Geraldton Coastal Hazard Risk Management and Adaptation Planning Project

Part 1: Coastal Hazard and Risk Assessment Report

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Part 1: Coastal Hazard and Risk Assessment Report

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Executive Summary

The City of Greater Geraldton (CGG) is facing the adverse impacts of coastal erosion and inundation along its coastlines, with the vulnerability of land use and development within the coastal zone expected to increase in the future. In accordance with Western Australia's State Planning Policy 2.6 – State Coastal Planning Policy (SPP2.6), coastal areas identified as being at risk of coastal hazard require coastal hazard risk management and adaptation planning (CHRMAP).

The CHRMAP process is a risk-based approach to ensure that the coastal hazard is factored into decision-making for future planning requirements. The CHRMAP project for Geraldton is being developed in consultation with CGG, the local community and a range of stakeholders, and will provide a range of recommendations to guide investment decisions by the City in terms of the location and maintenance of its coastal infrastructure and provide guidance for the development of statutory planning controls.

This report presents the findings from the initial phases of the Geraldton CHRMAP project based on the community consultation phase and coastal hazard risk assessment that has been completed. The following is reported:

- Potential risk arising from hazards in the coastal zone is presented in 12 unique Coastal Management Units (CMU) across the 30km of Geraldton's coastline.;
- Key coastal infrastructure and assets at risk within the coastal zone are identified;
- Community and cultural values of the coastal zone are reported;
- Within each of the CMU, the identified coastal assets are assessed against the likelihood and consequence of coastal hazard impact in the present day, 2030, 2070 and 2110 planning periods, supported by GIS mapping;
- The results of the risk assessment are presented for the coastal assets within each of the CMU rated at 'high' to 'extreme' level of risk across the planning timeframes; and
- Coastal adaptation options are outlined in an Adaptation Toolbox (Section 8), which cover the hierarchy of adaptation pathways recommended under CHRMAP - 'Avoid-Managed Retreat-Accommodate-Protect'. The toolbox provides engineering and planning based approaches to address the risk from coastal hazard;

The final phases of the CHRMAP project will identify and recommend adaptation pathways and management options that the City and other stakeholders can pursue to address the risks from coastal hazard. These recommendations are reported in the *Coastal Adaptation Report* (Baird 2019).

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1. Introduction

1.1 Overview

The City of Greater Geraldton (CGG) is facing the adverse impacts of coastal erosion and inundation along its coastlines, with the vulnerability of land use and development within the coastal zone to these changes expected to increase in the future. To determine the potential for coastal erosion and inundation along the Geraldton coast, the CGG has recently completed a suite of studies for the Geraldton coastal zone between Cape Burney and Drummond Cove (MRA 2015, MRA2016, MRA2017).

These studies have determined the sections of the CGG coastline that are at risk from inundation and erosion over the next 100-years (to 2110). The potential impacts from coastal hazard have been examined across several planning time frames - present day, 2030, 2070 and 2110. This provides a basis of understanding for both the impact from coastal inundation and erosion and the timing of the impact which increases in severity in future, as a result of natural coastal processes and the increasing influence of projected sea level rise under climate change.

In accordance with Western Australia's State Planning Policy 2.6 – State Coastal Planning Policy (SPP2.6), coastal areas identified as being at risk of coastal hazard require coastal hazard risk management and adaptation planning (CHRMAP). The CHRMAP process is a risk-based approach to ensure that the coastal hazard is factored into decision-making for future planning requirements.

The CHRMAP project for Geraldton is being developed in consultation with CGG, the local community and a range of stakeholders, and is delivered in accordance with local and national guidelines and standards (WAPC2014, AS5334-2013). The CHRMAP will provide a range of recommendations to guide investment decisions by the City in terms of the location and maintenance of its coastal infrastructure and provide guidance for the development of statutory planning controls.

This report presents the findings from the initial phases of the project based on the coastal hazard assessment and the community consultation phase that has been completed. The following is reported:

1. Potential risks arising from hazards in the coastal zone;
2. Key coastal infrastructure and assets at risk within the coastal zone; and
3. Community and cultural values of the coastal zone

The final phases of the CHRMAP project will identify and recommend adaptation pathways and management options that the City and other stakeholders can pursue to address the risks from coastal hazard. These recommendations are reported in the *Coastal Adaptation report* (Baird 2019).

1.2 Project Team

The CGG is the key Client, with a project team of City officers appointed to work with the multi-disciplinary consultant team composed of Baird Australia (Coastal Hazard), Element (Statutory and Strategic Planning, Community Consultation) and Rhelm (Economics).

A Project Steering Committee appointed to review project milestones and deliverables includes representatives from:

- Department of Transport Coastal Management Group
- Department of Planning, Lands and Heritage
- Department of Water and Environmental Regulation
- Northern Agricultural Catchments Council

- Department of Lands
- Mid-West Ports Authority
- Batavia Coast Network

1.3 Document Format

The format of the Geraldton CHRMAP closely follows the structure presented in the Western Australian Planning Commissions CHRMAP guideline document (WAPC 2014). The document sections are reported as follows:

- Section 2: Establishing the Context
- Section 3: Community and Stakeholder Engagement
- Section 4: Coastal Assets Identification
- Section 5: Coastal Hazard and Mapping
- Section 6: Existing Controls
- Section 7: Risk Analysis and Evaluation
- Section 8: Adaptation Options

2. Establishing the Context

This Section provides a brief overview of the Geraldton project area to provide a background on the importance of CHRMAP for the community. A summary of the documents that guide coastal management in Western Australia's coastal areas is provided, with an overview of the Geraldton CHRMAP project objectives and scope outlined.

2.1 Purpose

The City of Geraldton is a coastal community of approximately 40,000 people located 420 km north of Perth in Western Australia (Figure 2.1). The main town area is located on the foreshore adjacent the port of Geraldton, with residential areas extending north and south of the main town ship along the coast. The region is blessed with a warm Mediterranean climate and its coastal zone offers outstanding natural beauty, a diverse range of beaches and coastal types that support a wide range of activities including swimming, walking, fishing, boating, surfing, and diving.

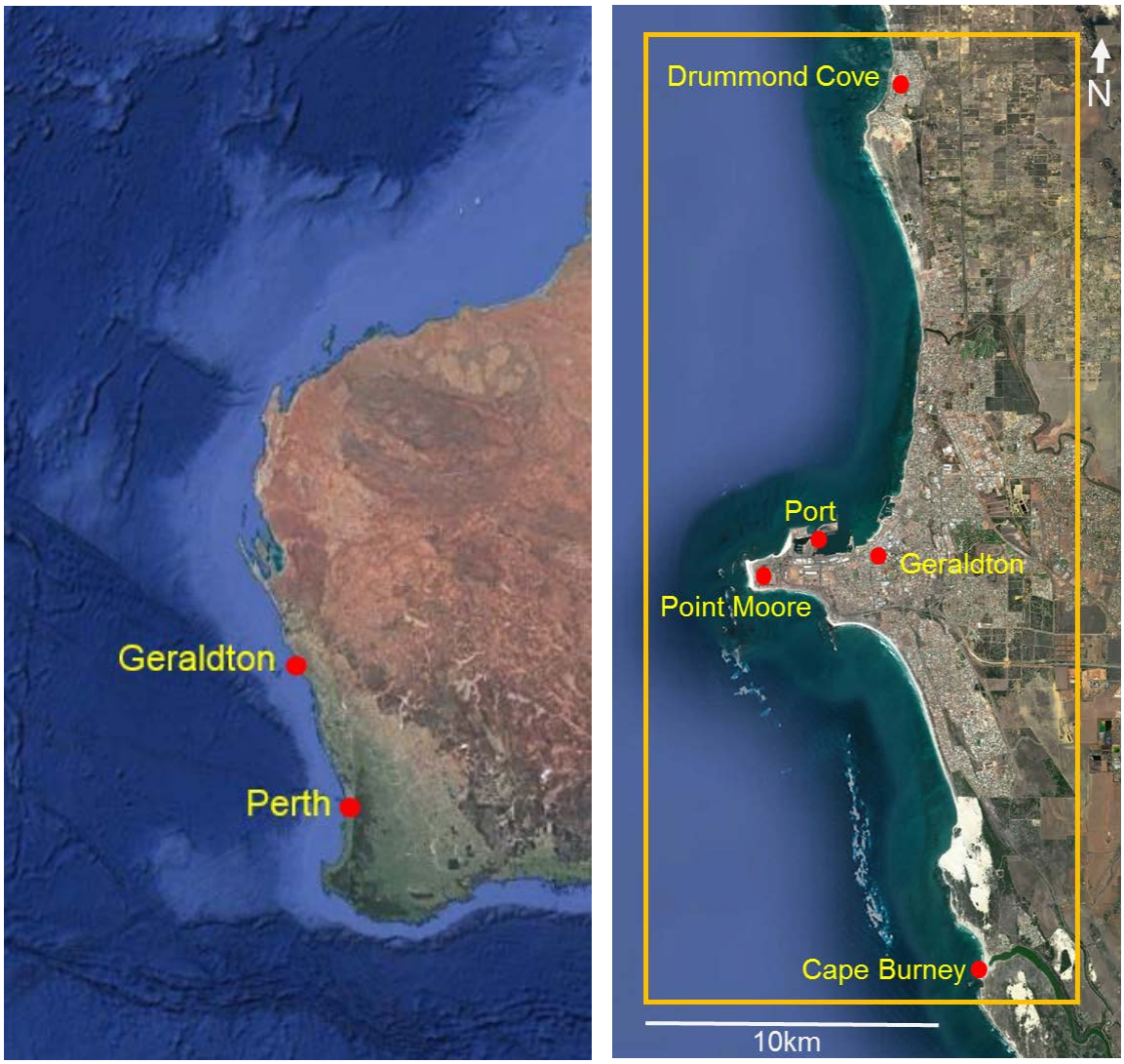

Figure 2.1: Project Location and Study Area (Google Earth)

The Greater Geraldton economy is valued at $5.32 billion (REMPLAN 2017) with mining, agriculture, fishing, small business, tourism, government services and tertiary industries strongly represented. The importance of the coastal areas to local industries (port, fishing, tourism) is critical. Local community and tourists place a high value on Geraldton's coastal areas, reflected in CGG Strategic Community Plan which identifies the coastal lifestyle as the city's most valuable asset. The Strategic Community Plan outlines the community vision is to provide 'a prosperous, diverse, vibrant and sustainable community' (CGG 2015).

The coastal areas of CGG have been identified as being at risk from coastal hazard from erosion and inundation in recent studies completed by the City (MRA 2015,2016,2017). The severity of erosion and inundation impact along Geraldton's coastal areas is determined by a range of factors, and over the next 100-years the coastal region is projected to experience adverse effects from coastal hazard impact at some time. Already there are sections of the CGG coast that are experiencing impacts from severe erosion, with infrastructure including roads, toilet blocks and houses being removed from the coast as shoreline areas have retreated.

The CHRMAP project is an important process to ensure that the coastal areas, values and benefits that are so important to the community can continue to be managed sustainably. The CHRMAP will support the future coastal planning decisions by the City that will consider the risk from coastal hazard so that future development and infrastructure supports the long-term benefit to the community.

2.1.1 Coastal Management Units

The CHRMAP study area covers the coastal zone of the City of Greater Geraldton, extending through approximately 30 km of coast between Cape Burney in the south to Drummond Cove in the north (Figure 2.1).

For the CHRMAP reporting and analysis the study area is divided into 12 distinct coastal management units (CMU), based on geographic and coastal characteristics. The CMU are as follows:

1. Drummond Cove
2. Glenfield
3. Sunset Beach
4. Bluff Point
5. Beresford
6. Geraldton
7. West End (Point Moore)
8. Beachlands
9. Mahomets Flats
10. Tarcoola Beach
11. Southgate Dunes
12. Cape Burney

The Coastal Management units are shown in Figure 2.2.

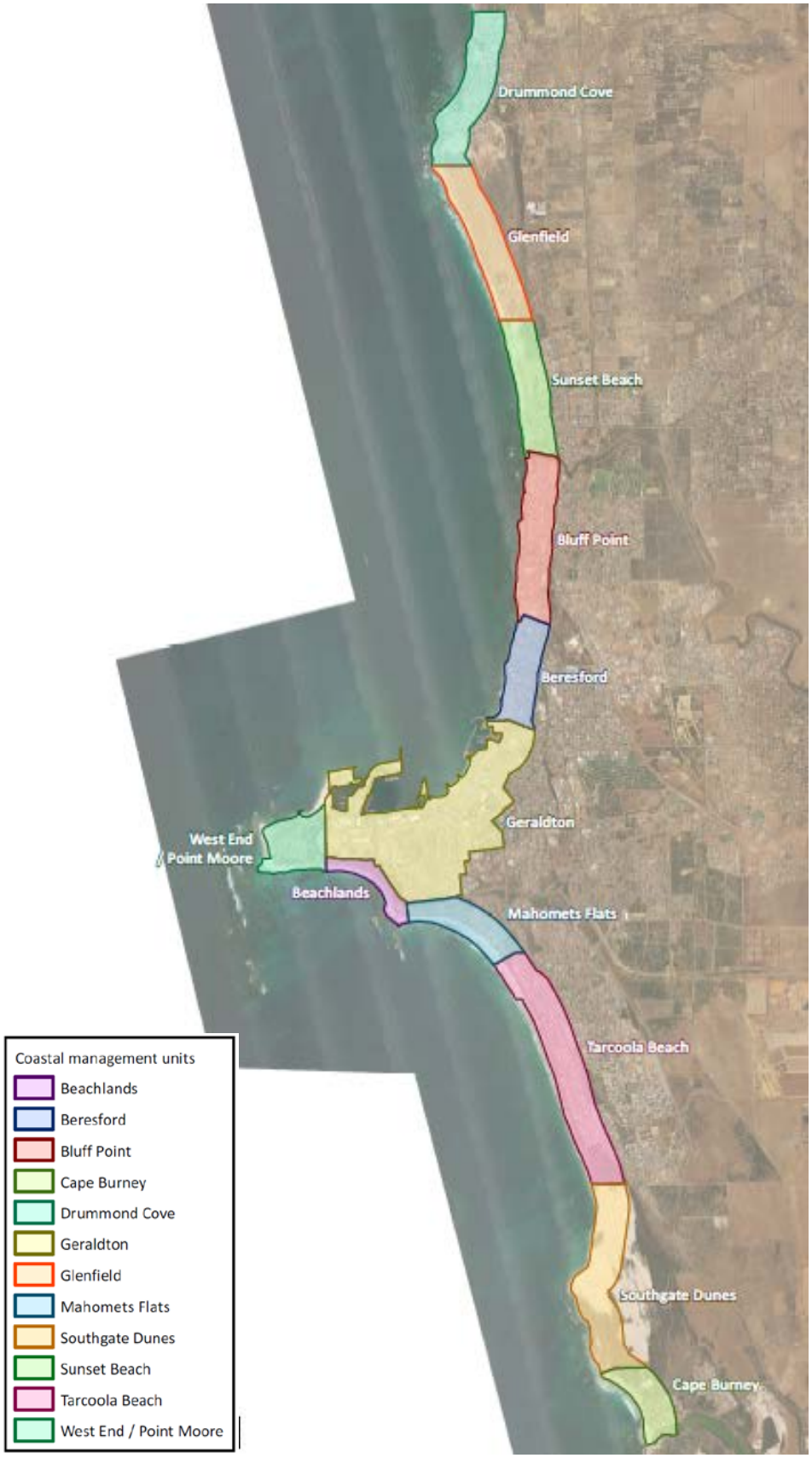

Figure 2.2: Coastal Management Units Defined for The Study Area

It is noted there are two locations where the CHRMAP will not be required:

- Geraldton Port area is under the control of Mid-West Ports; and
- Batavia Coast Marina is under the control of the Department of Transport.

These locations are in the Geraldton management unit (CMU6). The key stakeholders that manage these respective locations (Mid-West Ports, DoT) are included in the project steering group and will make their own decisions regarding future management and adaptation for the infrastructure.

2.2 Coastal Management Framework in Western Australia

There are two key documents for coastal hazard assessment and planning in Western Australia:

- State Planning Policy No. 2.6, State Coastal Planning Policy (SPP2.6, WAPC 2013)
- Coastal Hazard Risk Management and Adaptation Guidelines (CHRMAP guidelines, WAPC 2014)

The purpose of these documents and their application in this project is discussed briefly in this section.

2.2.1 State Coastal Planning Policy (SPP2.6)

SPP2.6 draws on and is supported by several WAPC state planning policies, development control policies and guidelines relevant to the coastal zone. For coastal matters, SPP2.6 is the prevailing policy.

The stated purpose of SPP2.6 is to provide guidance for decision-making within the coastal zone including managing development and land use change; establishment of foreshore reserves; and to protect, conserve and enhance coastal values. This policy recognises and responds to regional diversity in coastal types; requires that coastal hazard risk management and adaptation is appropriately planned for; and encourages innovative approaches to managing coastal hazard risk and provides public ownership of coastal foreshore reserves.

Schedule one of SPP2.6 provides guidance for calculating the component of the coastal foreshore reserve required to allow for coastal processes. The component of the coastal foreshore reserve to allow for coastal processes should be sufficient to mitigate the impacts of coastal hazards (including erosion and inundation). An appropriate coastal foreshore reserve will include a component to allow for coastal processes and be of an appropriate width to ensure a coastal foreshore reserve continues to provide the values, functions and uses prescribed should the coastal processes be realised over the planning timeframe.

It is recognised that development may need to occur within an area identified to be potentially impacted by physical coastal processes within the planning time frame. Such development should always be considered within a coastal hazard risk management and adaptation planning process (CHRMAP).

2.2.2 Coastal Hazard Risk Management and Adaptation Planning Guidelines

Coastal areas identified as at risk of being affected by coastal hazards require a CHRMAP to address coastal hazard. CHRMAP provides a risk management approach to decision making in the coastal zone, which assesses the risk to assets in the coastal zone for current and future planning periods, through consideration of the likelihood and consequence of coastal hazard impact (Figure 2.3).

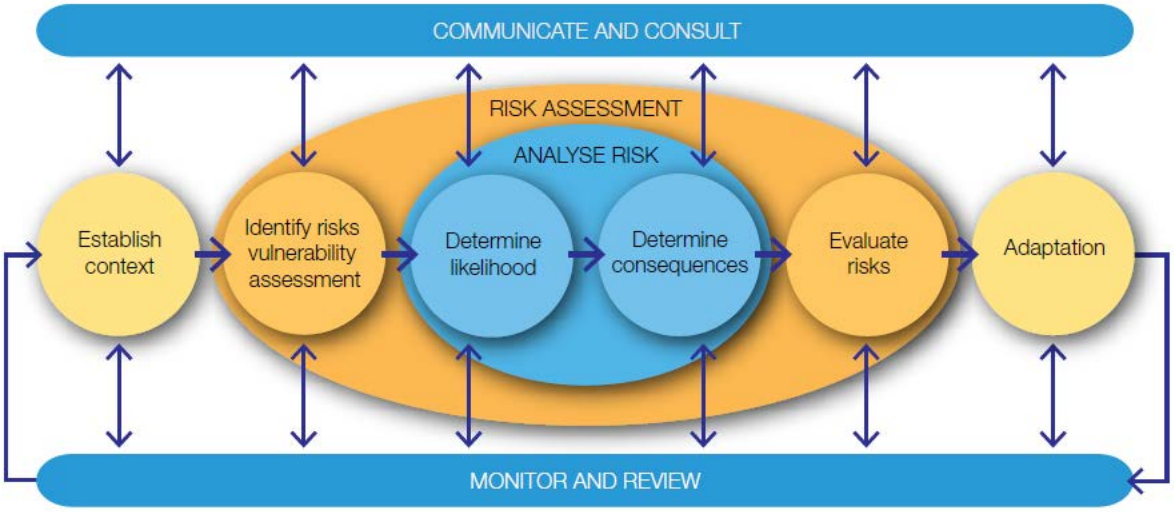

Figure 2.3: Risk Management and Adaptation Flow Chart (WAPC 2014)

The CHRMAP process is developed in consultation with community members and a range of stakeholders and in accordance with SPP2.6 requirements, WAPC guidelines and relevant Australian Standards (AS5334-2013). It is not a one-off linear process, but a continual cyclical process. Ongoing review is essential to ensure that the management plan remains relevant. Factors that may affect the likelihood and consequences of an outcome may change, as may the factors that affect the suitability or cost of the treatment options. It is therefore necessary to repeat the risk management cycle regularly.

2.3 Objectives

This project will deliver a CHRMAP that addresses the risk from coastal inundation and erosion hazards for the City of Greater Geraldton's coastal zone between Cape Burney and Drummond Cove.

The objective will be achieved through:

- GAINING an understanding of the vulnerability of assets within the coastal zone;
- IDENTIFYING significant vulnerability trigger points and respective timeframes for each sediment cell to mark the need for immediate or medium-term risk management and adaptation action;
- IDENTIFYING assets (natural and man-made) and the services and functions they provide situated in the coastal zone;
- VALUING value at risk of the assets that are vulnerable to adverse impacts from coastal hazards;
- DETERMINING the likelihood and consequence of the adverse impacts of coastal hazards on the assets, and assign a level of risk;
- IDENTIYING feasible management and adaptation measures;
- CONSIDERING the full range of planning instruments in order to plan for the short- and long-term management of the coast;
- INCOPORATING management and adaption measures into short- and longer-term decision making documentation; and
- ENGAGING stakeholders and the community throughout the adaptation planning process leading into the decision-making documentation.

The project is to be delivered in accordance with the State Coastal Planning Policy No. 2.6 (SPP 2.6) and Western Australian Planning Commission (WAPC) Coastal Hazard Risk Management and Adaptation Planning Guidelines. Upon its completion, the CHRMAP will incorporate short and long-term adaptation plans including implementation arrangements for the City's coastal zone between Cape Burney and Drummond Cove.

2.4 Scope

The project scope covers the City of Geraldton coastal areas between Cape Burney and Drummond Cove. Five components were outlined in the initial design brief issued by CGG and make up the CHRMAP project as follows:

Component 1 – Establish the Context

- Task 1 – Inception meeting
- Task 2 – Identify coastal assets
- Task 3 – Prepare community and stakeholder engagement plan
- Task 4 – Undertake community values assessment

Component 2 – Summarise Hazards and Asset Vulnerabilities

- Task 5 – Identify coastal hazards
- Task 6 – Assess assets vulnerability

Component 3 – Risk Analysis and Evaluation

- Task 7 – Evaluate risk likelihood and consequence
- Task 8 – Develop acceptances and tolerances
- Task 9 – Identify existing controls

Component 4 –Adaptation Options and Preparing a Plan

- Task 10 – Identify adaptation options
- *Task 11 – Evaluate adaptation options*
- *Task 12 – Develop long term adaptation pathways*
- *Task 13 – Develop short term implementation plan*
- *Task 14 – Prepare monitoring and evaluation plan*

Component 5 – Getting Ready for Resilience

- *Task 15 – Prepare draft CHRMAP report*
- *Task 16 – Finalise CHRMAP report*

The project scope items from Task 1 to Task 10 are included in this report. All remaining tasks are reported in the *Coastal Adaptation Report* (Baird 2019).

3. Community and Stakeholder Engagement

3.1 Community and Stakeholder Consultation

A Community and Stakeholder Engagement Strategy (CSES) was developed at project commencement to ensure that the community and stakeholders are actively and effectively engaged throughout the CHRMAP process. The CSES is provided in full in **Appendix A.1**.

The CSES incorporates a variety of communication and engagement activities that are structured to support the CHRMAP process throughout the project delivery including:

- Council briefing notes and Councillor briefings
- Government department and service authority communication
- Stakeholder and Community Survey for the project in October 2017
- Stakeholder/Community Workshops held in October 2017
- Stakeholder and Community Information Session during the Public Advertising Period scheduled for April 2018
- Stakeholder and Community Feedback during the Public Advertising Period scheduled for April 2018

A summary of the engagement tasks completed to date is provided in the sections that follow for:

1. Internal Engagement; and
2. Community Coastal Planning Survey and Workshops.

3.1.1 Internal Engagement

At project inception, a meeting in the CGG offices on 8 June 2017 was attended by the consultant team and representatives from key stakeholders which comprise the project steering committee which will review all deliverables for the project:

- City of Greater Geraldton
- Department of Transport Coastal Management Group
- Department of Planning, Lands and Heritage
- Department of Water and Environmental Regulation
- Northern Agricultural Catchments Council
- Department of Lands
- Mid-West Ports Authority
- Batavia Coast Network

This meeting was used to inform the group of the project objectives and approach, and examine any gaps in the data for the study.

3.1.2 Community Coastal Planning Survey and Workshops

A workshop outcomes report for the Community and Stakeholder Engagement is provided in **Appendix A.2**, with a summary of the approach presented below.

The City implemented a staged approach to engage with the community on coastal planning, which began with the Coastal Planning Community Survey followed by two Coastal Planning Community Workshops.

The City undertook extensive promotion of the Coastal Planning Community Survey and Workshops which involved:

- More than 350 letters of invitation mailed, emailed or hand delivered to project stakeholders

- Flyers hand delivered to residents/homeowners residing on the ocean side of coastal roads.
- Workshop promotion in the Coastal Planning Community Survey.
- Posters displayed at various venues across the City.
- Numerous City of Greater Geraldton Facebook posts and targeted social media advertising campaigns.
- Newspaper advertising.
- Everything Geraldton online advertising.
- City website consultation page and CHRMAP page.
- Various media releases.
- Face-to-face invitations extended by City staff members.

Community Coastal Planning Survey

The Community Coastal Planning Survey was conducted from 2-23 October 2017 in which 376 responses were submitted. The survey was designed to support the CHRMAP risk assessment process through questions designed to:

- Help identify assets at risk from coastal erosion, inundation and climate change threats
- Gain a better understanding of how the community values assets which are potentially at risk; and
- Gain an understanding of how the community rates the consequences of erosion and inundation on these assets.

Members of the community had the option of completing the survey via an online survey portal or in a hard copy format. Copies of the survey were available at the Civic Centre and Geraldton Regional Library.

Community Coastal Planning Workshops

Two Community Coastal Planning Workshops were held on Saturday 14 October 2017 in the Upper Hall of the QEII Seniors and Community Centre.

The half-day long workshops were designed to support the CHRMAP risk assessment process through tasks that have been able to:

1. Identify key coastal infrastructure/assets that hold economic, social and environmental value;
2. Determine the coastal hazards scale of consequence for the identified assets;
3. Define risk tolerances for the identified coastal hazard risks; and
4. Provide feedback on proposed adaptation options that could address the risks.

Participants were a mixture of identified stakeholders and self-selectors aged between nine and 85 years old. Participants sat together at tables of seven people each. The tables were individually facilitated which ensured all participants were able to contribute to the workshop process.

- Workshop 1, which focused on the coastal area from Cape Burney to Town Beach, was held in the morning and was attended by 23 members of the community, three Councillors and the Mayor. Although 30 people registered to attend, only 16 were able to participate on the day and seven people came and participated without prior registration.
- Workshop 2, which focused on the coastal area from the Marina to Drummond Cove, was held in the afternoon and was attended by 45 members of the community, three Councillors and the Mayor. Although 56 people registered to attend, only 40 were able to participate on the day and five people came and participated without prior registration.

Both workshops were externally facilitated by CHRMAP project consultants Baird Australia and TPG+Place Match. The City provided table facilitators and staff members specialising in the coastal zone were also present to assist with the workshop process and answer questions related to the topics under discussion.

Figure 3.1: Community Coastal Planning Workshop Table

3.1.3 Coastal Asset Definition

During the community engagement workshops and survey, a series of tasks were completed by the participants (community and stakeholders) to define coastal assets in the coastal zone around Geraldton. The coastal assets were grouped into natural, social/cultural and economic/physical categories. Community were asked to identify the coastal assets within the 12 CMU of the study area and for each one to provide a statement to explain its function, service or value.

Additional coastal assets in the study area were identified through GIS information received from CGG as outlined in Section 4.1. A complete list of the identified coastal assets is presented in **Appendix A.2** by Coastal compartment and these were applied throughout the CHRMAP risk assessment.

3.1.4 Likelihood and Consequence Scales

The concept of coastal hazard likelihood and the consequence of impact to coastal assets from erosion and inundation was explained. A consequence scale was adopted and used by the community to rate the impact of coastal hazard on the identified coastal assets using a scale moving through Catastrophic, Major, Moderate, Minor and Insignificant.

The consequence ratings from the community were defined for each asset in terms of economic, natural, social and heritage impact and used in the risk assessment process (refer Section 7.3).

3.1.5 Priority Assets

The community were asked to prioritise the coastal assets they consider most important to them. This was important to understand to ensure that at the completion of the risk management process, assets that are highly valued by the community can be managed appropriately. Assets that are highly valued by the community but defined with low risk, will be highlighted in the CHRMAP. This is further discussed in Section 7.9.2.

3.1.6 Adaptation Options and Tolerance

The community were asked to provide their ideas for adaptation of coastal areas. This welcomed ideas from the community that could address coastal hazard (erosion, inundation) recognising the community

understanding of their local beaches. This process provided a range of potential coastal adaptation ideas, used to inform the Adaptation Toolbox (Section 8.2).

3.1.7 Success Criteria

The community engagement process underlined the importance of the coastal lifestyle to the Geraldton community. The survey and workshops provided the opportunity to qualify the key areas of interest and concern from the community, and articulate the values that they hold in the coastal areas. The community connection to the coast was highlighted by the overwhelming response to nominating beaches and coastal dune and foreshore areas as being the key coastal assets of importance to them in the survey (Figure 3.2).

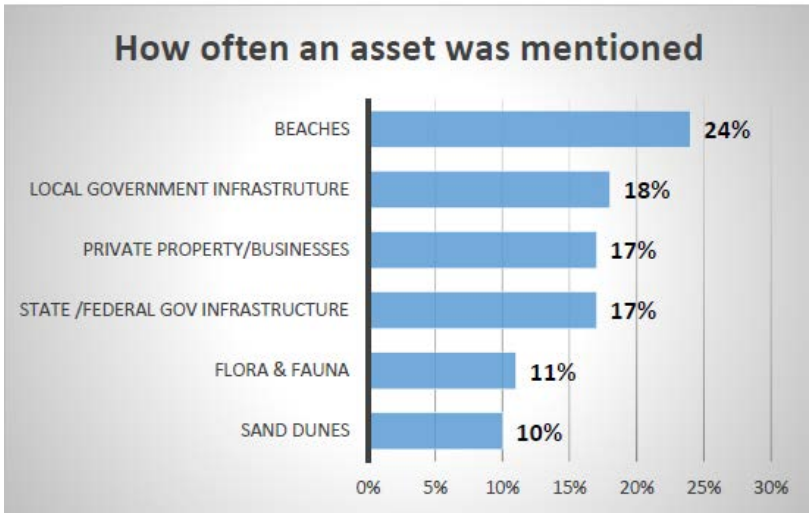

Figure 3.2: Survey Outcomes from Community Workshop Discussion (Appendix A.2)

The assets identified in the survey and workshop sessions and the value that people derived from them were captured (**Appendix A.2**). This sets a basis for how the CHRMAP can deliver adaptation responses that meet community expectations, and a means by which future evaluation of the effectiveness of the CHRMAP can be determined.

4. Coastal Asset Identification

4.1 Identification of Coastal Assets

The CHRMAP process requires identifying the coastal assets that will be impacted by coastal erosion and inundation in future planning periods. Coastal assets are broadly described in three categories:

- Social - examples include community use of coast, recreation along the coast;
- Economic – examples include facilities, services, jobs, industry; and
- Natural – examples include environmental values, coastal flora and fauna, ecosystem, dunes.

The coastal assets in the study area were defined by three primary methods:

- Through the community engagement workshops and survey;
- The CGG provided its asset database to the study in GIS format;
- A search of service providers registered in the Dial Before You Dig network was undertaken to determine the utilities (Telstra, Water Corporation etc)

An overview of each of these sources follows.

4.1.1 Community Identified Assets

The workshop tasks and the online survey were designed to get the community and stakeholders to describe coastal assets within each of the CMU (refer Section **Appendix A.2**), together with the functions, services and value that they deliver. The process also assessed the consequences of those assets being impacted by the coastal hazard of erosion and inundation.

An example of the assets and values defined from the survey and workshop sessions is presented in Table 4.1.

Table 4.1: Example of Coastal Assets Identified in the Geraldton Coastal Survey and Workshops

Asset	Functions / Services and Values Cited by Community
Social	
Public Open Spaces	Social and recreational opportunities
Coastal Walking / Cycle Paths	Exercise
Economic	
The Marina	Financial asset, tourism
Houses and Properties	Investment, lifestyle
Natural	
Beaches	Natural Landscape
Coastal Dunes	Natural environmental asset
Heritage	
Aboriginal Midden Site	Site of cultural importance
Lighthouse	Unique structure, historical importance

4.1.2 City of Greater Geraldton Asset Database

The CGG provided their asset database data in a GIS format with the following data categories:

1. Cadastral information (includes description of property boundaries, rateable value, land use type)
2. Roads and Pathways
3. Coastal Structures (seawalls, groynes)
4. CGG Assets (artworks, lighting, street furniture etc)
5. Open Space (parks, playgrounds, reserves etc)

The CGG data was provided only for the section of the foreshore area impacted by coastal hazard.

4.1.3 Utilities Infrastructure

Dial Before You Dig (DBYD) were contacted to provide asset listings for infrastructure networks in the study area. This was incorporated into the main GIS asset database with spatial data made available to the study from the following list of providers:

- Water Corporation
- ATCO Gas Australia
- Optus
- Western Power
- Mid West Ports
- AARNet Pty Ltd
- Telstra

4.2 Coastal Asset Register

4.2.1 Compilation of Survey Data

The coastal asset data was compiled in the Coastal Asset Register, summarised by CMU and assigned a data type category as either Economic, Natural, Heritage or Social.

4.2.2 GIS Database Spatial Format

The Asset Register is recorded spatially within each of the Coastal Management Units, and mapping of the assets is presented in **Appendix A.3.** Registering the spatial data into a GIS database format allows for the interrogation of the data for coastal hazard impact.

4.3 Value of Coastal Assets

The valuation of coastal assets in the Asset Register has been undertaken through a series of methods:

- For assets managed by CGG, a unit cost ($ per m) estimation of replacement value is used. Examples include roads and landscaping;
- For residential and commercial property, the rateable value from the current CGG rates database has been used as a proxy for value;
- For CGG infrastructure in the CMU's, the estimated replacement cost has been supplied by CGG. Examples include toilets, playgrounds and artworks;
- For utilities identified in DBYD, a unit cost ($ per m) estimation of replacement value is used;
- Intangible assets such as beaches and foreshore reserve areas have been valued based on relevant literature and a range of assumptions

Further details on the valuation methods and unit costs is available in the economic reporting section reported in **Appendix A.7.**

5. Coastal Hazard and Mapping

5.1 Identification of Coastal Hazard

5.1.1 Coastal Sediment Cells

In Western Australia, a series of coastal sediment cells have been identified which describe areas of influence that should be considered in coastal processes assessments (Stul et al 2013a and 2013b). The coastal sediment cells delineate areas of coast in which sediment transport processes are strongly related.

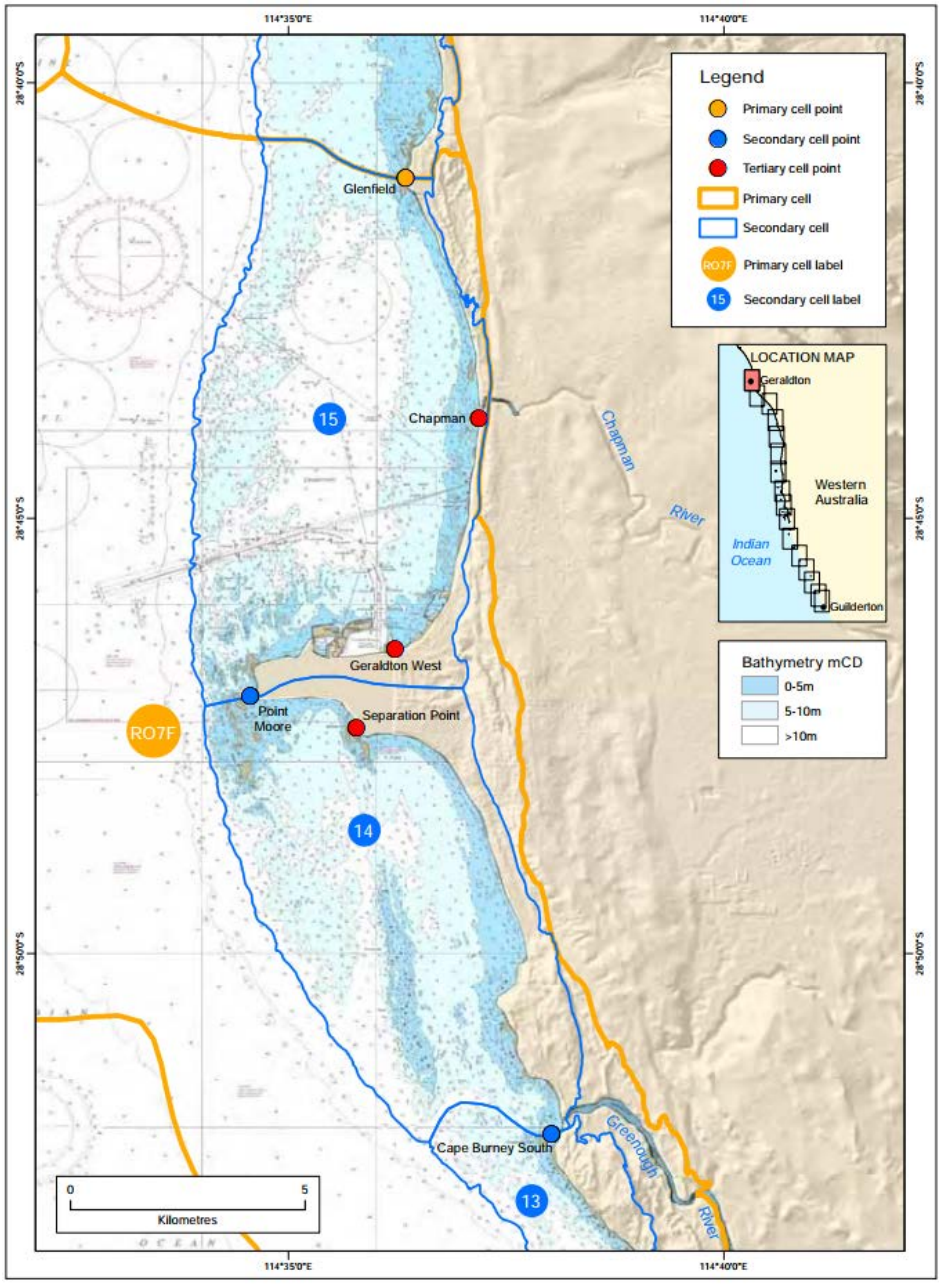

Figure 5.1: Secondary cells and tertiary cell points of the Mid-West Region (Stul et al 2013a)

The coastal sediment cells that extend across the project study area are summarised in Table 5.1. The nearshore sediment dynamics were considered within each of the Tertiary cells and at larger scale (e.g. Secondary cell and Primary cell level) in the coastal inundation and processes allowance studies and will be considered as part of recommendations in the Geraldton CHRMAP.

Table 5.1: Geraldton Coastal Sediment Cells – Cell Hierarchy

Primary	Secondary	Tertiary	Tertiary ID
R08A. Glenfield Beach to Whale Boat Cove	1. Glenfield Beach to Coronation Beach	a. Glenfield to Coronation Beach	R08A1a
R07F Philips Road Coast to Glenfield	15 Point Moore to Glenfield	c. Chapman to Glenfield	R07F15c
		b. Geraldton West to Chapman	R07F15b
		a. Point Moore to Geraldton West	R07F15a
	14 Cape Burney South to Point Moore	b. Separation Point to Point Moore	R07F14b
		a. Cape Burney South to Separation Point	R07F14a

5.1.2 Coastal Inundation and Processes Allowances Studies

The City of Greater Geraldton have completed three studies to define the coastal inundation and processes allowances for the study area:

- Point Moore Coastal Inundation and Processes Allowances Study (MRA 2015)
- Town Beach to Drummond Cove Coastal Inundation and Processes Allowances Study (MRA 2016)
- Cape Burney to Greys Beach Inundation and Processes Allowances Study (MRA 2017)

The studies have been completed based on SPP2.6 guidelines, and determine the foreshore area over which projected coastal erosion and inundation processes could occur, at different planning periods out to the year 2110. The key components of coastal erosion and coastal inundation are discussed in brief below.

Coastal processes allowance for erosion

The coastal processes allowance for erosion is a horizontal distance measured from the shoreline (HSD) which is typically referred to as 'coastal setback' or 'coastal erosion setback'. The setback lines for the CGG study area have been defined for the years 2015, 2030, 2070 and 2110. The coastal erosion setback line for the sandy coastlines of Geraldton is calculated from the sum of four components:

- S1: The loss of beach width resulting from the impact of a storm with a 1 in 100 chance of occurring;
- S2: The historical rate of change along the shore (i.e. accreting or eroding coast);
- S3: Sea level rise allowance; and
- S4: Uncertainty (allowance of 0.2 m annually)

The setback distance changes along a section of coast as the relative contribution from S1 and S2 vary due to local characteristics. For example, in Drummond Cove and Sunset Beach, the S2 component is high, whilst for Pages Beach the S2 component is low.

Sea level rise is applied in setback calculations based on the Western Australia's recommendations for planning purposes (WAPC 2013), which are summarised on Table 5.2.

Table 5.2: Sea Level Rise and Horizontal Setback Requirements by Planning Period

Planning Period	Sea Level Rise (Vertical) Recommendation (DoT 2010)	Horizontal S3 Component in Coastal Erosion Setback Allowance
2015	0 m	0 m
2030	0.07 m	7 m
2070	0.39 m	39 m
2110	0.90 m	90 m

It is noted that the Geraldton port and town beach foreshore area are heavily modified coastlines that are protected from erosion due to a combination of rock structures and sand nourishment (Figure 5.2). In this section of the coast (CMU6), coastal erosion setback lines do not extend landward, reflecting the decision to defend these shorelines from coastal erosion in the future.

Figure 5.2: Geraldton Foreshore shoreline area protected by coastal structures, Upper 2016 Aerial, Lower plot Oblique (MRA 2016)

Coastal inundation hazard

Under SPP2.6, development in the coastal zone must consider the risk to low lying coastal areas at risk of coastal inundation hazard under extreme coastal flooding events. For Geraldton, this extreme flooding event is a large storm surge generated by a tropical cyclone, which can elevate the ocean level above the normal tidal regime. Geraldton has a small tidal range with the highest astronomical tide level at 0.65 m AHD (1.20 m CD). Due to this relatively small tide range, the City's coastal areas are particularly susceptible to storm surge.

Under SPP2.6 guidelines, the inundation from a 500-year ARI event needs to be considered in coastal planning of habitable structures (residential property). This is an event with a 1 in 500 chance of occurring in any year. Whilst this is a very low probability event, over a 100-year planning period there is approximately 20% chance that this event could occur.

In the coastal inundation studies completed for the CGG, the coastal inundation hazard has been defined for a range of ARI and time periods as summarised in Table 5.3. The extent of the inland coastal areas that are flooded as a result of the water levels in Table 5.3 are shown in the coastal hazard mapping, discussed in sections to follow.

Table 5.3: Coastal Inundation Water Levels for Geraldton in Future Planning Periods (From MRA2015, 2016, 2017)

Planning Timeframe and ARI Water level	Cape Burney to Greys Beach (m AHD)	Point Moore (m AHD)	Geraldton Port to Drummond Cove (m AHD)
2015 20yr ARI	2.0	2.0	2.0
2015 100yr ARI	2.2	2.6	2.9
2015 500yr ARI	3.0	3.3	3.6
2030 20yr ARI	2.1	2.1	2.1
2030 100yr ARI	2.3	2.7	3.0
2030 500yr ARI	3.1	3.4	3.7
2070 20yr ARI	2.4	2.4	2.4
2070 100yr ARI	2.6	3.0	3.3
2070 500yr ARI	3.4	3.7	4.0
2110 20yr ARI	2.9	2.9	2.9
2110 100yr ARI	3.1	3.5	3.8
2110 500yr ARI	3.9	4.2	4.5

For the information presented in Table 5.3:

- The storm surge levels are calculated in three sections of the coast from south to north. For the 100 yr and 500 yr ARI, the inundation risk is higher in the north of the project area compared to the south, due to the higher relative exposure of the coast to tropical cyclones.
- Sea level rise values for the relevant planning period from Table 5.2 are included in the calculated coastal inundation levels.

- The coastal inundation hazard does not consider stormwater runoff or groundwater impacts as a result of elevated coastal water levels; and
- Tsunami risk was assessed in the MRA studies, with a consideration of the 2004 Boxing Day tsunami event that impacted water levels at Geraldton. It was determined that no additional inundation allowance to account for tsunami risk was required for the study area.

5.2 Coastal Hazard Mapping

The GIS-based outputs from the coastal processes and inundation studies were applied to define the coastal hazard mapping for the CHRMAP.

5.2.1 Mapping for Coastal Processes Allowance – Erosion Setback

The erosion hazard in the 12 CMUs is presented in **Appendix A.5** showing the setback for all planning periods**.** The setback lines were provided to the CHRMAP project in GIS format from the completed coastal processes studies (MRA 2015, 2016 and 2017).

It is noted the coastal erosion setbacks were not provided from the MRA studies for the section of coast immediately north and south of the Chapman River Mouth, and these have been updated in the CHRMAP mapping data by Baird based on advice from MRA. It is noted that the coastal processes allowance for this area only considers erosion setback due to storm impact to a sandy coastline. This does not consider the interaction between the river and the coast which could affect how the coast immediately north and south of Chapman River Mouth and the river mouth itself responds to erosion events, either due to storm surge or inland runoff. Whist the CHRMAP has adopted the calculated erosion lines in the determination of coastal erosion risk to coastal assets around the river mouth, caution should be applied to the extended mapping results around this area. As part of future revisions of the CHRMAP it will be recommended the natural changes for this section of the coast and impacts following large storm surge or erosion events is monitored to ensure the risk to coastal assets is accurately classified.

5.2.2 Mapping for Coastal Inundation

The coastal hazard mapping is presented in **Appendix A.6** for the 12 CMUs**.** The inundation depth for the 500 yr ARI event in the 2110 planning period has been presented, as this is the key inundation risk that must be considered in coastal planning for residential property in the 100-year planning period (to 2110). The inundation depth for the 100 yr ARI event in the 2110 planning period has also been presented for comparison in **Appendix A.6** for the 12 CMUs.

The mapping of inundation areas in **Appendix A.6** shows flood depth. The depth has been determined applying the design flooding levels from Table 5.3 to the land surface, defined by LiDAR data flown in March 2013 (NACC 2013). To improve the spatial mapping from a simple ‘bathtub’ flooding approach, all inundated areas have been defined using a ‘hydro-connectivity’ algorithm. Hydro-connectivity ensures that the flooded areas inland connect to the offshore ocean region. The hydro-connected surface overcomes the limitation of the bathtub method where isolated inland pockets of inundation will occur, and this provided a more robust product when presenting results to the community and later developing adaptation approaches for the inland areas which would incorrectly show as flooded under the bathtub approach. It is noted that finished floor levels of properties in the coastal areas is not considered in the inundation mapping. The accuracy of the inundation mapping in Appendix A.6 is considered applicable at the coastal compartment scale that CHRMAP adopts (refer Figure 5.3). It is recommended that the flood assessment be refined for detailed site-specific adaptation assessments and planning policy requirements that will follow the CHRMAP study.

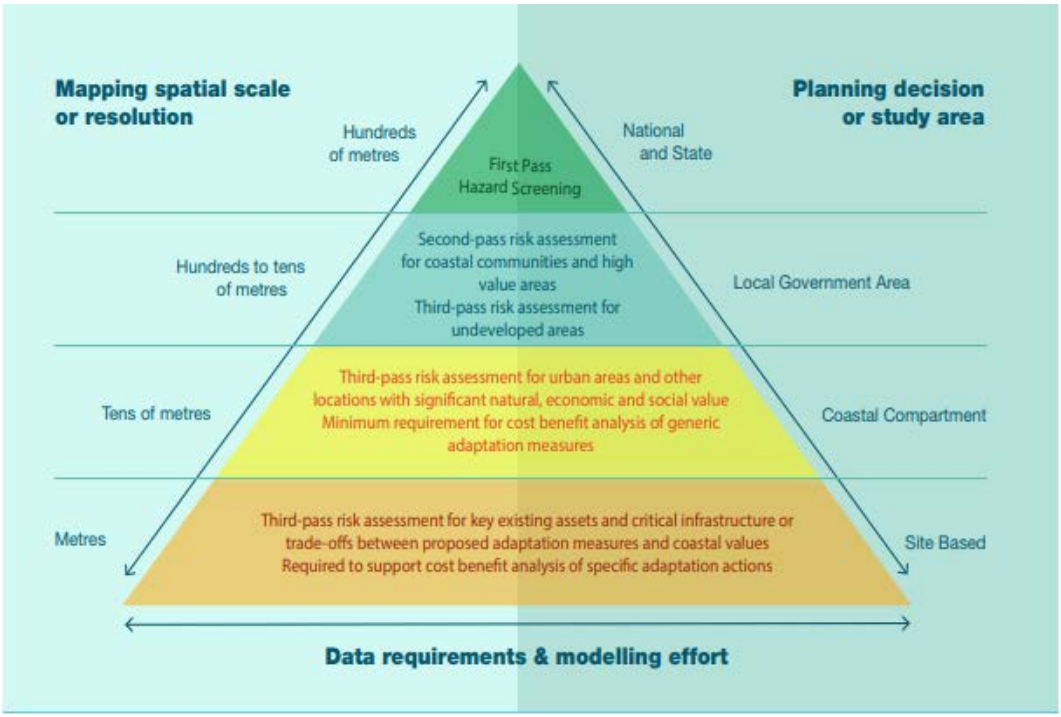

Figure 5.3: Coastal hazard mapping scale and level of data and modelling effort (NCCARF from Eliot 2013)

5.2.3 Coastal Hazard Summary by Coastal Management Unit

A high-level summary of the coastal hazard affecting each of the CMUs is shown in Table 5.4.

Table 5.4: Coastal Hazard Summary by Coastal Management Unit

No.	CMU	Erosion Impacts for Coastal Assets and Projected Timeframe	Inundation Impacts for 500yr ARI event in 2110
1	Drummond Cove	• Current: Roads, foreshore, foreshore infrastructure • 2030 – 2110: Residential	Foreshore Areas and Roads Residential 0.1m - 1.5m
2	Glenfield	• Current: Beach, Dunes • 2070: Water Treatment Plant	Dune Areas
3	Sunset Beach	• Current: Carparks, foreshore, dunes, caravan park • 2030 – 2110: Residential	None
4	Bluff Point	• Current: Residential, foreshore, dunes, car park, boat ramp, roads • 2030 – 2110: Residential	Foreshore areas, Roads Residential: 0.1m - 1.5m

No.	CMU	Erosion Impacts for Coastal Assets and Projected Timeframe	Inundation Impacts for 500yr ARI event in 2110
5	Beresford	Current erosion risk to landward costal assets has been removed by the construction of the Beresford Beach revetments across the Batavia Coast Marina to Trigg St section. The City has adopted a **Protect** position against coastal erosion for the CMU. It is noted that the revetments are discontinuous, however it is assumed that to maintain structural integrity the unprotected sections will be maintained. Under this assumption, the entire coastal compartment is acknowledged as protected against erosion in the future in CHRMAP.	Roads, Commercial Properties Phelps St / Chapman Rd
6	Geraldton	• No erosion risk – CMU highly modified by coastal structures. CGG to protect this section of coast	Low lying section of coast. Significant impacts for commercial and residential properties and infrastructure >2m depth
7	West End (Point Moore)	• Current: Foreshore, dunes, roads (Marine Terrace South) • 2070 – 2110: Carparks, residential, lighthouse	Low lying section of coast. Significant residential impacts >2m depth
8	Beachlands	• Current: Dunes, foreshore • 2030 – 2110: Roads, carparks, rail, Commercial	Residential impacts to 1.5m depth
9	Mahomets Flats	• Current: Dunes, foreshore • 2070 – 2110: Roads, carparks, surf club, residential	None
10	Tarcoola Beach	• Current: Dunes, foreshore • 2070 – 2110: Roads, residential	Minor flooding of residential property south Tarcoola Beach
11	Southgate Dunes	• Current: Dunes, foreshore	Dune Areas
12	Cape Burney	• Current: Dunes, foreshore • 2040 – 2110: Carparks, roads, foreshore infrastructure	Dunes

5.3 Assumptions and Limitations

The assumptions and limitations of the hazard mapping are summarised in Table 5.5.

Table 5.5: Hazard Mapping Assumptions and Limitations

Data Source / Feature	Assumptions and Limitations
LiDAR capture date and accuracy	The NACC LiDAR acquisition date is March 2013. Modification to ground levels in developed areas following this date are not described. For the shorelines along Sunset Beach and Drummonds Cove there has been significant erosion following this capture date, and the shoreline area has shifted landward, confirmed by comparison of contours to the most recent Aerial data (captured 2016). The data was collected at minimum two points per m^2 (2ppm) with vertical accuracy stated as +/- 0.1m, and horizontal accuracy +/- 0.15m. The crest height of structures in the foreshore may not be fully described.
Geotechnical Conditions	Detailed geotechnical data is not available for most of the coastal areas. In the absence of site specific data, coastal areas have been assessed as Sandy Coast under the SPP2.6 guidelines.
Bathtub Flooding	The inundation mapping has been completed using a 'bathtub' type approach. The approach incorporates a routine to establish hydraulic connection to the coast for all flooding areas ensuring isolated islands are not present in the data. The impediment to overland flow (e.g. roughness, structures / obstacles) is not factored into the assessment. The method is contingent on the accuracy of the LiDAR data. Stormwater connectivity is not considered in this type of assessment, whereby stormwater could be directed through the drainage network.
Flood Velocity	Velocity of flood waters in extreme events has not been determined
Catchment Flooding and River Entrances	The flooding impact from rainfall runoff and the possibility of joint occurrence with elevated ocean levels in an extreme event has not been considered. For the Chapman River mouth the coastal inundation hazard lines do not include the impact of catchment based flooding (i.e. from rainfall). The Chapman River catchment flooding levels are being assessed in a separate study with CGG.
Finished Floor Levels	The finished floor levels of built structures are not considered in the mapping, with flood depth based on ground level data as defined in the LiDAR
Existing Hard Structures	It is assumed the structures that are currently in place through the Geraldton CMU will be maintained in their current location delivering the equivalent level of protection from erosion in future planning periods
Groundwater	Groundwater is not considered in the study.
Tsunami	The Tsunami risk for Geraldton is examined in the Coastal Processes and Inundation studies. It was determined that no additional inundation allowance is required for tsunami risk.
SPP2.6 hazard definition ARI and application into CHRMAP	The coastal erosion setback S1 component has been calculated in the MRA studies for the 100 yr ARI storm in accordance with SPP2.6 guidelines. Inundation is defined at the 20yr, 100yr and 500yr ARI. As part of CHRMAP, hazard definition is assessed in terms of likelihood and probability and this likelihood definition range is constrained by only having access to a limited number of ARI events in the risk analysis.

Data Source / Feature	Assumptions and Limitations
Chapman River Mouth Erosion Setback	Coastal erosion setbacks were not provided from the MRA studies for the section of coast immediately north and south of the Chapman River Mouth, and these have been updated in the CHRMAP mapping data by Baird based on advice from MRA. It is noted that the coastal processes allowance for this area only considers erosion setback due to storm impact to a sandy coastline. This does not consider the interaction between the river and the coast which could affect how the coast immediately north and south of Chapman River Mouth and the river mouth itself responds to erosion events, either due to storm surge or inland runoff.

6. Existing Controls

This section details the controls that are in place currently in the Geraldton study area that provide a defence against erosion or inundation hazard. These control instruments can be planning controls, man-made or natural features Each of these controls is factored into the risk assessment of the coastal areas in the CHRMAP assessment.

6.1 Planning Controls

In managing the coastal zone, a number of planning instruments may be relevant. It is important to identify and summarise the key legislation, policies and guidelines that need to be considered as part of the process including their relevance and how they may inform, complement or enhance this process. These requirements may have a bearing on the assets and their values and ultimately the risk management and adaptation actions. In addition, various adaptation measures identified in the risk assessment process may target amendments to one or more of these instruments (WAPC 2014).

Statutory planning is one of the key adaptation planning mechanisms available to the CHRMAP process. A summary of the existing planning controls in the CGG was completed with a particular focus on coastal planning in the context of the CHRMAP process. The review is presented in **Appendix A.7** and included the following documents:

- State Planning Policy 2.6: State Coastal Planning Policy
- Draft Planned or Managed Retreat Guidelines
- State Planning Policy 3.4: Natural Hazards and Disasters
- Planning and Development (Local Planning Schemes) Regulations 2015
- City of Greater Geraldton Strategic Community Plan
- City of Greater Geraldton Corporate Business Plan
- Key Infrastructure Projects City of Greater Geraldton Local Planning Strategy
- Point Moore Inundation and Coastal Processes Study
- Geraldton Greenough Coastal Strategy & Foreshore Management Plan 2005
- City of Greater Geraldton Local Planning Scheme 1.0
- Local Planning Policy 3.1 - Climate Change
- Local Planning Policy - Geraldton City Centre Revitalisation Plan 2017
- Local Planning Policy - Sunset Beach Precinct Plan
- Local Planning Policy - City Centre
- Local Planning Policy – Design Guidelines: Beresford Beachfront Mixed Use
- Local Planning Policy – Design Guidelines: Marine Terrace Foreshore Precinct Mixed Use

6.1.1 Summary of options

Statutory planning mechanisms available to address coastal hazards within the City of Greater Geraldton are outlined in Table 6.1.

Table 6.1: Statutory planning mechanisms available to address coastal hazard in Geraldton

Statutory Measure	Advantages	Disadvantages
Structure Plan	• Can address location specific issues i.e. identification of coastal physical setbacks and areas affected by storm surge.	• Does not have the force and effect of the Scheme. Decision makers to have due regard only. • Cannot specify / enforce built form requirements. • Location specific only and therefore cannot address coastal hazard issues on a broad scale. • Generally requires the land to be appropriately zoned to require the preparation of a structure plan.
Local Development Plan	• Can specify built form requirements to address location specific coastal hazard issues i.e. increased setbacks, minimum habitable floor levels etc. • Has statutory weight of the local planning scheme. • Can vary 'deemed-to-comply' development requirements.	• Location specific only and therefore cannot address coastal hazard issues on a broad scale.
Local Planning Policy	• Can address coastal hazard and risk issues at a district (broad) level and/or at a location specific level. • Can include mapping of coastal hazard issues with flexibility to update mapping as and when amendments are required to be undertaken. • Has statutory weight of the local planning scheme. • Can vary 'deemed-to-comply' development requirements.	
Special Control Area	• SCAs may establish specific provisions to address a specific issue such as storm surge and or coastal processes. • SCAs can broadly address unique issues that extend across multiple zones and / or reserves.	• A scheme amendment would potentially need to be progressed every time mapping of the coastal issue is amended and/or updated. • Alternatively, a Local Planning Policy in which the mapping etc. is contained could be established (with reference to the LPP in the SCA). In this instance updates etc. can be undertaken to the policy when new information is available without having to amend the Scheme.

Of the mechanisms listed in Table 6.1, a Local Planning Policy and/or special control area (SCA) are considered the most suitable to address coastal hazard within the planning framework. These will be discussed further as planning based coastal hazard adaptation recommendations in Section 8.

6.2 Existing Controls

The natural and man-made controls in each of the CMU are summarised on Table 6.2.

Table 6.2: Summary of Existing Controls in the Coastal Management Units

CMU	Control	Comment
1. Drummond Cove	Sand Nourishment at closed section of Whitehill Rd	Temporary solution since 2015. Provided twice yearly as sacrificial management for erosion. Short term solution only
1. Drummond Cove	Rock seawall in front of Community centre	Seawall has been in place since approximately 2014 to protect against erosion. The CGG has not committed to long-term protection, but the structure is estimated to continue to offer protection from erosion over the next 10 years.
1. Drummond Cove	Natural Dune System in Southern Section	Provides buffer against erosion and natural cover provides a means of trapping windblown sand. Potential to erode naturally over time
2. Glenfield	Natural Dune System throughout	Provides buffer against erosion and natural cover provides a means of trapping windblown sand. Potential to erode naturally over time
2. Glenfield	Coastal Foreshore Reserve	Other than the Water Treatment Plant site, development has not been established inside the coastal hazard area. Effective avoidance through provision of coastal foreshore reserve in accordance with SPP2.6 Cl. 5.9.
3. Sunset Beach	Natural Dune System in Northern Section	Provides buffer against erosion and natural cover provides a means of trapping windblown sand. Potential to erode naturally over time
3. Sunset Beach	Managed Retreat Conditions	The Sunset Caravan Park is on a lease that incorporates managed retreat provisions triggered by erosion of the foreshore within a prescribed distance of the property boundary
4. Bluff Point	Geotextile Groyne at St Georges Beach	In place since 2017, to date stabilising the foreshore area through accretion on south side. Some erosion potential is noted on the north side. Structure is semi-permanent, and control is localised to the immediate area.
5. Beresford	Beresford Beach Coastal Protection Works	Due for completion 2018. Will provide buried seawalls from Midalia's Beach north to Trigg St. Effective protection against erosion. Does not remove risk from inundation in extreme events
5. Beresford	Coastal Protection Structures and	Completed 2018. The reconfiguration of the groynes and tombolo is designed to provide the beach greater protection from erosion. The beach sand size is coarser than historically used which offers greater resilience against

CMU	Control	Comment
	Sand nourishment Midalia's Beach.	erosion. Designed to provide effective erosion protection but will not guard against inundation in extreme events
5. Beresford , 6. Geraldton	Sand Nourishment	Under ministerial Act, Mid-West ports will continue to supply sand from Pages Beach. Offers amenity and short term erosion solution. Sand is moved off the beach and northwards under general longshore transport.
6. Geraldton	Seawalls, Rock Armouring and Groynes - Town Beach, Batavia Coast Marina, Geraldton Port	Effective control against erosion landward, potential for erosion of beaches in front. Will not protect from inundation in extreme events
7. Point Moore	Managed Retreat Conditions Seawall constructed on the south side of Point Moore to protect against erosion	Lease agreements for Point Moore residents have managed retreat conditions specified based on erosion and inundation triggers Seawall has been in place since approximately 2013 to protect Marine Terrace (Greys Beach). Sand fence has been added at the base to trap sediment more recently. The CGG has not committed to long-term protection, but the structure is designed for 25yrARI storm and estimated to continue to offer protection from erosion over the immediate -short term (10yrs +)
10. Tarcoola Beach	Coastal Foreshore Reserve	Coastal Foreshore Reserve extents afford a higher degree of protection than for the northern section of town
7,8,9,10,11,12	Natural Dune System	Provides buffer against erosion and natural cover provides a means of trapping windblown sand. Potential to erode naturally over time

It is noted that the port structures are a significant control on the natural movement of sand northwards. Under ministerial Act, Mid-West ports supplies sand from Pages Beach to the northern Beaches.

A strong sentiment expressed in the community engagement was that the deepening of the port channel in recent years had increased the level of erosion for the northern beaches, due to the perception that the deepened channel had led to focusing of swell waves on the coast to the north due to incoming swell trains interacting with the channel (so called 'channel effect'). It may be useful for the port to review and update any modelling studies completed for the channel deepening project and release the studies to the community.

7. Risk Analysis

7.1 Risk Analysis Framework

The risk analysis framework for the Geraldton CHRMAP is based on the WAPC guidelines (WAPC 2014) and Australian Standard *AS 5334:2013 Climate change adaptation for settlements and infrastructure – A risk based approach*).

To determine the coastal assets that are most vulnerable to coastal hazard requires consideration of the assets exposure to coastal hazard, the sensitivity of the impact and the assets adaptive capacity. This approach is presented in Figure 7.1 (WAPC 2014).

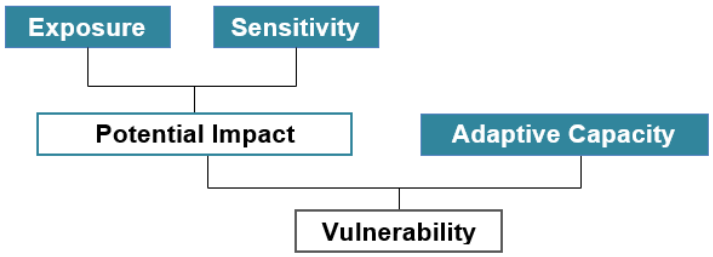

Figure 7.1: Vulnerability Assessment Flowchart (from WAPC 2014).

Risk is defined in WAPC 2014 as 'as a hazardous event or circumstance and the consequences that may flow from it'. The risk for the coastal assets identified in the Geraldton study area has been determined as a combination of the likelihood of a hazard occurring and the consequence of that hazard occurring. The approach is summarised in Figure 7.2 from Bicknell 2017, illustrating the components where:

- Exposure = *Likelihood* of coastal hazard occurring
- Sensitivity = *Consequence* of coastal asset being impacted
- Potential impact = *Risk* to coastal assets as a product of likelihood and consequence
- Adaptive Capacity = The ability for an asset to accommodate the coastal hazard impact and recover
- Vulnerability = Final risk rating which incorporates the adaptive capacity of the asset

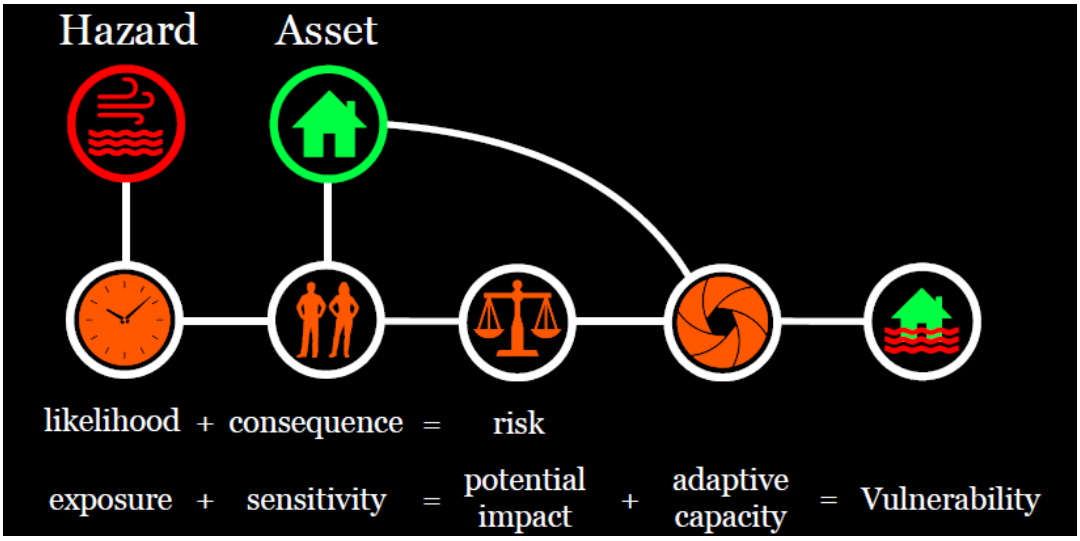

Figure 7.2: Vulnerability Assessment Flowchart (Bicknell 2017).

7.2 Likelihood

In risk management terms, 'likelihood' is the chance of something happening, and is similar to the concept of probability. The likelihood scale that has been developed for the Geraldton CHRMAP follows the guidance presented in WAPC2014 and the CGG Risk framework (CGG 2015). The definitions for the likelihood scale are shown on Table 7.1 with each category associated in terms of a generalised description and approximate Annual Exceedence Probability (AEP).

Table 7.1: Likelihood Scale Definitions (WAPC 2014, AS5334-2013)

Rating	Description	Indicative Annual Exceedance Probability (AEP)
Almost Certain	The event is expected to occur in most circumstances	Has a greater than 85% chance of occurring in the identified time period if the risk is not mitigated
Likely	The event will probably occur in most circumstances	Has a 50-85% chance of occurring in the identified time period if the risk is not mitigated
Possible	The event should occur at some time	Has a 25-50% chance of occurring in the identified time period if the risk is not mitigated
Unlikely	The event could occur at some time	Has a 10-25% chance of occurring in the identified time period if the risk is not mitigated
Rare	The event may only occur in exceptional circumstances	May occur in exceptional circumstances, i.e. less than 10% chance of occurring in the identified time period if the risk is not mitigated

7.2.1 Coastal Erosion Likelihood Scale

The coastal erosion likelihood scale is shown in Table 7.2. To fill the likelihood categories, the coastal hazard defined in Section 5 is applied on a sliding scale through the planning periods. The sliding scale is a means of recognising that a level of erosion risk that is considered 'possible' today becomes more likely in future time periods. The coastal erosion setback lines in Appendix A.4 are used as the basis for providing erosion scenarios across likelihood definitions. For example, the 'Likely' erosion definition in 2030 becomes the definition for the 'Almost Certain' category in 2070 and the 'Possible' erosion level in 2030 is considered as 'Likely' in 2070.

Table 7.2: Geraldton CHRMAP Likelihood Scale for Coastal Erosion (2040 to 2110 planning period)

Rating	2030 Planning Period	2070 Planning Period	2110 Planning Period
Almost Certain	-	2015 Erosion	2030 Erosion
Likely	2015 Erosion	2030 Erosion	2070 Erosion
Possible	2030 Erosion	2070 Erosion	2110 Erosion
Unlikely	2070 Erosion	2110 Erosion	-
Rare	2110 Erosion	-	-

The coastal erosion likelihood categories are shown spatially in mapping presented in **Appendix A.8** for the 12 Coastal Management Units.

There are limitations on the approach in Table 7.2, most notably the design storm in the coastal erosion setback is based on a 100yr ARI storm and no shorter return period outcomes are available to apply in the likelihood categories (previously noted in Table 5.5).

7.2.2 Coastal Inundation Likelihood Scale

The coastal inundation likelihood scale categories are shown in Table 7.3. The inundation likelihood is developed through application of the available coastal hazard inundation levels for the study area:

- The ARI categories selected to represent the likelihood categories 'Possible', 'Unlikely' and 'Rare' are based on the 20 yr, 100 yr and 500 yr ARI respectively and include the sea level rise corresponding to the planning year (refer Table 5.2).
- For the 'Likely' category, a 5 yr ARI level has been determined based on log normal plotting of the 20 yr, 100 yr and 500 yr ARI water level results.
- The Almost Certain category has been established based on the highest astronomical tide level (HAT).

The water level corresponding with each of the likelihood categories at the Geraldton Town Centre is shown in Table 7.4. The water level values in Table 7.4 apply 0.4m sea level rise by 2070 and 0.9m by 2110 as recommended in DoT 2010, as a fixed assumption.

Table 7.3: Inundation Likelihood Categories

Rating	2015	2030	2070	2110
Almost Certain	2015 HAT	2030 HAT	2070 HAT	2110 HAT
Likely	2015 5yr ARI	2030 5yr ARI	2070 5yr ARI	2110 5yr ARI
Possible	2015 20yr ARI	2030 20yr ARI	2070 20yr ARI	2110 20yr ARI
Unlikely	2015 100yr ARI	2030 100yr ARI	2070 100yr ARI	2110 100yr ARI
Rare	2015 500yr ARI	2030 500yr ARI	2070 500yr ARI	2110 500yr ARI

Table 7.4: Inundation Likelihood Water Levels for Geraldton (Geraldton Port to Drummond Cove)

Rating	2015 WL (mAHD)	2030 WL (mAHD)	2070 WL (mAHD)	2110 WL (mAHD)
Almost Certain	0.7	0.8	1.1	1.6
Likely	1.3	1.4	1.7	2.2
Possible	2.0	2.1	2.4	2.9
Unlikely	2.9	3.0	3.3	3.8
Rare	3.6	3.7	4.0	4.5

The coastal inundation likelihood categories are shown spatially in mapping presented in **Appendix A.9** for the 12 Coastal Management Units.

7.3 Risk Consequence

Consequence is used to describe the impact to assets when coastal hazard is realised and the way in which the 'Sensitivity' of assets is captured in the potential impact assessment described in Figure 7.2. For the Geraldton coastal areas, the scale of impact is rated in a five-stage severity scale from 'Insignificant' to 'Catastrophic' as shown on Table 7.5. The consequence is outlined in categories for Physical,

Environmental and Social impact based on CGG (2015). In the community engagement workshops, stakeholders and community worked with the consequence scale on Table 7.5 to rate the impact of erosion and inundation on assets identified within each of the CMUs. Through a series of tasks, the consequence scale was found to work appropriately for this process with workshop outcomes reported in **Appendix A.2.**

Table 7.5: Consequence Scale

Rating	Physical / Economic Impact	Environmental Impact	Social / Cultural Impact
Catastrophic	Permanent loss or damage > $5 million	Permanent loss of flora and fauna – will not recover	Long-term or permanent loss of function >75% of community affected
Major	Permanent loss or damage $2 - $5 million	Long term loss of flora and fauna, limited chance of recovery	Medium-term disruption to function <50% of community affected
Moderate	Permanent loss or damage $200k -$2mil	Medium term loss of flora and fauna. Recovery likely	Minor long Term or major Short-Term loss of function <25% of community affected
Minor	Permanent loss or damage $20k - $200k	Short term loss of flora and fauna. Strong Recovery	Small to medium disruption to function <10% of community affected
Insignificant	Permanent loss or damage < $ 20k	Negligible to no loss of flora and fauna	Minimal short-term inconvenience <5% of community affected

The consequence rating is shown for each of the coastal assets in the Coastal Asset Register in **Appendix A.10** for erosion and **Appendix A.11** for inundation.

7.4 Potential Impact

The risk evaluation phase for the identified coastal assets works through the process of prioritising risk management and adaptation. The following description of this process is given in WAPC2017:

Evaluation of the risk analysis is about prioritising risk management and adaptation. It is an important part of the process as it may not be possible or necessary to treat every risk. Also, the cost of implementing management and adaptation measures may outweigh the benefits gained. In prioritising management and adaptation actions, comparison of the results of the risk analysis is undertaken to determine the acceptability/tolerability, unacceptability/intolerability of the risks based on the outcomes of the risk assessment (WAPC2014).

A potential impact scale was developed for the Geraldton CHRMAP and is the product of the likelihood and consequence as shown in Table 7.6. Risk categories are rated from low to extreme.

For each of the coastal assets identified in the Geraldton CMU's, the risk was determined using the risk scale in Table 7.6. The existing controls identified in Table 6.1 and Table 6.2 are incorporated into the risk assessment process. The process was repeated for the four planning periods, and summarised in **Appendix A.10** for erosion risk and **Appendix A.11** for inundation risk.

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Table 7.6: Potential Impact Scale - Likelihood / Consequences matrix to assess level of risk

		CONSEQUENCE				
		Insignificant	Minor	Moderate	Major	Catastrophic
LIKELIHOOD	Almost Certain	Low	Medium	High	Extreme	Extreme
	Likely	Low	Medium	High	High	Extreme
	Possible	Low	Medium	Medium	High	High
	Unlikely	Low	Low	Medium	Medium	High
	Rare	Low	Low	Low	Low	Medium

7.5 Adaptive Capacity

Rating the adaptive capacity of the assets was undertaken based on classifying the degree to which an asset can potentially respond to coastal hazard impact. The rating falls into one of three categories shown in Table 7.7 (Bicknell 2017).

Table 7.7: Adaptive Capacity Rating for Coastal Assets (Bicknell 2017).

Adaptive Capacity Rating	Description
Low	• Impact of coastal hazard will cause long-term or significant reduction in asset's function or performance. • Major modifications will be required. • Early renewal of infrastructure by 50-90%
Moderate	• Impact of coastal hazard will cause medium-term or moderate reduction in asset's function or performance. • Minor modifications will be required. • Early renewal of infrastructure by 20-50%
High	• Impact of coastal hazard will cause short-term or localised reduction in asset's function or performance. • Minor modifications may be required but could be undertaken as part of routine maintenance. • Early renewal of infrastructure by 10-20%

The potential for an asset to recover from the impact of either erosion or inundation is generally different and has been rated separately. A summary of the sensitivity ratings is provided in Table 7.8.

Table 7.8: Adaptive Capacity Ratings of Coastal Assets.

Asset Type	Adaptive Capacity Rating	
	Erosion	Inundation
House / Commercial Premises	Low	Moderate[1]
Beach north of Port	Moderate	High
Beach South of Port	High	High
Dunes	Moderate	High
Beach Access Paths	High	High
Foreshore Reserve / Open Space	Moderate	High
Roads	Low	Moderate
Beach Toilets	Low	Moderate
Car Parks	Low	High
Cycle or Walking Paths	Moderate	High
Beach Shelter, BBQs	Moderate	High
Playgrounds	High	High
Minor Infrastructure (e.g. bins, fences)	High	High
Trees	Moderate	High
Natural Vegetation	Moderate	High
Landscaping	Moderate	High
Fauna / Aquatic Life	High	High

Notes

1. For houses and commercial business with depth of flooding >1.0m over the Finished Floor level the adaptive capacity is rated as low.

7.6 Inundation Depth, Safety and Structural Considerations

Inundation depth in extreme events and the safety and stability limits for people and structures in floodwaters generally requires consideration of flood depth and velocity. Safety limits for people and infrastructure based on velocity and depth is presented in Figure 7.3 (from Smith et al 2014). A limitation of the flooding results available to the Geraldton CHRMAP study is that velocity is not available for the extreme events. In the absence of velocity information, a flood level of 1m over the finished floor level has been adopted as representing a threshold where structures would fail, unless specifically constructed to withstand flooding (category H5 in Figure 7.3). This is recognised in the adaptive capacity rating for inundation of houses and business premises through a depth of flooding constraint set at 1.5m (includes assumed 0.5m freeboard). Inundation levels over this threshold are categorised at low adaptive capacity.

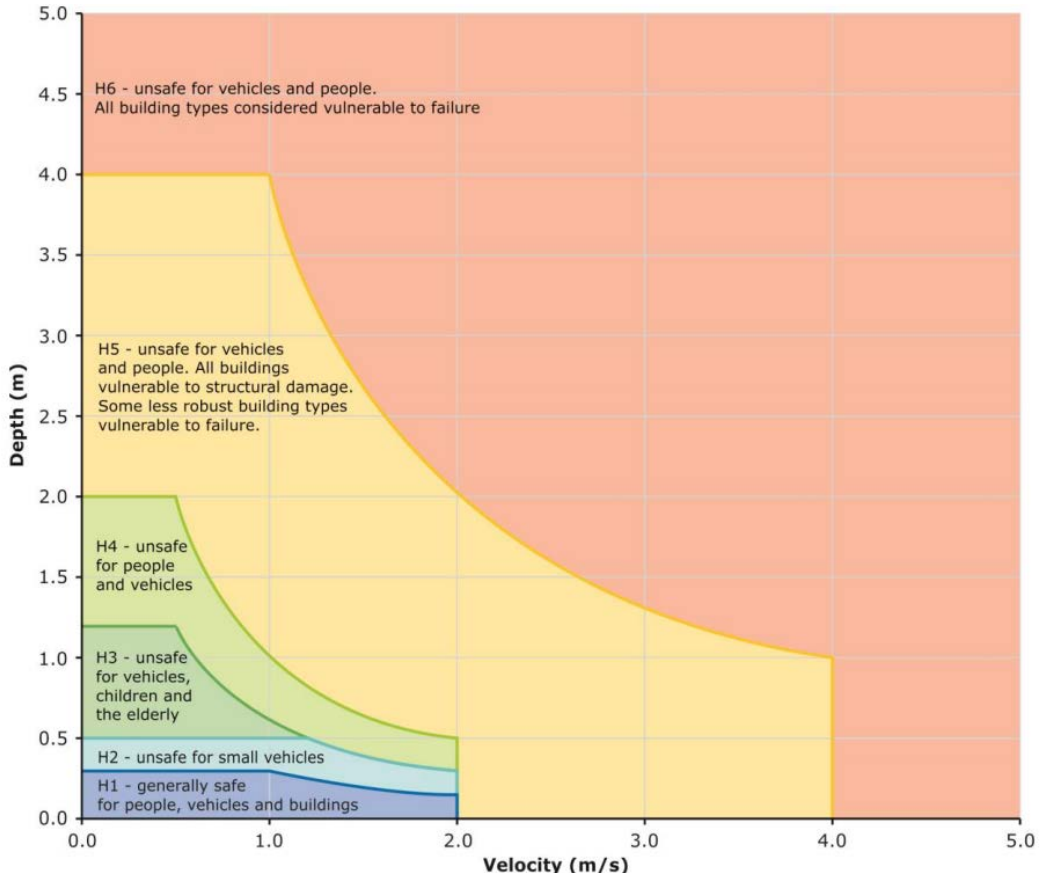

Figure 7.3: Flood Hazard Curve – Vulnerability thresholds as a Product of Inundation Depth and Velocity (from Smith et al 2014)

7.7 Calculated Asset Vulnerability

The calculated potential impact for each asset type was updated for each of the assets based on their adaptive capacity. The process is shown in Table 7.9, and summarised as:

- for assets rated with moderate adaptive capacity the asset vulnerability risk rating remains unchanged;
- for assets with high adaptive capacity, the asset vulnerability is downgraded; and
- for assets with low adaptive capacity have their risk level upgraded.

Table 7.9: Asset Vulnerability – Final Risk Rating of Coastal Assets based on Adaptive Capacity

Potential Impact	Adaptive Capacity Rating		
	Low	Moderate	High
Extreme	Extreme	Extreme	High
High	Extreme	High	Medium
Medium	High	Medium	Low
Low	Medium	Low	Low

The final vulnerability rating of the assets is summarised in **Appendix A.10** for erosion risk and **Appendix A.11** for inundation risk.

7.8 Risk Acceptance and Tolerance

For the level of risk defined for the coastal assets, the corresponding tolerance scale is shown on Table 7.10. The tolerance scale has been developed from WAPC 2014 and describes the tolerance to risk levels for vulnerable assets. For risk level at the 'High' and 'Extreme' level, action to mitigate the risk is required. At lower level of risk, the risk is acceptable and no action is required.

Table 7.10: Tolerance Scale

Risk Level	Action Required	Acceptance / Tolerance
Extreme	Immediate action required to eliminate or reduce the risk to acceptable levels	Unacceptable / Intolerable
High	Immediate to short term action required to eliminate or reduce the risk to acceptable levels	Tolerable
Medium	Short to medium term action to reduce the risk to acceptable levels, or accept risk	Tolerable / Acceptable
Low	Accept Risk	Acceptable

7.9 Coastal Assets at Risk

7.9.1 Summary of Key at Risk assets requiring action by Coastal Management Unit

The risk assessment outcomes indicate that the key risk for the coastal assets is coastal erosion. A number of assets are at 'High' to 'Extreme' risk from erosion in future planning periods. For the Geraldton management unit (CMU6) which is protected against erosion, the comparatively lower lying area of the CBD is subject to risk from coastal inundation though this is only at the 'Moderate' to 'High' level.

The full list of coastal assets and their vulnerability rating for erosion is presented in **Appendix A.10**. Assets rated at 'High' or 'Extreme' risk by the planning year 2110 are summarised in Table 7.11 to Table 7.23 for all the coastal management units. It is noted that Beresford (CMU5) and Geraldton City Centre (CMU6) are not considered at risk of erosion due to the protection structures in place along the foreshore.

The full list of coastal assets and their vulnerability rating for inundation is presented in **Appendix A.11**. Assets rated at 'Moderate' to 'High' inundation risk by the planning year 2110 are included in the lower section of Table 7.11 to Table 7.23. The inundation risk has been considered in CMUs as follows:

- Drummond Cove;
- Bluff Point;
- Beresford;
- Geraldton;
- Point Moore;
- Beachlands;
- Mahomet Flats; and
- Tarcoola Beach.

Table 7.11: Key Assets at Risk – Drummond Cove (CMU1)

Erosion Risk				
Asset	**2018**	**2030**	**2070**	**2110**
Houses (Whitehill Rd, Surfside Tce)	M	H	E	E
Houses (Tailer St, Stillwater Ave)	M	M	H	E
Toilets	H	H	E	E
Community Hall	H	E	E	E
Foreshore Reserve	M	H	H	E
Roads (Whitehill Rd, Surfside Tce)	M	H	H	E
Whitehill Rd (Closed Section)	E	E	E	E
Carpark Drummond Cove Rd	H	E	E	E
Carpark JB Hall	H	H	E	E
Carpark Smugglers Pass	M	H	H	E
Skate Park	H	H	E	E
Tennis Courts	H	E	E	E
Dunes	H	E	E	E
Watercorp Pumping Station	H	E	E	E
Boat Ramp	M	H	H	H
Beach Shelters	M	M	H	H
Beaches, Flora and Fauna	M	M	H	H
Inundation Risk				
Asset	**2018**	**2030**	**2070**	**2110**
Houses - Whitehill Rd	L	L	M	M
Beaches	M	M	M	M
JB Community Hall	L	L	M	M
Boat Ramp	M	M	M	M
Whitehill Rd Closed Section	M	M	M	M
Skate Park	L	L	M	M
Tennis Courts	L	L	M	M
Flora and Fauna	L	L	M	M
Watercorp Pumping Station	M	M	M	M

Table 7.12: Key Assets at Risk of Erosion– Glenfield (CMU2)

Erosion Risk				
Asset	**2018**	**2030**	**2070**	**2110**
Water Treatment Plant	H	E	E	E
Dunes	M	M	H	H
Beaches, Flora and Fauna	M	M	H	H

Table 7.13: Key Assets at Risk – Sunset Beach (CMU3)

Erosion Risk				
Asset	**2018**	**2030**	**2070**	**2110**
Houses West of Volute Street	M	H	E	E
Houses East of Volute Street	M	M	H	E
Beaches	M	M	H	H
Swan Park Toilets	H	H	E	E
Triton Ave Toilets	H	E	E	E
Beach Shelter	M	M	H	H
Foreshore Reserve	M	H	H	E
Roads General	M	H	H	E
Triton Place Carpark	H	E	E	E
Caravan Park	H	E	E	E
Dunes	M	M	H	H
Walking and Cycling Paths	M	H	H	H
Trees	M	M	H	H
Swan Drive Park	M	H	H	E
Swan BBQ / Grassed Areas	H	H	E	E

Table 7.14: Key Assets at Risk – Bluff Point (CMU4)

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

Table 7.15: Key Assets at Risk – Beresford (CMU5)

Inundation Risk				
Asset	**2018**	**2030**	**2070**	**2110**
Houses - Marina (Mayhill Quay, Stanford Cove, Windsor Ct)	L	L	M	M
Industrial / Commercial Chapman / Phelps St	L	L	M	M
Beaches	L	L	M	M
Foreshore Reserve Marina Park	L	L	M	M
Cycling and Walking Paths	L	L	M	M
Coastal Vegetation	L	L	M	M
Minor Infrastructure (bins, fences, signs)	L	L	M	M
Beach Access Paths	L	L	M	M

Table 7.16: Key Assets at Risk – Geraldton (CMU6)

Inundation Risk				
Asset	**2018**	**2030**	**2070**	**2110**
CBD Foreshore Amenities	M	M	M	M
Foreshore Beaches	M	M	H	H
Dome - Foreshore	M	M	M	M
Toilet Block and Café - Foreshore Playground	M	M	M	M
Houses - Marine Terrace, Foreshore Drive	M	M	H	H
Houses - Low Lying Block of Marine Terrace, Crowther, Duboulay, Burgess, Shenton, Cunningham St	H	H	E	E
Houses - Shenton St, Gregory St, Fitzgerald St, Chapman Rd	L	L	M	M
Houses - Batavia Coast Marina	L	L	M	M
Commercial Premises- Batavia Coast Marina, Foreshore Drive	M	M	H	H
Business and Commercial Premises in CBD	M	M	H	H
Business and Commercial Premises at low lying section Cnr Foreshore Drive and Marine Terrace	H	H	E	E
Port Loading, Storage and Berth Areas	L	L	M	M
Port Administration	M	M	H	H
Southern side Marine Terrace	M	M	H	H
Batavia Marina Foreshore Elements	L	L	M	M
Carparks Francis St Foreshore	L	L	M	M
Roads - Foreshore Drive, Marine Terrace, Augustus St, Fitzgerald St	M	M	M	M
Roads - Chapman Rd, Fitzgerald St, Shenton St	L	L	M	M
Groyne Structures	M	M	M	M

Table 7.17: Key Assets at Risk of Erosion– Point Moore (CMU7)

Erosion Risk				
Asset	**2018**	**2030**	**2070**	**2110**
Point Moore Lighthouse	H	H	E	E
Lighthouse Keepers Cottage and Storage	M	M	H	H
Houses South Side - Astrolabe Lane	M	M	H	E
Marine Terrace South Side	H	E	E	E
Marine Terrace West Side	M	M	H	H
Beach Pages Beach1	M	M	H	H
Toilets Pages Beach	M	M	H	H
Car Park Pages Beach	M	H	H	E
Foreshore Park Pages Beach	L	M	H	H
Beach Point Moore	M	M	H	H
Foreshore Park Point Moore	L	M	M	H
Volunteer Rescue	M	H	E	E
Carpark Point Moore	M	H	H	E
Toilets Point Moore	M	H	H	E
Carpark Greys Beach West (Closed)	H	E	E	E
Carpark Greys Beach East	H	H	E	E
4WD Access to Beach	M	M	H	H
Cycle / Walking Paths (South Side)	M	H	H	H
Dunes - NW	H	H	E	E
Dunes - South	M	H	H	E
Trees and Coastal Vegetation	M	H	H	H
Wetland Heritage Site	M	M	H	E

Table 7.18: Key Assets at Risk of Inundation– Point Moore (CMU7)

Inundation Risk				
Asset	**2018**	**2030**	**2070**	**2110**
Point Moore Lighthouse	L	L	M	M
Lighthouse Keepers Cottage and Storage	L	L	M	M
Houses	H	H	E	E
Marine Terrace West Side	M	M	M	M
Beach Pages Beach	M	M	M	M
Toilets Pages Beach	M	M	M	M
Car Park Pages Beach	M	M	M	M
Foreshore Park Pages Beach	M	M	M	M
Beach Point Moore	M	M	M	M
Foreshore Park Point Moore	M	M	M	M
Volunteer Rescue	M	M	H	H
Carpark Point Moore	L	L	M	M
Toilets Point Moore	L	L	M	M
Beach Access Paths	L	L	M	M
Dunes - NW	L	L	M	M
Trees and Coastal Vegetation	L	L	M	M

Table 7.19: Key Assets at Risk– Beachlands (CMU8)

Erosion Risk				
Asset	**2018**	**2030**	**2070**	**2110**
Batavia Coast Marine Institute	M	H	E	E
Rail Lines	M	H	E	E
John Willcock Link	M	H	H	E
Separation Point Close	H	H	E	E
Car Park Separation Point Lookout	H	E	E	E
Cycle / Walking Paths West	M	H	H	H
Cycle / Walking Paths East	M	M	H	H
Beach Greys, Separation Point	M	M	H	H
Dunes	H	H	E	E
Trees and Coastal Vegetation	M	H	H	H

Table 7.20: Key Assets at Risk– Mahomet Flats (CMU9)

Erosion Risk				
Asset	**2018**	**2030**	**2070**	**2110**
Surf Club - Main Building	M	H	E	E
Surf Club - Storage	M	M	H	H
Surf Club - Foreshore Area	L	L	M	H
Surf Club - Playground	M	M	H	H
Surf Club - Toilets	M	M	H	H
Car Park - Surf Club	M	M	H	H
Car Park - Hadda Way (north of Surf Club)	M	M	H	H
Car Park - South Pipe (south of Surf Club)	M	M	H	H
Houses	M	M	H	E
Willcock Drive	M	M	H	H
Hadda Way	M	M	H	H
Rail Lines	M	M	H	E
Separation Point Close	M	H	H	E
Car Park - Wimps, Wilcock Drive	M	M	H	H
Car Park - Wimps, Hadda Way	M	M	H	H
Beaches	M	M	H	H
Dunes	M	H	H	E
Trees and Coastal Vegetation	M	H	H	H

Table 7.21: Key Assets at Risk – Tarcoola Beach (CMU10)

Erosion Risk				
Asset	**2018**	**2030**	**2070**	**2110**
Houses	M	M	H	E
Willcock Drive	M	H	H	E
Glendenning Rd	M	M	H	H
Glendenning Park	M	M	H	H
Car Park - Glendenning Rd North	M	M	H	H
Car Park - Glendenning Rd Opp Buchanan	M	H	H	E
Car Park - Glendenning Foreshore Southern	M	M	H	H
Beaches	M	M	H	H
Dunes	M	H	H	E
Trees and Coastal Vegetation	M	H	H	H
Inundation Risk				
Asset	**2018**	**2030**	**2070**	**2110**
Houses - Glendinning Rd	L	L	M	M
Beaches	M	M	M	M

Table 7.22: Key Assets at Risk– Southgate Dunes (CMU11)

Erosion Risk				
Asset	**2018**	**2030**	**2070**	**2110**
Southgate Dunes	M	H	H	E
Beaches	M	M	H	H
Rare Vegetation	H	H	E	E
Aboriginal Heritage Site	H	H	E	E
Trees and Coastal Vegetation	M	H	H	H

Table 7.23: Key Assets at Risk– Cape Burney (CMU12)

Erosion Risk				
Asset	**2018**	**2030**	**2070**	**2110**
Beach Lookout and Pathway	H	E	E	E
Toilet	M	H	H	E
Greenough River Rd	M	M	H	H
Car Park	H	H	E	E
Beaches	M	M	H	H
Dunes	M	H	H	E
Trees and Coastal Vegetation	H	H	E	E

7.9.2 Highly Valued Community Assets

From the community engagement process, the most highly valued coastal assets were identified through a series of tasks outlined in the workshop summary report (**Appendix A.2**). The list of assets valued most highly by the community are summarised by CMU in Table 7.24.

These high value assets have been captured in the risk summary in Table 7.11 to Table 7.23. In recognition of the high value placed on these assets by the community, they will feature with higher importance in the adaptation assessment (Baird 2019).

Table 7.24: Most Valued Assets by Coastal Management Unit Identified by the Community

No.	CMU	Asset/s
1	Drummond Cove	Houses and Properties Beaches John Batten Hall Sand Dunes and Vegetation
2	Glenfield	Houses and Properties Beach and Sand Dunes
3	Sunset Beach	Houses and Properties Beaches and Sand Dunes
4	Bluff Point	Rundle Park Coastal Pathways and Cycling Paths
5	Beresford	Beach and Foreshore
6	Geraldton	The Port CBD and Businesses The Foreshore
7	West End (Point Moore)	Sand Dunes and Beaches Lighthouse
8	Beachlands	Aboriginal Wetlands Marine Terrace Beach Ecosystem
9	Mahomets Flats	Surf Club Beaches
10	Tarcoola Beach	Beaches and Dunes
11	Southgate Dunes	Beaches and Dunes
12	Cape Burney	Greenough River Mouth Beach

8. Adaptation Options

8.1 Risk Management and Adaptation

Effective risk management and adaptation planning requires putting in place controls to manage the identified coastal hazard risks, using approaches which meet the needs and expectations of the affected community and stakeholders.

The community and stakeholder engagement for the Geraldton CHRMAP has been designed to gain an understanding of the community values in the coastal areas. The community involvement will be used to guide development of adaptation options that can meet the objective of mitigating coastal hazard risk and that are supported by the general community.

8.1.1 Adaptation Hierarchy

The risk management and adaptation hierarchy (WAPC2014) provides a platform for decision making that aims to build coastal resilience and maintain flexibility for future decision makers in coastal areas. The hierarchy is built on a tiered approach of adaptation response as presented in Figure 8.1.

Figure 8.1: Risk Management and Adaptation Hierarchy (WAPC 2014)

There are four broad categories of potential adaptation options (WAPC 2014):

1. **Avoid**: avoid new development in areas at risk of coastal hazard;
2. **Planned or Managed Retreat**: allow existing development until coastal impacts arise. Relocate or remove assets within an area identified as likely to be subject to intolerable risk of damage from coastal hazards over the planning time frame;
3. **Accommodate**: If sufficient justification can be provided for not avoiding development of land that is at risk from coastal hazards then Accommodation adaptation measures should be provided that suitably address the identified risks. Can involve design and/or management strategies that render the risks from the identified coastal hazards acceptable for example design of assets to withstand the impact of coastal hazard; and
4. **Protect**: where sufficient justification can be provided for not avoiding the use or development of land that is at risk from coastal hazards and accommodation measures alone cannot adequately address the risks from coastal hazards then coastal protection works may be proposed where there is a need to preserve the foreshore reserve, public access and public safety, property and infrastructure that is not expendable.

Generally, as risk management and adaptation options are selected further down the hierarchy (from avoiding areas at risk to protecting development from those risks), future adaptation options will diminish and the coastal resilience to future coastal hazard reduces. The category of 'Avoid' allows the greatest flexibility for future coastal decision making, down to 'Protect' which offers the least flexibility.

The coastal hazard and risk level identified for the assets within each of the coastal management units is considered with reference to the adaptation approaches in the adaptation hierarchy. Adaptation responses can vary within coastal compartments, and in many instances a range of complementary adaptation responses that mitigate the coastal risk may be required.

8.2 Adaptation Options Toolbox

A range of adaptation tools available to mitigate coastal risk in the Avoid-Managed Retreat -Accommodate-Protect categories is summarised in Table 8.1. A full description of the options is provided in an Adaptations Toolbox in **Appendix A.12**.

Options have been developed from a range of sources including WAPC 2014 and the National Climate Change Adaptation Research Facility (NCARF) Coast Adapt tools, as well as incorporating options provided through the community involvement in the CHRMAP workshops.

Table 8.1: Adaptation Options Toolbox Summary for Risk Mitigation of Coastal Assets

	Code	Adaptation Type	Applicable
Avoid	Av.1	Setback Controls	Erosion and Inundation
Managed Retreat	MR.1	Leaving Assets Unprotected	Erosion and Inundation
	MR.2	Removal of Assets	Erosion and Inundation
	MR.3	Prevent Further Development	Erosion and Inundation
	MR.4	Land Swap	Erosion and Inundation
Accommodate	Ac.1	Notification on Title	Erosion and Inundation
	Ac.2	Building Design	Inundation
	Ac.3	Emergency Evacuation	Inundation
	Ac.4	Appropriate Finished Floor Levels	Inundation
	Ac.5	Filling Land	Inundation
Temporary Protect / Improve Resilience	TPIR.1	Coastal Re-Vegetation	Erosion
	TPIR.2	Dune Management	Erosion and Inundation
	TPIR.3	Beach Nourishment	Erosion
	TPIR.4	Geotextile Sand Bags – Groynes and Seawalls	Erosion
Protect	Pr.1	Groynes	Erosion
	Pr.2	Seawalls	Erosion
	Pr.3	Flood Mitigation Structure	Erosion and Inundation
	Pr.4	Artificial Reefs	Erosion

8.3 Economic Framework

The economic framework for the CHRMAP is detailed in **Appendix A.7**. The economic evaluation of adaptation options follows the following broad steps:

- Determining economic value of assets at risk to coastal hazards;
- Determining the current and future annual cost of hazards to susceptible assets in the CGG Coastal Zone;
- Determining the cost of options to mitigate coastal hazards; and
- Economic evaluation of reduction in costs of hazards to susceptible assets as a result of mitigation options.

The evaluation of the adaptation options task has two key components:

- Multi-Criteria Analysis (MCA); and
- Cost Benefits Analysis (CBA).

8.3.1 Multi-Criteria Analysis

The multi-criteria analysis would be used to compare and contrast the identified list of adaptation options within CMUs. The analysis would incorporate criteria related to economic, social and environmental impacts. A score for each option, including the base case (business as usual scenario) as an option, will be derived based on:

- The asset types present within each CMU
- The importance of the asset types to the community at each CMU
- The manner and extent in which erosion will affect each asset under the option (either a quantitative of qualitative metric will be used to evaluate this) at both 2030 and 2070
- The manner and extent in which inundation will affect each asset under the option (either a quantitative of qualitative metric will be used to evaluate this) at both 2030 and 2070

For each option, a score will be assigned for each asset type. Based on the relative importance of the asset type to the local community and cumulative score for each option within each CMU will be determined. This cumulative score would then be compared against an estimate of the option implementation capital, operational and maintenance costs, to derive a Cost Effectiveness Ratio. The relative performance of each option within each CMU will be able to be ranked and compared in terms of the costs of hazard faced given the cost of implementation.

8.3.2 Cost Benefit Analysis

The identified short-list of preferred options within each CMU will be assessed for their economic feasibility through a cost-benefit analysis. This process will also enable options between CMUs to be compared and contrasted (e.g. the multi-criteria process may identify that beach nourishment is the preferred option in two CMUs. The CBA would aid in determining which, of the two investments in beach nourishment, would generate the greatest net benefit to CGG and community as a whole).

The cost benefit analysis for each option will determine the dollar value of costs/benefits (direct and indirect) for both the base case, business as usual, scenario and the option scenario. The difference between the costs/benefits of the scenarios representing the net value associated in undertaking the proposed coastal management measure, over continuing with the current level of coastal management.

The costs and benefits would consider both erosion and inundation contributions to loss/reductions. The cost benefit analysis will focus on the planning period to 2070, as the longer planning period (to 2110) involves too many uncertainties and economic discounting makes any benefits generated in these later years, largely negligible. Standard economic indicators (NPV, IRR, BCR) will be provided for each option,

and sensitivity testing undertaken on “Almost Certain” and “Rare” erosion scenarios to provide a better understanding of the resilience associated with each of the options.

In addition, a discussion and evaluation of distribution analysis will be provided. The distribution analysis will assess the degree to which the costs and benefits are born by a concentrated or diverse number of individuals / agencies / communities.

The full details of the economic assessment framework are outlined in **Appendix A.7.**

8.4 Future Work

The next phase of this CHRMAP project is to evaluate the adaptation options within each of the CMU that will mitigate the coastal risk. From the toolbox of adaptation options available (Appendix A.12), a suite of preferred options will be determined within each of the CMU. The decision-making process will be supported by the multi-criteria analysis and cost benefit analysis process outlined in the economic framework (Appendix A.7).

Once the preferred adaptation options are determined the CHRMAP will:

- Develop long-term adaptation pathways for assets rated at high to extreme risk;
- Develop adaptation options to address the most highly valued assets as identified in the community consultation process;
- Based on adaptation response make recommendations to update local planning strategies and formulate new planning policies;
- Determine relevant trigger points which will be used as a basis for increased levels of adaptation response;
- Provide references to current coastal practice in WA and around Australia relevant to the adaptation responses developed; and
- Provide indicative costs for the adaptation responses recommended

The outcomes are reported in the *Geraldton CHRMAP Coastal Adaptation Report* (Baird 2019).

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Appendix A

Technical Appendices

A.1 Community Engagement Plan

A.2 Community Engagement Workshop Summary

A.3 Local Planning Summary

A.4 Coastal Asset Register

A.5 Coastal Hazard Mapping for Erosion

A.6 Coastal Hazard Mapping for Inundation

A.7 Economic Analysis

A.8 Likelihood Mapping for Coastal Erosion

A.9 Likelihood Mapping for Coastal Inundation

A.10 Erosion Risk Assessment

A.11 Inundation Risk Assessment

A.12 Adaptation Toolbox