance with WAPC (2019), a risk based approach will be used to assess the hazards and required mitigation and adaptation options for the City's public assets. As coastal hazards are the focus of this assessment, it is the likelihood and consequences of these coastal hazards that need to be considered.

When completing the risk assessment, it is imperative that the likelihood and the consequence speak to each other in order to provide an appropriate level of risk for each asset. This is completed to provide a conservative approach to the risk assessment. This can result in likelihood or consequence levels that at first may appear to not align with present conditions but provide an accurate representation of the likely risk. It is also noted that as the planning horizon is extended the inundation level and erosion lines become less certain with a reduced statistical likelihood of impacts being experienced, also influencing likelihood levels.

4.1 Likelihood

Likelihood is defined as the chance of something happening (AS/NZS ISO 31000:2009). WAPC (2019) defines the likelihood as the chance of erosion or storm surge inundation occurring or how often they impact on existing and future assets and values. This requires consideration of the frequency and probability of the event occurring over a given planning timeframe.

The probability of an event occurring is often related to the Average Exceedance Probability (AEP) or the ARI. The use of the AEP to define impacts of coastal hazards over the planning timeframe assumes that events have the same probability of occurring each year. In the case of climate change and sea level rise, which has a large influence on the assessed coastal hazard risk, this is not true. In addition, there is insufficient data available to properly quantify the probability of occurrence. A scale of likelihood from the City's Risk & Opportunity Management Framework, which follows the Australian Standard Risk Management Principles and Guidelines (AS/NZS ISO 31000:2009), has been used and is presented in Table 4.1.

Table 4.1 Scale of Likelihood

Level	Description	Context	Operational Frequency	Project Frequency
5	Almost Certain	Expected to occur in most circumstances	More than once in 12 months	Greater than 90% chance of occurrence
4	Likely	Will probably occur in most circumstances	At least once in 12 months	60% - 90% chance of occurrence
3	Possible	Should occur at some time	At least once in three years	40% - 60% chance of occurrence
2	Unlikely	Could occur at some time	At least once in ten years	10% - 40% chance of occurrence
1	Rare	May occur, only in exceptional circumstances	Less than once in fifteen years	Less than 10% chance of occurrence

The likelihood and consequences of coastal hazards are different for erosion and inundation. As a result, the likelihood and consequence of erosion and inundation should are considered separately. The likelihood of coastal erosion and inundation hazard impact is discussed separately in the following sections.

4.1.1 Coastal Erosion

The likelihood ratings given to the relevant assets are based on the coastal erosion hazard lines presented in Appendix B and the consideration of the probabilities of each of the allowances occurring within the respective planning horizons.

It is important to note that the hazard lines reaching a particular asset at the end of the planning horizon do not necessarily mean that this will occur. This is due to the fact that it requires all of the following to occur.

- The upper estimate of erosion caused by sea level rise.
- Long term chronic erosion of the shoreline at a rate equal to or greater than what has previously been observed.
- The 100 year ARI or 1% AEP severe storm event to be experienced at the end of the planning timeframe (ie when the other allowances have been realised).

Only if all of these occur will the erosion hazard lines be realised. This has been considered in the assessment of likelihood for the relevant assets.

An assessment of the relative likelihood of each of the identified key assets being impacted by coastal erosion hazards has been completed and is presented in Table 4.2. The assessment was completed using the coastal hazard lines presented in Appendix B.

Table 4.2 Assessment of Likelihood of Coastal Erosion Impact

Asset	Present Day	2041	2061	2081	2101	2121
Gravel Access Road	Possible (3)	Likely (4)	Almost Certain (5)	Almost Certain (5)	Almost Certain (5)	Almost Certain (5)
Lower Gravel Parking	Possible (3)	Likely (4)	Almost Certain (5)	Almost Certain (5)	Almost Certain (5)	Almost Certain (5)
Boat Access Point	Likely (4)	Almost Certain (5)	Almost Certain (5)	Almost Certain (5)	Almost Certain (5)	Almost Certain (5)
Beach Access Stairs	Likely (4)	Almost Certain (5)	Almost Certain (5)	Almost Certain (5)	Almost Certain (5)	Almost Certain (5)
Lower Bitumen parking	Possible (3)	Likely (4)	Almost Certain (5)	Almost Certain (5)	Almost Certain (5)	Almost Certain (5)
Bitumen access Road	Rare (1)	Unlikely (2)	Unlikely (2)	Possible (3)	Possible (3)	Likely (4)
Concrete stairs	Rare (1)	Rare (1)	Unlikely (2)	Unlikely (2)	Possible (3)	Likely (4)
Top parking area	Rare (1)	Rare (1)	Rare (1)	Unlikely (2)	Unlikely (2)	Likely (4)
Eastern Picnic Area	Possible (3)	Likely (4)	Almost Certain (5)	Almost Certain (5)	Almost Certain (5)	Almost Certain (5)
Eastern BBQ, tables and Associated Structures	Possible (3)	Likely (4)	Almost Certain (5)	Almost Certain (5)	Almost Certain (5)	Almost Certain (5)
Central Picnic Area	Rare (1)	Unlikely (2)	Possible (3)	Likely (4)	Almost Certain (5)	Almost Certain (5)
Central BBQ, tables and Associated Structures	Rare (1)	Unlikely (2)	Possible (3)	Likely (4)	Almost Certain (5)	Almost Certain (5)

Asset	Present Day	2041	2061	2081	2101	2121
Western Picnic Area	Rare (1)	Unlikely (2)	Possible (3)	Likely (4)	Almost Certain (5)	Almost Certain (5)
Western BBQs, tables and Associated Structures	Rare (1)	Unlikely (2)	Possible (3)	Likely (4)	Almost Certain (5)	Almost Certain (5)
Toilet Block	Rare (1)	Rare (1)	Rare (1)	Unlikely (2)	Unlikely (2)	Likely (4)
Lookout	Rare (1)	Rare (1)	Rare (1)	Unlikely (2)	Unlikely (2)	Possible (3)

Notes: 1. Based on most exposed location of each asset.

The assessment of the likelihood of coastal erosion impact shows that it is more than possible that coastal erosion will impact the assets closets to the shoreline over a 20 year planning horizon to 2041. Furthermore, over the 100 year timeframe to 2121, it is almost certain that these assets will be impacted by coastal erosion.

4.1.2 Coastal Inundation

Assessment of the likelihood of coastal inundation is slightly different to that for coastal erosion. This is due to the fact that the potential for coastal inundation will change in the future as the sea level rises. This means that an area that would only be inundated during a very severe event in the present day could potentially be inundated by a much less severe event in the future.

Assessment of the probability of an area being inundated within a given planning horizon therefore needs to consider the changing probability of event occurrence throughout that planning timeframe.

The results of the assessment of likelihood of coastal inundation for each of the key assets is presented in Table 4.3.

Table 4.3 Assessment of Likelihood of Coastal Inundation Impact

Asset	Present Day	2041	2061	2081	2101	2121
Gravel Access Road	Rare (1)	Unlikely (2)	Possible (3)	Likely (4)	Almost Certain (5)	Almost Certain (5)
Lower Gravel Parking	Rare (1)	Unlikely (2)	Possible (3)	Likely (4)	Almost Certain (5)	Almost Certain (5)
Boat Access Point	Almost Certain (5)	Almost Certain (5)	Almost Certain (5)	Almost Certain (5)	Almost Certain (5)	Almost Certain (5)
Beach Access Stairs	Almost Certain (5)	Almost Certain (5)	Almost Certain (5)	Almost Certain (5)	Almost Certain (5)	Almost Certain (5)
Lower Bitumen parking	Rare (1)	Rare (1)	Rare (1)	Rare (1)	Unlikely (2)	Unlikely (2)
Bitumen access Road	Rare (1)	Rare (1)	Rare (1)	Rare (1)	Unlikely (2)	Unlikely (2)
Concrete stairs	Rare (1)	Rare (1)	Rare (1)	Rare (1)	Rare (1)	Rare (1)
Top parking area	Rare (1)	Rare (1)	Rare (1)	Rare (1)	Rare (1)	Rare (1)
Eastern Picnic Area	Rare (1)	Unlikely (2)	Unlikely (2)	Possible (3)	Likely (4)	Almost Certain (5)
Eastern BBQ, tables and Associated Structures	Rare (1)	Rare (1)	Unlikely (2)	Possible (3)	Likely (4)	Almost Certain (5)
Central Picnic Area	Rare (1)	Rare (1)	Rare (1)	Rare (1)	Rare (1)	Unlikely (2)
Central BBQ, tables and Associated Structures	Rare (1)	Rare (1)	Rare (1)	Rare (1)	Rare (1)	Unlikely (2)
Western Picnic Area	Rare (1)	Rare (1)	Rare (1)	Unlikely (2)	Possible (3)	Likely (4)

Asset	Present Day	2041	2061	2081	2101	2121
Western BBQs, tables and Associated Structures	Rare (1)	Rare (1)	Rare (1)	Unlikely (2)	Possible (3)	Likely (4)
Toilet Block	Rare (1)	Rare (1)	Rare (1)	Rare (1)	Rare (1)	Rare (1)
Lookout	Rare (1)	Rare (1)	Rare (1)	Rare (1)	Rare (1)	Rare (1)

Notes: 1. Based on most exposed location of each asset.

The assessment of the likelihood of coastal inundation impact predicts that within the 40 year planning timeframe to 2061 the low lying assets may begin to be affected. Additionally, by the 100 year planning horizon the group of low lying assets at the bottom of the hill will have possibly been affected by inundation. While the more elevated assets are predicted to not be affected. It is noted that the beach access stairs and the boat access point have a higher exposure to inundation.

4.2 Consequence

Consequence is the impact of erosion and storm surge inundation on existing and future assets and the value assigned to that asset (WAPC 2019). Within the context of the risk assessment, consequence is used to consider the sensitivity of an asset to coastal erosion and inundation hazards over the respective timeframes.

A scale of consequence has been developed which provides a range of impacts and is generally consistent with the Australian Standard Risk Management Principles and Guidelines (ISO 31000:2009) and the Coastal Hazard Risk Management and Adaptation Planning Guidelines (WAPC 2019). The consequence scale is presented in Table 4.4.

A scale of consequence has been developed by the City which provides a range of impacts and is generally consistent with the Australian Standard Risk Management Principles and Guidelines (ISO 31000:2018). The consequence scale is presented in Table 4.4

Table 4.4 Scale of Consequences

Risk Category	Severe	Major	Moderate	Minor	Insignificant
Level	5	4	3	2	1
Service Delivery Interruption (Business Continuity Plan)	More than 24 hours, indeterminate prolonged interruption of services, non – performance.	11 to 24 hours, prolonged interruption of services, additional resources, and performance affected.	5 to 10 hours, medium term, temporary interruption, backlog cleared by additional resources.	2 to 4 hours, Short term, temporary interruption, backlog cleared < 1 day.	Less than 2 hours, No material service interruption.
Community	Major/multiple disruptions to the widespread community.	Substantiated disruptions to the wider spread community.	Significant disruption to the nearby community.	Minor disruptions to the nearby community.	Little or no disruption to the community.
Environment	Major breach of legislation or extensive environmental damage requiring third party investigation.	Significant breach of legislation/significant contamination or damage requiring third party assistance.	Environmental damage requiring restitution or internal clean-up.	Minor impact to the environment.	Little impact on environment.
Financial	More than $150,000	$50,000 to $150,000	$20,000 to $50,000	$5,000 to $20,000	Less than $5,000
Legal & Compliance	Custodial sentencing for responsible officers, multiple class actions and high-end penalties.	Major litigation & class action against Council and responsible officers. Prosecution and fines imposed.	Serious breach of regulations, with investigation and report by 3rd party, Prosecution and fines imposed.	Minor legal implications, non-compliance and breach of regulations.	Minor regulation breach.
Operational	Non-achievement of all organisation's deliverables.	Non-achievement of major organisation deliverables.	Significant delays to achieving deliverables.	Inconvenient delays in achieving deliverables.	Small impact on City deliverables.
People Health & Safety	Death(s) or severe permanent injuries, mass hospitalisation, Post-traumatic Stress Disorder.	Extensive injuries requiring hospital admission, severe trauma, extended incapacity.	Onsite medical treatment by ambulance personnel longer term illness, recovery 1 to 6 months.	First aid treatment required by first aid officer, sick leave, short term impact, recovery 1 to 3 weeks.	No injuries or injuries but not requiring first aid treatment, no leave taken.
Property	Extensive property damage resulting in prolonged period of recovery.	Significant property damage requiring external resources.	Localised damage rectified by internal and external arrangements.	Localised damage rectified by internal arrangements.	Inconsequential or no damage to property.
Reputation	Substantiated public embarrassment, very high multiple impacts, high widespread multiple news profile.	Substantiated public embarrassment, high impact news profile, third party actions.	Substantiated public embarrassment, moderate impact, and moderate news profile.	Substantiated low impact, low news profile.	Unsubstantiated, low impact, low profile, no news item.

4.2.1 Coastal Erosion

The assessed consequences of coastal erosion for each of the planning horizons are outlined in Table 4.5. As shown in the table, the consequences of erosion vary for some key assets over different timeframes due to the potential effects of increased erosion.

Table 4.5 Assessment of Consequence of Coastal Erosion Impact

Asset	Present Day	2041	2061	2081	2101	2121
Gravel Access Road	Moderate (3)	Moderate (3)	Moderate (3)	Moderate (3)	Moderate (3)	Moderate (3)
Lower Gravel Parking	Moderate (3)	Moderate (3)	Moderate (3)	Moderate (3)	Moderate (3)	Moderate (3)
Boat Access Point	Minor (2)	Minor (2)	Minor (2)	Moderate (3)	Moderate (3)	Moderate (3)
Beach Access Stairs	Minor (2)	Moderate (3)	Moderate (3)	Moderate (3)	Moderate (3)	Moderate (3)
Lower Bitumen parking	Moderate (3)	Moderate (3)	Moderate (3)	Moderate (3)	Moderate (3)	Moderate (3)
Bitumen access Road	Moderate (3)	Moderate (3)	Moderate (3)	Moderate (3)	Moderate (3)	Moderate (3)
Concrete stairs	Minor (2)	Minor (2)	Minor (2)	Minor (2)	Minor (2)	Minor (2)
Top parking area	Insignificant (1)	Insignificant (1)	Insignificant (1)	Moderate (3)	Moderate (3)	Moderate (3)
Eastern Picnic Area	Minor (2)	Minor (2)	Moderate (3)	Moderate (3)	Moderate (3)	Moderate (3)
Eastern BBQ, tables and Associated Structures	Minor (2)	Minor (2)	Moderate (3)	Moderate (3)	Moderate (3)	Moderate (3)
Central Picnic Area	Minor (2)	Minor (2)	Moderate (3)	Moderate (3)	Moderate (3)	Moderate (3)
Central BBQ, tables and Associated Structures	Minor (2)	Minor (2)	Moderate (3)	Moderate (3)	Moderate (3)	Moderate (3)
Western Picnic Area	Minor (2)	Minor (2)	Moderate (3)	Moderate (3)	Moderate (3)	Moderate (3)

Asset	Present Day	2041	2061	2081	2101	2121
Western BBQs, tables and Associated Structures	Minor (2)	Minor (2)	Moderate (3)	Moderate (3)	Moderate (3)	Moderate (3)
Toilet Block	Insignificant (1)	Insignificant (1)	Moderate (3)	Major (4)	Major (4)	Major (4)
Lookout	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)	Minor (2)	Minor (2)

Notes: 1. Based on most exposed location of each asset.

For the assets well landward of the coastal hazard line for the assessed planning horizon, the consequence of costal erosion is deemed insignificant. A large amount of assets are seaward of early planning horizon coastal hazard lines and thus the potential consequences are greater. It is important to note that if a large quantity of the assets were impacted at the same time the consequence of the erosion to the asset is deemed to have increased compared to if only a small portion of the asset would be impacted.

4.2.2 Coastal Inundation

The assessed consequence of coastal inundation for each of the key assets and each of the planning horizons is presented in Table 4.6. Similar to erosion, the consequence of inundation changes over the planning horizons due to the likely increased consequence of a higher water level and potentially greater inundation extents as sea level rise are realised over time.

Table 4.6 Assessment of Consequence of Coastal Inundation Impact

Asset	Present Day	2041	2061	2081	2101	2121
Gravel Access Road	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)
Lower Gravel Parking	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)
Boat Access Point	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)
Beach Access Stairs	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)
Lower Bitumen parking	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)
Bitumen access Road	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)
Concrete stairs	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)
Top parking area	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)
Eastern Picnic Area	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)
Eastern BBQ, tables and Associated Structures	Insignificant (1)	Insignificant (1)	Insignificant (1)	Minor (2)	Minor (2)	Minor (2)
Central Picnic Area	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)
Central BBQ, tables and Associated Structures	Insignificant (1)	Insignificant (1)	Insignificant (1)	Minor (2)	Minor (2)	Minor (2)
Western Picnic Area	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)
Western BBQs, tables and Associated Structures	Insignificant (1)	Insignificant (1)	Insignificant (1)	Minor (2)	Minor (2)	Minor (2)

Asset	Present Day	2041	2061	2081	2101	2121
Toilet Block	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)
Lookout	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)	Insignificant (1)

Notes: 1. Based on most exposed location of each asset.

Whilst inundation of the of the public assets would cause short term disruption to access and use, the long term use and value of the asset is expected to not be affected once the water recedes and the interruption to access is only likely to be during the storm. This results in the majority of the consequences for inundation being classified as insignificant. The BBQs, tables and associated structures have a consequence rating of minor, this is because any possible electric parts could become damaged by the water.

5. Risk Evaluation

5.1 Risk Evaluation Matrix

The risk rating is assessed through a matrix of “likelihood” vs “consequence”. A risk matrix developed by the City that defines the levels of risk has been used. This risk matrix is generally consistent with WAPC (2019) and the principles of AS 5334 (Standards Australia 2013) and is presented in Table 5.1.

Table 5.1 Risk Matrix

RISK LEVELS			CONSEQUENCE				
			Insignificant	Minor	Moderate	Major	Catastrophic
			1	2	3	4	5
LIKELIHOOD	Almost Certain	5	Medium (5)	High (10)	High (15)	Extreme (20)	Extreme (25)
	Likely	4	Low (4)	Medium (8)	High (12)	High (16)	Extreme (20)
	Possible	3	Low (3)	Medium (6)	Medium (9)	High (12)	High (15)
	Unlikely	2	Low (2)	Low (4)	Medium (6)	Medium (8)	High (10)
	Rare	1	Low (1)	Low (2)	Low (3)	Low (4)	Medium (6)

A risk tolerance scale assists in determining which risks are acceptable, tolerable and unacceptable. The risk tolerance scale used for the assessment is presented in Table 5.2. The risk tolerance scale shows that the extreme and high risks need to be managed.

Table 5.2 Risk Tolerance Scale

Level of Risk	Description	When is the Risk Acceptable	Who is Responsible	Timeline for Action
Low (1 – 4)	Acceptable	Risk acceptable with adequate controls, managed by routine procedures.	Responsible Officer	Review controls every 6 months
Medium (5 – 9)	Monitor	Risk acceptable by observing, assessing and improving current controls and council procedures.	Responsible Officer	Review controls every 3 months or as per risk register
High (10 – 16)	Urgent Attention Required	Risk acceptable by establishing and implementing new controls.	Executive & CEO	Controls implemented within 2 weeks of reporting. Review controls every month
Extreme (17 – 25)	Unacceptable	Risk only acceptable with excellent controls and all treatment plans to be explored and implemented where possible, managed by highest level of authority.	Audit & Risk Committee & Council	Controls implemented within 1 week of reporting. Review controls 2 weeks

5.2 Risk Assessment

The risk assessment for the study area will be completed in accordance with the recommendations of AS5334 (2013). The results of the risk assessment are presented below for both coastal erosion and coastal inundation.

5.2.1 Coastal Erosion

Table 5.3 presents the assessed coastal erosion risk levels for each of the identified key assets potentially at risk over the 100 year planning timeframe.

Table 5.3 Assessment of Risk of Coastal Erosion Impact

Asset	Present Day	2041	2061	2081	2101	2121
Gravel Access Road	Medium (9)	High (12)	High (15)	High (15)	High (15)	High (15)
Lower Gravel Parking	Medium (9)	High (12)	High (15)	High (15)	High (15)	High (15)
Boat Access Point	Medium (8)	High (10)	High (10)	High (15)	High (15)	High (15)
Beach Access Stairs	Medium (8)	High (15)	High (15)	High (15)	High (15)	High (15)
Lower Bitumen parking	Medium (9)	High (12)	High (15)	High (15)	High (15)	High (15)
Bitumen access Road	Low (3)	Medium (6)	Medium (6)	Medium (9)	Medium (9)	High (12)
Concrete stairs	Low (2)	Low (2)	Low (4)	Low (4)	Medium (6)	Medium (8)
Top parking area	Low (1)	Low (1)	Low (1)	Medium (6)	Medium (6)	High (12)
Eastern Picnic Area	Medium (6)	Medium (8)	High (15)	High (15)	High (15)	High (15)
Eastern BBQ, tables and Associated Structures	Medium (6)	Medium (8)	High (15)	High (15)	High (15)	High (15)
Central Picnic Area	Low (4)	Medium (6)	High (12)	High (15)	High (15)	High (15)
Central BBQ, tables and Associated Structures	Low (4)	Medium (6)	High (12)	High (15)	High (15)	High (15)
Western Picnic Area	Low (4)	Medium (6)	High (12)	High (15)	High (15)	High (15)
Western BBQs, tables and Associated Structures	Low (4)	Medium (6)	High (12)	High (15)	High (15)	High (15)

Asset	Present Day	2041	2061	2081	2101	2121
Toilet Block	Low (1)	Low (1)	Low (3)	Medium (8)	Medium (8)	High (16)
Lookout	Low (1)	Low (1)	Low (1)	Low (2)	Low (4)	Medium (6)

Notes: 1. Based on most exposed location of each asset.

The results of the risk assessment show that many assets are have High or Medium risk from coastal erosion hazards during the coming 20 year planning timeframe to 2041. The risk increases over the 100 year planning timeframe, with the majority of the assets deemed to be at high risk by the end of this timeframe.

5.2.2 Coastal Inundation

Table 5.4 below is a summary of the outcomes from the risk analysis, noting the coastal inundation risk levels for each of the identified key assets.

Table 5.4 Assessment of Risk of Coastal Inundation Impact

Asset	Present Day	2041	2061	2081	2101	2121
Gravel Access Road	Low (1)	Low (2)	Low (3)	Low (4)	Medium (5)	Medium (5)
Lower Gravel Parking	Low (1)	Low (2)	Low (3)	Low (4)	Medium (5)	Medium (5)
Boat Access Point	Medium (5)	Medium (5)	Medium (5)	Medium (5)	Medium (5)	Medium (5)
Beach Access Stairs	Medium (5)	Medium (5)	Medium (5)	Medium (5)	Medium (5)	Medium (5)
Lower Bitumen parking	Low (1)	Low (1)	Low (1)	Low (1)	Low (2)	Low (2)
Bitumen access Road	Low (1)	Low (1)	Low (1)	Low (1)	Low (2)	Low (2)
Concrete stairs	Low (1)	Low (1)	Low (1)	Low (1)	Low (1)	Low (1)

Asset	Present Day	2041	2061	2081	2101	2121
Top parking area	Low (1)	Low (1)	Low (1)	Low (1)	Low (1)	Low (1)
Eastern Picnic Area	Low (1)	Low (1)	Low (2)	Low (3)	Low (4)	Medium (5)
Eastern BBQ, tables and Associated Structures	Low (1)	Low (2)	Low (2)	Medium (5)	Medium (8)	High (10)
Central Picnic Area	Low (1)	Low (1)	Low (1)	Low (1)	Low (1)	Low (2)
Central BBQ, tables and Associated Structures	Low (1)	Low (1)	Low (1)	Low (2)	Low (2)	Low (4)
Western Picnic Area	Low (1)	Low (1)	Low (1)	Low (2)	Low (3)	Low (4)
Western BBQs, tables and Associated Structures	Low (1)	Low (1)	Low (1)	Low (4)	Medium (6)	Medium (8)
Toilet Block	Low (1)	Low (1)	Low (1)	Low (1)	Low (1)	Low (1)
Lookout	Low (1)	Low (1)	Low (1)	Low (1)	Low (1)	Low (1)

Notes: 1. Based on most exposed location of each asset.

The results of the risk assessment show that other than the Boat Access Point and beach access stairway, the assets are at low risk from coastal inundation hazards for the coming 40 year planning timeframe to 2061. With only the eastern BBQ, tables and associated structures increasing in risk for the further 20 years to 2081. Beyond this timeframe through to 2121, the risk to the assets from coastal inundation increases. It is important to note that the assessed risks from coastal inundation are less than those determined for potential coastal erosion impacts, therefore the coastal erosion risks are considered the most critical for future coastal adaptation planning.

6. Vulnerability

As per the recommendations of AS 5334 *Climate change adaptation for settlements and infrastructure*, a detailed risk analysis should include a vulnerability analysis to thoroughly examine how coastal hazards and climate change may affect the assets. This includes consideration of the adaptive capacity and vulnerability of the assets previously assessed for coastal hazard risk.

The vulnerability of the identified public assets are related to the risk from coastal hazards, as well as their sensitivity to the impacts caused by these hazards and their ability to respond to them (termed adaptive capacity). This is demonstrated in the *CHRMAP Guidelines* (WAPC 2019) by the following Figure 6.1.

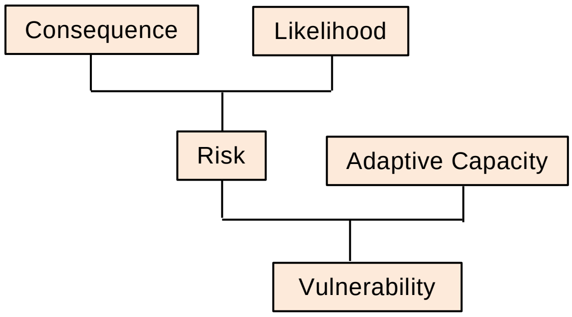

Figure 6.1 Vulnerability Assessment Flowchart (WAPC 2019)

6.1 Adaptive Capacity

Adaptive capacity is defined in AS5334 as the ability to respond to climate change to moderate potential damage, to take advantage of opportunities, or to cope with the consequences. For assets where the impact of the coastal hazard was insignificant or where the asset would be re-established naturally before further damage would likely occur, the adaptive capacity of the asset will be rated as insignificant impact or N/A

The adaptive capacity should be considered in conjunction with any changes to the current risk factors over time which may influence an assets future vulnerability. A scale of adaptive capacity has been developed for this assessment and is presented in Table 6.1.

Table 6.1 Adaptive Capacity Ratings

Rating	Description / Frequency
Insignificant Impact; N/A	The impact of the coastal hazard on the asset would have an insignificant impact. This includes where the control or asset would be re-established naturally before further damage would likely occur.
Very High	Very high ability to absorb coastal hazard impacts or where capacity can be restored at relatively low cost. Capacity would be restored naturally over time.
High	Reasonable ability to absorb coastal hazard impacts, with functionality able to be restored . Natural restoration of capacity may occur slowly over time.
Moderate	Small amount of ability to absorb coastal hazard impacts. Restoration of functionality would be difficult, though possible.
Low	Little to no ability to absorb coastal hazard impacts. Functionality would be unable to be restored.

The adaptive capacity of an asset is likely to be different in response to coastal erosion or inundation hazards. The assessed adaptive capacities are outlined in the following sections. As with the risk from coastal hazards, the adaptive capacity of an asset is likely to change over the various planning horizon. For instance, structures with very deep foundations (piles, etc) may be less prone to impacts from coastal hazards than assets with shallow foundations, which could easily be undermined. The potential extent of coastal hazard impact (i.e. the depth of erosion) would also have an impact, for similar reasons to those just described.

6.1.1 Coastal Erosion

The adaptive capacity of each of the identified assets have been determined in regards to coastal erosion and are presented in Table 6.2.

Table 6.2 Coastal Erosion Adaptive Capacity Ratings

Asset	Present Day	2041	2061	2081	2101	2121
Gravel Access Road	Moderate	Moderate	Low	Low	Low	Low
Lower Gravel Parking	Moderate	Moderate	Low	Low	Low	Low
Boat Access Point	Moderate	Moderate	Low	Low	Low	Low
Beach Access Stairs	Moderate	Moderate	Low	Low	Low	Low
Lower Bitumen parking	Moderate	Low	Low	Low	Low	Low

Asset	Present Day	2041	2061	2081	2101	2121
Lower Bitumen parking	Moderate	Low	Low	Low	Low	Low
Bitumen access Road	Insignificant Impact; N/A	Low	Low	Low	Low	Low
Concrete stairs	Insignificant Impact; N/A	Insignificant Impact; N/A	Low	Low	Low	Low
Top parking area	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Low	Low	Low
Eastern Picnic Area	Moderate	Moderate	Low	Low	Low	Low
Eastern BBQ, tables and Associated Structures	Moderate	Moderate	Low	Low	Low	Low
Central Picnic Area	Moderate	Moderate	Low	Low	Low	Low
Central BBQ, tables and Associated Structures	Moderate	Moderate	Low	Low	Low	Low
Western Picnic Area	Moderate	Moderate	Low	Low	Low	Low
Western BBQs, tables and Associated Structures	Moderate	Moderate	Low	Low	Low	Low
Toilet Block	Insignificant Impact; N/A	Insignificant Impact; N/A	Low	Low	Low	Low
Lookout	Insignificant Impact; N/A	Insignificant Impact; N/A	Low	Low	Low	Low

Notes: 1. Based on most exposed location of each asset.

The adaptation capacity of the City's assets in regards to erosion relate directly to the availability of space to reinstate the assets or the ability to repair the asset in situ to allow continued use. It's noted that individual items within these assets have noticeably higher adaptive capacity such as bin or signs that can be easily moved or reinstated. As the erosion is likely to continue to increase, the available appropriate space is likely going to be significantly reduced subsequently reducing the adaptive capacity of the assets.

6.1.2 Coastal inundation

The adaptive capacities of each of the identified assets in regard to inundation have been determined and are presented in Table 6.3.

Table 6.3 Coastal Inundation Adaptive Capacity Ratings

Asset	Present Day	2041	2061	2081	2101	2121
Gravel Access Road	Very High	Very High	Very High	Very High	Very High	Very High
Lower Gravel Parking	Very High	Very High	Very High	Very High	Very High	Very High
Boat Access Point	Very High	Very High	Very High	Very High	Very High	Very High
Beach Access Stairs	Very High	Very High	Very High	Very High	Very High	Very High
Lower Bitumen parking	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Very High	Very High	Very High
Bitumen access Road	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Very High	Very High
Concrete stairs	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A
Top parking area	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A
Eastern Picnic Area	Very High	Very High	Very High	Very High	Very High	Very High
Eastern BBQ, tables and Associated Structures	Very High	Very High	Very High	High	High	High
Central Picnic Area	Very High	Very High	Very High	Very High	Very High	Very High
Central BBQ, tables and Associated Structures	Very High	Very High	Very High	Very High	High	High
Western Picnic Area	Very High	Very High	Very High	Very High	Very High	Very High

Asset	Present Day	2041	2061	2081	2101	2121
Western BBQs, tables and Associated Structures	Very High	Very High	Very High	Very High	High	High
Toilet Block	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A
Lookout	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A

Notes: 1. Based on most exposed location of each asset.

As shown in the assessment, the majority of the assets are unlikely to be affected by inundation. Those that are impacted by inundation are expected to retain all of their functionality after the water recedes and the inundation event is over.

6.2 Vulnerability Assessment

The following matrix was developed for the assessment of the vulnerability of the key public assets. The vulnerability of each identified asset is defined by the adaptive capacity and risk level, where a high adaptive capacity decreases the initial risk rating of an asset. The vulnerability matrix is shown in Table 6.4 below.

Table 6.4 Vulnerability Matrix

VULNERABILITY LEVELS		ADAPTIVE CAPACITY				
		Insignificant Impact; N/A	Very High	High	Moderate	Low
RISK LEVEL	Extreme	Low	Medium	High	Extreme	Extreme
	High	Low	Low	Medium	High	High
	Medium	Low	Low	Low	Medium	Medium
	Low	Low	Low	Low	Low	Low

A vulnerability tolerance scale is important to define the level at which adaptive capacity is deemed acceptable, tolerable or intolerable/unacceptable. The following tolerance scale has been adopted for this assessment.

Table 6.5 Vulnerability Tolerance Scale

Vulnerability Level	Further Action Required	Vulnerability Tolerance
Extreme	Asset has minimal capacity to cope with the impacts of coastal hazards without additional action. Adaptation needs to be considered as a priority.	Unacceptable / Intolerable
High	Asset has limited ability to cope with the impacts of coastal hazards. Adaptation should be considered to reduce vulnerability to acceptable levels.	Tolerable, if as low as possible
Medium	Asset has some ability to cope with the impacts of coastal hazards. Actions should be considered to reduce vulnerability as low as reasonably practical (ALARP).	Tolerable / Acceptable
Low	Assets has high resilience and is able to cope with the impacts of coastal hazards without additional action.	Acceptable

The vulnerability tolerance scale shows that assets with ***High*** and ***Extreme*** vulnerability need to be managed to reduce vulnerability levels to ***Medium*** or ***Low***. Despite being considered acceptable, assets with ***Medium*** or ***Low*** vulnerabilities should also be considered for adaptation measures to reduce vulnerability levels as low as reasonably practical. This is discussed in Section 7 of this CHRMAP.

6.2.1 Coastal Erosion

The vulnerabilities of each of the identified assets have been calculated and are shown in Table 6.6. The assets identified as having ***High*** vulnerability from coastal erosion impact are expected to require management over the respective planning horizons.

Table 6.6 Assessment of Vulnerability of Coastal Erosion Impact

Asset	Present Day	2041	2061	2081	2101	2121
Gravel Access Road	Medium	High	High	High	High	High
Lower Gravel Parking	Medium	High	High	High	High	High
Boat Access Point	Medium	High	High	High	High	High
Beach Access Stairs	Medium	High	High	High	High	High
Lower Bitumen parking	Medium	High	High	High	High	High
Bitumen access Road	Low	Medium	Medium	Medium	Medium	High
Concrete stairs	Low	Low	Low	Low	Medium	Medium
Top parking area	Low	Low	Low	Medium	Medium	High
Eastern Picnic Area	Medium	Medium	High	High	High	High
Eastern BBQ, tables and Associated Structures	Medium	Medium	High	High	High	High
Central Picnic Area	Low	Medium	High	High	High	High
Central BBQ, tables and Associated Structures	Low	Medium	High	High	High	High
Western Picnic Area	Low	Medium	High	High	High	High
Western BBQs, tables and Associated Structures	Low	Medium	High	High	High	High
Toilet Block	Low	Low	Low	Medium	Medium	High
Lookout	Low	Low	Low	Low	Low	Medium

The results of the vulnerability assessment show that the key assets will likely require management within the short term. Most assets are identified as having either a High or Medium vulnerability to coastal erosion hazards within 20 years and are assessed as having a Medium to Low level of vulnerability in the present day. The majority of assets reach a High level of vulnerability to coastal erosion hazards in the 2061 planning horizon. These high vulnerability assets require additional adaptation measures to be implemented. These measures will be discussed in the following section of the report.

6.2.2 Coastal inundation

The vulnerabilities of each of the identified assets in regard to costal inundation have been calculated and are shown in Table 6.7.

Table 6.7 Assessment of Vulnerability of Coastal Inundation Impact

Asset	Present Day	2041	2061	2081	2101	2121
Gravel access road and parking	Low	Low	Low	Low	Low	Low
Gravel Access Road	Low	Low	Low	Low	Low	Low
Lower Gravel Parking	Low	Low	Low	Low	Low	Low
Boat Access Point	Low	Low	Low	Low	Low	Low
Beach Access Stairs	Low	Low	Low	Low	Low	Low
Lower Bitumen parking	Low	Low	Low	Low	Low	Low
Bitumen access Road	Low	Low	Low	Low	Low	Low
Concrete stairs	Low	Low	Low	Low	Low	Low
Top parking area	Low	Low	Low	Low	Low	Low
Eastern Picnic Area	Low	Low	Low	Low	Low	Low
Eastern BBQ, tables and Associated Structures	Low	Low	Low	Low	Low	Medium
Central Picnic Area	Low	Low	Low	Low	Low	Low
Central BBQ, tables and Associated Structures	Low	Low	Low	Low	Low	Low
Western Picnic Area	Low	Low	Low	Low	Low	Low
Western BBQs, tables and Associated Structures	Low	Low	Low	Low	Low	Low
Toilet Block	Low	Low	Low	Low	Low	Low
Lookout	Low	Low	Low	Low	Low	Low

The result of the coastal inundation vulnerability assessment show that for the majority of the planning timeframe the assets will not be affected by the inundation. There is a possibility that any electric systems associated with the BBQ or gazebos my be damaged by the inundation and thus the slightly increased rating. It is likely that the adaptation requirements to overcome the coastal erosion risks will negate any need for specific requirement to manage inundation. These adaptation measures are discussed in the following section of the report.

7. Risk Adaptation & Mitigation Strategies

7.1 Available Risk Mitigation Strategies

Risk adaptation and mitigation strategies are required for the city to address the coastal hazard risks and asset vulnerabilities identified in Sections 5 and 6. SPP2.6 outlines a hierarchy of risk adaptation and mitigation options, where options that allow for a wide range of future strategies are considered more favourably. This hierarchy of options is reproduced in Figure 7.1.

Figure 7.1 Risk Management & Adaptation Hierarchy

These four broad option categories are generally outlined below.

- Avoid – avoid new development within the area impacted by coastal hazards.
- Retreat – the relocation or removal of assets within an area identified as likely to be subject to intolerable risk of damage from coastal hazards.
- Accommodation – measures which suitably address the identified risks.
- Protect – used to preserve the foreshore reserve, public access and public safety, property and infrastructure.

The assessment of these options is generally done in a progressive manner, moving through the various options until an appropriate mitigation strategy is found. Adaptation options can vary depending on the type of asset, and often a range of complementary strategies may be required to mitigate coastal hazard risks.

7.2 Proposed Management Strategy

The potential future movement of the shoreline and risks posed from coastal hazards necessitates the requirement for coastal adaptation and risk mitigation planning. The public assets are currently at risk from coastal erosion and, to a much lesser extent, inundation. These assets are already constructed therefore the most applicable risk management and adaption strategy is to retreat the assets as the erosion increases.

The behaviour of the coastline is complex and subject to change, with coastal hazard lines possibly not being reached until many years after the suggested timeframes due to the justifiable level of conservatism that is included within the assessment methodology. As the assets at risk are public assets and are actively used by the community and tourists alike, the most practical management option is to retreat the assets as they are actively impacted by coastal erosion. This method would allow for high levels of public access to the area for the largest timeframe. This will increase the risk to public safety unless monitoring and active management is completed.

As part of the management of the area it is expected the City will remediate small issues and defects cause by general use and coastal processes to maintain the safe use of assets. This is expected to include regrading of the boat access point and gravel areas and maintenance of the beach access stairs. As part of these works the City could consider adaptation measures to increase the time that the assets are available to the public. These could include works similar to the recent stabilisation works all the way up to the sand nourishment and interim protection through geosynthetic sand containers.

The remediation and adaptation works could be used to provide an erosion buffer to accommodate coastal hazards over an assets remaining life. The asset would likely still need to be removed when these adaptation measures and the erosion buffer have been diminished, this would likely be closer to the end of an asset's useful life.

The retreat of all assets will be triggered by an individual assessment relating to the risk each asset poses to public safety and City management, these triggers are outlined below.

- Vehicle accessible assets, such as the boat access point and parking areas, should be retreated once the area can no longer be maintained through regular works and voids or erosion scarps could begin to impact user safety.

- Public use assets such as the beach assess stairs, BBQs, tables, gazebos and associated structures, should be retreated before they are no longer able to be safely used by the public. These structures are expected to be retreated once the erosion scarp is in close proximity to the base or footing.

- For the picnic areas it is expected that they should gradually be retreated to allow as much access to the foreshore area into the future. This is likely to include the gradual shrinking of the picnic areas to account for the coastal erosion.

- Regarding the Toilet block, this asset is expected to be one of the last to be retreated. This asset is expected to be retreated once the top of the erosion scarp is within 10 m of the building or at the end of its service life.

- The ways to currently access the foreshore are a vehicle access way and a set of stairs. These assets should be maintained for as long as possible to allow public access to the beach and foreshore area. These assets are expected to be closed, adapted and retreated based on the remaining assets available within the foreshore area. This could include the adaption of the vehicle access way to a pedestrian access way once the lower vehicle accessible assets have been retreated.

- It is noted that for heritage assets the management plan outlined by the City is to allow for in-situ arrested decay. Appropriate signage should be monitored and retreated appropriately to provide historical knowledge to any visitors.

As public assets are retreated there is an option to reinstate these assets to allow for continued public access. The reinstatement of retreated assets should consider the location of the coastal erosion lines and ensure that any reinstatement is behind the hazard line corresponding to the relevant planning timeframe of the asset's life span. A new assessment may be required to ascertain updated coastal hazard lines depending on when the asset is to be reinstated.

It is noted that some assets will be difficult to reinstate in similar locations due to the topography of the area.

To ensure the safe implementation of the management strategy, appropriate monitoring and inspection of the foreshore and beach area is required. The proposed monitoring is outlined in detail in Table 7.2.

Table 7.2 Proposed Coastal Monitoring

Type of Monitoring	Description	Requirement / Frequency
Visual Inspections	Visual inspection and monitoring of the beach to identity any significant changes in the shoreline. Changes would be evident through the erosion of the beach and presence of an erosion scarp with or without the loss of vegetation.	Ongoing as part of the city's management of the area. Visual inspections are especially important post storm events as these can produce significant erosion.
Shoreline Mapping	Ortho-rectified aerial photographs will be purchased and the coastal vegetation line mapped to track the movement of the shoreline. This method will help to ascertain if there is any creep in shoreline position that is not being picked up through the visual inspections.	Every 5 years or when the visual inspections suggest a significant change in the beach/shoreline.
Survey Cross Sections	Survey of the beach and foreshore along profiles fronting the high cost assets such as the toilet block. The profiles would seek to capture the foreshore out to a water depth of approximately 5 m. These surveys would help to determine the extent of the change in the shoreline profile that is occurring.	This level of survey would only be required if the eroded shoreline came within a horizontal distance of the S1 allowance plus 15m (approximately 30 m for the toilet block). If this were to occur then the survey cross sections should be completed every 1 to 2 years depending on the recommendations of a coastal engineer at that time.

This monitoring should be used to identify if the shoreline erodes to the extent that a trigger position is reached where the risk of coastal hazards becomes too great. If this were to occur, then the at-risk asset should be removed and relocated to an area that is considered safe based on the results of a coastal hazard assessment at that time.

The management of the public assets has been outlined above, with the long term adaption strategy being retreat.

8. Conclusion

This CHRMAP has been completed to provide guidance on required adaptation and management actions associated with the public assets within the foreshore. The coastal hazard assessment completed previously, and referred to in Section 3, as well as this CHRMAP report have been completed in line with the recommendations of SPP2.6 and WAPC (2019).

An assessment of the potential future areas of impact caused by the action of coastal hazards was completed in accordance with the requirements of SPP2.6. The results of this assessment show that the shoreline fronting the site could be vulnerable to change caused by a combination of severe storm erosion and sea level rise. In this regard, it is prudent to consider the potential future shoreline changes and the possible impacts on the public assets from future coastal adaptation and management requirements. It is noted however that an assessment of the historical movement of the shoreline fronting the site shows that the beach has experienced very little gross movement over the last half a century with the exception of the erosion adjacent to, and likely caused by, the redundant historical seawall. This demonstrates the apparent stability of the shoreline and highlights that the results of the coastal hazard assessment are likely to be conservative for this location.

The completion of the coastal hazard risk assessment for the public assets has shown that there is a risk of coastal hazard impact over the 100 year planning timeframe, while some assets are at risk in the present timeframe. As such, the short term (20 year plan) is to adapt, mitigate and retreat the assets while providing continued use and access to the foreshore area. The long term (100 year plan) is a managed retreat, which shall be initiated by erosion beyond the trigger points as mentioned in section 7 of this report.

A coastal management and adaptation strategy was presented within this report that outlines the proposed future management strategy. This strategy is based on retreating assets to avoiding future risk while preserving access and assets for the public. The managed retreat proposed is triggered by erosion of the shoreline, or at such time as the structures need to be replaced.

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10. Appendices

Appendix A Frenchman Bay Coastal Hazard Assessment

Appendix B Coastal Erosion Hazard Lines – SK1944-01-02

Appendix A Frenchman Bay Coastal Hazard Assessment

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Limitations of this Document

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1. Introduction

Frenchman Bay is located on the southern shoreline of King George Sound and, unique for a shoreline along the south coastal region, has a northerly aspect (refer Figure 1.1). Frenchman Bay has an interesting history, being the site of a Norwegian whaling station which was constructed in 1913. The tenure at the whaling station was short lived, with the station ultimately closing in 1915. Much of the infrastructure was removed following the closure of the whaling station; however, some relics remain on the beach (refer Figure 1.2). These relics have influenced the shoreline behaviour over the ensuing century.

Figure 1.1 Location of Frenchman Bay

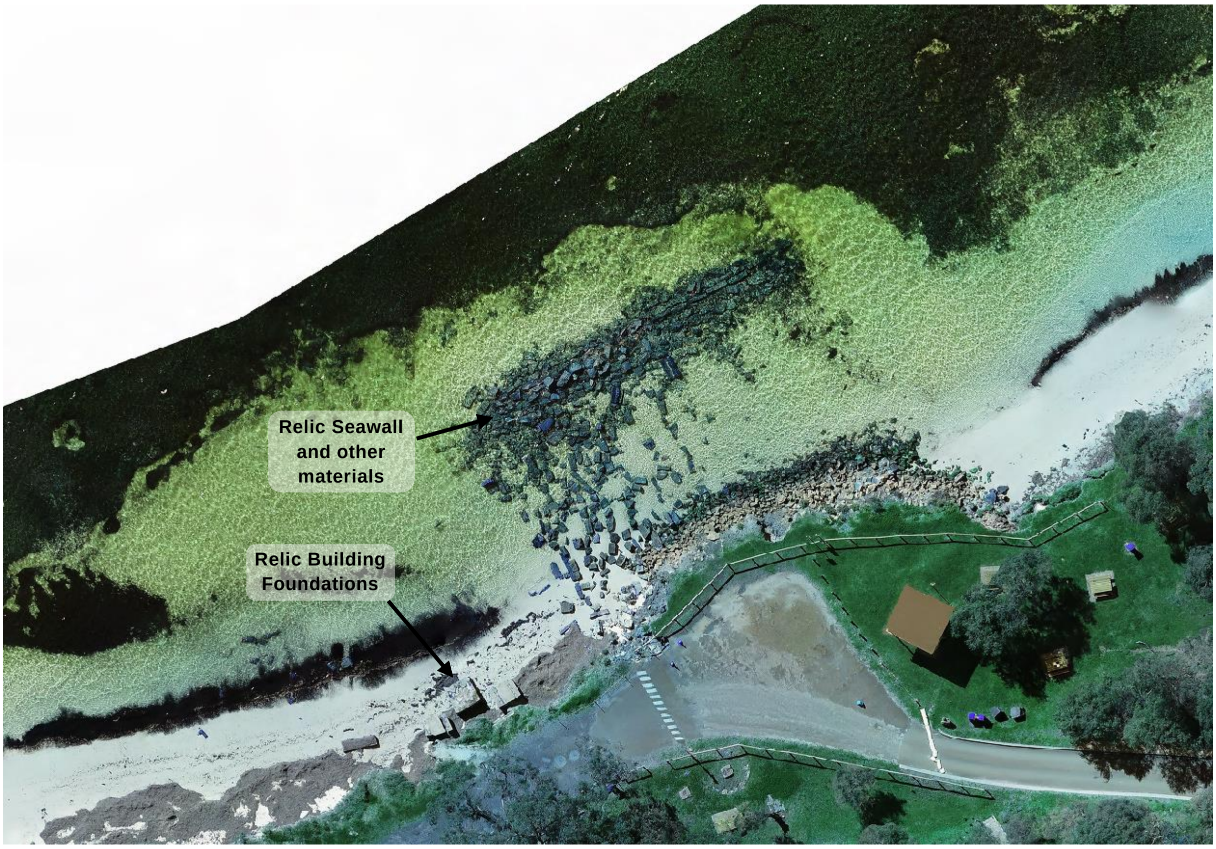

Figure 1.2 Relics from the Norwegian Whaling Station

In the present day, Frenchman Bay is a popular beach and foreshore area with both locals and tourists alike. Lots 1 and 2 Frenchman Bay Road are also slated for the development of Tourist Accommodation within the City of Albany Local Planning Scheme No. 1. Whilst an approval for the development of Lots 1 and 2 is in place, the approved development is understood to not be commercially viable, so modifications to the Local Development Plan (LDP) are proposed.

To enable review of the proposed development in the context of coastal hazard risk, as well as to enable planning for the siting of public infrastructure within the foreshore, the City of Albany engaged specialist coastal engineers M P Rogers & Associates Pty Ltd (MRA) to complete a coastal hazard assessment for Frenchman Bay. The requirement for the assessment of coastal hazard risk is even more profound given that the shoreline fronting the main coastal node has experienced noticeable erosion over the past few years.

Provision of guidance with regard to future coastal hazard risk requires an understanding of the potential zones of impact from local coastal processes. Within Western Australia, State Planning Policy 2.6 – the State Coastal Planning Policy (SPP2.6; WAPC, 2013) provides a methodology to determine the extent of areas adjacent to the coastline that could be influenced by coastal processes.

This report presents the results of investigations into the potential extent of impacts from coastal processes over a variety of planning horizons. These coastal hazard risk areas can then be used to guide a coastal hazard risk management and adaptation planning process in future stages of work.

2. Site Setting

2.1 Location

Frenchman Bay is a curved 700 m long north-facing beach located between Vancouver Point to the west and Waterbay Point to the east (Short, 2006). The presence of the Flinders Peninsula to the south and east provides protection to Frenchman Bay from offshore wave conditions, with refracted and diffracted wave heights generally less than around 1 m at the shoreline. The protrusion of Waterbay Point also provides further sheltering to the shoreline, and wave energy generally decreases from west to east along the beach (Short, 2006).

These local features are shown in Figure 2.1, which is an extract of the local nautical chart for the area.

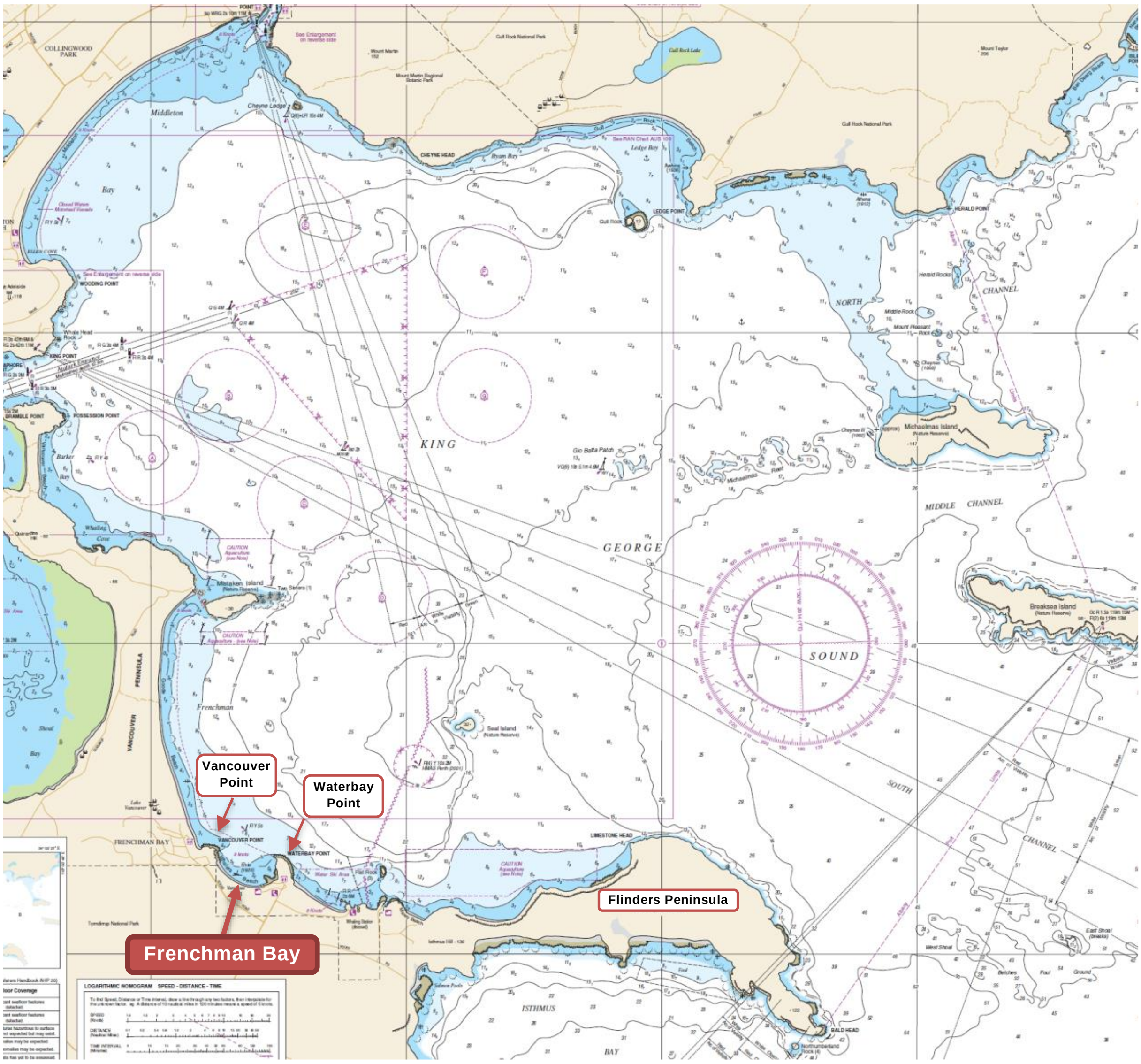

Figure 2.1 Extract from Local Nautical Chart (WA1083: DoT 2014)

2.2 Geology & Geomorphology

The Frenchman Bay shoreline consists of a reflective sandy beach. Behind the beach the land slopes steeply up to an elevation of approximately 25 mAHD before the land continues to rise at a gentler grade. The area is underlain by a basement that is PreCambrian “Granitoid Gneiss” which is overlain by a Tertiary Planagenet Group (Landform Research, 2008). The Granitoid basement outcrops to form both Vancouver and Waterbay Points.

Given the northerly aspect of the beach, which faces away from the prevailing conditions, a conventional dune system is conspicuously absent along this shoreline.

In 2008, Landform Research completed geotechnical drilling within Lots 1 and 2 to further review the local geology. The drilling determined that there was a deep layer of sand which was underlain by a siltier material. Significantly, none of the boreholes intersected the granitoid rock basement despite drill depths down to -1.7 mAHD in some areas. Whilst this drilling assessment was limited to the areas within Lots 1 and 2, it is anticipated that similar geological conditions would be encountered over the full extent of Frenchman Bay. As a result, assessment of the shoreline will be based on a sandy coastline classification.

Figure 2.2 View of Granitoid Outcrop that Forms Waterbay Point

Figure 2.3 View West Along Frenchman Bay Towards Vancouver Point

2.3 Historical Norwegian Whaling Station

The Norwegian Whaling Station was originally constructed in 1913, but was ultimately closed in 1915. At its peak, the whaling station boasted a range of different buildings, as shown in Figure 2.4.

Figure 2.4 Image of the Norwegian Whaling Station from 1913 (Frenchman Bay Association, 2021)

The Frenchman Bay Association (2021) provides a succinct summary of the history of the site. In particular, it is noted that following closure of the station the owners disassembled much of the machinery and relocated it to the site of their new facility at Point Cloates. However, it is noted that a large storm in 1921 wrecked the remaining slipway and loading jetty and eroded the seawall that protected the foundations of some buildings, causing them to topple. Whilst an amount of material was salvaged or removed, some of the material remained on site. An image of the remaining material is shown in Figure 2.5. This figure shows the remnants footings of some of the buildings as well as what is understood to be the remains of the initial seawall.

Figure 2.5 Remnant Material from the Norwegian Whaling Station (Frenchman Bay Association, 2021)

Given their location on the beach, the remains of the Whaling Station have impacted the local coastal processes along the eastern portion of Frenchman Bay. It is currently understood that the City of Albany are reviewing heritage preservation opportunities and requirements for these relics. It must be acknowledged that any changes to the location or configuration of these relics could further influence the local shoreline dynamics. This will be discussed further in latter sections of this report.

2.4 Metocean Conditions

Consideration of beach stability and coastal processes is enhanced by an understanding of the fundamental driving forces. Consequently, data on the magnitude and variation in the winds, waves, tides and currents is important in assessing the coastal processes.

2.4.1 Wind Regime

The seasonal weather patterns at Albany 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 (latitudes of 20 degrees to 40 degrees). Throughout the year, 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 lies across Australia typically between 25 to 30 degrees south and is to the north of Albany which is located at around 35 degrees south. Consequently, the migrating low pressure systems which exist to the south of the High Pressure Ridge, are located sufficiently northward to bring a westerly wind regime to the southwest of Western Australia and the adjacent waters. Cold fronts associated with these low pressure systems pass over the Albany region. These can bring storm force winds with directions from northwest, through west, to southwest.

During summer, the High Pressure Ridge moves south of Albany and lies between 35 and 40 degrees south. Under these circumstances, the Albany region comes under the influence of the high pressure cells of the High Pressure Ridge. These cells cause anti-cyclonic winds that rotate anti-clockwise in the Southern Hemisphere. At Albany, these winds arrive from the southeast to east as the high pressure cell approaches from the west.

In addition to these synoptic scale effects which cause seasonal variations, the meso-scale phenomenon of a land / sea-breeze system is commonly experienced during summer at Albany and adjacent coastal regions.

The Bureau of Meteorology has recorded the wind speed and direction at Albany Airport since 1965 and have used this data to prepare seasonal wind roses. These are presented as Figures 2.6 and 2.7 for the expanded winter (May to September) and summer (October to April) periods. Figure 2.6 shows the predominance of winter winds from the northwest and southwest sectors. Often the wind speeds exceed 50 kph in the winter storms.

The wind roses for summer, Figure 2.7, shows the common wind directions in summer as southeast and southwest. The detailed wind records show the land sea-breeze effect with the summer morning winds typically from the east and southeast at 20 to 40 kph, while the afternoon winds in summer tend to be of slightly stronger and generally from the southeast to southwest.

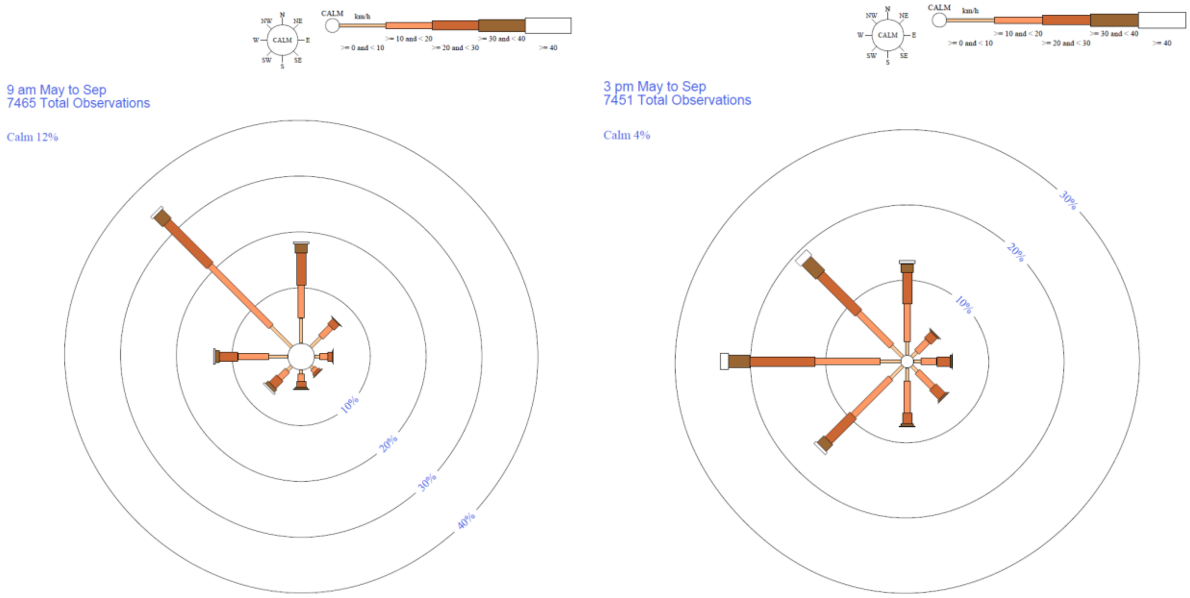

Figure 2.6 Albany Wind Roses for the Expanded Winter Period (BoM, 2014)

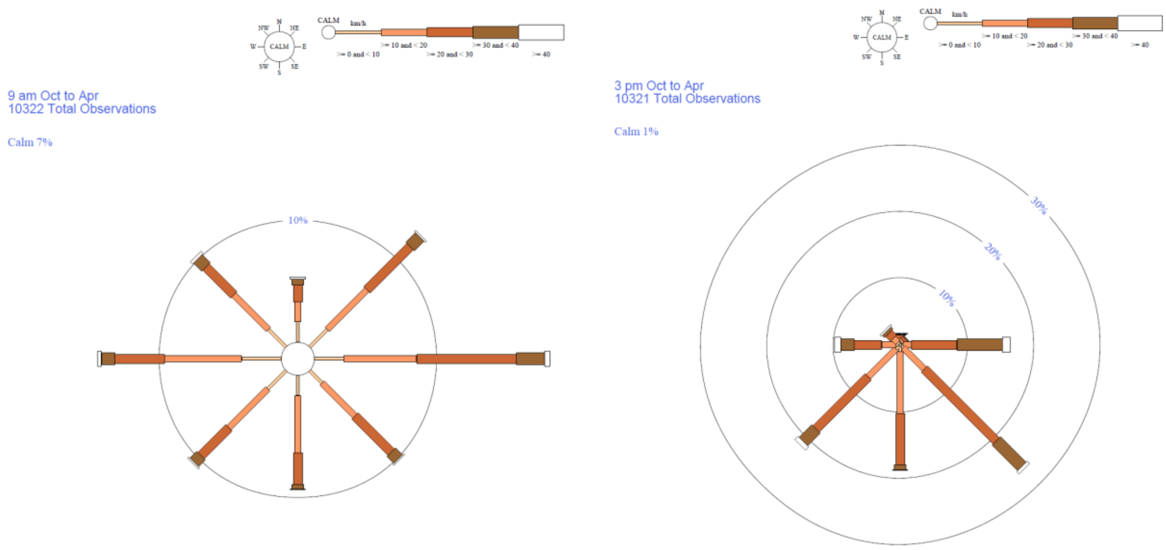

Figure 2.7 Albany Wind Roses for the Expanded Summer Period (BoM, 2014)

These records were taken at the Albany Airport which is about 20 km from Frenchman Bay. Differences in the local topography are likely to cause changes in the wind speeds and local directions. Nevertheless, the records presented are believed to be fairly representative of the main wind patterns and the seasonal changes that are experienced at Frenchman Bay.

The wind regime influences coastal processes through the generation of waves and currents.

2.4.2 Wave Climate

The nearshore wave climate at Frenchman Bay comprises two distinct sources. The first is that from the open ocean to the south of Albany, and the second are those waves that are generated by local winds across the short fetches of King George Sound.

This local generation of waves across King George Sound that causes waves to be directly incident upon Frenchman Bay is caused by winds from the north-easterly quadrant. However, as seen in the previous wind roses, strong winds from this quadrant are not overly persistent.

The deepwater wave climate to the south of Albany is quite severe. The Department of Transport record wave conditions in 60m of water south of Albany using a Waverider buoy. The location of the Waverider is shown in Figure 2.8. Wave measurements from this location are available since 2005.

Figure 2.8 Location of the DoT Waverider Buoy

The data recorded from the Albany Waverider is plotted in Figure 2.9. This figure shows both the time history of recorded wave heights as well as cross plots of the sea and swell wave heights verses their associated directions.

Figure 2.9 shows that the most common direction for these offshore waves is from the southwest, but they also approach King George Sound from the south and occasionally the southeast. The severity of the wave heights also mirrors the persistence, with the most severe waves from the south through west. Interestingly, the plot of recorded wave heights shows that the winter of 2020 was relatively severe, with a cluster of higher wave heights than previously observed within the data record. This may explain some of the erosion pressures that have been experienced at Frenchman Bay over the past couple of years.

Figure 2.9 Wave Data Recorded from the Albany Waverider Buoy

The shape of King George Sound provides Frenchman Bay with excellent natural protection from these open ocean waves (refer to Figure 2.1). In particular, the extent and position of Flinders Peninsula limits the energy of ocean waves that reach Frenchman Bay. The large ocean waves are greatly attenuated by the processes of refraction, diffraction, bottom friction and breaking as they travel from the open ocean to the sheltered shore.

Small to very small swell waves reach the shores of Frenchman Bay throughout the year. Because of the extensive refraction, the swell waves are bent around and arrive at the shore with crests generally parallel to the beach. This is an important feature as it means that if there are changes to swell conditions then the alignment of the beach will likely change as a result.

Given the location of Frenchman Bay, the most important fetches for locally generated waves are from the north-east quadrant. During the summer months there will be periods of winds that generate local seas from this direction across King George Sound. These seas will often reach 1 metre in height with wave periods of about 4 seconds. During very extreme events of strong winds from the east, the local seas may reach 2 metres in Frenchman Bay.

The waves that break on the beach are very important in the transport of sand in the littoral zone.

2.4.3 Tides & Water Levels

The astronomical tides at Albany are predominantly diurnal (one tidal cycle each day) and relatively limited in range. The daily range is typically about 0.6 metres during spring tides and about 0.3 metres during neap tides.

Seasonal shifts in the sea level occur due to meteorological effects. Typically, the mean sea level at Albany rises 0.1 metre during winter and falls 0.1 metre during summer.

During storms events, barometric and wind effects can cause significant storm surges. In typical winter storms, the surge is often about 0.4 metres above the astronomical tide level. The storm surge can be in the order of 1 metre during a very rare winter storm.

Given the small astronomical tides, the level of the sea would generally have a secondary effect on the sand transport along the beaches, except during storm events when high water levels would enable the waves to attack the rear of the sandy beaches.

2.4.4 Nearshore Currents

As the tidal range is quite small, it is likely that the nearshore tidal currents in Frenchman Bay are also small. From work in Princess Royal Harbour (Environmental Protection Authority, 1990) it is expected that the largest currents in the nearshore area at Frenchman Bay would result from the action of the wind blowing over the water surface. These wind driven currents are generally less than 0.5 m/s.

The magnitude of these nearshore currents is such that they will have a minor effect on the movement of sand on the adjacent beaches.

2.5 Coastal Processes

Frenchman Bay is located within the Possession Point to Bald Head coastal compartment (refer Figure 2.10). This compartment is characterised by embayed beaches generally separated by granite outcrops that exhibit morphological control.

Over the planning horizons considered in this assessment (up to 100 years) Frenchman Bay can be treated as a closed sediment cell. This is due to the fact that Vancouver and Waterbay Points essentially restrict sediment transport into or out of the Bay.

Figure 2.10 Extent of Coastal Sediment Cells

Based on the above information regarding the various physical processes, the movement of sand within Frenchman Bay is believed to be dominated by wave induced processes.

The transport of sand along a coast is a fundamental mechanism in beach dynamics. A simplistic description of this mechanism 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.

At Frenchman Bay the swell waves generally approach normal to the shoreline, though there is the potential for changes to the swell wave periods to change the alignment of the swell waves slightly as they approach the beach. Given the protection provided by Waterbay Point, the incident wave heights will also be higher at the western end of the Bay than they are at the eastern end. The western end of the Bay is also more exposed to summer easterly seas, increasing the potential for sediment transport along the western shoreline. Despite these different processes, the fact that Frenchman Bay is essentially a closed sediment cell means that the alignment of the shoreline would not be expected to change markedly over time. There may be reorientations or rotations of the overall beach driven by the incident wave energy, but ultimately such changes are expected to be relatively small.

The other significant coastal process, is by the onshore / offshore movement of beach sand. During storm events the steep waves and high water levels would cause sand to be eroded from the beach and carried offshore. The long, low swell that persistently arrives at this coast between storm events would tend to move sand back onto the beach. This cyclical onshore / offshore movement of sand is not expected to be large by volume within Frenchman Bay, however the absence of a defined dune, which would typically provide a buffer against storm erosion, means that any erosion effects are generally more noticeable.

3. Coastal Hazard Identification

An understanding of potential future coastal hazards and risks is critical for the assessment and determination of appropriate locations for siting of new development as well as for the development of management and adaptation actions.

SPP2.6 provides guidance on the assessment criteria and methodology required to determine the potential extent of coastal hazard impacts, whilst incorporating an appropriate level of conservatism for coastal planning. This assessment methodology seeks to incorporate allowances for landform stability, natural variability and climate change over the proposed planning horizon. Specifically, the following items are considered in order to assess the appropriate allowances for coastal processes and climate change over the proposed planning timeframes.

- Severe storm erosion (S1 Allowance).
- Historical shoreline movement (S2 Allowance).
- Climate change induced sea level rise (S3 Allowance).
- Storm surge inundation (S4 Allowance).

These criteria are discussed in further detail in the following sections of this report. This coastal hazards assessment has been completed for a 100 year planning horizon in accordance with SPP2.6 requirements. Interim planning horizons of 25, 50 and 75 years have also been considered in order to assess the changes to coastal vulnerability over time.

3.1 Severe Storm Erosion (S1 Allowance)

SPP2.6 outlines that the S1 allowance should provide an adequate buffer to accommodate the potential erosion caused by a storm with an Annual Encounter Probability (AEP) of 1%. This is equivalent to a 100 year average recurrence interval (ARI) storm.

Estimation of the S1 allowance for Frenchman Bay first requires selection of an appropriate storm event. This is particularly relevant given the level of sheltering that the shoreline receives. The selected storm will then be modelled to determine the potential extent of shoreline erosion that could result.

3.1.1 Storm Event

As outlined previously, Frenchman Bay has a northerly aspect and so is protected from the most severe wave energy from the south by the Flinders Peninsula. As a result, wave energy that arrives at the shoreline during the largest wave events (typically from the south to south west) is significantly attenuated due to the extent of diffraction required for the waves to reach the shoreline. For example, based on diffraction diagrams provided in Goda (2010) (refer Figure 3.2), even a wave coming directly from the south would be attenuated to less than 10% of its total offshore wave height by the time that it diffracted around Bald Head and made it to the nearshore area fronting Frenchman Bay.

Given the above, storm events that are predominately from the west through south would be expected to have little impact on the shoreline fronting the resort. Events with the majority of the wave energy originating from the south through east would have a much greater impact on this section of shoreline since less wave diffraction would be required for the wave to reach the shoreline.

MRA (2018) completed a review of storm conditions appropriate for the simulation of potential coastal erosion events and discussed the effects of event directionality with particular focus on the Albany region. Results of that analysis showed that even though a storm event experienced in August 1984 was not classified as one of the top storm events, the directionality of the event being from the south east, resulted in significant erosion of shorelines within King George Sound. The extent of erosion observed during the August 1984 event was actually greater than for any other storm event within the period of record, which dated back to 1943.

Given the critical nature of a south easterly wave for the realisation of storm erosion impacts within Frenchman Bay, wave records were therefore interrogated to assess only those events with severe waves arriving from the south through east. The assessed wave data included the information from the DoT Waverider Buoy as well as results from the WW3 global hindcast wave model (NOAA 2016), and other available hindcast modelling results completed by WNI (1996).

An extreme analysis was completed on the filtered wave events to show the average recurrence of wave heights from the south through east. Results of this extreme analysis are presented in Figure 3.1.

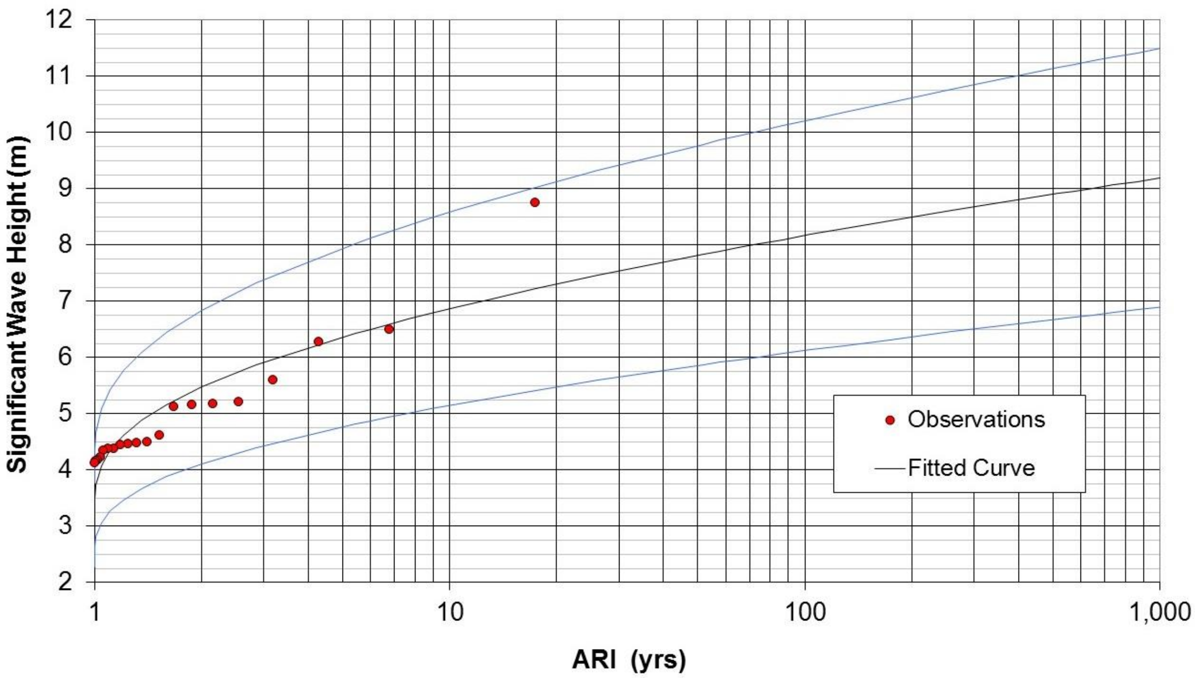

Figure 3.1 Extreme Wave Height Analysis for Waves from the South through East

The most notable feature of the extreme analysis is that there is one event that is significantly more severe than the over events. This event is the August 1984 event.

Even though this event was predominately from a south easterly direction, waves still need to diffract around Bald Head in order to reach the nearshore area adjacent to Frenchman Bay. The hindcast wave conditions were therefore adjusted to account for the attenuation caused by this diffraction using the diffraction diagrams presented in Goda (2010) (refer Figure 3.2). Using this diffraction diagram, it was possible to estimate the wave conditions offshore from Frenchman Bay.

This method is akin to that used by MRA (2017). For clarity, two examples showing how the wave transformation was completed are shown in Figure 3.3.

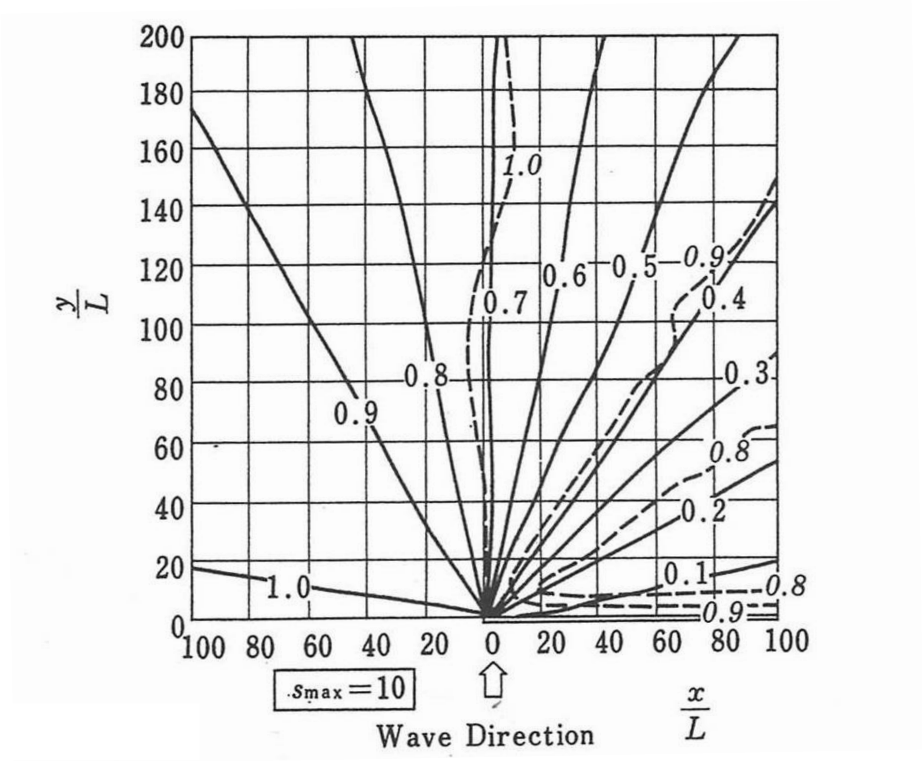

Figure 3.2 Diffraction Diagram from Goda (2010)

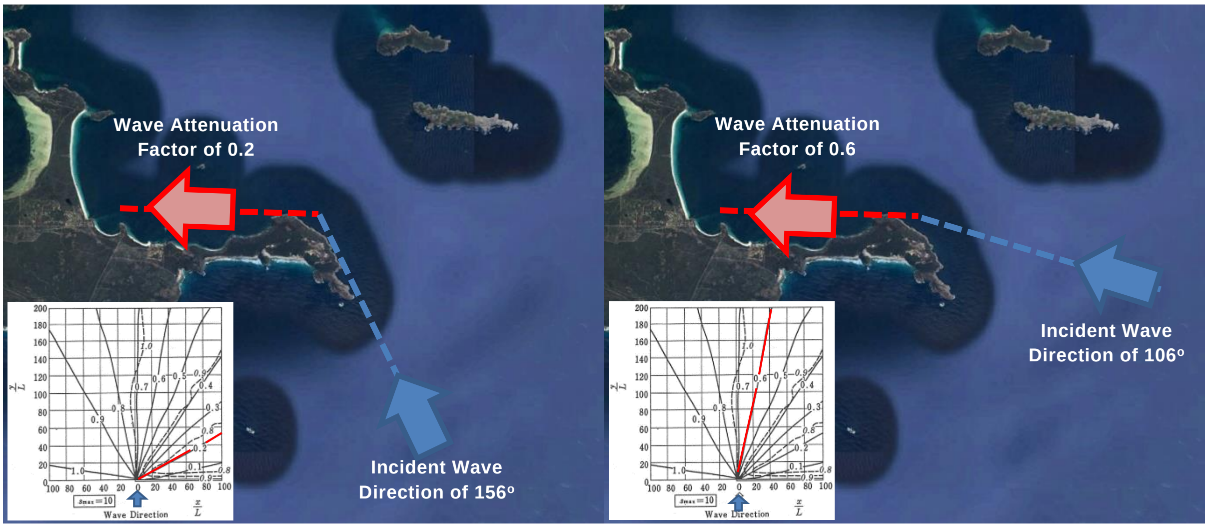

Figure 3.3 Examples of Wave Diffraction Attenuation Calculations

The diffracted wave conditions were determined for a location offshore from Waterbay Point. From this location incident waves would be further diffracted around the point or would be refracted over the local bathymetry. However, as the ensuing processes are relatively complex and will not necessarily result in energy losses that are consistent with an additional application of the diffraction diagrams due to changes in the incident wave directions, the conditions as determined at this location have been used to assess the potential for beach erosion. This is a somewhat conservative approach.

Unfortunately no water level records are available for the duration of the August 1984 event. As a result, the predicted tidal level during this event was scaled to peak at the 10 year ARI water level as determined within MRA (2018).

It is noted that scaling of the water level to peak at the 10 year ARI level is likely to be conservative for this event since the event was actually associated with the passage of a strong high pressure system. The high atmospheric pressure of this system is likely to have resulted in a set-down of water level over the general area, rather than a storm surge. However in the absence of more detailed information the 10 year ARI water level has been used to maintain conservatism within the assessment.

The August 1984 event had sustained waves from the south through east for a period of around 60 hours. The full duration of this event was therefore used for the modelling of the severe storm erosion impact. In accordance with the recommendation of SPP2.6, three repeats of this event have been used to determine the potential extent of storm erosion within Frenchman Bay. The wave heights and water level used in the modelling are presented in Figure 3.4.

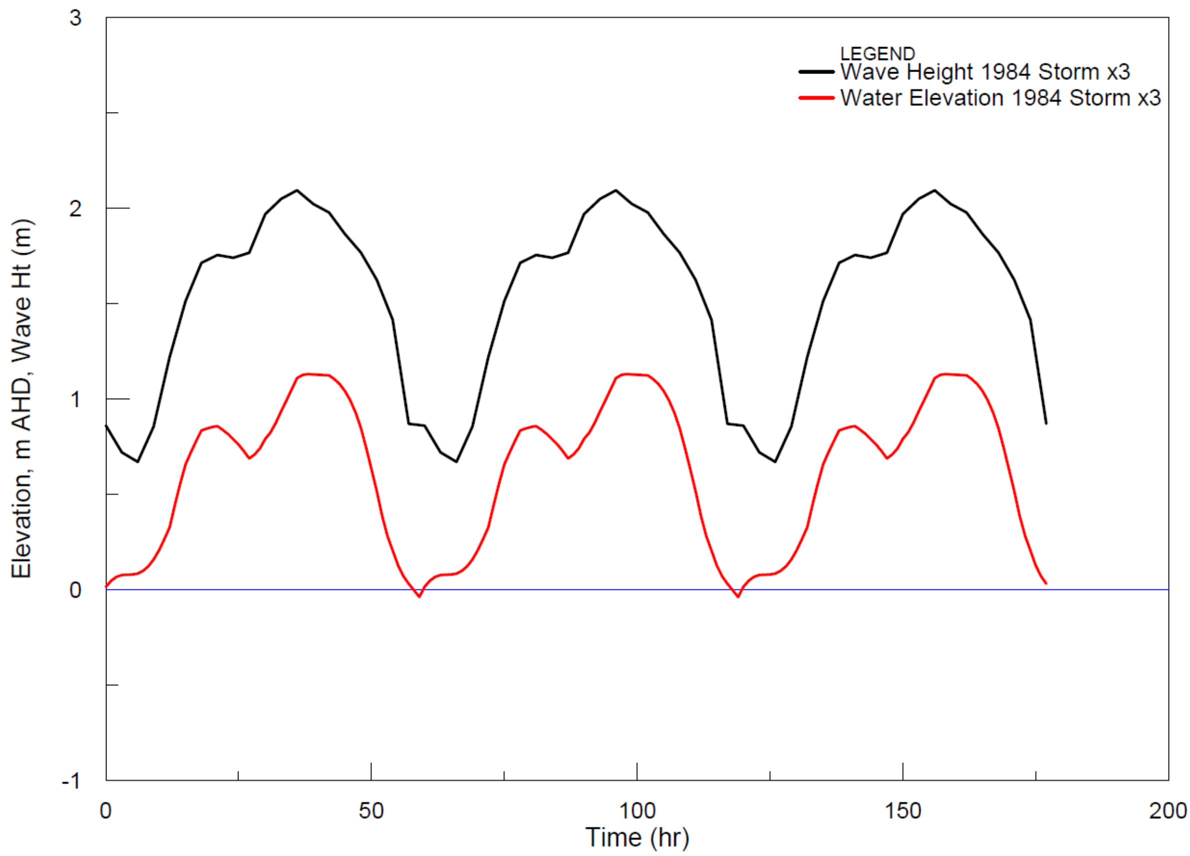

Figure 3.4 Storm Conditions for use in Storm Erosion Modelling (as determined for the area immediately offshore from the Resort site)

3.1.2 SBEACH Storm Modelling

The SBEACH computer model was developed by the Coastal Engineering Research Centre (CERC) to simulate beach profile evolution in response to storm events. It is described in detail by Larson & Kraus (1989). Since this time the model has been further developed, updated and verified based on field measurements (Wise et al 1996, Larson & Kraus 1998, Larson et al 2004).

MRA has validated SBEACH for use on sandy coasts in Western Australia (Rogers et al 2005). This validation has shown that SBEACH can provide useful and relevant predictions of the storm induced erosion, provided the inputs are correctly applied and care is taken to ensure that the model is accurately reproducing the recorded wave heights and water levels. Primary inputs include time histories of wave height, period and water elevation, as well as pre-storm beach profile and median sediment grain size.

Given the change in aspect of Frenchman Bay, two different beach profiles have been used to simulate the potential extent of severe storm erosion. The input beach profiles used in the modelling were taken from a combination of topographic survey data, hydrographic survey information and local nautical charts. The approximate location and alignment of the profiles are presented in Figure 3.5.

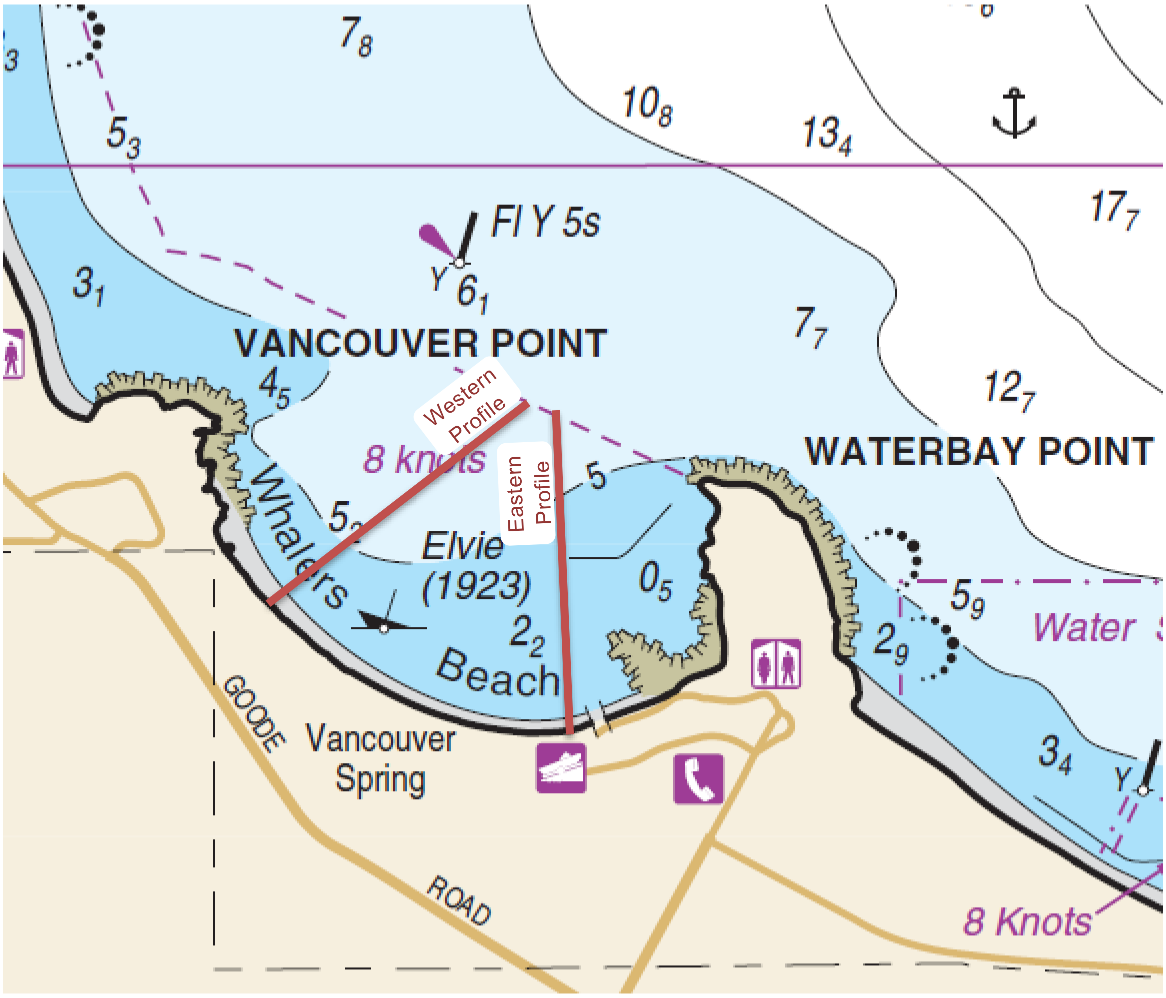

Figure 3.5 SBEACH Profile Location & Alignment

The results of the storm simulation are presented in Figures 3.6 and 3.7. These figure present the pre- and post-storm beach profiles, the maximum water elevation and maximum wave height during the event. The output from the model, the SBEACH Reports, have also been included in Appendix A.

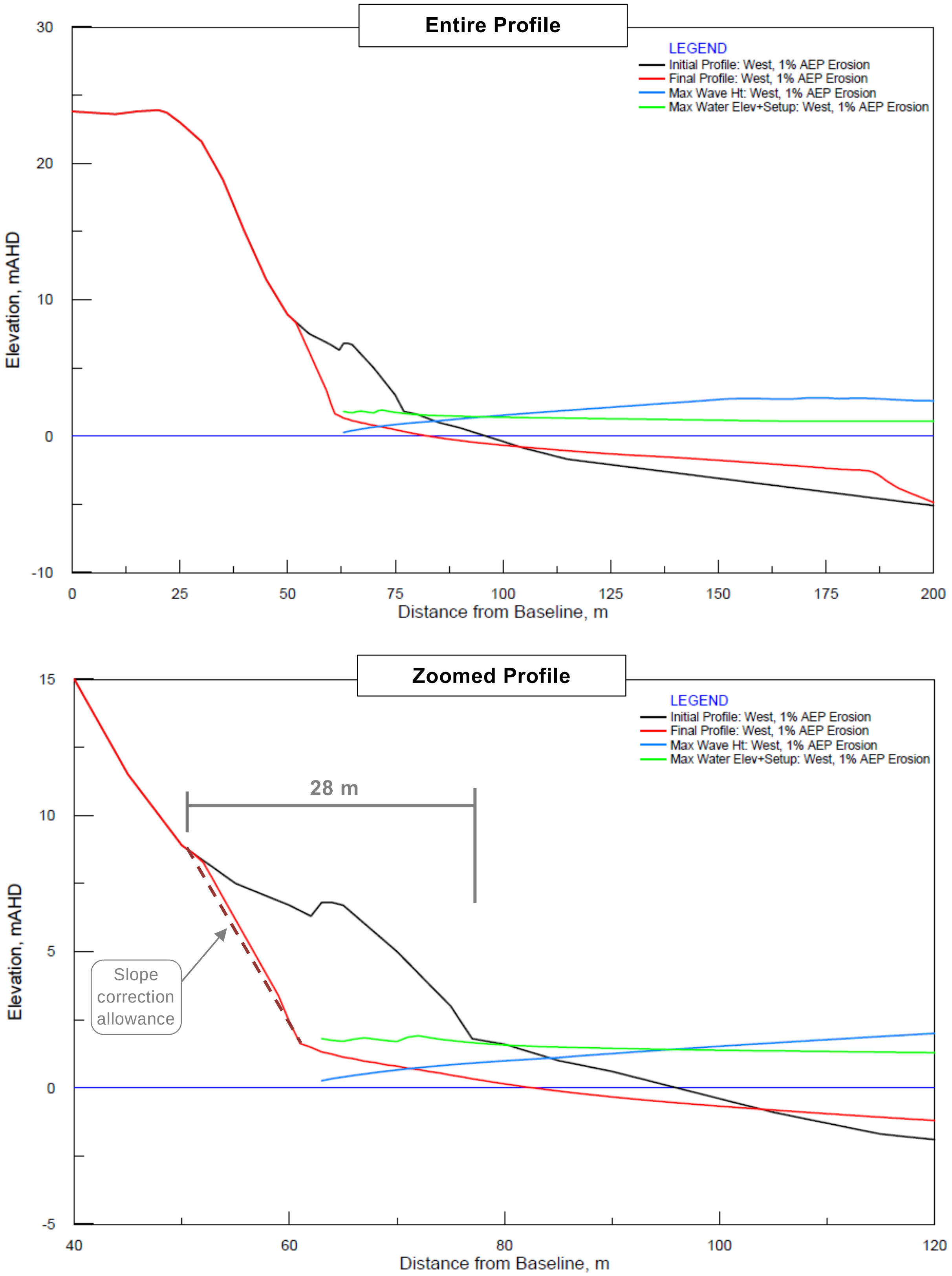

Figure 3.6 Severe Storm Erosion Modelling Results for the Western Profile

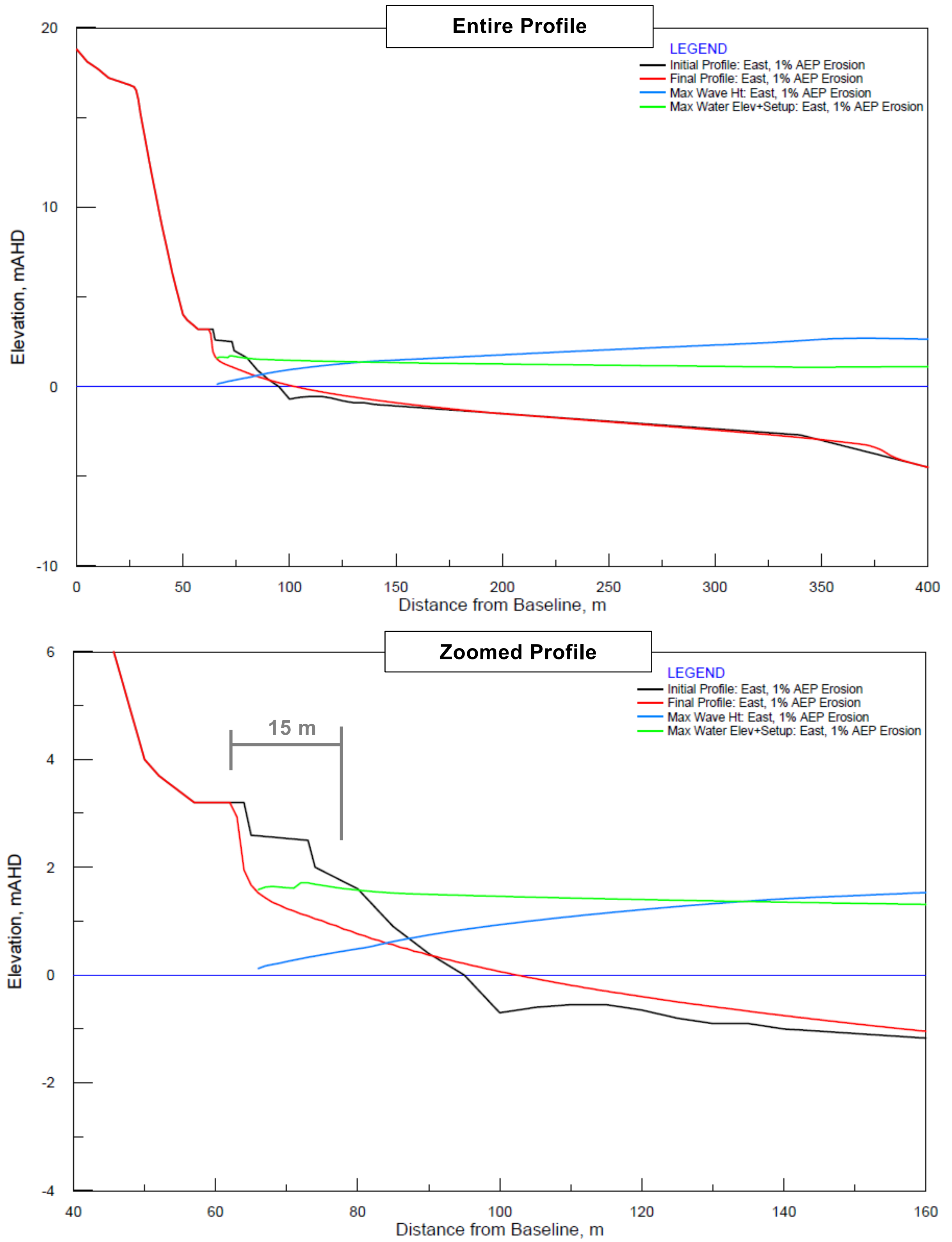

Figure 3.7 Severe Storm Erosion Modelling Results for the Eastern Profile

The S1 allowance is determined as the maximum extent of erosion behind the Horizontal Shoreline Datum (HSD). The HSD corresponds to the seaward shoreline contour representing the peak steady water level of the modelled event. The HSD was calculated as the 1.8 mAHD contour based on the results of the SBEACH modelling.

The results of the modelling show that there is potentially a greater degree of erosion potential along the western end of the bay compared to the east. There are a number of contributing factors to this, however the modelling shows that differences arise due to the shallower offshore bathymetry at the eastern end of the bay, which helps to reduce wave heights at the shoreline.

The total extents of predicted shoreline erosion caused by the storm sequence were 28 m and 15 m respectively for the western and eastern profiles. This estimate includes an allowance for dune slope correction based on a maximum avalanching slope of 30° to the horizontal to ensure stability of the eroded dune face. This applies to the result from the modelling of the western profile as shown on Figure 3.6.

Given that different erosion extents have been predicted between the western and eastern ends of the bays, and the fact that there is an intuitive understanding of why this result is reasonable, it follows that a different S1 allowance should be applied along the western and eastern ends of the shoreline. The areas covered by each allowance have been reviewed based on the nearshore bathymetry and the required allowances are shown in Figure 3.8. It should be noted that the same S1 allowance is required for each planning timeframe, as SPP2.6 requires a design storm with 1% AEP, regardless of the timeframe being considered.

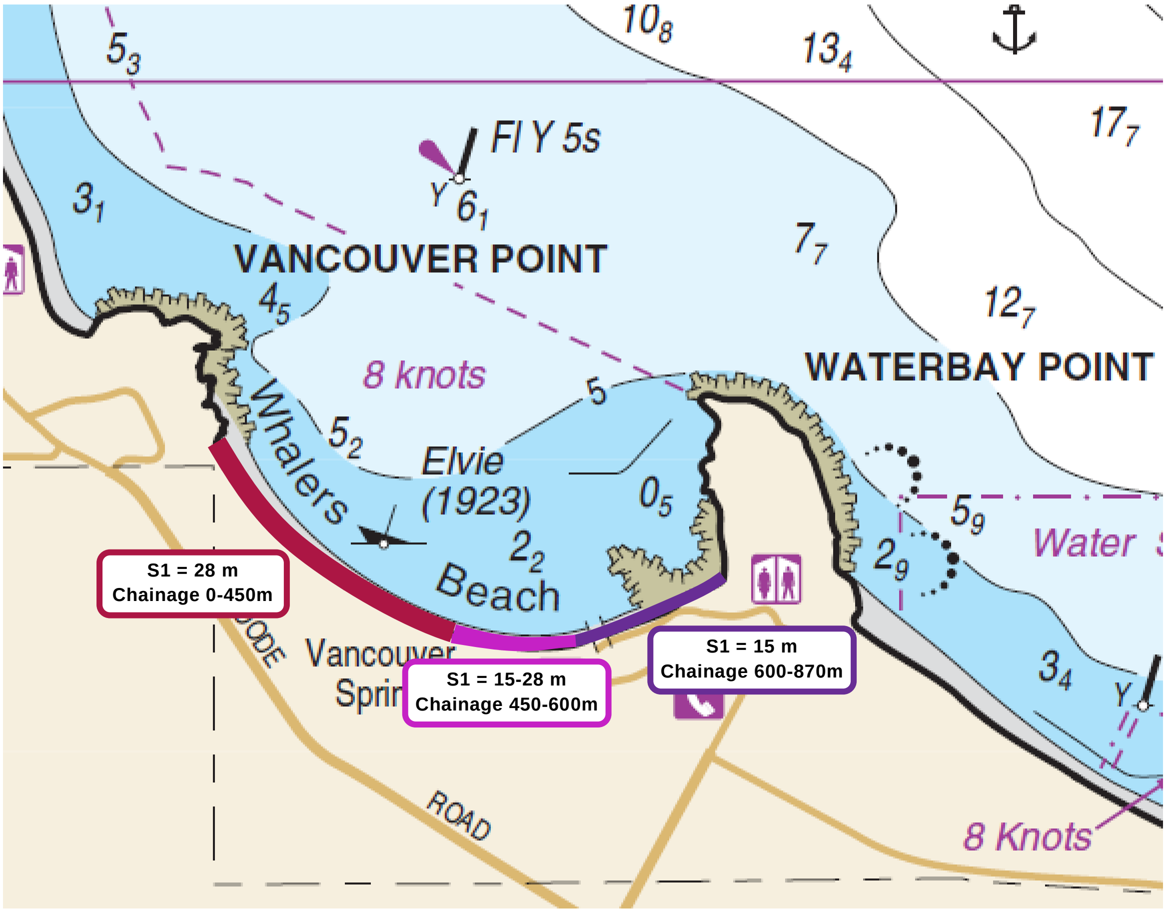

Figure 3.8 Summary of S1 Allowances

3.2 Historical Shoreline Movement (S2 Allowance)

Historically, 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 long term trends allowed for in the Historical Shoreline Movement (S2) Allowance account for the chronic 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.

3.2.1 Shoreline Movement

MRA mapped the position of the coastal vegetation line from aerial photography captured in 1977, 1988, 1996, 2001, 2007, 2011, 2014, 2016, 2019, 2020 and 2021. Mapping of the coastal vegetation lines was completed in accordance with DoT's methodology and specification for mapping (DoT, 2009). 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. A shoreline movement plan presenting the mapped vegetation lines is presented in Appendix B.

Using the mapped vegetation lines, the position of the shoreline was determined at intervals of 50 m or less along Frenchman Bay. The chainage intervals for the measurement of shoreline change are shown in Figure 3.9. The position of the shoreline relative to the 1977 location was determined at each interval from the shoreline movement plan, with results presented in Figure 3.10.

Figure 3.9 Intervals for Measurement of Shoreline Movement

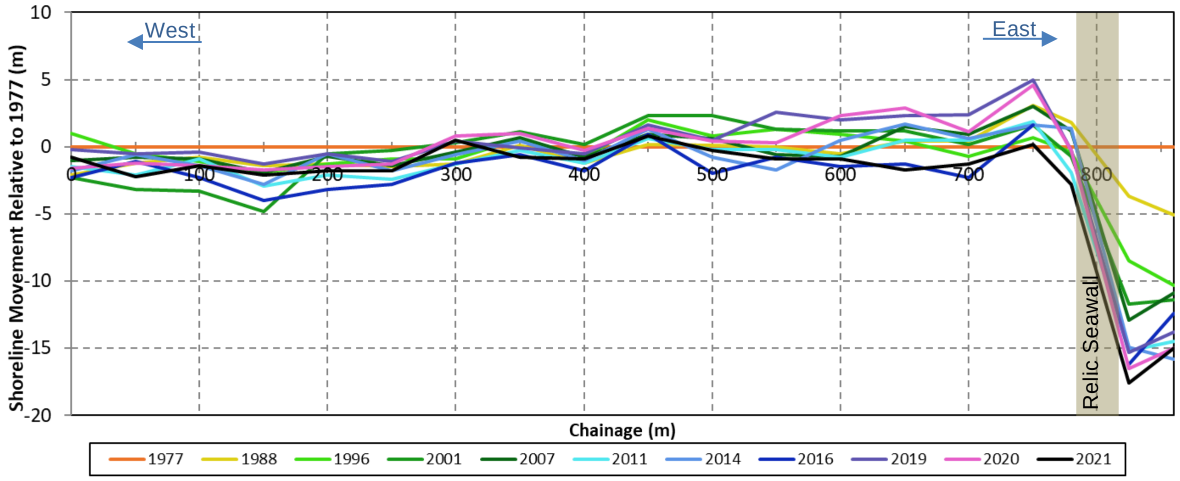

Figure 3.10 Historical Shoreline Movement Relative to 1977

The historical shoreline movement plot shows a stark difference between the behaviour of the majority of the Frenchman Bay shoreline and the small section of shoreline to the east of the relic seawall. The area to the east of the relic seawall has experienced erosion in the order of 15 to 20 metres since 1977, whilst the remainder of the bay has experienced a slight rotation, with a general accretion at the eastern end and erosion at the western end. Nevertheless, total movement of the shoreline across the majority of the Bay has been less than plus or minus 5 metres from the 1977 position.

Overall, the observed movements of the shoreline confirm the assertion that the shoreline is essentially an enclosed sediment cell, as the volume of sediment within the Bay appears to be conserved. Importantly for the management of the current infrastructure and assets at the site, the shoreline movements do show an erosion of the eastern end of the beach in the period between 2020 and 2021. Noting that these lines are from the 1st of May 2020 and September 2021 respectively, this period covers two winter seasons. It was identified through the review of metocean conditions that the 2020 winter appeared to be quite severe, and the expectation is that 2021 would also have been similar. This likely provides the reasoning behind the observed erosion in this area.

To better illustrate the trends in shoreline movement over time, time history plots have been prepared for selected chainages. These time history plots are shown in Figure 3.11.

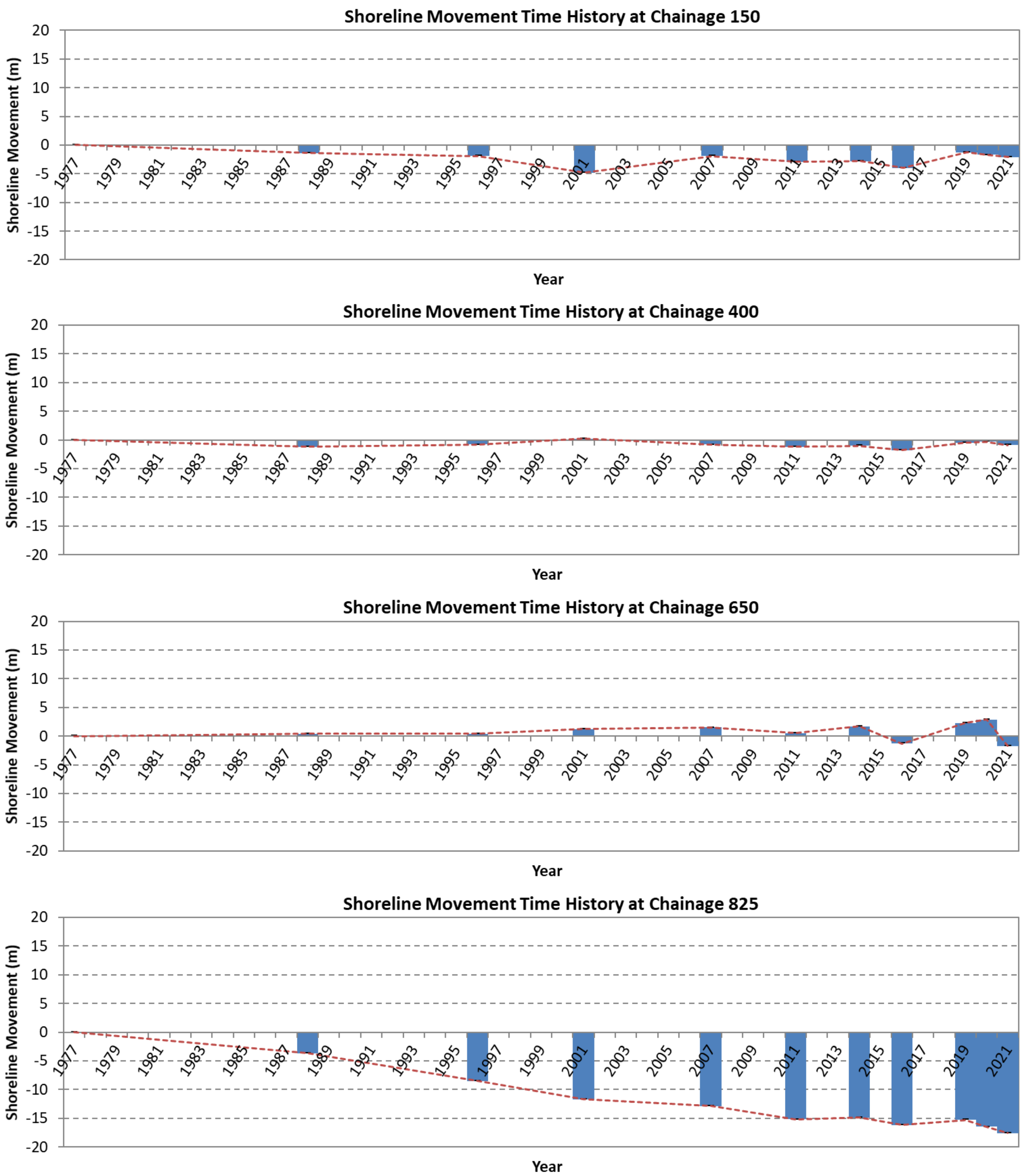

Figure 3.11 Time History Plots of Shoreline Movements at Selected Chainages

The time history plots show generally consistent trends across the duration of the record at each location. In particular the time history plots show the following.

- At the western end of the site, the plot from chainage 150 shows a reasonably consistent erosion trend, with some degree of fluctuation.
- The plot from the eastern end of the beach at chainage 650 shows a slight accretion trend, with the observed recent erosion between 2020 and 2021, though a similar erosion event was also observed in 2016.

- Chainage 400 is approximately the midpoint of the Bay and shows very little movement. This observation is not uncommon for enclosed bays such as this, as sediment dynamics generally result in rotations of the beach about the midpoint of the Bay.

- The shoreline movement at chainage 825 shows a consistent rate of erosion across the duration of record. The rate of erosion observed in this area is far greater than across the remainder of the bay. In this regard, it must be considered that this rate of erosion is attributable to other factors, in particular the presence of the relic seawall and its resultant impact on the position of the shoreline.

Figure 3.12 shows a zoomed in view of a selection of mapped shoreline positions adjacent to the relic seawall. The figure shows an obvious disparity between the historical positions of the shoreline to the west and east of the structure. Note that this figure also includes a coastal vegetation line from 1961 which was mapped for this project but ultimately not used due to issues at the western end of Frenchman Bay.

Figure 3.12 Shoreline Positions Adjacent to the Relic Seawall

The figure shows that the shoreline position to the east of the seawall was very similar between 1961 and 1977, though this position was significantly further seaward than the shoreline to the west of the seawall. Thereafter the shoreline east of the structure began to experience the observed erosion, although in some areas this erosion hasn't really continued beyond 2011.

Based on review of aerial imagery and the associated shoreline movement lines, it seems that the relic seawall was providing a strong degree of shoreline control and was holding material on its eastern side. As a result, the shoreline to the east of the seawall was essentially an artificial shoreline. At some point, most likely between 1977 and 1988, it appears that the degree of shoreline control provided by the structure decreased and sediment held to the east of the seawall was able to be transported westwards out of this area. The change in the structure that resulted in this reduction in shoreline control could have been associated with a settlement of the structure under storm conditions, such as those associated with the 1984 storm event.

Regardless of the cause of the change to the seawall, and its associated level of shoreline control, it appears that the shoreline east and west of the structure are now better aligned and as a result, it is anticipated that chronic movement of the shoreline in this area would reduce in the future. Nevertheless, the fact that between 15 and 20 m of foreshore has been lost in this area means that the existing foreshore does not interface well with the adjoining beach. The absence of a dune system, or the mechanism for the natural formation of a dune system, in this area therefore further exacerbates the issue as it means that the foreshore is prone to impacts from severe storm erosion events and high water levels. This has been observed over the winter of 2021, with the City of Albany installing coir logs (refer Figure 3.13) to try and combat erosion of the foreshore area.

Figure 3.13 Coir Logs Installed by the City of Albany in 2021 to Combat Erosion

On the whole, the examination of shoreline movement suggests that the shoreline is likely to be quite stable in the future from a chronic shoreline movement perspective. This is on the basis that the erosion to the east of the relic seawall has now reached a point where the embayed alignment of the shoreline is generally consistent along its entire extent. Impacts associated with storm events and high water levels would still be expected in this area, however these considerations are dealt with by the S1 Allowance.

To determine the appropriate S2 allowance a review of longer term shoreline movement rates has been completed. These long term shoreline movement rates are shown in Figure 3.14. Rates across different long term periods have been considered to reduce the potential for a single abnormal shoreline position to influence the results. Based on this review, it is apparent that a 0.05 m/year allowance should be provided across the full extent of Frenchman Bay. This will provide security against fluctuations in shoreline position over and above those caused by storm events.

The resulting S2 allowances for the different planning horizons are provided in Table 3.1.

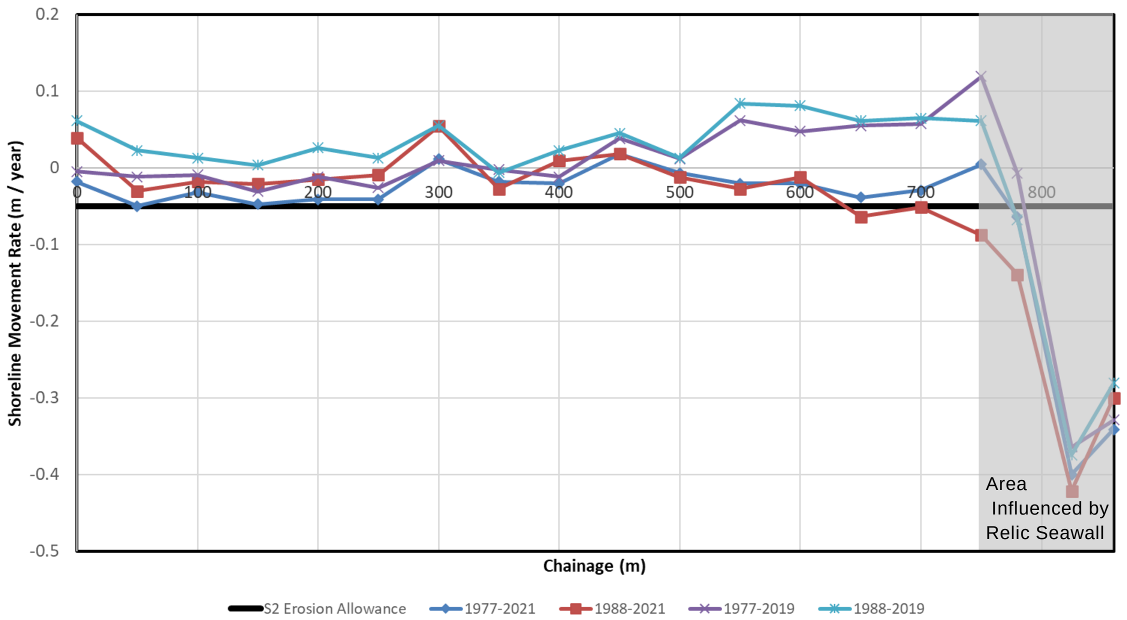

Figure 3.14 Shoreline Movement Rates

Table 3.1 S2 Shoreline Movement Allowances

Planning Timeframe	S2 Allowance (m)
Present Day (2021)	0
2041	1
2061	2
2081	3
2101	4
2121	5

3.3 Sea Level Rise (S3 Allowance)

Climate change is believed to cause an increase in mean sea level as a result of two main processes:

- the melting of land based ice, increasing the volume and height of the ocean waters; and
- a decrease in ocean density through thermal expansion, which increases the volume and thus the ocean height (CSIRO 2007).

Observations of sea levels have been carried out for centuries, at some locations, allowing historical trends to be identified. The global mean sea level rose by between 0.12 to 0.22 m over the 20th century, which equates to an average of around 1.8 mm/yr (IPCC 2007).

Within Western Australia reliable water level data is available from Fremantle for the period from 1950. The Fremantle records indicate that between 1950 and 1991, there was a relatively slow rise in sea levels, however over the ensuing period there has been a more rapid sea level rise. Figure 3.15, shows a plot of sea level rise at Fremantle since 1950.

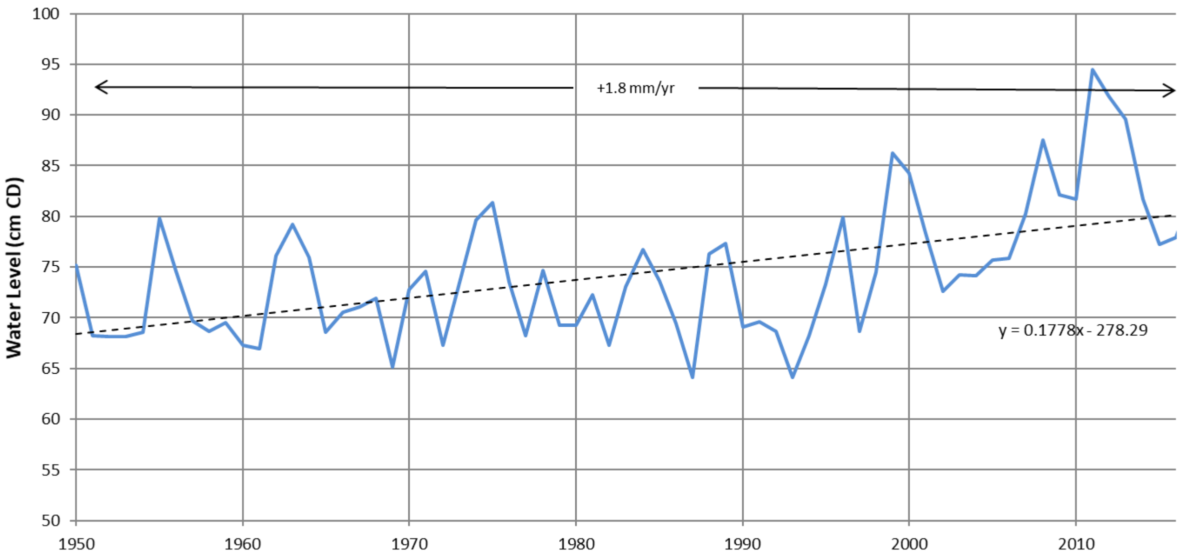

Figure 3.15 Fremantle Water Level 1950 to 2020

Through review of this and other data and research, DoT released recommendations on the appropriate allowances for future climate change and sea level rise to be used for coastal planning and development in Western Australia (DoT 2010). These recommendations were adopted by SPP2.6 and are presented in Figure 3.16.

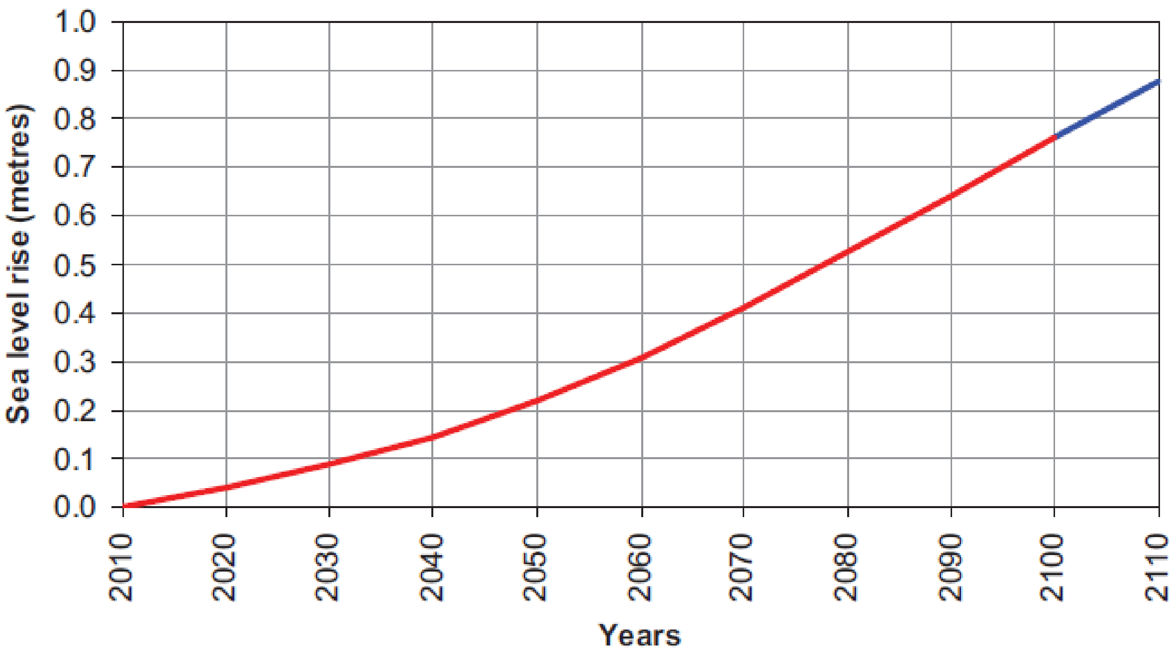

Figure 3.16 Recommended Allowance for Sea Level Rise (DoT 2010)

The recommended allowances for future sea level rise for each of the planning timeframes have been determined and are presented in Table 3.2. All of these increases in sea level are referenced to 2021.

Table 3.2 Sea Level Rise Allowances

Planning Timeframe	SLR Allowance (m)
Present Day (2021)	0.00
2041	0.11
2061	0.27
2081	0.49
2101	0.73
2121	0.97

The effect of sea level rise on the coastline is difficult to predict. Komar (1998) provides a reasonable treatment for sandy shorelines, including examination of the Bruun Rule (Bruun 1962).

The Bruun Rule relates the recession of the shoreline to the sea level rise and slope of the nearshore sediment bed:

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

where: R = recession of the shore.

θ = average slope of the nearshore sediment bed.

S = sea level rise.

Komar (1998) suggests that the general range for a sandy shore is R = 50S – 100S. SPP2.6 requires that for sandy shorelines the recession be taken as 100 times the estimated rise in sea level. Therefore, the required allowances for shoreline recession due to sea level rise are presented in Table 3.3.

Table 3.3 S3 Shoreline Recession Due to Sea Level Rise Allowances

Planning Timeframe	SLR Allowance (m)
Present Day (2021)	0
2041	11
2061	27
2081	49
2101	73
2121	97

3.4 Summary of Coastal Erosion Allowances

The allowances for coastal processes determined hereto are presented in Table 3.4. As required by SPP2.6, a 0.2 m/year allowance for uncertainty has also been included. The total allowances should be measured from the HSD.

Table 3.4 Summary of Allowances for Coastal Erosion Hazards

Timeframe	Chainage (m)	S1 (m)	S2 (m)	S3 (m)	Uncertainty (0.2 m/yr)	Total Allowance (m)
Present Day (2021)	0 - 450	28	0	0	0	**28**
	450 - 600	28 - 15				**28 - 15**
	600 - 870	15				**15**
2041	0 - 450	28	1	11	4	**44**
	450 - 600	28 - 15				**44 - 31**
	600 - 870	15				**31**
2061	0 - 450	28	2	27	8	**65**
	450 - 600	28 - 15				**65 - 52**
	600 - 870	15				**52**
2081	0 - 450	28	3	49	12	**92**
	450 - 600	28 - 15				**92 - 79**
	600 - 870	15				**79**
2101	0 - 450	28	4	73	16	**121**
	450 - 600	28 - 15				**121 - 108**
	600 - 870	15				**108**
2121	0 - 450	28	5	97	20	**150**
	450 - 600	28 - 15				**150 - 137**
	600 - 870	15				**137**

The sum of each of the allowances outlined in the above table provides an indication of the areas that may be at risk from coastal erosion in the respective planning timeframes. These are presented on Coastal Hazard Maps included in Appendix C. In preparing the coastal hazard maps it should be note that the presence of the existing seawall has been neglected. This is on the basis that the seawall structure is in extreme disrepair and it is expected that the influence it will have on the coastline will diminish over time. This has already been seen with respect to the loss of shoreline control, and therefore its stabilising effect, on the beach immediately east of the structure.

3.5 Storm Surge Inundation (S4 Allowance)

With respect to inundation, SPP2.6 requires that development consider the potential effects of an event with an AEP of 0.2% per year. This is equivalent to an inundation event with an ARI of 500 years.

Assessment of the inundation level requires consideration of peak storm surge, including wave setup. A storm surge occurs when a storm with high winds and low pressures approaches the coastline (refer Figure 3.17). The strong onshore winds and large waves push water against the coastline (wind and wave setup) and the barometric pressure difference creates a region of high water level. These factors acting in concert create the storm surge. The size of the storm surge is influenced by the following factors.

- Wind strength and direction.
- Pressure gradient.
- Seafloor bathymetry.
- Coastal topography.

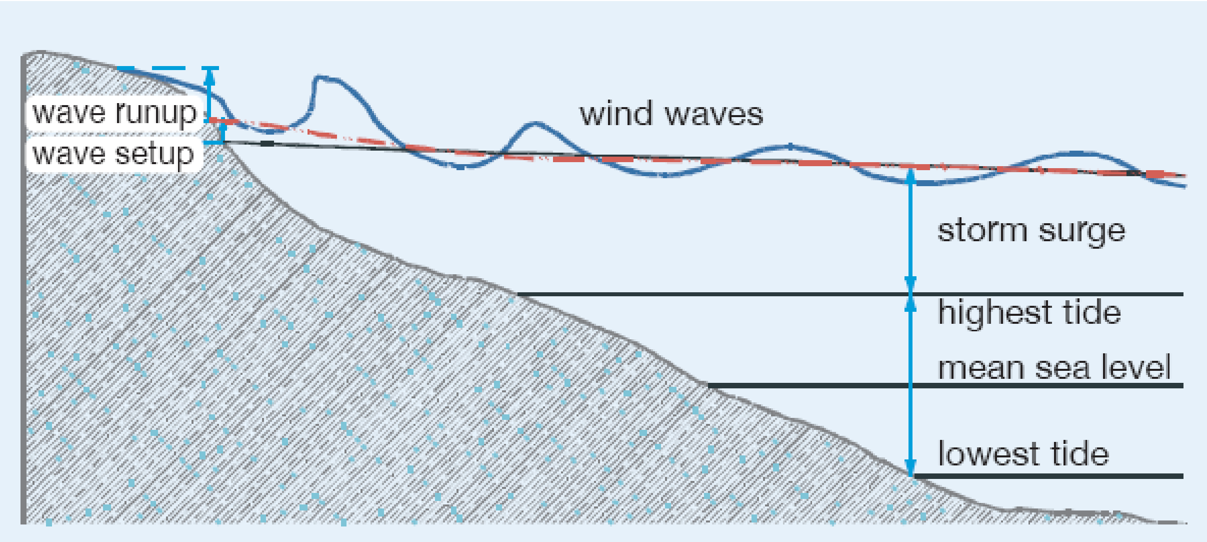

Figure 3.17 Storm Surge Components

The extreme analysis of the Albany water level record was completed by MRA (2018). This analysis showed that the estimated 500 year ARI water level at the tide gauge is approximately 1.13 mAHD (refer Figure 3.18).

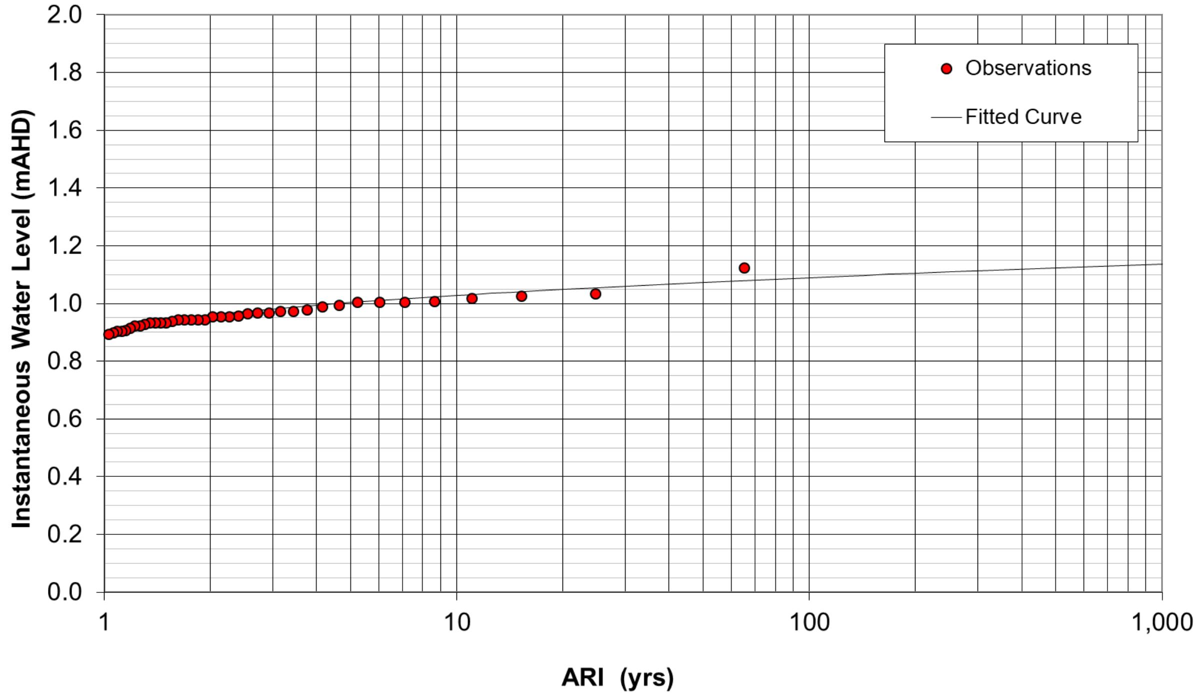

Figure 3.18 Extreme Water Level Analysis for Albany (MRA, 2018)

As indicated in Figure 3.17, closer to the shore, wave setup can increase the water levels. Dean and Walton (2008) provide a comprehensive review of wave setup on beaches, which confirms that the majority of setup occurs on the beach face. This is not entirely accounted for in the measurements at the Albany tide gauge and therefore needs to be determined.

The SBEACH model was setup and run for the 500 year ARI water level, to translate the water level from the nearshore area to the shoreline to estimate the additional wind and wave setup. It was estimated that an additional setup in the order of 0.8 metres could be expected at the site. This has been included in estimates of the appropriate inundation levels for the various planning timeframes, presented in Table 3.5. It is noted that these inundation levels are likely to be conservative given that the shoreline has a northerly aspect yet the majority of the conditions that cause elevated water levels along the south coast will have a southerly component to the incident event directions.

Table 3.5 S4 Inundation Levels

Component	Planning Timeframe					
	Present Day (2021)	2041	2061	2081	2101	2121
500 year ARI peak steady water level at tide gauge (mAHD)	1.13					
Allowance for nearshore setup - wind and wave (m)	0.80					
Allowance for sea level rise (m)	0.00	0.11	0.27	0.49	0.73	0.97
Total Inundation Level (mAHD)	**1.93**	**2.04**	**2.20**	**2.42**	**2.66**	**2.90**

These potential inundation levels should be considered in the planning for any future development along the foreshore. Nevertheless, it is noted that due to the topography of the site, any development associated with Lots 1 and 2 would be well above these elevations.

4. Conclusions

This report presents the results of the coastal hazard assessment for the Frenchman Bay shoreline. The coastal hazard assessment has been completed in accordance with the recommendations and requirements of SPP2.6. As such, the potential extent of coastal hazard impacts that have been mapped provide a justifiably conservative representation of areas that could potentially be vulnerable to coastal hazard risk in the future. It must be noted that the coastal hazard lines are not a prediction of future shoreline location, but rather a representation of areas that could be at low risk of coastal hazards over each of the respective timeframes. Coastal hazard risk management and adaptation planning is therefore required as the next step in this process to ascertain the interplay between the likelihood and consequence of each of these lines being realised and what it would mean for any existing or proposed assets or infrastructure.

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6. Appendices

Appendix A SBEACH Reports

Appendix B Shoreline Movement Plan

Appendix C Coastal Hazard Map

Appendix A SBEACH Reports

K1944 Frenchman Bay
Reach: West Storm: 1% AEP Erosion

Report

Project: K1944 Frenchman Bay
Reach: West
Storm: 1% AEP Erosion

MODEL CONFIGURATION

INPUT UNITS (SI=1, AMERICAN CUST.=2): 1
NUMBER OF CALCULATION CELLS: 215
GRID TYPE (CONSTANT=0, VARIABLE=1): 0
CONSTANT CELL WIDTH: 1.0
NUMBER OF TIME STEPS AND VALUE OF TIME STEP IN MINUTES: 2124, 5.0
TIME STEP(S) OF INTERMEDIATE OUTPUT 1: 708
TIME STEP(S) OF INTERMEDIATE OUTPUT 2: 1416
NO COMPARSION WITH MEASURED PROFILE.
PROFILE ELEVATION CONTOUR 1: 5.00
PROFILE ELEVATION CONTOUR 2: 0.00
PROFILE ELEVATION CONTOUR 3: -1.00
PROFILE EROSION DEPTH 1: 0.50
PROFILE EROSION DEPTH 2: 1.00
PROFILE EROSION DEPTH 3: 1.50
REFERENCE ELEVATION: 0.00
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: 180.0
WAVE ANGLE INPUT (CONSTANT=0, VARIABLE=1): 0
CONSTANT WAVE ANGLE: 0.0
WATER DEPTH OF INPUT WAVES (DEEP WATER = 0.0): 5.0
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: 60.0
WIND SPEED AND ANGLE INPUT (CONSTANT=0, VARIABLE=1): 1
TIME STEP OF VARIABLE WIND SPEED AND ANGLE INPUT IN MINUTES: 180.0

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: 0.26
MAXIMUM PROFILE SLOPE PRIOR TO AVALANCHING IN DEGREES: 45.0

NO BEACH FILL IS PRESENT.

NO SEAWALL IS PRESENT.

NO HARD BOTTOM IS PRESENT.

COMPUTED RESULTS

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

MAXIMUM VALUE OF WATER ELEVATION + SETUP FOR SIMULATION
1.91 m

K1944 Frenchman Bay
Reach: West Storm: 1% AEP Erosion

TIME STEP AND POSITION ON PROFILE AT WHICH MAXIMUM VALUE
OF WATER ELEVATION + SETUP OCCURRED
447, 72.0 m
MAXIMUM ESTIMATED RUNUP ELEVATION: 5.20 m
(REFERENCED TO VERTICAL DATUM)

POSITION OF LANDWARD MOST OCCURRENCE OF A 0.50 m EROSION DEPTH:
54.0 m

DISTANCE FROM POSITION OF REFERENCE ELEVATION ON INITIAL PROFILE
TO POSITION OF LANDWARD MOST OCCURRENCE OF A 0.50 m EROSION DEPTH:
42.0 m

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

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

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

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

MAXIMUM RECESSION OF THE 5.00 m ELEVATION CONTOUR:
13.33 m

MAXIMUM RECESSION OF THE 0.00 m ELEVATION CONTOUR:
13.78 m

MAXIMUM RECESSION OF THE -1.00 m ELEVATION CONTOUR:
6.09 m

K1944 Frenchman Bay

Reach: East Storm: 1% AEP Erosion

Report

Project: K1944 Frenchman Bay
Reach: East
Storm: 1% AEP Erosion

MODEL CONFIGURATION

INPUT UNITS (SI=1, AMERICAN CUST.=2): 1
NUMBER OF CALCULATION CELLS: 440
GRID TYPE (CONSTANT=0, VARIABLE=1): 0
CONSTANT CELL WIDTH: 1.0
NUMBER OF TIME STEPS AND VALUE OF TIME STEP IN MINUTES: 2124, 5.0
TIME STEP(S) OF INTERMEDIATE OUTPUT 1: 708
TIME STEP(S) OF INTERMEDIATE OUTPUT 2: 1416
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: 0.50
PROFILE EROSION DEPTH 2: 1.00
PROFILE EROSION DEPTH 3: 1.50
REFERENCE ELEVATION: 0.00
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: 180.0
WAVE ANGLE INPUT (CONSTANT=0, VARIABLE=1): 0
CONSTANT WAVE ANGLE: 0.0
WATER DEPTH OF INPUT WAVES (DEEP WATER = 0.0): 5.0
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: 60.0
WIND SPEED AND ANGLE INPUT (CONSTANT=0, VARIABLE=1): 1
TIME STEP OF VARIABLE WIND SPEED AND ANGLE INPUT IN MINUTES: 180.0

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: 0.26
MAXIMUM PROFILE SLOPE PRIOR TO AVALANCHING IN DEGREES: 45.0

NO BEACH FILL IS PRESENT.

NO SEAWALL IS PRESENT.

NO HARD BOTTOM IS PRESENT.

COMPUTED RESULTS

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

MAXIMUM VALUE OF WATER ELEVATION + SETUP FOR SIMULATION
1.71 m

K1944 Frenchman Bay

Reach: East Storm: 1% AEP Erosion

TIME STEP AND POSITION ON PROFILE AT WHICH MAXIMUM VALUE
OF WATER ELEVATION + SETUP OCCURRED
438, 73.0 m
MAXIMUM ESTIMATED RUNUP ELEVATION: 3.10 m
(REFERENCED TO VERTICAL DATUM)

POSITION OF LANDWARD MOST OCCURRENCE OF A 0.50 m EROSION DEPTH:
64.0 m

DISTANCE FROM POSITION OF REFERENCE ELEVATION ON INITIAL PROFILE
TO POSITION OF LANDWARD MOST OCCURRENCE OF A 0.50 m EROSION DEPTH:
31.0 m

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

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

A 1.50 m EROSION DEPTH DID NOT OCCUR ANYWHERE ON THE PROFILE.

THE 5.00 m CONTOUR DID NOT RECEDE

MAXIMUM RECESSION OF THE 0.00 m ELEVATION CONTOUR:
0.08 m

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

Appendix B Shoreline Movement Plan

m p rogers & associates pl
coastal and port engineers

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Western Australia
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admin@coastsandports.com.au

DRAWN	C Doak
CHECKED	C Doak

Shoreline Movement Plan

Frenchman Bay Coastal Hazard Assessment

SCALE AT A3 1:2,000

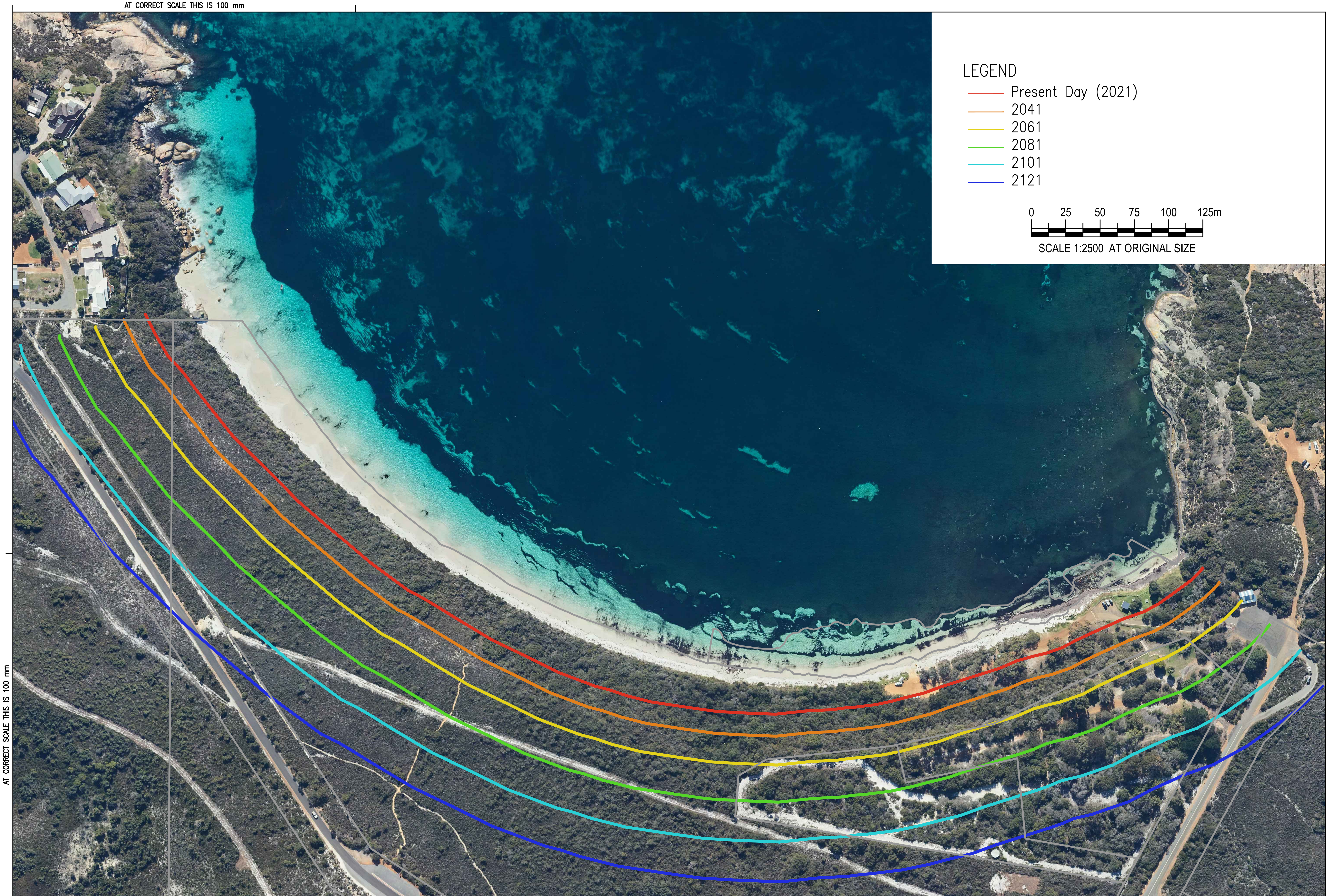
January 2021

SK1944-01-01

P:\MRA Paying Jobs\K1944 CoA – Frenchman Bay CHA\5 MRA Dwgs\Sketches\211210 Coastal Hazard Lines

Appendix C Coastal Hazard Map

AT CORRECT SCALE THIS IS 100 mm



AT CORRECT SCALE THIS IS 100 mm

m p rogers & associates pl coastal and port engineers	Suite 1, 128 Main Street Osborne Park 6017 t: +61 8 9254 6600 Western Australia admin@coastsandports.com.au	DRAWN C Doak CHECKED C Doak	Coastal Erosion Hazard Lines Frenchman Bay Coastal Hazard Assessment SCALE AT A3 1:2,500 January 2021 SK1944-01-02

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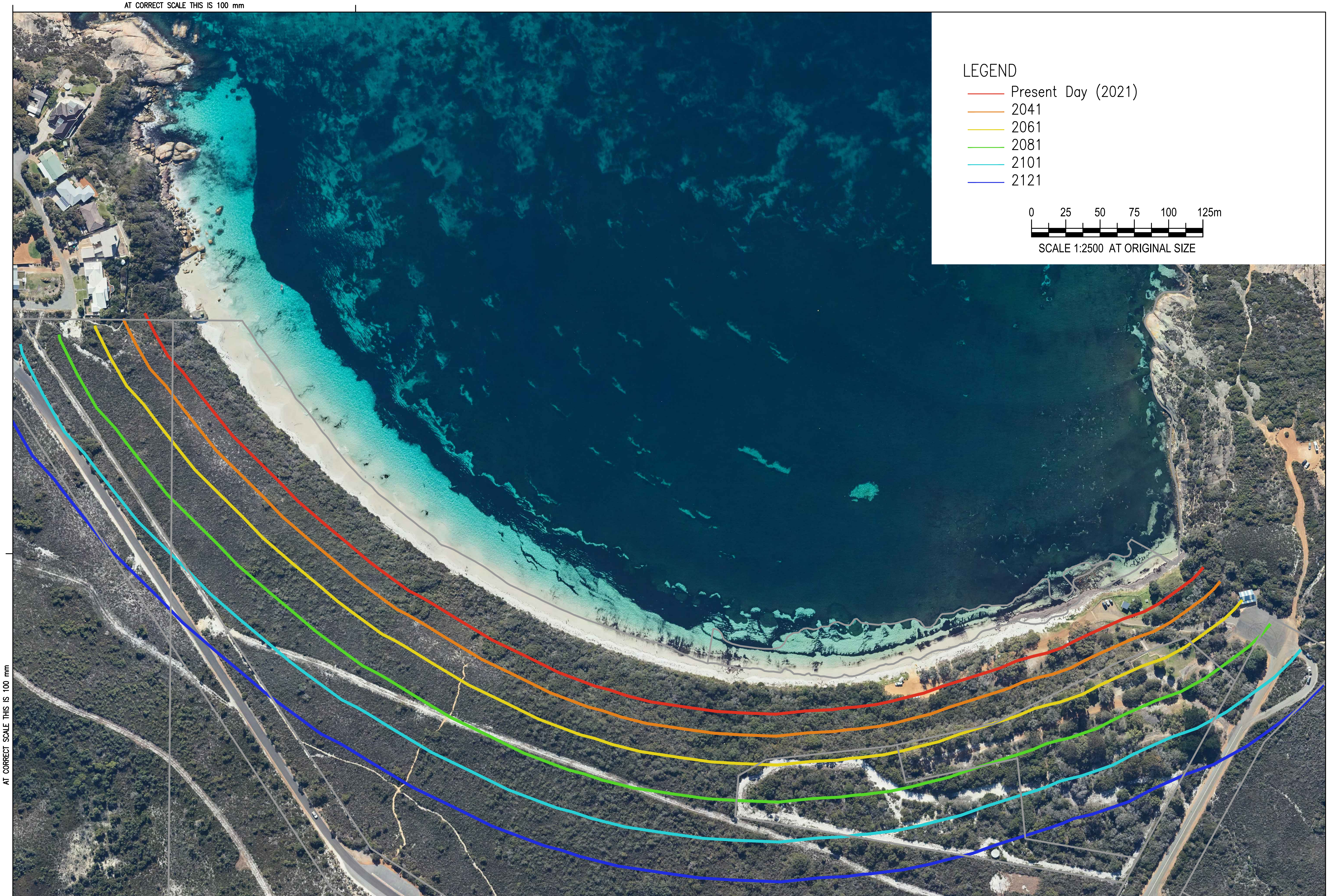
Appendix B Coastal Erosion Hazard Lines – SK1944-01-02

AT CORRECT SCALE THIS IS 100 mm



AT CORRECT SCALE THIS IS 100 mm

m p rogers & associates pl coastal and port engineers	Suite 1, 128 Main Street Osborne Park 6017 t: +61 8 9254 6600 Western Australia admin@coastsandports.com.au	DRAWN C Doak CHECKED C Doak	Coastal Erosion Hazard Lines Frenchman Bay Coastal Hazard Assessment SCALE AT A3 1:2,500 January 2021 SK1944-01-02

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