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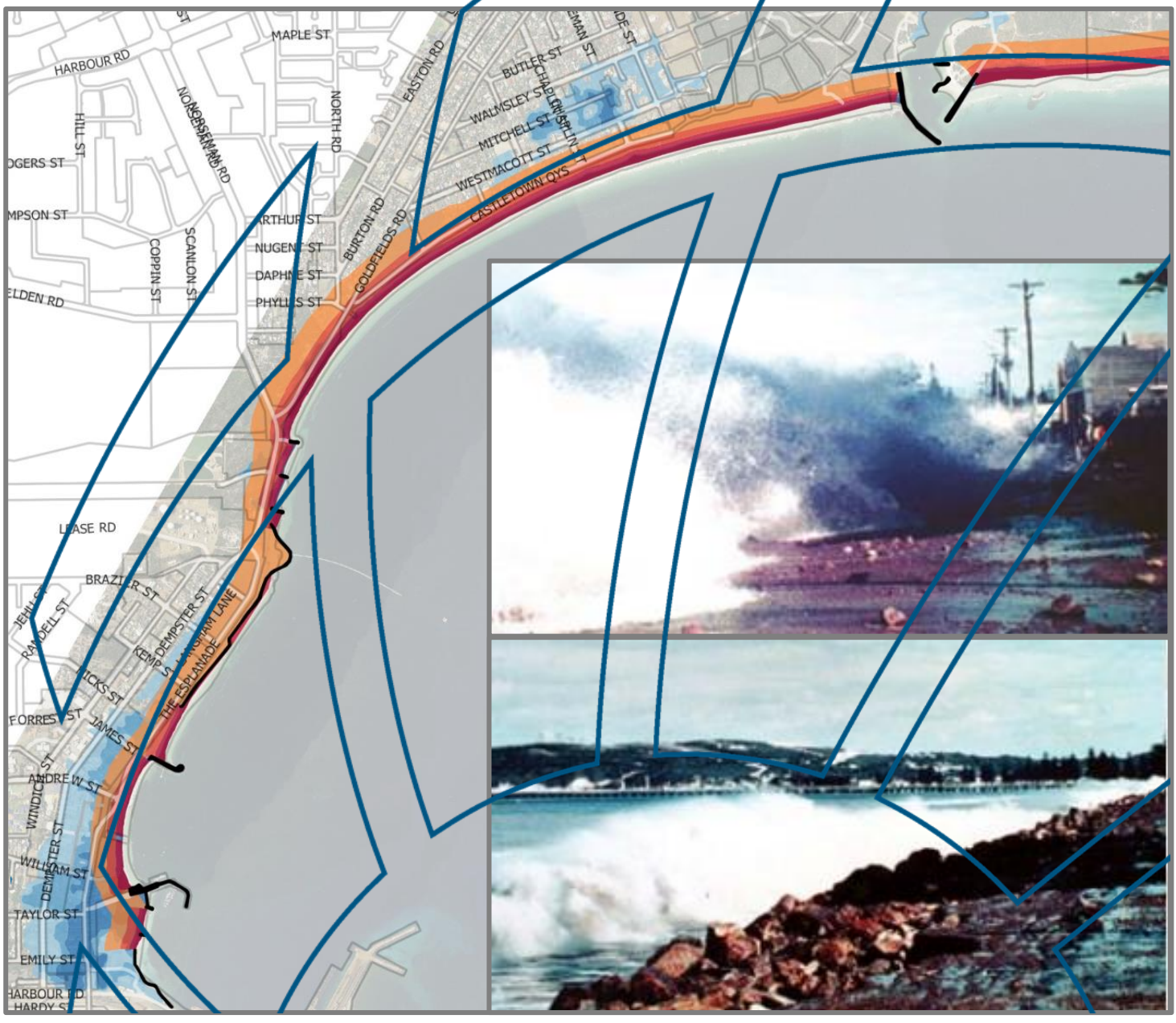
"Where will our knowledge take you?"

ESPERANCE COASTAL HAZARD ADAPTATION STRATEGY

Final Report

Reference: 224.10-01 - REV 0
Date: July 2016



SHIRE OF ESPERANCE

ESPERANCE COASTAL HAZARD ADAPTATION STRATEGY

FINAL REPORT

Prepared for

By

BMT JFA Consultants

Front page illustrations:
Top - Erosion and inundation hazard areas in Esperance town centre overlaid with land planning zones
Bottom - "First-hand accounts exist from the 1920s of the old railway line that ran between the old Town Jetty, located in front of the Pier Hotel and the Newtown Jetty, being washed away, and five blocks of land near where the old Fresh Air League building is located being swallowed up by the ocean. […] Some locals can still recall standing in the bar of the old Pier Hotel in 1948 in ankle deep seawater, seeing the streets and laneways that run off The Esplanade being awash, and picking up seagrass in Andrew Street in front of the post office. […] These photos were taken in the 1960s and show a building on the foreshore (and some people) about to be swamped by a giant wave. The building still stands and is today a restaurant. Also the rock wall that was placed along the Esplanade to protect the road (not the beach) is still there, but has been covered up. […]". [A Community newsletter from Esperance Ports Sea and Land, July 2009 Issue #9].

Rev	Issue	Prepared by	Submitted to	Date	Copies
A	Working Draft – First Review	Frederic Saint-Cast	Brad Saunders Richard Hindley	20/08/2015	1 pdf
B	Working Draft – First Review	Frederic Saint-Cast	Brad Saunders Richard Hindley	15/09/2015	1 pdf
C	Final Draft - for Client Review	Frederic Saint-Cast	Brad Saunders Richard Hindley	20/05/2016	1 pdf
D	Final Draft – for Steering Committee Review	Frederic Saint-Cast	Brad Saunders Richard Hindley	01/06/2016	1 pdf
0	Final Report	Frederic Saint-Cast	Brad Saunders Richard Hindley	14/07/2016	1 pdf

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EXECUTIVE SUMMARY

This report presents the Shire of Esperance Coastal Hazard Adaptation Strategy (CHAS) for Esperance Bay, the 10.5km strength of coast comprising the Town Centre & Foreshore, Castletown, Flinders, Bandy Creek & Surrounds and Wylie Head.

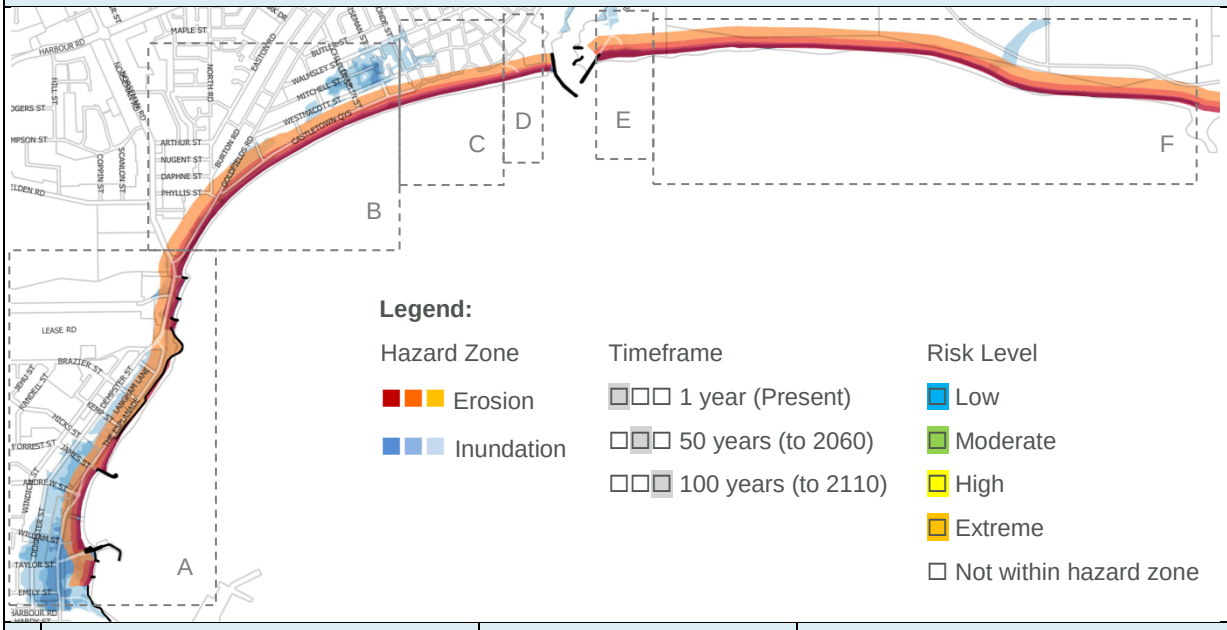
Context - There is an increasing possibility that coastal erosion and inundation have negative impact on coastal assets and values enjoyed by the community and stakeholders over the next century. Therefore, it is essential that settlement strategies are appropriately planned for. For that reason, a CHAS was developed in accordance the State Coastal Planning Policie (SPP2.6) and the Coastal Hazard Risk Management and Adaptation Planning (CHRMAP) guidelines, as they apply at local government level, to assist strategic decision-making in the creation of value and protection of value(s) in the coastal zone with an appreciation of the potential risk and stakeholders and community preferences. As a result, the CHAS aims at reducing vulnerability to coastal hazards in the developed and planned to be developed coastal zone of Esperance, and build the long-term adaptive capacity of the Esperance community to manage coastal hazard risk. It is anticipated that the recommendations of the CHAS will be incorporated into the Shires' reviews of the Local Planning Strategy and Scheme commenced in 2014/15.

Coastal Hazard Risk Identification - A detailed identification of coastal hazard risk was developed in the Esperance Coastal Hazard and Vulnerability Assessment study completed by BMT JFA in January 2015. Here, a summary of the erosion and inundation planning scenarios developed previously is presented and completed with a review of the coastal assets (values) at risk, comprising of beaches, coastal protection and facilities, several infrastructure and land use categories.

Coastal Hazard Risk analysis and evaluation - A thorough analysis and evaluation of coastal hazard risk was undertaken to prioritise management actions. First, the likelihood of each erosion and inundation hazard scenarios was rated against the likelihood scale of the Shire's risk framework. Then, in collaboration with the Shire, the consequence of coastal values and assets being impacted by erosion or inundation was rated against the consequence scale of the Shire's risk framework.

As a result, hazard zones and risk zones were mapped to illustrate the extent and the severity of coastal hazard risk in the near (present day), medium (to 2060) and long-term (to 2110). These zones reflected the presence and effectiveness of time of existing control measures such as foreshore reserve, linear coastal protection (i.e. Esperance Seawall) and sand nourishment activities. Having characterised the impact of coastal hazards scenarios on values and assets within the Shire's risk framework, risk profiles have been drawn across strategic coastal areas (as shown in the table hereafter).

Coastal Hazard Zones and Risk Profile Summary



	Values and Assets at Risk	Risk Level & Timeframe		Key controls in place
		Erosion	Inundation	
A	Central area	1 yr	100 yr	Protection scheme Foreshore reserves Special Control Areas – Disclosure of coastal hazard
	Local road	1 yr	50 yr	
	Parks, recreation and conservation	50 yr	1 yr	
	Public purpose	1 yr	100 yr	
	Regional road	100 yr	1 yr	
	Residential	1 yr	100 yr	
	Tourist residential	1 yr	100 yr	
	Tourist zone	1 yr	1 yr	
	Infrastructures (utilities)	100 yr	100 yr	
B	Local road	50 yr	50 yr	Foreshore reserves Special Control Areas – Disclosure of coastal hazard
	Parks, recreation and conservation	50 yr	1 yr	
	Regional road	100 yr	1 yr	
	Residential	1 yr	100 yr	
	Tourist zone	1 yr	100 yr	
	Infrastructures (utilities)	100 yr	100 yr	
C	Parks, recreation and conservation	50 yr	1 yr	Foreshore reserves Special Control Areas – Disclosure of coastal hazard
	Residential	1 yr	1 yr	
D	Parks, recreation and conservation	50 yr	1 yr	Foreshore reserves Special Control Areas – Disclosure of coastal hazard
	Residential	1 yr	1 yr	
E	Future residential	50 yr	1 yr	Foreshore reserves Special Control Areas – Disclosure of coastal hazard
	Parks, recreation and conservation	50 yr	1 yr	
	Public purpose	1 yr	50 yr	
F	Agricultural – general	1 yr	1 yr	Foreshore reserves Special Control Areas – Disclosure of coastal hazard Low intensity land use
	Local road	1 yr	50 yr	
	Parks, recreation and conservation	50 yr	1 yr	
	Public purpose	1 yr	50 yr	

Coastal Hazard Risk Adaptation Planning - Based on the risk profiles developed in the risk analysis and evaluation phase, three strategic regions with common characteristics were identified namely:

- Town Centre & Foreshore (A) – for its high to extreme existing land use inundation risk and infrastructure erosion risk throughout the planning timeframe
- Castletown (B) – for its high to extreme existing erosion (infrastructure and land use) and inundation risk throughout the planning timeframe
- Flinders (C), Bandy Creek & Surround (D, E) and Wylie Head (F) – for its moderate to high erosion (future development) and inundation risk.

Various coastal hazard risk mitigation measures, their effectiveness and the way to implement them were considered before selecting a preferred strategic pathway among the four broad categories of potential adaptation options through a collaborative multi-criteria appraisal process. The preferred pathways for each strategic region are illustrated in Figure 0-1 along the CHRMAP pathway hierarchy. The hierarchy of the proposed pathways is also indicative of the spatial gradation of the risk profile and adaptive capacity around Esperance Bay.

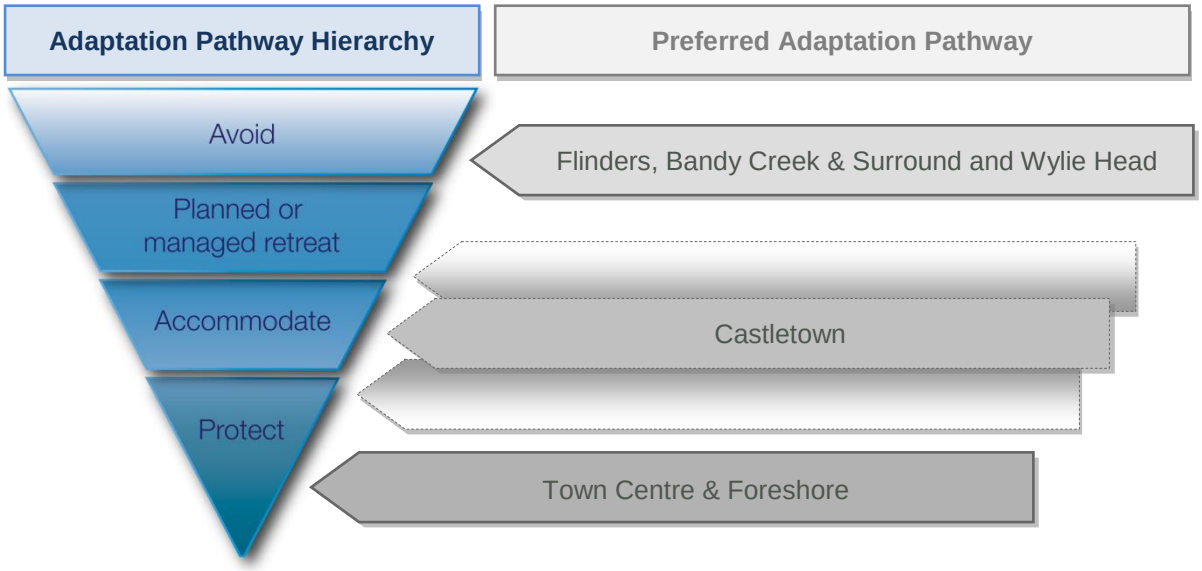
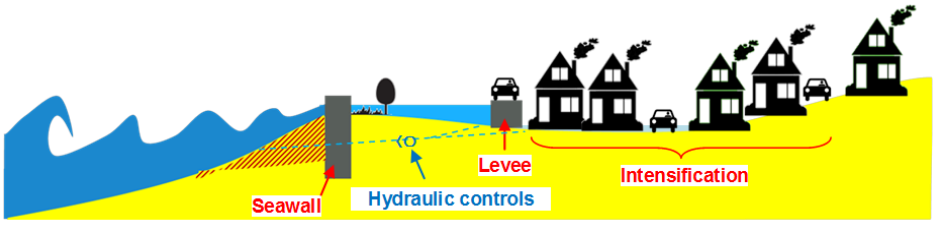


Figure 0-1: Preferred adaptation pathway for each strategic region of the CHAS

Each preferred strategic pathway has the potential to achieve the desired coastal hazard risk reduction. Strategies' underpinnings were summarised including: key driving issues, controls in place, priorities/hotspots, strategic aims, anticipated results and community acceptance, trade-offs, adaptation measures (nature, timing and cost of implementation), trigger points, local monitoring and review requirements. An overview of each strategy and related staging is shown in Table 0-1, Table 0-2 and Table 0-3.

Table 0-1: Overview of the preferred strategy and staging for Town Centre & Foreshore

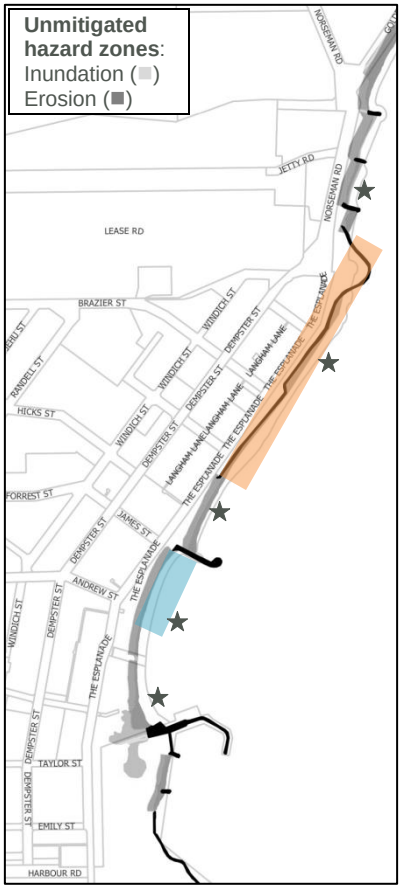
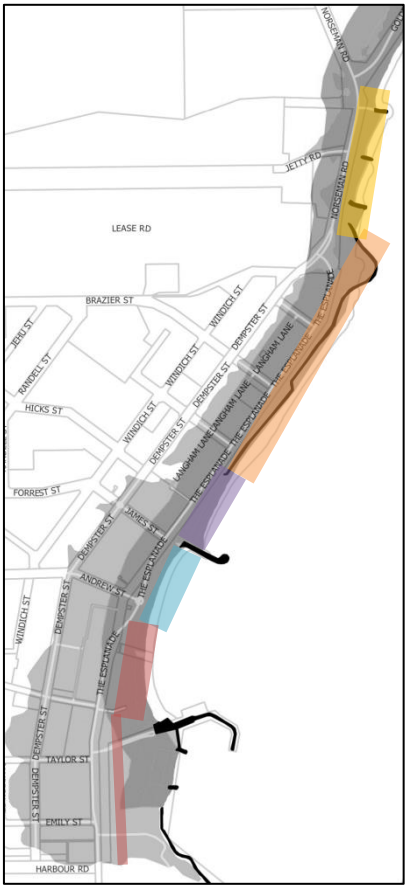
Protect	Sketch of a typical cross-section after implementation of the strategy
	

Defence of existing core strategic assets and intensification of the land use.

Community acceptance is strong despite the progressive loss of natural beach amenity.

Coastal hazard risk reduction sought through adequate planning and protection of the foreshore.

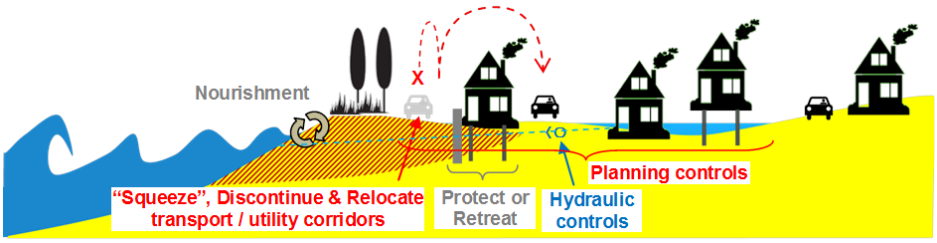
Scenario: Protect

Near Term	Medium Term	Long Term
		

Protective structures (■,■,■,■,■) are added and maintained along the foreshore progressively in repsonse to the erosion of foreshore reserve at key trigger points locations (★). Inundation controls measures are integrated to the protection scheme.

The average captial and maintenance expeditures over time is estimated in the order of $300kpa.

Table 0-2: Overview of the preferred strategy and staging for Castletown

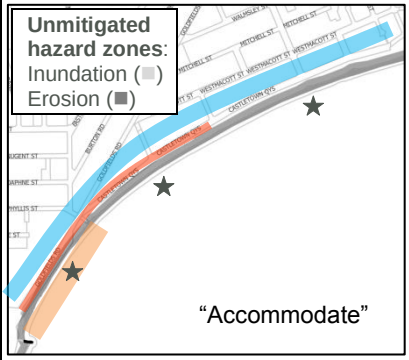
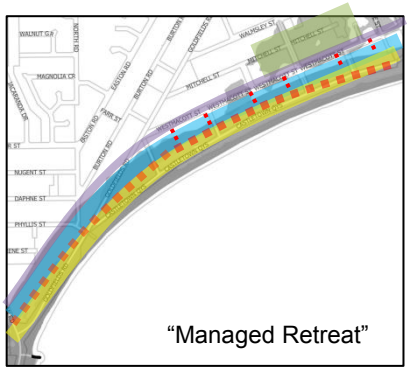
Pathway	Sketch of a typical cross-section after implementation of the strategy
	

Preserve key infrastructure corridors and maintain the land use level.

Community acceptance is neutral due to potential reduction in environmental and social values locally.

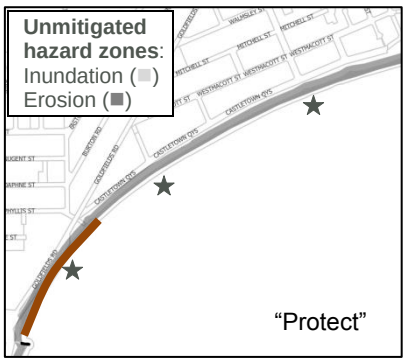
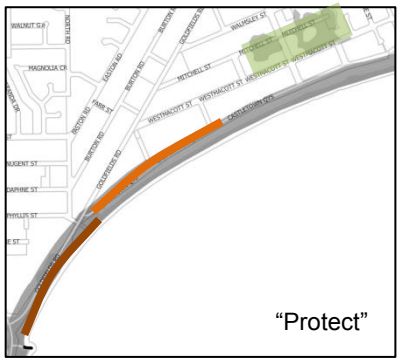
Coasatal hazard risk reduction sought through adequate planning and management of the foreshore.

Scenario : Accommodate / Retreat

Near Term	Medium Term	Long Term
		

The foreshore reserve buffer (■) is maintined in the short term, while "squeezing" the services corridor (■) along foreshore properties (■) in repsonse to the erosion of foreshore reserve at key trigger points locations (★), with the view to redirecting them to the back of properties in the future (■). Inundation controls are integrated to the strategy (■).This strategy could result in a manged retreat of affected services and residential land use (▬) in the long term, as coastal processes are allowed to enfold naturally (■).

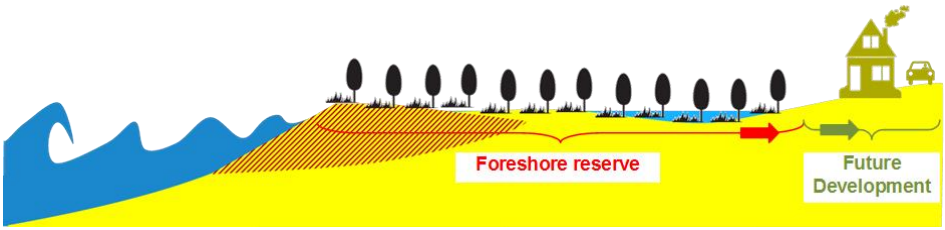
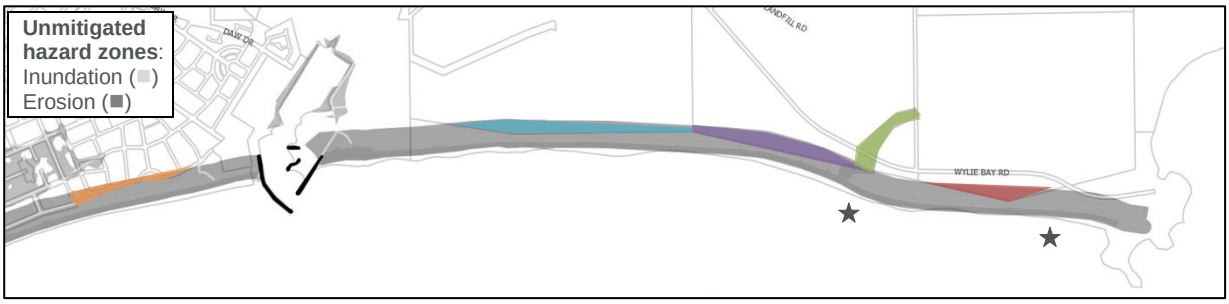
Scenario : Accommodate / Protect

Near Term	Medium Term	Long Term
		

Protective structures (■,■,■) are added along the foreshore progressively in repsonse to the erosion of foreshore reserve at key trigger points locations (★). Inundation controls are integrated to the protection scheme (■).

The average captial and maintenance expeditures over time is estimated in the order of 400kpa.

Table 0-3: Overview of the preferred strategy and staging for Flinders, Bandy Creek & Surround and Wylie Head

Pathway	Sketch of a typical cross-section after implementation of the strategy
	
Avoid the presence of significant assets (other than foreshore reserves) within the hazard zone. Community acceptance of the strategy is strong. Coasatal hazard risk reduction sough through adequate planning of foreshore reserves.	
Scenario : Avoid **Medium to Long Term**	
	
The witdth of foreshore reserves is adjusted locally (, , ,), including inundation controls ( ) to provides sufficent setbacks for future development so that they do not overlap the coastal hazard zone.	

Stakeholder and Community Engagement - A stakeholder and community engagement strategy was developed and implemented. As a result, a high level of communication was undertaken throughout the CHAS process, which not only met the statutory and "standard" consultation requirements with the community and affected landowners about planning matters, but also ensured openness and accountability in the decision-making process. In particular, the overall coastal hazard adaptation strategy, including the consequence rating of erosion and inundation across all asset categories and the appraisal of preferred adaptation pathways benefited from the coordinated review and feedback from representative of the community and key stakeholders (e.g. the Shire Council, Strategic Planning Services manager, Asset Management Services manager, DoP, DoT, DPAW).

Monitoring and Review – At the adaptation measure implementation level, monitoring and review focus on the physical and economical environmental indicators. The systematic collection of information at key locations along the foreshore and its interpretation is necessary to develop recommendations regarding the statues of the coast so that the Shire can take a specific course of actions (e.g. not action required at this stage, implement staged protection works). Also, because protection schemes require maintenance and upgrade to sustain an acceptable level of functionality, access to adequate funding should be

maintained at all times. Deterioration of funding capability may prompt the review of the strategy.

At the CHAS level, monitoring and review completes the risk management framework by ensuring the desired risk reduction is actually realised. Any hindrances with successful implementation may mean the management plans need to be reviewed to see if the obstacles can be overcome or whether other options may be viable and require further investigation.

Conclusion – The preferred pathway strategies for Esperance Bay were complemented with short term action plans aiming at positioning the Shire to take immediate, corrective actions in accordance with the adopted strategy thereby avoiding the serious consequences of not acting quickly enough and/or misallocating resources in the long run.

The procedure outlined in this report should be seen within the context of risk-informed, rather than risk-based, strategic decision making at local government level. Ultimately, coastal development should be further assessed at a smaller scale (e.g. district, locality) and undertaken responsibly, not only with due consideration given to the economically optimal pathway but also to the preservation of key environmental features at the site and its vicinity to ensure that ecosystem services are not compromised by excessive development.

While this report focuses on the use of quantitative risk analyses for establishing preferred coastal hazard risk adaptation pathways for land-use planning purpose, such analyses may also be useful for other related applications. For example, the quantitative risk analysis can form the basis for reviewing the effectiveness of instruments and approaches that could apply to fund the adaption, while addressing concerns about distributive fairness and moral hazard that government guarantees would pose.

1 INTRODUCTION

The Shire of Esperance commissioned BMT JFA Consultants in March 2015 to prepare a Coastal Hazard Assessment Strategy (CHAS) for the Esperance Bay coastal zone, Dempster Head in the west through to Wylie Head in the east, as per the requirements of the Shire's RFT14-14.

Future climate change is likely to cause major impacts and costs on the natural environment and human systems, land development and uses, settlements and infrastructure. In the coastal zone, erosion and inundation hazards may have a detrimental impact on existing and future community values and assets.

Adaptation to such coastal hazards are key issues that need to be addressed so that settlement strategies are appropriately planned for at multiple scales in accordance with the WA planning system in general and the Coastal State Planning Policy SPP2.6 more specifically (Figure 1-1).

The Esperance Coastal Hazard and Vulnerability Assessment (CHVA) completed by BMT JFA in January 2015, initiated the coastal planning process with a primarily focused on the identification of coastal hazards in accordance with SPP2.6. The CHVA Report:

- Discusses how the natural sediment transport processes for the study area have been altered by development as early as 1914;
- Discusses how several artificial beach nourishment programs and coastal protection schemes have been implemented in an attempt to maintain the stability of the Esperance foreshore;
- Describes the key coastal processes influencing the study area; describes the condition of existing coastal structures in the coastal study are and their performance;
- Provides a summary of the historical shoreline movements for each management unit in the study area; and
- Sets out preliminary risk profiles for each management unit by assigning scores to the consequence of each relevant coastal hazard and the likelihood of the coastal hazard impacting the management unit under present day conditions.

Section 5.5 of SPP 2.6 advises that the Shire should now develop a Coastal Hazard Adaptation Strategy (CHAS). The Council of the Shire of Esperance has subsequently commissioned this study to prepare a CHAS to assist strategic decision-making in the creation and protection of value(s) in the coastal zone at local government scale.

The Esperance Coastal Hazard Adaptation Strategy (CHAS) aims at reducing vulnerability to coastal hazards in the developed and planned to be developed coastal zone of Esperance, and build the long-term adaptive capacity of the Esperance community to manage coastal hazard risk. The preparation of the CHAS will assist in managing the environmental significance of the Esperance coastline and the protection, conservation and enhancement of the coastal values of the project area, by ensuring that coastal hazard risk management and adaptation is appropriately planned for. This approach is fully consistent with the State Planning Strategy and recognises the settlement strategies of the Local Planning Strategy. It

is anticipated that the recommendations of the CHAS will be incorporated into the Shires' reviews of the Local Planning Strategy and Scheme commenced in 2014/15.

The Esperance Coastal Hazard Adaptation Strategy (CHAS) has been prepared within a Coastal Hazard Risk Management and Adaptation Planning (CHRMAP) framework consistent with State Coastal Planning guidelines (WAPC, 2014). The CHAS report presents each of the required CHRMAP components as follow:

- Establish The Context (Section 2) – This section sets the framework within which the risk assessment should be undertaken, ensures the reasons for carrying out the risk assessment are clearly known, and provides the backdrop of circumstances against which risks can be identified and assessed;
- Community and Stakeholder Consultation Strategy (Section 2.8) – This section present the strategy adopted to engage with community and stakeholders so that the CHRMAP meet the statutory and 'standard' consultation requirements with the community or affected landowners about planning matters to ensure openness and accountability in the decision-making process;
- Coastal Hazard Risk Identification (Section 3) - This section draws on the work reported in the CHAS and involves finding, recognising, and describing the risks that could affect the achievement of the objectives stated in the CHRMAP context;
- Coastal Hazard Risk Analysis (Section 4) and Evaluation (Section 5) – These sections present a thorough risk assessment in accordance with the international standard and reflect the perceived importance of each risk from the point of view of the Shire;
- Coastal Hazard Risk Adaptation Planning (Section 6) - This section identifies the possible risk mitigation pathways and adaptation options that are applicable to reduce the risk identified in specific part of the study area. It also summarises the adaption option appraisal process, including community and stakeholder preferences;
- Preferred adaptation Strategies (Section 7) – This section characterises each preferred strategic option with a summary of environmental, social and economic considerations and includes a five year implementation plan supporting short term actions within the broader long term strategy;
- Monitoring and Reviewing (Section 8) – This section introduces a set of key performance indicators to assist with tracking the effectiveness of the Shires' CHRMAP process in achieving its objectives.

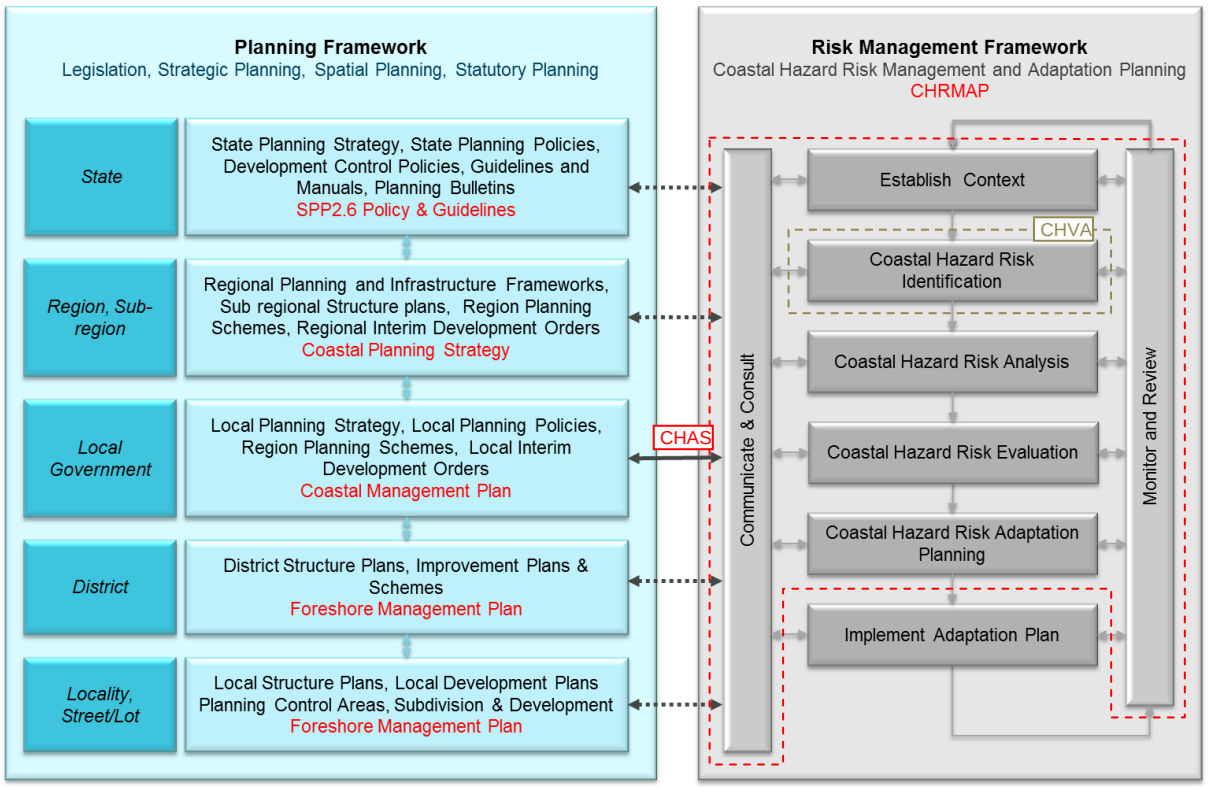


Figure 1-1: Integration of the Coastal Hazard Risk Management and Adaptation Planning framework (CHRMAP) within the broader Planning framework

2 ESTABLISH THE CONTEXT

This section aims at establishing the framework surrounding the Shire's CHRMAP. It seeks to enable stakeholders to start from a common understanding of the CHRMAP process and to reflect the unique present characteristics of the study area.

2.1 Purpose

Coastal zones are vulnerable to adverse impacts from inundation and erosion hazards. The extent of the hazards is expected to increase in the future as it would be exacerbated by the projected sea level rise associated with climate change.

Despite the uncertainty surrounding the magnitude and extent of the adverse impact of combined sea level rise and storm surge, early consideration of coastal hazards and the adaptation and management of appropriate planning responses can provide economic, environmental and social benefits.

2.2 Objectives

The CHRMAP objectives are to

- Meet the requirements of the State Planning Policy No. 2.6 State Coastal Planning Policy (WAPC, 2013) that are to:
  - Ensure that development and the location of coastal facilities takes into account coastal processes, landform stability, coastal hazards, climate change and biophysical criteria
  - Ensure the identification of appropriate areas for the sustainable use of the coast for housing, tourism, recreation, ocean access, maritime industry, commercial and other activities
  - Provide for public coastal foreshore reserves and access to them on the coast
  - Protect, conserve and enhance coastal zone values, particularly in areas of landscape, biodiversity and ecosystem integrity, indigenous and cultural significance
- Provide a long term pathway to reduce vulnerability to coastal hazards and build the long-term adaptive capacity of the Esperance community to manage coastal hazard risk and to adapt
- Identify effective management and adaptation measures and how these can be incorporated into short and longer term decision making
- Be developed through a broad and iterative engagement process that nurtures ownership of the challenges ahead and the pathways to meet those challenges
- Be satisfactory to Department of Planning (DoP), Department of Transport (DoT), Western Australian Planning Commission (WAPC), and Department of Park and Wildlife (DAPW).

2.3 Scope

The hazard zones developed in the CHRMAP focus on the coastal region, meaning the areas of water and land that may be influenced by coastal erosion and storm surge inundation processes (SPP2.6) within the planning horizon/timeframe. It does not include assessment of possible impacts or adaptation strategies outside the coastal zone and mitigating the risks associated with other natural hazards and disasters (e.g. flood, high winds, bush fires, landslides, and earthquakes) considered in the State Planning Policy No. 3.4.

The geographical extent of the CHAS is further described in the Study Area section 2.5.

The planning scale of the CHAS is at local government scale and may recommend further sub-scale investigations, i.e. district, locality, lot.

2.4 Success Criteria

The aim of the CHAS is:

- To reduce vulnerability to coastal hazards in the developed and planned to be developed coastal zone of Esperance, and build the long-term adaptive capacity of the Esperance community to manage coastal hazard risk.

It was envisaged that the CHAS would:

- Propose strategic adaptation measures derived from broad categories of potential adaptation options available for the management of risks from coastal hazards that the urban areas of Esperance will face over the medium to long term, and establish an implementation program
- Consider how or if intensification of development in coastal hazard areas can address the current and future threats
- Assist the Shire to develop and implement coastal strategies and plans, develop community appreciation for the coast as a contested space, facilitate community input into local decision making about coastal planning issues; implement SPP2.6; and implement an "outstanding" coastal planning task (Status of Coastal Planning in Western Australia, WAPC, 2012)
- Focus on the coastal zone, meaning the areas of water and land that may be influenced by coastal processes (SPP 2.6) within the 100 year planning timeframe.

It is anticipated that the implementation of the CHAS will result in:

- Mitigation of the adverse impacts of inundation and coastal erosion of current or proposed development to improve community resilience to these threats
- Improvements in the community's awareness and preparedness for actions required to mitigate future hazard risks
- Maximisation of the functionality of essential community service infrastructure during and immediately following inundation events
- A framework for monitoring the coastal hazards and the effectiveness of the CHAS over the planning period

- Appropriate and contemporary technical support for managing development and land use change in the coastal zone of the project area through planning instruments, other council plans (e.g. Strategic Community Plan, Corporate Business Plan, Long Term Financial Plan, and Infrastructure Asset Management Plan) and community programs
- Appropriate and sustainable enhancement, establishment and maintenance of foreshore reserves in the project area
- The protection, conservation and enhancement of the coastal values of the study area.

2.5 Study Area

The geographic extent of the study area runs from Dempster Head in the west through to Wylie Head in the east, a shoreline of approximately 12km in length. The study area encompasses the developed and planned to be developed coastal zone of Esperance. The study area excludes Esperance Port and DoT vested land at Bandy Creek Boat Harbour.

The Esperance town site is situated at the western end of Esperance Bay and is relatively protected from the dominant south-westerly wave climate of the region by Dempster Head. Exposure increases along the shoreline to the east where wave influence is greater despite protection from the Archipelago of the Recherche.

While the study shorelines of the bay form a coastal compartment at one scale, there are a number of discrete management units within the bay with different hazard and vulnerability profiles that must be considered.

The study area for Esperance Bay CHRMAP is shown in Figure 2-1.

Figure 2-1: *Esperance Coastal Hazard and Vulnerability Assessment* study area (excluding Port Industrial Area and Bandy Creek Boat Harbour as DoT reserve)

2.6 Legislation and Regulations Administered by the Shire

The Shire is functioning and operating under a number of frameworks and constraints that may be directly or indirectly affected by the CHRMAP. An overview of the legislation and regulatory environment, including standards and codes of practice is presented in in the Shire of Esperance Information Statement (July 2013) and in the Shire's Asset Management Plans which introduces the Asset Management Framework and Guidelines that underpin the sustainable delivery of those important services to meet community needs now and in the future.

2.7 Planning Considerations

The Shire, through its Planning Services, is responsible for the guidance of all development and land uses within the Shire through the implementation of orderly and proper planning principles, as they apply to all matters relating to urban and regional planning, including land use structure planning, rezoning of land, subdivision of land, built form and urban design within the Shire.

Planning decisions shall take into account a number of planning instruments and influential authorities, including:

- Local Planning Scheme No. 23 (LPS23)
- Local Planning Scheme No. 24 (LPS24)
- Local Planning Strategy
- Local Planning Policies
- State Planning Policy 3.4 Natural Hazards and Disasters (SPP3.4)
- Department of Water - Floodplain management plans
- State Planning Policy No. 2.6 State Coastal Planning Policy (SPP2.6)
- The Australian Building Codes Board
- Department of Fire and Emergency Services (DFES).

Application of the relevant provisions and planning controls are important tools in the implantation of adaption strategies in response to projected coastal hazard risk.

2.7.1 *Local Planning Scheme No. 23 (LPS23)*

The Shire of Esperance Local Planning Scheme No. 23 (LPS 23, the Scheme) applies to the Scheme Area which covers the whole of the local government district of the Shire of Esperance as shown on the Scheme Map and includes land, waterways, the ocean foreshore to low watermark and all the outlying islands of the Recherche Archipelago.

The purposes of the Scheme are to –

(a) Set out the local government's planning aims and intentions for the Scheme area;

(b) Set aside land as reserves for public purposes;

(c) Zone land within the Scheme area for the purposes defined in the Scheme;

(d) Control and guide land use and development;

(e) Set out procedures for the assessment and determination of planning applications;

(f) Make provision for the administration and enforcement of the Scheme; and

(g) Address other matters set out in the Seventh Schedule to the Planning and Development Act.

The Scheme divides the local government district into zones to identify areas for particular uses and identifies land reserved for public purposes. Most importantly, the Scheme controls the types of uses and development allowed in different zones. There are particular controls included for heritage and special control areas.

Part 4 of the Scheme set out the objectives of distinct zones and the uses permitted in the Scheme Area in the various zones (i.e. Residential Zone, Tourist Residential Zone, Central Area Zone, Shops & Offices Zone, Country Town Zone, Industry – Business Zone, Industry – General Zone, Rural Residential Zone, Rural Smallholdings Zone, Agriculture – General Zone, Rural Unsettled Zone, Future Residential Zone, Future Commercial/Industrial Zone, Tourist Zone)

Part 5 of the Scheme sets out the general requirements which apply to land use and development within the Scheme area and the specific requirements which apply to particular uses and forms of development, such as site requirements, access, parking, building design, setbacks and landscaping, for residential, commercial, industrial, rural and other uses.

Unless otherwise provided for in the Scheme, the development of land for any of the residential purposes dealt with by the Residential Design Codes is to conform with the provisions of those Codes.

Coastal Development

Coastal Development includes but is not limited to rezoning, structure planning, subdivision, strata subdivision and/or development of coastal land, as determined by Council and may apply in any zone. In this case, the following provisions apply:

5.21.1.1) All coastal development is to comply with the provisions of State Planning Policy 2.6 - State Coastal Planning Policy.

5.21.1.2) In accordance with section77(b) of the Planning and Development Act 2005, the provisions of State Planning Policy 2.6 - State Coastal Planning shall apply as if they were part of this Scheme.

5.21.1.3) An application for planning approval will be required for Coastal Development, notwithstanding clause 8.2 of this Scheme.

As noted in clause 4.11, Section 191 of the Planning and Development Act enables the local government to purchase, or, with the consent of the Governor, compulsorily acquire land for the purpose of a Local Planning Scheme, subject to Part 9 of the Land Administration Act 1997, that section and the Scheme.

2.7.2 *Local Planning Scheme No. 24 (LPS24)*

The Shire of Esperance Local Planning Scheme No. 24 is a draft Scheme that will apply to the Scheme Area that covers the whole of the local government district of the Shire of Esperance as shown on the Scheme Map and includes land, waterways, the ocean foreshore to low watermark and all the outlying islands of the Recherche Archipelago. This Scheme will replace LPS23 in due course.

Local Planning Scheme No. 24 along with a reviewed Local Planning Strategy will incorporate recommendations and outcomes contained within the CHRMAP.

2.7.3 *Local Planning Strategy*

The Shire of Esperance Local Planning Strategy (the Strategy) guides the management of population growth, land use planning and development over a 10 to 15 year period, to balance the needs and expectations for varying lifestyles, economic and community development of the Shire and to ensure appropriate management of the built and natural environment that makes the Shire of Esperance a unique place to live.

The Strategy consists of both written text and maps, illustrating the future direction for growth and land use within the Local Government area. The Strategy provides the basis for the zoning and provisions of the Shire of Esperance Local Planning Scheme No. 23 (LPS 23). LPS 23 provides the statutory framework to achieve the vision and strategies of the Strategy.

Although the Strategy does not form part of the LPS 23, the Council and the State Government (e.g. Department of Planning, Western Australian Planning Commission, the Minister for Planning and the State Administrative Tribunal in particular) are required to have due regard to the direction set by the Strategy when considering applications for development, subdivision or amendment to the Scheme, as the Strategy is the basis upon which the local content associated with the statutory provisions of the LPS 23 has been developed.

The Strategy was endorsed and took effect on 4 February 2010. Maps extracts are shown in Figure 2-2.

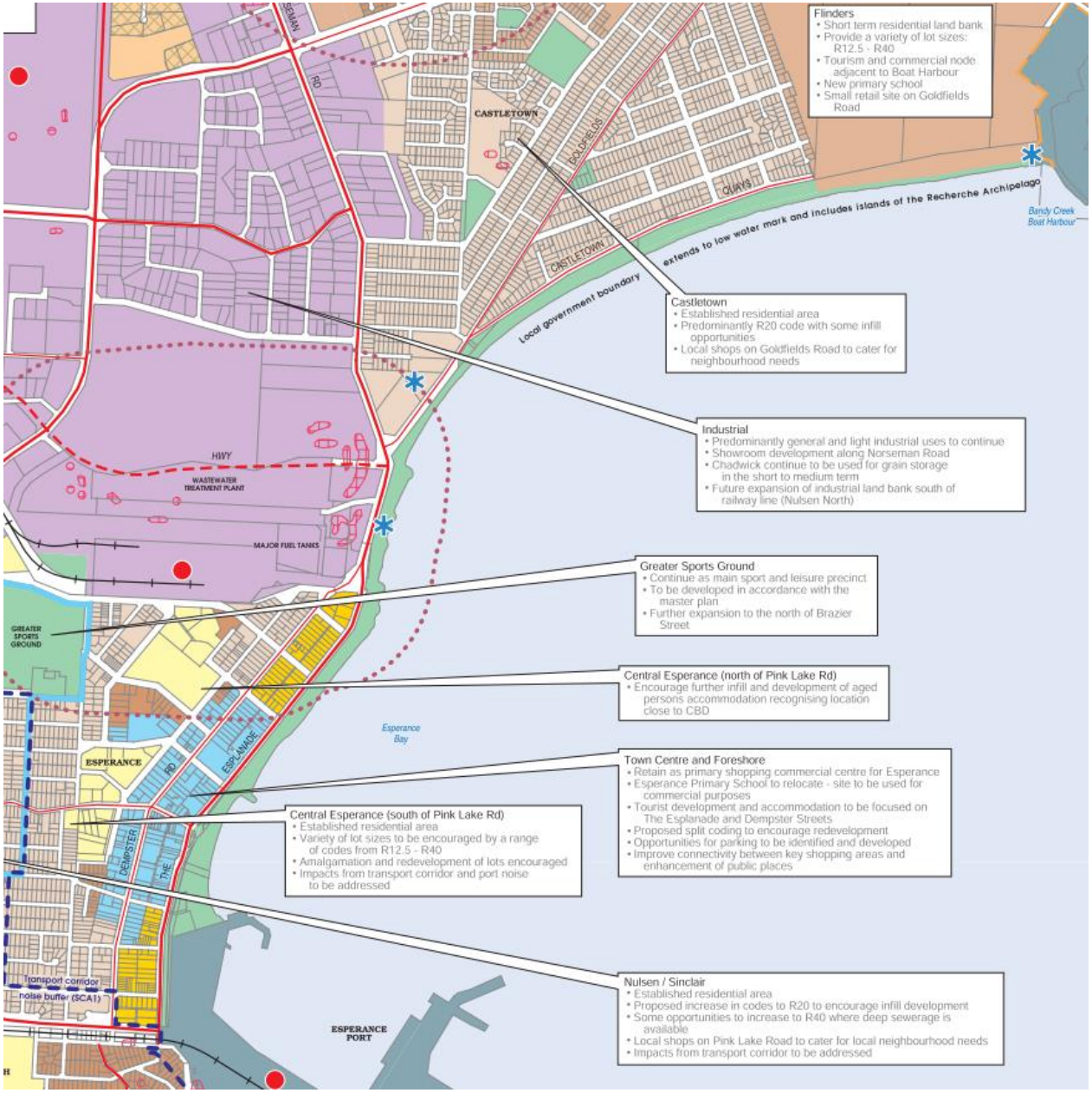


Figure 2-2: Extract of Shire of Esperance Local Planning Strategy maps (4 February 2010)

2.7.4 *Local Planning Policies*

Local Planning Policies are guidelines used to assist the local government in making decisions under the Scheme and may address land use as well as development requirements. Although Local Planning Policies are not part of the Scheme they must be consistent with, and cannot vary, the intent of the Scheme provisions, including the Residential Design Codes. If a provision of a Local Planning Policy is inconsistent with the Scheme, the Scheme prevails.

2.7.5 *State Planning Policy 3.4 Natural Hazards and Disasters (SPP3.4)*

The State Planning Policy 3.4 Natural Hazards and Disasters is made under Section 26 of the Planning and Development Act 2005. It applies to the planning and development of land that may be affected by natural disasters and hazards.

A number of natural hazards are addressed in the policy, including flood, bush fire, landslides, karst, earthquakes, cyclone, coastal erosion, severe storms, storm surge and tsunami.

Flood

In the case of flood, proposed development on a floodplain is considered acceptable with regard to major flooding as long as it does not produce an adverse impact on surrounding development and it has an adequate level of flood protection. Land uses in flood prone areas should not allow development that will obstruct floodways.

The 100 year average recurrence interval flood should be used as the defined flood event. The floodplain of a defined flood event should be used as the area over which controls on land use and development need to recognise the impacts of flooding.

All habitable, commercial and industrial buildings should have their floor levels above the level of the defined flood event. The Department of Water is the state government's lead agency in floodplain mapping and floodplain management strategies.

Storm surge

Where storm surge studies have been undertaken and show that inundation may occur, new permanent buildings should be constructed to take account of the effects of storm surge (including wind and wave set-up).

In areas where storm surge studies have not been undertaken, but evidence is available to demonstrate vulnerability to inundation, any development proposals should be supported by studies that demonstrate inundation will not occur.

Reference should also be made to the state coastal planning policy (SPP 2.6), for assistance in determining appropriate setbacks in coastal locations.

Coastal erosion

Development in areas affected by coastal processes, especially erosion, should take into account the requirements contained in the state coastal planning policy (SPP 2.6).

2.7.6 *Department of Water - Floodplain management plans*

Water Facts 14 Water and Rivers Commission July 2000 highlight the principles of flood plain management. In particular, floodplains should be managed for the benefit of the whole community so that the risk and damages are minimised and environmental values are protected. Sound floodplain management should:

- Ensure land use minimises flood risk and damage costs;
- Ensure all three levels of government and the local community accept their responsibilities in floodplain management;
- Ensure appropriate floodplain mitigation measures minimise damage and are acceptable to the local community;
- Promote the use of non-structural rather than structural mitigation measures where possible;
- Ensure floodplain management measures have beneficial economic, social and environmental outcomes; and
- Provide flood forecasting and warning systems and emergency management arrangements to help minimise the impact of flooding

The typical recommended floodplain management strategy includes:

- Development (i.e. filling, building, etc.) that is located within the flood fringe (i.e. areas are generally covered by still or very slow moving waters during a 100 year ARI flood) is considered acceptable with respect to major river flooding. However, a minimum habitable floor level of 0.50m above the adjacent 100 year flood level is recommended to ensure adequate flood protection.
- Development (i.e. filling, building, etc.) that is located within the floodway and is considered obstructive to major river flows, thereby affecting areas which may not have been previously affected, is to be avoided wherever possible.

2.7.7 *State Planning Policy No. 2.6 State Coastal Planning Policy (SPP2.6)*

The State Planning Policy No. 2.6 State Coastal Planning Policy (SPP2.6) is a State Planning Policy made under Part 3 of the Planning and Development Act 2005.

Section 77 of the Planning and Development Act 2005 requires local governments, when preparing or amending a local planning scheme, to have due regard to this State Coastal Planning Policy where it affects its district. The local governments may decide to make a new or amended scheme consistent with particular aspects of this State Coastal Planning Policy, or include in a new or amended scheme a provision that this State Coastal Planning Policy is to be read as part of the scheme.

SPP2.6 applies state-wide and draws on and is supported by other WAPC state planning policies, development control policies and guidelines relevant to the coastal zone.

For coastal matters this State Planning Policy No. 2.6 State Coastal Planning Policy is to be viewed as the higher order and prevailing policy.

SPP2.6 objectives are to:

- Ensure that development and the location of coastal facilities takes into account coastal processes, landform stability, coastal hazards, climate change and biophysical criteria;
- Ensure the identification of appropriate areas for the sustainable use of the coast for housing, tourism, recreation, ocean access, maritime industry, commercial and other activities;
- Provide for public coastal foreshore reserves and access to them on the coast; and
- Protect, conserve and enhance coastal zone values, particularly in areas of landscape, biodiversity and ecosystem integrity, indigenous and cultural significance

Summary of Coastal Planning Policy (SPP2.6) Measures

- General
  - Comply with the policy measures in planning decisions and supporting instruments, including:
    - [1] Local and regional planning strategies
    - [2] Structure plans
    - [3] Schemes
    - [4] Subdivisions
    - [5] Strata subdivisions
    - [6] Development applications
    - [7] Coastal planning strategies
    - [8] Foreshore management plans
- Development and settlement
  - Encourage concentration of development in and around existing settlements
  - Consider existing infrastructure capacity, conditions and future needs
- Coastal Hazard Risk Management Adaptation Planning (CHRMAP)
  - Require CHRMAP by responsible authority and/or proponent
  - Disclosure of identified coastal hazards to those likely affected
  - Reduce unacceptable coastal hazards risk through adequate adaptation measures
  - Monitor coastal hazards risk
  - Review CHRMAP regularly
- Infill development
  - Choose the least vulnerable portion of the site
- Coastal protection
  - Allow new coastal protection as measure of last resort
  - Allow repair and upgrade of existing coastal protection as measure of last resort

  - Consent to no significant environmental impact
  - Secure whole of life funding requirements
  - Integrate with planning decision
  - Support public interest
  - Protect non expendable high value property and infrastructure
  - Consider future protection requirements of adjoining development
- Public interest
  - Engage with community throughout CHRMAP process
  - Provide public access to the coast
  - Support public ownership of the coast
  - Support the removal of existing unlawful dwellings
- Coastal foreshore reserve
  - Accommodate a range of values and functions, including:
    [1] Conservation
    [2] Buffer against coastal hazards (see spp2.6 schedule one - calculation of coastal processes)
    [3] Public access
    [4] Recreation
  - Integrate with planning decision
  - Is clearly separated from private land
- Precautionary principal
  - Not use the lack of certainty as a reason to postpone measures to prevent environmental degradation
  - Demonstrate
    [1] Low risk of environmental impact by proponent; or
    [2] Show that the risk can be managed

SPP2.6 Schedule One – Calculation of Coastal Processes

SPP2.6 Schedule One provides guidance for calculating the component of the coastal foreshore reserve required to allow for coastal processes. Factors other than coastal processes will often require additional foreshore reserve width and should be considered on a case-by-case basis.

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) by allowing for landform stability, natural variability and climate change. Notwithstanding this, where the effects of coastal processes would ordinarily preclude development, but where application of those policy measures are not realistic nor feasible, coastal hazard risk

management and adaptation planning (CHRMAP) should be undertaken to reduce the risk from coastal hazards over the full planning timeframe, to an acceptable level.

CHRMAP should be undertaken by the responsible management authority and/or proponent where existing or proposed development or landholders are in an area at risk of being affected by coastal hazards over the planning timeframe.

CHRMAP should include as a minimum, a process that establishes the context, vulnerability assessment, risk identification, analysis, evaluation, adaptation, funding arrangements, maintenance, monitoring and review, and communicate and consult. Where risk assessments identify a level of risk that is unacceptable to the affected community or proposed development, adaptation measures need to be prepared to reduce those risks down to acceptable or tolerable levels.

The Western Australian Planning Commission (WAPC) and the Department of Planning published guidelines which provide more detail on CHRMAP to assist statutory decision makers to:

- Consider coastal hazards and to evaluate their likelihood and the consequence for specific assets;
- Identify realistic and effective management and adaptation responses to those risks; and
- Prioritise the management and adaptation responses.

Erosion

On a sandy coast, the allowance for erosion should be measured from the active limit of the shoreline under storm activity and calculated as the sum of the factors:

- Allowance for current risk of storm erosion under three successive storm events with a 1% annual exceedance probability (AEP) or 100 years average return interval (ARI)
- Allowance for historic shoreline movement trends
- Erosion caused by future sea level rise
- Allowance of 0.2m per year for uncertainty over the planning timeframe.

Storm surge

The allowance for the current risk of inundation should be the maximum extent of storm inundation, defined as the peak steady water level (including wind and wave set-up, Figure 2-3) plus wave run-up that have a 0.2 percent or one-in-five hundred probability of being equaled or exceeded in any given year over the planning time frame.

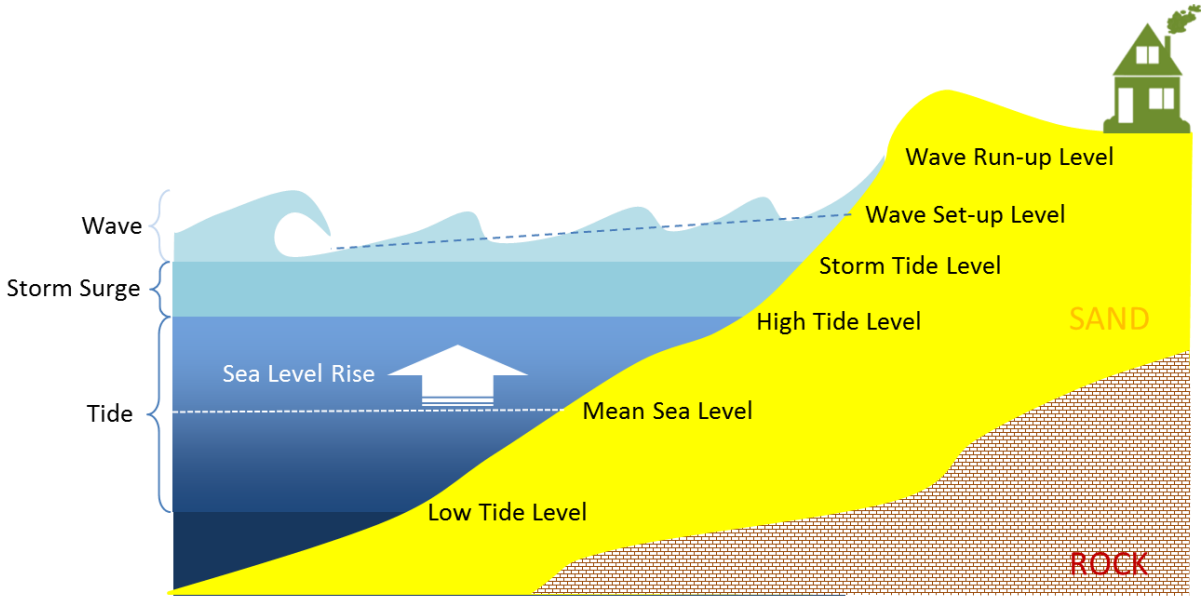


Figure 2-3: Contributions to coastal sea level from tides, storm surge and wave processes

Sea level rise

The WA Planning Commission Statement of Planning Policy No. 2.6: State Coastal Planning Policy provides guidance for the incorporation of mean sea level change in the determination of a coastal setback for new development.

As the rate of sea level rise is projected to increase through the 21st century, it is recommended that the IPCC AR4 projections for sea level rise up to 2100 be extended to 2110 to provide an estimate for a 100 year planning time frame. As a simple estimate it is recommended that this be done by assuming that the rate of global average sea level rise beyond 2100 will be a continuation of the rate of rise between 2090 to 2100, refer to Figure 2-4.

The guidance does not consider the changes to extreme water levels which will occur as a result of sea level rise. However, future sea level rise will increase the frequency, and potentially severity, of existing storm inundation events and these impacts will need to be considered for new and existing development.

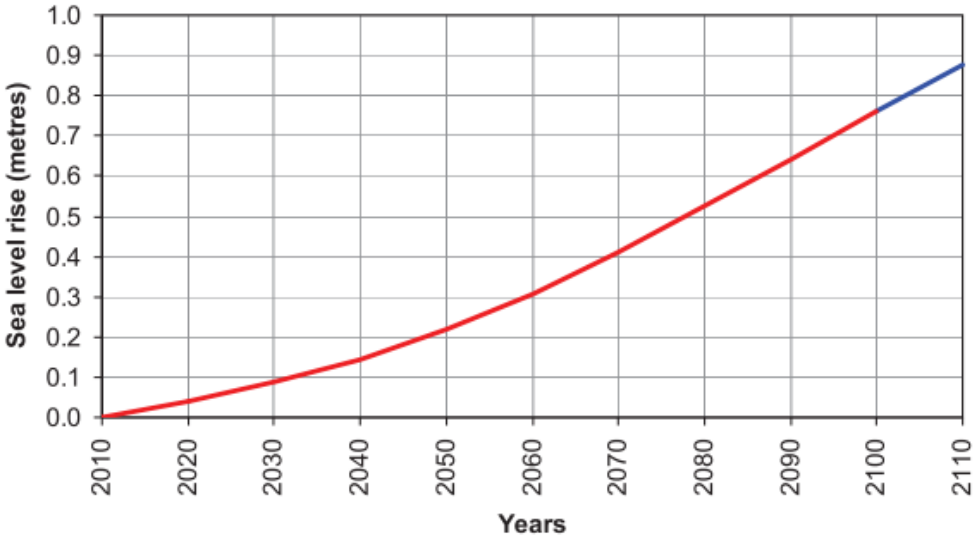


Figure 2-4: Recommended allowance for sea level rise in coastal planning for WA (from Sea Level Change in Western Australia, Department of Transport, Coastal Infrastructure, Coastal Engineering Group, 2010)

2.7.8 *The Building Code of Australia (BCA)*

Land use planning and the Building Code of Australia (BCA) often work closely in tandem. Coastal hazards impose loads and risks to buildings for which design events with annual probabilities of exceedance are specified. Notwithstanding reliance cannot be placed on building controls to guarantee occupant safety in all cases, building standards have undergone constant review, particularly after major hazard events and through research, to ensure adequate levels of health and safety are maintained for the community.

The Australian Building Codes Board (ABCB) is a Council of Australian Government (COAG) standards writing body that is responsible for the National Construction Code (NCC) which comprises the Building Code of Australia (BCA) and the Plumbing Code of Australia (PCA). It is a joint initiative of all three levels of government in Australia and was established by an Inter-government agreement (IGA) signed by the Commonwealth, States and Territories on 1 March 1994.

The Office of the Australian Building Codes Board recently published *An Investigation of Possible Building Code of Australia (BCA) Adaptation Measures for Climate Change (2010)*, which includes a chapter dealing with the impacts of sea level rise and storm surge. This was followed by *Proposals to address the risk of floods to new residential buildings (2012) Regulation Impact Statement* which was prepared with the assistance of a consultant and in accordance with the requirements of *Best Practice Regulation: A Guide for Ministerial Councils and National Standard Setting Bodies*, endorsed by the Council of Australian Governments in 2007. Its purpose is to inform stakeholders and provide a basis for decision-making by the Board in its consideration of proposals to address the risk of floods to new residential buildings.

ABCB provides a summary of the existing requirements of the States and Territories. For Western Australia, the provisions include:

- Section 23 of the Town Planning (Buildings) Uniform General By-laws 1989, under the Planning and Development Act 2005, states that “a building shall not be constructed on land defined by the council as being liable to flooding or inundation.”
- Local governments that face the risk of flooding incorporate provisions into their individual Town Planning Schemes (TPS) to deal with the risk. Common ways the risk is dealt with include:
  - The requirement for developments to receive planning approvals;
  - Providing councils with the power to not issue approvals in flood risk areas;
  - Ability for councils to consult other government departments; and
  - Giving councils the responsibility to determine the finished floor level (FFL).

The recommended NCC provisions apply to flood hazard areas designated by local councils and include:

- Performance Requirements under which industry may propose an “Alternative Solution” for a new residential building to resist the actions of flood. These Performance Requirements apply to any flood – flash floods or onset floods – and must be effective in resisting flood actions in the local topography.
- Deemed-to-Satisfy (DTS) standard, comprising a set of specific provisions on the construction requirements for new residential buildings in flood hazard areas, incorporated into the NCC as a new standard. Note that the DTS standard is limited to floods, also known as “rising water”, where the rate of flow does not exceed 1.5 meters per second.

Performance Requirements

The proposed provisions are as follows:

- “A building in a flood hazard area, to the degree necessary, must be designed, constructed, connected and anchored to resist flotation, collapse or significant permanent movement resulting from the action of hydrostatic, hydrodynamic, erosion and scour, wind and other actions during the designed flood event or lesser event in accordance with the requirements of this standard.”

To satisfy the above requirements, the proposed provisions include consideration of the following areas:

- Flood actions;
- Elevation requirements;
- Foundation requirements;
- Requirements for enclosures below the flood hazard level;
- Requirements for structural connections;
- Material requirements;
- Flood proofing;
- Requirements for utilities;
- Requirements for egress; and

- Impacts to other structures and properties.

Deemed-to-Satisfy (DTS) Standard

The proposed NCC provisions also provide a technical Deemed-to-Satisfy (DTS) standard designed to meet the above Performance Requirements for new construction in flood hazard areas.

The technical standard will apply to the design and construction of Class 1, 2, 3, 4, 9a and 9c buildings, and is focused on reducing the risk of death or injury of building occupants as a result of the building being subjected to certain flood events.

The DTS standard is limited to situations where the maximum flow velocity is no greater than 1.5 meters per second. Where a flood flow velocity exceeds this value it becomes more difficult to develop appropriate DTS construction criteria because the higher hydrostatic and hydrodynamic actions, together with increased risk of scour and foundation damage, preclude the use of traditional construction methods. However, where the flood flow velocity exceeds 1.5 meters per second, the Performance Requirements still apply and competent practitioners (e.g. hydrologists and engineers) would be able to develop an appropriate design solution that meets the applicable Performance Requirements.

Table 2-1 below summarises the key elements of the proposed DTS standard to address each identified life safety risk. A full copy of the draft standard is included as Appendix D to *Proposals to address the risk of floods to new residential buildings (2012) Regulation Impact Statement*, however, this standard does not apply to parts of flood hazard areas with the following characteristics:

- The part of the flood hazard areas is subject to mudslide or landslide during periods of rainfall and runoff
- The part of the flood hazard areas is subject to storm surge or coastal wave action.

Table 2-1: Deemed-to-Satisfy elements contained in the proposed provisions

Risk Area	DTS Standard
Injury or fatality to occupants from structural failure of a building due to the effects of water at rest or in motion.	Foundations and footings of structures must provide the required support to prevent flotation, collapse or permanent movement resulting from flood action. This is to be determined by a qualified engineer at the design stage. Compliance will require consideration of geotechnical conditions, footing depth, piers, post, columns or pole; and adequate design for use of slabs-on-ground. This is to be determined by a qualified engineer at the design stage. Fill must be designed to ensure support under conditions of flooding. Strength of walls must be able to resist hydrostatic and hydrodynamic actions. Water resistant materials to be used for structural items such as bracing, columns, connections, fasteners, wall framing members, etc. Impacts from horizontal loads caused by debris action must be determined using a rational approach at the most critical location at or below the defined flood level.
Health issues due to the loss of amenity to the household from inundation	Finished floor level of • Habitable room must be above the flood hazard level, which includes any required freeboard (i.e. 1:100 year inundation level +0.5m freeboard in Western Australia) • Enclosed non-habitable rooms must be no more than 1.0m below the defined flood level.
Injury or illness caused by loss of utilities	Increase protection for utilities, including: • Utilities must not be placed below the flood hazard level unless they have been designed to cope with flood water inundation; • Buried systems protected from scour and erosion; and • Greater level of fixing of HVAC equipment.
Injury, illness or fatalities by failure of a structure or auxiliary structure resulting in additionally damage being caused to the same property or to another property	Decks, patios, stairways, ramps, etc. are to be structurally adequate to not reduce the structural capacity of the building they are attached to.
Injury or illness caused by not being able to safely evacuate	Egress from a balcony, verandah, deck, door, window or the like must be available to allow a person to be rescued by emergency services personnel

2.7.9 *Department of Fire and Emergency Services (DFES)*

As Western Australia's leading hazard management agency, the Department of Fire and Emergency Services (DFES) (formerly the Fire and Emergency Services Authority of WA) performs a critical role coordinating emergency services for a range of natural disasters and emergency incidents threatening life and property.

DFES was established to improve the coordination and planning of emergency services in Western Australia.

DFES has adopted an 'all hazards' approach to emergency management, working in partnership with the community and other government agencies to:

- Prevent;
- Prepare for;
- Respond to; and
- Recover from natural disasters and emergencies.

The Department of Fire and Emergency Services (DFES) was established on 1 January 1999 under the Fire and Emergency Services Act of 1998.

DFES administers the following Acts on behalf of the Minister for Emergency Services; Corrective Services; Small Business; Veterans:

- Fire and Emergency Services Act of 1998
- Fire Brigades Act 1942
- Bush Fires Act 1954
- Emergency Services Levy Act 2002
- Emergency Management Act 2005

Local governments also have responsibilities under the Bush Fires Act 1954 in relation to preventing and responding to bushfires in addition to establishing and running volunteer bush fire brigades.

2.8 Community and Stakeholder Consultation Strategy

In its mission statement (July, 2013), "the Shire of Esperance will listen to its people and provide services in a caring, responsive and consultative manner through Councillors and staff that are well equipped to meet community needs, show leadership in development at regional and higher levels".

In this context, stakeholder engagement can be mutually beneficial for the Shire and its stakeholders.

2.8.1 *Benefits of Stakeholder Engagement*

Effective stakeholder engagement enables better planned and more informed policies, projects, programs and services. For stakeholders, the benefits of engagement include the opportunity to contribute as experts in their field to policy and program development, have their issues heard and participate in the decision-making process. For the Shire, the benefits of stakeholder engagement include improved information flows by tapping into local

knowledge and having the opportunity to 'road-test' policy initiatives or proposals with stakeholders. The earlier stakeholders are engaged, the more likely these benefits are to be realised.

Table 2-2: Benefits of stakeholder engagement

Benefits for the Shire include:	Benefits for stakeholders include:
• Higher quality decision-making • Increased efficiency in and effectiveness of service delivery • Improved risk management practices – allowing risks to be identified and considered earlier, thereby reducing future costs • Streamlined policy and program development processes • Greater engagement with stakeholder interests – ensuring services are delivered in collaboration with stakeholders and provide outcomes which meet community needs • Enhanced community confidence in projects undertaken • Enhanced capacity to innovate	• Greater opportunities to contribute directly to policy and program development • More open and transparent lines of communication – increasing the accountability of Government and driving innovation • Improved access to decision-making processes, resulting in the delivery of more efficient and responsive services • Early identification of synergies between stakeholder and Government work, encouraging integrated and comprehensive solutions to complex policy issues

2.8.2 *Identification of Stakeholders*

The Shire interacts with a broad range of stakeholders, from key stakeholders who have an interest in the study area, to those who are recipients of the Shire services or subject to its regulations.

For the matters related to the CHRMAP, stakeholders have been identified in collaboration with the Shire. This included the principal (the Shire), stakeholders central or internal to the Shire and Stakeholders external to the Shire, such as various government levels, utilities and services providers, community groups. A list of key contact is provided in Table 2-3.

2.8.3 *Purpose of Stakeholder Engagement*

The Community and Stakeholders Consultation Strategy has an overarching influence throughout the CHRMAP project delivery.

Some key objectives in the consultation process are to:

- Facilitate greater understanding and appreciation of issues to be resolved through the CHRMAP;
- Confirm values at risk due to coastal hazard;
- Influence the appraisal of adaptation options;
- Get feedback on the draft strategy; and

- Obtain council approval for the of CHRMAP.

2.8.4 *Stakeholder Engagement Plan*

Engagement Level

Considering the range of stakeholder levels of influence over and interest in the CHRMPA outcomes, the Community and Stakeholders Consultation Strategy allows for multiple level of engagement, as advocated by the International Association of Public Participation (IAP2), including:

- Informing;
- Consulting with;
- Involving;
- Collaborating with; and
- Empowering stakeholders.

Engagement Method(s)

There are a number of stakeholder engagement methods that can be applied at different stages of the CHRMAP. Here the following methods were selected:

- Fact sheet / Newsletter
- Expert panel / Public meeting
- Workshop / video conference
- Advisory committee : Review of adaptation plan
- Participatory editing : Reviews of CHRMAP documentation

These methods are considered appropriate for the project constraints (e.g. scope/quality, schedule and budget) and draw on resources and insight available within the project team. In particular, the Shire assisted in resourcing the recording of comments and feedback from stakeholders. Table 2-4 provides the selected methods of engagement, outlining their benefits and limitations.

Engagement Plan

The engagement plan is tabulated in Table 2-5. It summarises the following elements:

- Level of Engagement
- Goal
- Promise to stakeholder
- Key Message
- Stakeholder
- Method of engagement
- Outcome
- Responsibility / Resources

- Timeframe

Table 2-3: Key Stakeholder List

Position	Stakeholder	Scope	Representative/coordinator
Stakeholders central or internal to the Shire	Shire of Esperance Statutory Services	Responsible for health services such as water and food inspection, immunisation services, toilet facilities, noise control and meat inspections and animal control, building services, including rangers, inspections, licensing, certification and enforcement, planning and development approval and environmental services.	Executive Manager Statutory Division Richard Hindley 9071 0631 Richard.Hindley@esperance.wa.gov.au
	Shire of Esperance Community Services	Responsible for a range of services within the Shire, including senior citizens centre, home and community care centre, museum, library, culture, volunteer resource centre, community development funds and events.	Executive Manager Community Division Rod Hilton 9071 0654 rod.hliton@esperance.wa.gov.au
	Shire of Esperance Asset Management	Responsible for infrastructure and property services, local roads, bridges, footpaths, drainage, asset management, airport, waste collection and recycling, cemeteries, foreshore erosion management and development, environmental services recreation reserves and playgrounds.	Acting Director Asset Management Mathew Walker 9071 0685 mathew.walker@esperance.wa.gov.au
Stakeholders external to the Shire	Public and Community	Small businesses, local residents, special interest groups, visitors.	Executive Manager Statutory Division Richard Hindley 9071 0631 Richard.Hindley@esperance.wa.gov.au

Position	Stakeholder	Scope	Representative/coordinator
	Goldfields Esperance Development Commission	Responsible for encouraging and promoting economic and social activity in the Goldfields-Esperance region of Western Australia.	District Manager Shane Liddelow 9083 2202 shane.liddelow@gedc.wa.gov.au
	Department of Parks and Wildlife	Responsible for protecting and conserving the State's natural environment on behalf of the people of Western Australia.	District Manager Robert Blok 9083 2101 robert.blok@dpaw.wa.gov.au
	Department of Planning	Responsible for planning the State's cities and towns, transport networks, parks and recreation reserves, and a range of social and physical infrastructure well-ahead of their predicted need.	Senior Planning Officer Ben Bassett 6551 9343 Ben.Bassett@planning.wa.gov.au
	Department of Lands	Responsible for the management of the State's Crown land and pastoral estates.	Manager Goldfields Esperance and Wheatbelt Chris Ziatas 6552 4549 chris.ziatas@lands.wa.gov.au
	Department of Fire and Emergency Services	Performs a critical role coordinating emergency services for a range of natural disasters and emergency incidents threatening life and property.	Esperance regional office Secretary 9071 3393

Position	Stakeholder	Scope	Representative/coordinator
	Department of Transport	Focuses on operational transport functions and strategic transport planning and policy across the range of public and commercial transport systems that service Western Australia.	Coastal Management Officer Karl Illich 9435 7500 Karl.ilich@transport.wa.gov.au
	Esperance Ports Sea and Land	Oversees the operations of the Port of Esperance, a major exporter of nickel concentrate, iron ore and grain and importer of fuel and fertilizer.	Acting Chief Operating Office and General Manager of Operations Neil Pearson 9072 3376 0447 993 242 npearson@epsl.com.au
	Horizon Power	Responsible for generating, procuring, distributing and retailing electricity to regional Western Australia.	District Manager Layton Baker 9072 3408 layton.baker@horizon.power.com.au
	Telstra	Responsible for the provision of telecommunication services. As the National Broadband Network (NBN) is built across Australia, NBN will take over (in most areas) the copper-wire network previously owned by Telstra.	Area General Manager WA South & Central Boyd Brown 9726 7312 Boyd.M.Brown@team.telstra.com

Position	Stakeholder	Scope	Representative/coordinator
	Water Corporation	Principal supplier of water, wastewater and drainage services in Western Australia	Capability Manager Ken Pearce 9842 4233 -
	Esperance Gas Distribution Company Pty Ltd	Responsible for gas trading and distribution through a system of pipelines, mains, gas service pipes, and any associated apparatus, facilities, structures, plant, or equipment.	Esperance Area Manager Neville Selby 9072 1422 www.esperance-energy.com.au
	Esperance Bay Yacht Club	The club has a marina, hard stand, parking, bar and dining with views across the Esperance Bay and facilities for private and business functions.	Secretary Sue Elliot 90713323 ebyc@westnet.com.au

Table 2-4: Selected methods of engagement

Level of Engagement	Method	Benefits	Limitations
Inform	**Fact sheets/Newsletter** • Usually brief, paper based on online documents which summarises the 'facts'. • Should be tailored to the relevant needs of the recipients.	• Able to reach a large number of stakeholders in a simple, efficient way • Can be targeted to a particular stakeholder group and developed into languages other than English	• May not be accessible to people with visual impairment or low literacy levels
Consult	**Expert panel / Public meeting** • Used to gather concentrated opinions from a range of experts on a particular issue. • A meeting open to all interested, rather than those specifically invited.	• Focus intently on a specific subject • Produce in-depth analysis • Experts can often be objective • Opportunity for stakeholders to raise issues and ask questions • Opportunity to gather support for new ideas and build relationships • Communicate with large groups	• The process needs to be carefully focused • Breadth may be limited • May be too 'exclusive'
Involve	**Workshop** • Facilitated events designed to enable stakeholders to work actively and collaboratively on a common problem or task.	• Discussing complex issues, analyzing competing options and generating ideas • Encourages joint working and problem solving • Builds ownership of results	• The process needs to be carefully focused

Level of Engagement	Method	Benefits	Limitations
Collaborate	**Advisory committee** • Committees made up of representatives from a profession, industry, peak bodies, etc. who are appointed to provide detailed or specific information	• Value a wide range of technical and local expert knowledge • Support a range of engagement processes (ie. research) • Enables information to be distributed to different stakeholder groups	• May be too brief for people to provide their full opinions • Results may be influenced if questions are worded incorrectly
Empower	**Participatory editing** • Stakeholders co-write reports and documents and endorse the final document.	• Builds ownership • Reflects their informed views and contributes to the quality of a document	• Need to consider the stakeholder's organizational structures and resources • May attract criticism if final result is not reflective of input

Table 2-5: Key Stakeholder Engagement Plan

Level of Engagement	Goal	Promise to stakeholder	Key Message	Stakeholder	Method of engagement	Outcome	Responsibility / Resources	Timeframe
Inform	To provide balanced, objective, accurate and consistent information to assist stakeholders to understand the problem, alternatives, opportunities and/or solutions.	We will keep you informed	• Coastal Planning (SPP2.6) • Coastal process (Storm + Sea level rise) • Inundation Hazard zone • Erosion Hazard zone	All	Fact sheet / Newsletter	Facilitate greater understanding and appreciation of issues to be resolved through the CHRMAP	Shire to prepare material based on consultant documentation	After final issue of *Option Discussion Paper*
Consult	To work directly with stakeholders throughout the process to ensure that their concerns and needs are consistently understood and considered.	We will work with you to ensure that your concerns and aspirations are directly reflected in the alternatives developed and provide feedback on how stakeholder input influenced the outcome.	• Values at Risk (present and future) • Risk profile • Existing controls	All	Expert panel / Public meeting	Confirm values at risk due to coastal hazards	Shire to organize venue and invitation Shire to chair the panel Subject matter specialist: • Shire of Esperance • Department of Planning • Consultant	Following release of Fact sheet / Newsletter
Involve	To obtain feedback from stakeholders on analysis, alternatives and/or outcomes.	We will keep you informed, listen to and acknowledge concerns and aspirations, and provide feedback on how stakeholder input influenced the outcome.	• Adaptation pathways (avoid, planned retreat, accommodate, protect) • Adaptation options(Regenerative, Protective, Design, Land use).	Shire of Esperance	Workshop / video conference	Influence the appraisal of adaptation options	Consultant to facilitate	After Expert panel / Public meeting

Level of Engagement	Goal	Promise to stakeholder	Key Message	Stakeholder	Method of engagement	Outcome	Responsibility / Resources	Timeframe
Collaborate	To partner with the stakeholder including the development of alternatives, making decisions and the identification of preferred solutions.	We will look to you for advice and innovation in formulating solutions and incorporate your advice and recommendations into the outcomes to the maximum extent possible.	• Adaptation plan • Residual risk • Emergency response	All	Advisory committee / Review of adaptation plan	Get feedback on the draft strategy	Shire to coordinate dissemination, aggregate feedback and prioritise comments to consultant Consultant to issue response to Shire and implement agreed changesin revised documentation	After draft issue of *Adaptation Plan*
Empower	To place final decision-making in the hands of the stakeholder. Stakeholders are enabled/equipped to actively contribute to the achievement of outcomes.	We will implement what you decide. We will support and complement your actions.	• CHRMAP	Shire of Esperance Department of Planning	Participatory editing / Reviews of CHRMAP documentation	Obtain council approval for the of CHRMAP	Shire to coordinate dissemination, aggregate feedback and prioritise comments to consultant Consultant to issue response to Shire and implement agreed changes in revised documentation	After final issue of *Adaptation Plan*

2.9 Coastal Assets (Values) at Risk

A coastal asset register (Table 2-6) was established to identify the relevant assets located in the coastal hazard zone together with their functions/services. In addition, the register was expanded to include an appreciation of the asset value, scale and key stakeholder representatives from the list in Table 2-3.

The register was populated based on existing GIS databases and information provided by the Shire and updated with elements recorded during the video conference meeting with the Shire conducted on the 20/08/2015 and subsequent communication.

The consequence rating for the key asset categories impacted by erosion and inundation was subsequently undertaken and reported in the risk analysis section 4.4.3, summarised in Table 4-8 and mapped in Figure 5-8 and Figure 5-19.

Table 2-6: Key categories of the asset inventory

Category	Key Items retained	Scale	Total Value	Function	Reference	Key Stakeholder Representatives	Identified	Value at Risk: erosion	Value at Risk: inundation
Beaches	Beaches	$4-23/m^2 (low – high use) Assume $5,000/m Emily St to Taylor St: 0.2km Taylor St to Emily St: 0.6km Emily St to Tanker jetty: 1.0km Tanker jetty to Norseman Rd: 0.4km Norseman Rd to Bandy Creek: 3.2km Bandy Creek to Wylie Head: 4.6km	$50M	Recreation: Fishing, four-wheel-driving, boogie- or body-board, dog	Aerial Image (2014), BMT Oceanica (2014)	Shire of Esperance	☑	Yes	Yes
Coastal Protections	Groynes Breakwaters Seawall (see Esperance Waterfront)	$10,000/m (approx.) James St (x1): $1.5M Taylor St (x1): $2.0M Seawall (x1): $10M Norseman Rd (x3): $1.5M Bandy creek(x6): $7M	$22M	Shoreline management, erosion protection, wave sheltering, entrance stabilisation	Aerial Image (2014), Cost estimate for Esperance Seawall	Shire of Esperance Department of Transport	☑	Yes	Yes
Boating Facilities	Yacht Club Facilities	Not available	Not available	Recreational boating facilities, access	Aerial Image (2014)	Esperance Bay Yacht Club	☑	Yes	Yes

Category	Key Items retained	Scale	Total Value	Function	Reference	Key Stakeholder Representatives	Identified	Value at Risk: erosion	Value at Risk: inundation
Boating Facilities	Taylor Street Marina Bandy Creek Boat Harbour	$0.5M/boat pen (approx.) Taylor St (x34) Bandy Ck(x46)	$40M	Recreational boating facilities, access	Aerial Image (2014), BMT Oceanica (2014)	Department of Transport	☑	Yes, Out of scope	Yes, Out of scope
Gas Infrastructures	Gas mains	Not available	Not available	Utilities, heating, cooking appliances	Shire of Esperance, GIS	Esperance Gas Distribution Company Pty Ltd	☑	Yes	Yes
Heritage	Aboriginal Heritage Places	150% of the average land values	Not available	Social and Cultural	Shire of Esperance, GIS	Department of Aboriginal Affairs	☑	Not at risk	Not at risk
Heritage	State Heritage Places	150% of the average land values Cannery Art Centre Museum Theatre RSL Building, Norfolk Island Pine Trees and War Memorial Dempster Homestead (fmr)	Not available	Social and Cultural	Shire of Esperance, GIS	Shire of Esperance	☑		
Heritage	State Heritage Places	Tanker Jetty	Not available	Social and Cultural	Shire of Esperance, GIS	Shire of Esperance	☑	Yes, Out of scope	Yes, Out of scope

Category	Key Items retained	Scale	Total Value	Function	Reference	Key Stakeholder Representatives	Identified	Value at Risk: erosion	Value at Risk: inundation
Power Infrastructures	Power lines	Not available	Not available	Utilities, heating, cooking appliances	Shire of Esperance, GIS	Horizon Power	☑	Yes	Yes
Zoning	Agriculture - general Central Area Future Residential Industry - Business Local Road Park, Recreation and Conservation Public purpose Railway and Port Instalation Regional Road Residential Tourist residential Lodged Cadastre	Rateable Value Residential (3439x): $46.2M Commercial (370x): $19.2M Vacant (197x) : $3.4M Gross Rental Value (GRV) Rate: 9% $600/m2 residential land (417m^2) $380/m2 residential land (1500m^2) $330/m2 residential land (1000m^2)	Rateable value $68.7M Rate Revenue $6.2M	Residential, Commercial estate	Shire of Esperance Annual Report (2013/2014)	Shire of Esperance	☑	Yes	Yes
Petroleum Infrastructures	Underground petroleum transfer pipeline. Built in 1978.	3km	Not available	Utilities	Public Works Department – WA and Esperance Port Authority drawing (1976)	Esperance Ports Sea and Land	☑	Yes	Yes
Communication Infrastructures	Telephone line Fibre Optic Cable	Not available	Not available	Communication	Not available	Telstra	☐	Yes	Yes

Category	Key Items retained	Scale	Total Value	Function	Reference	Key Stakeholder Representatives	Identified	Value at Risk: erosion	Value at Risk: inundation
Buildings	Administration Building Aged Care Building Caravan Park Building Cultural Building Depot Building Halls Heritage Building Housing Period Village Sports House Toilet Blocks Waste Services	40 Masonry Structures 71 fit-out 56 Frame Structures 96 Roof Structures 30 mechanical services	$23.6M $17.8M $12.5M $2.9M $0.9M	Community leisure and services facilities	SoE Building Asset Management Plan (2011)	Shire of Esperance	☐	Yes	Yes
Roads	Road network Kerbing Culverts Bridges Carparks	4,570km 202km 27km 4 63,500m^2	$472M $4.2M $7.4M $8.7M $2.0M	Efficient mobility on high volume, fast moving urban and rural roads Low traffic volume, pedestrian and cyclist friendly access throughout residential areas Linkages between towns in rural areas Access to properties in agricultural and remote pastoral areas.	SoE Roads Infrastructure Asset Management Plan (2013)	Shire of Esperance	☑	Yes	Yes

Category	Key Items retained	Scale	Total Value	Function	Reference	Key Stakeholder Representatives	Identified	Value at Risk: erosion	Value at Risk: inundation
Footpaths & Cycleways	Footpaths & Cycleways	114km	$12.1M	Pedestrian and cyclist friendly access throughout residential areas	SoE Footpath & Cycleway Asset Management Plan (2011)	Shire of Esperance	☑ (Esp. Waterfront only)	Yes	Yes
Recreation – Parks & Reserves	Park Furniture Playground equipment Irrigation systems Lighting Synthetic Surfaces Playing Surfaces	$3/m^2$	$1M $1.3M $2.5M $0.2M $2.0M $1.8M	Recreation	SoE - Recreation – Parks & Reserves Asset Management Plan (2011), BMT Oceanica (2014)	Shire of Esperance	☐	Yes	Yes
Drainage	Drainage Pits Drainage Pipes Subdivision Developments Budget Drainage Works 1999-2010	n/a	$3.7M $4.7M $3.9M $2.7M	Stormwater collection, retention and disposal	SoE Drainage Asset Management Plan (2011)	Shire of Esperance	☑	Yes	Yes
Coastal	Surfaces (unsealed roads & car parks) General (steps, walkway, seating, etc.) Marine (boat ramps, jetty, safety facilities)	27 locations	$0.9M $0.8M $0.6M	Maritime and coastal access	SoE Coastal Infrastructure Asset Management Plan (2012)	Shire of Esperance	☐	Yes	Yes
Esperance Bay foreshore Reserves	R 28207	$3/m^2$ From Esperance Port to Talyor St:0.3km	high use beaches tend to be used on a daily basis	Recreation: Fishing, four-wheel-driving, boogie- or body-board, dog	SoE Coastal Management Plan (2014), BMT Oceanica (2014)	Shire of Esperance	☑	Yes	Yes

Category	Key Items retained	Scale	Total Value	Function	Reference	Key Stakeholder Representatives	Identified	Value at Risk: erosion	Value at Risk: inundation
Esperance Bay foreshore Reserves	R 27318	$3/m^2 From Talyor St to Straker St :3.3km	high use beaches tend to be used on a daily basis	Recreation: Fishing, four-wheel-driving, boogie- or body-board, dog	SoE Coastal Management Plan (2014), BMT Oceanica (2014)	Shire of Esperance	☑	Yes	Yes
Esperance Bay foreshore Reserves	Unallocated Crown Land	$3/m^2 From Straker St to Bandy Creek:1.7km	high use beaches - tend to be used on a daily basis	Recreation: Fishing, four-wheel-driving, boogie- or body-board, dog	SoE Coastal Management Plan (2014)	Shire of Esperance, Landgate	☑	Yes	Yes
Bandy Creek Reserve	R 39635	$3/m^2 Bandy Creek: 0.5km	high use beaches - tend to be used on a daily basis	Recreation, boating	SoE Coastal Management Plan (2014)	Department of Transport	☑	Yes, Out of scope	Yes, Out of scope
Wylie Bay foreshore Reserves	R 15238	$3/m^2 From Bandy Creek to Wylie head:4.0km	high use beaches - tend to be used on a daily basis	Recreation: Fishing, four-wheel-driving, boogie- or body-board, dog	SoE Coastal Management Plan (2014)	Shire of Esperance	☑	Yes	Yes

Category	Key Items retained	Scale	Total Value	Function	Reference	Key Stakeholder Representatives	Identified	Value at Risk: erosion	Value at Risk: inundation
Esperance Waterfront	Seawall Carparks Footpath	1km long section along the foreshore. The project includes: 1. Construction of a seawall, headland around the base of the tanker jetty, community infrastructure and landscaping 2. Upgrade of southern foreshore area (James St Precinct) including environmental infrastructure, landscaping and picnic related infrastructure 3. Replacement of the Tanker Jetty 4. Cultural and commercial property Development	$59M ($20M Seawall, earthwork)	Protection from coastal erosion Foreshore recreation Commercial development	Esperance Waterfront Project factsheet (2012)	Shire of Esperance	☑	Yes	Yes

3 COASTAL HAZARD RISK IDENTIFICATION

The preliminary coastal erosion and inundation hazards zones and likelihood for Esperance Bay study area (Figure 2-1) were detailed in *Esperance Coastal Hazard and Vulnerability Assessment* (BMT JFA Consultants, 2015). The final coastal erosion and inundation hazards zones adopted in accordance with State Planning Policy No. 2.6 State Coastal Planning Policy (WAPC, 2013) are presented hereafter.

3.1 Planning Extreme Event Definition

SPP2.6 provides a definition of the planning hazard events, as follows:

- The erosion hazard scenario considered in the policy corresponds to three successive storm events with a 1% annual exceedance probability (AEP) or 100 years average return interval (ARI)
- The inundation hazard event considered in the policy corresponds to storm events with a 0.2% AEP or 500 years ARI
- The recommended allowance for sea level rise (i.e. +0.3m to 2060 and +0.9m to 2110) are provided on the basis of the SRES scenario A1FI 95th percentile (DoT, 2010).

3.1.1 *Erosion Hazards Scenarios and Allowances Summary*

The following scenarios were considered to establish coastal erosion hazard zones:

- *2010 1% AEP Storm Erosion*: hazard zone accounts for three successive 1% AEP storm erosion allowance (S1)
- *2060 1% AEP Storm Erosion*: hazard zone accounts for three successive 1% AEP storm erosion allowance (S1), the historical shoreline movement trend (S2) to 2060, the future sea level rise allowance (S3) to 2060, and the uncertainty allowance to 2060
- *2110 1% AEP Storm Erosion*: hazard zone accounts for three successive 1% AEP storm erosion allowance (S1), the historical shoreline movement trend (S2) to 2110, the future sea level rise allowance (S3) to 2110, and the uncertainty allowance to 2110

3.1.2 *Inundation Hazards Scenarios and Allowances Summary*

The following scenarios were considered to establish coastal inundation hazard zones:

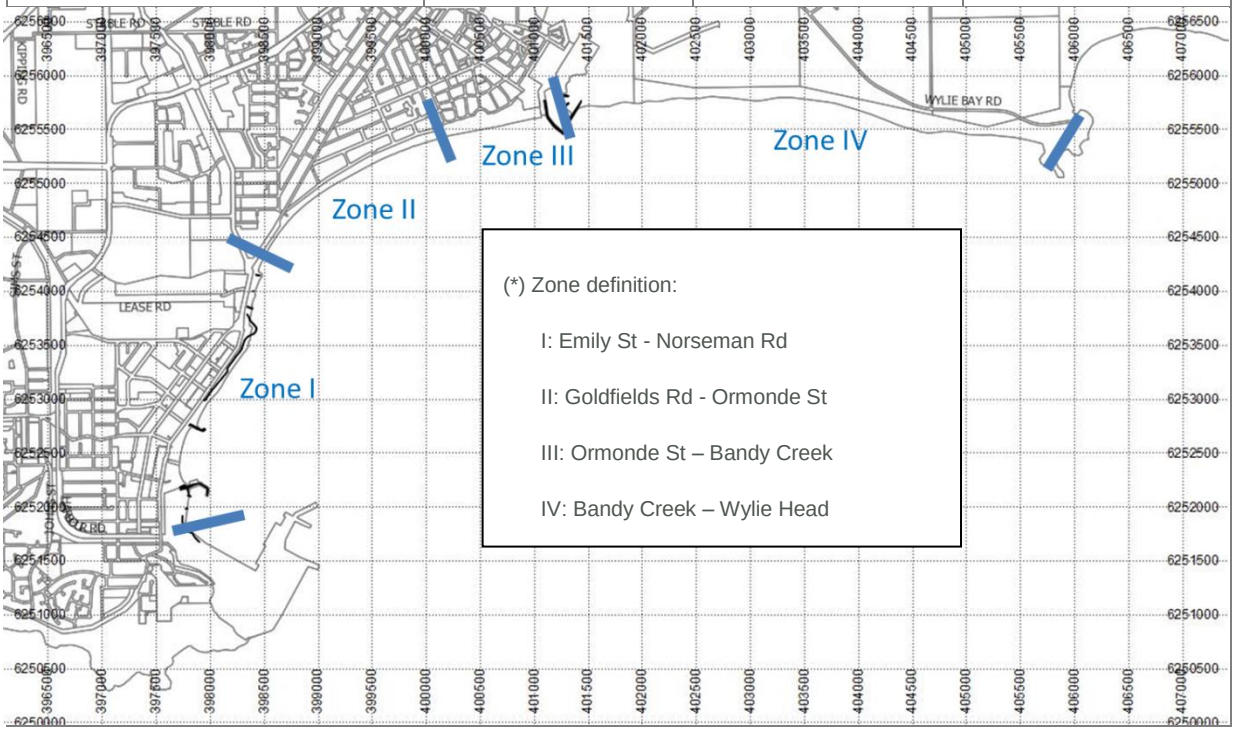
- *2010 1% AEP Storm Inundation*: hazard zone accounts for the 1% AEP storm tide allowance. This level sits in the range 1.6-2.7mCD, where the spatial variability is directly related to changes in wave conditions.
- *2010 0.2% AEP Storm Inundation*: hazard zone accounts for the 0.2% AEP storm tide allowance. This level sits in the range 2.3-3.3mCD, where the spatial variability is directly related to changes in wave conditions.
- *2060 0.2% AEP Storm Inundation*: hazard zone accounts for the 0.2% AEP storm tide allowance (S4) including a future sea level rise allowance to 2060. This level sits in the range 2.6-3.6mCD, where the spatial variability is directly related to changes in wave conditions.

- *2110 0.2% AEP Storm Inundation*: hazard zone accounts for the 0.2% AEP storm tide allowance (S4) including a future sea level rise allowance to 2110. This level sits in the range 3.2-4.2mCD, where the spatial variability is directly related to changes in wave conditions.

A summary of semi-permanent water level (i.e. HAT) and extreme water level (including wave run-up) is presented in Table 3-1.

Table 3-1: Summary of semi-permanent water level (i.e. HAT) and extreme water level (including wave run-up) for various planning horizon.

Planning horizon	2010				2060				2100			
Water Level (mAHD) for zone*	I	II	III	IV	I	II	III	IV	I	II	III	IV
1:500 ARI Wave Run-up Level	2.3	2.6	3.3	3.2	2.6	2.9	3.6	3.5	3.2	3.5	4.2	4.1
1:100 ARI Wave Run-up Level	2.0	2.2	2.7	2.6	2.3	2.6	3.0	2.9	2.9	3.1	3.6	3.5
1:500 ARI Storm Tide Level (exc. wave)	1.3	1.5	1.6	1.6	1.6	1.8	1.9	1.9	2.2	2.4	2.5	2.5
1:100 ARI Storm Tide Level (exc. wave)	1.2	1.2	1.3	1.3	1.5	1.5	1.6	1.6	2.1	2.1	2.2	2.2
Highest recorded tide (23/05/2009)	1.2				1.5				2.1			
Highest Astronomical Tide (HAT)	0.7				1.0				1.6			
Mean High Higher Water (MHHW)	0.4				0.7				1.3			
Mean Sea Level (MSL)	0.0				+0.3				+0.9			



3.2 Esperance Coastal Hazard Mapping

A summary of coastal hazard allowances adopted in accordance with State Planning Policy No2.6 State Coastal Planning Policy (WAPC, 2013) for various planning horizon is shown in Table 3-2. The geospatial extent of coastal hazard zones is detailed in the Erosion map (Figure 4-2) and Inundation map (Figure 4-3).

Table 3-2: Summary of Coastal Hazard Allowances adopted in accordance with State Planning Policy No. 2.6 State Coastal Planning Policy (WAPC, 2013) for various planning horizon.

Zone		Datum	Erosion Hazard Allowance - measured landward from the horizontal shoreline datum (HSD)						Inundation Hazard Allowance	
Management Unit	Frontage	HSD (mAHD)	S1 (Storm Erosion)	S2 (Historical Trend)	S3 (Sea level Rise)	Uncertainty (0.2m/year)	Total	Comment	S4 (Inundation)	Comment
1	Emily St - Taylor St Groyne	1.07	20m	0m	2010: 0m 2060: 30m 2110: 90m	2010: 0m 2060: 10m 2110: 20m	2010: 20m 2060: 60m 2110: 130m	Storm erosion controlled by port and marina protections to 2060	2010: 2.0mAHD# 2010: 2.3mAHD 2060: 2.6mAHD 2110: 3.2mAHD	Nearshore inundation driven by erosion. Dune breaching locally.
	Taylor St Groyne – James St Groyne	1.07	20m	0m	2010: 0m 2060: 30m 2110: 90m	2010: 0m 2060: 10m 2110: 20m	2010: 20m 2060: 60m 2110: 130m	Storm erosion controlled by port and marina protections to 2060	2010: 2.0mAHD# 2010: 2.3mAHD 2060: 2.6mAHD 2110: 3.2mAHD	Nearshore inundation driven by erosion.
2	James St. Groyne - Norseman Rd	1.07	2010: 0m 2060: 0m 2110:25m	0m	2010: 0m 2060: 0m 2110: 90m	2010: 0m 2060: 0m 2110: 20m	2010: 0m 2060: 0m 2110: 135m	Storm erosion controlled by seawall to 2060	2010: 2.0mAHD# 2010: 2.3mAHD 2060: 2.6mAHD 2110: 3.2mAHD	Storm inundation controlled by seawall to 2060 Nearshore inundation driven by erosion.
3	Norseman Rd	1.17	2010: 30m 2060: 30m 2110: 30m	0m	2010: 0m 2060: 30m 2110: 90m	2010: 0m 2060: 10m 2110: 20m	2010: 30m 2060: 70m 2110: 140m	Storm erosion not fully controlled by short groynes	2010: 2.0mAHD# 2010: 2.3mAHD 2060: 2.6mAHD 2110: 3.2mAHD	Nearshore inundation driven by erosion.
	Goldfields Rd	1.17	30m	2010: 0m 2060:15m 2110: 30m	2010: 0m 2060: 30m 2110: 90m	2010: 0m 2060: 10m 2110: 20m	2010: 30m 2060: 85m 2110: 170m	Erosion controlled by beach nourishment currently	2010: 2.2mAHD# 2010: 2.6mAHD 2060: 2.9mAHD 2110: 3.5mAHD	Nearshore inundation driven by erosion.
	Castletown Quay	1.27	30m	0m	2010: 0m 2060: 30m 2110: 90m	2010: 0m 2060: 10m 2110: 20m	2010: 30m 2060: 70m 2110: 140m		2010: 2.2mAHD# 2010: 2.6mAHD 2060: 2.9mAHD 2110: 3.5mAHD	Nearshore inundation driven by erosion.

Zone		Datum	Erosion Hazard Allowance - measured landward from the horizontal shoreline datum (HSD)						Inundation Hazard Allowance	
Management Unit	Frontage	HSD (mAHD)	S1 (Storm Erosion)	S2 (Historical Trend)	S3 (Sea level Rise)	Uncertainty (0.2m/year)	Total	Comment	S4 (Inundation)	Comment
	Ormonde St – Bandy Creek	1.27	30m	0m	2010: 0m 2060: 30m 2110: 90m	2010: 0m 2060: 10m 2110: 20m	2010: 30m 2060: 70m 2110: 140m		2010: 2.7mAHD[#] 2010: 3.3mAHD 2060: 3.6mAHD 2110: 4.2mAHD	Nearshore inundation driven by erosion. No ground water connectivity assumed.
4	Bandy Creek – Wylie Head	1.27	25m	0m	2010: 0m 2060: 30m 2110: 90m	2010: 0m 2060: 10m 2110: 20m	2010: 25m 2060: 65m 2110: 135m		2010: 2.6mAHD[#] 2010: 3.2mAHD 2060: 3.5mAHD 2110: 4.1mAHD	Nearshore inundation driven by erosion. No ground water connectivity assumed. Dune breaching locally.

(#) 1% AEP

4 Coastal Hazards Risk Analysis

In this section a thorough risk analysis is presented in accordance with the international standard which reflects the perceived importance of each risk from the point of view of the Shire. A risk based prioritisation is achieved by considering the two following risk dimensions:

- The likelihood of each hazard scenario; and
- The consequence of identified assets being impacted by erosion or inundation over the planning timeframe(s), one can achieve a proper.

Accordingly, each hazard scenario identified previously must be attributed a likelihood rating and each asset class at risk identified previously must be attributed a consequence rating. The framework for scaling and rating likelihood and consequence is developed in this section.

4.1 Risk Assessment Framework

The CHRMAP process reflects the commonly used risk management framework applied to coastal zone management (ISO 31000:2009, Rollason et al. 2010), where:

- Risk considers the consequence and likelihood of an event having an effect on the objectives
- Events are the erosion and inundation hazards defined in the policy
- Consequence characterises the outcome of an event for a specific asset
- Likelihood characterises the chance that an event might happen over a specific timeframe
- Asset includes economic, environment and social values for existing and future timeframes
- Timeframes considered are 1 year (to 2010), 50 year (to 2050) and 100 year (to 2110) planning horizons.

Whilst using a perceived level of tolerance to a risk as a mechanism for prioritisation is the first step, it is also necessary to prioritise on the basis of the timeframe of expected impact.

Risks that are high or extreme for the present day scenario require treatment as a priority. For the high and extreme risks which only manifest themselves under the longer term scenario (i.e. at the 2110 planning horizon), it is unlikely that direct action will need to be undertaken under this initial adaptation plan. Instead, for those longer-term risks the plan should develop a sequence of response, to include the following:

- Identifying a trigger for when more substantial action is required, such as an erosion volume or shoreline recession distance - and also using the asset replacement cycle (such as for public foreshore assets)
- Describing preliminary actions that can be undertaken now to improve our response to that risk in the future, e.g. planning controls that reduce the risk profile over time
- Monitoring of triggers, which then forms a key action in the present day adaptation plan.

Figure 4-1 illustrates the process of developing a sequence of responses as part of the adaptation planning process.

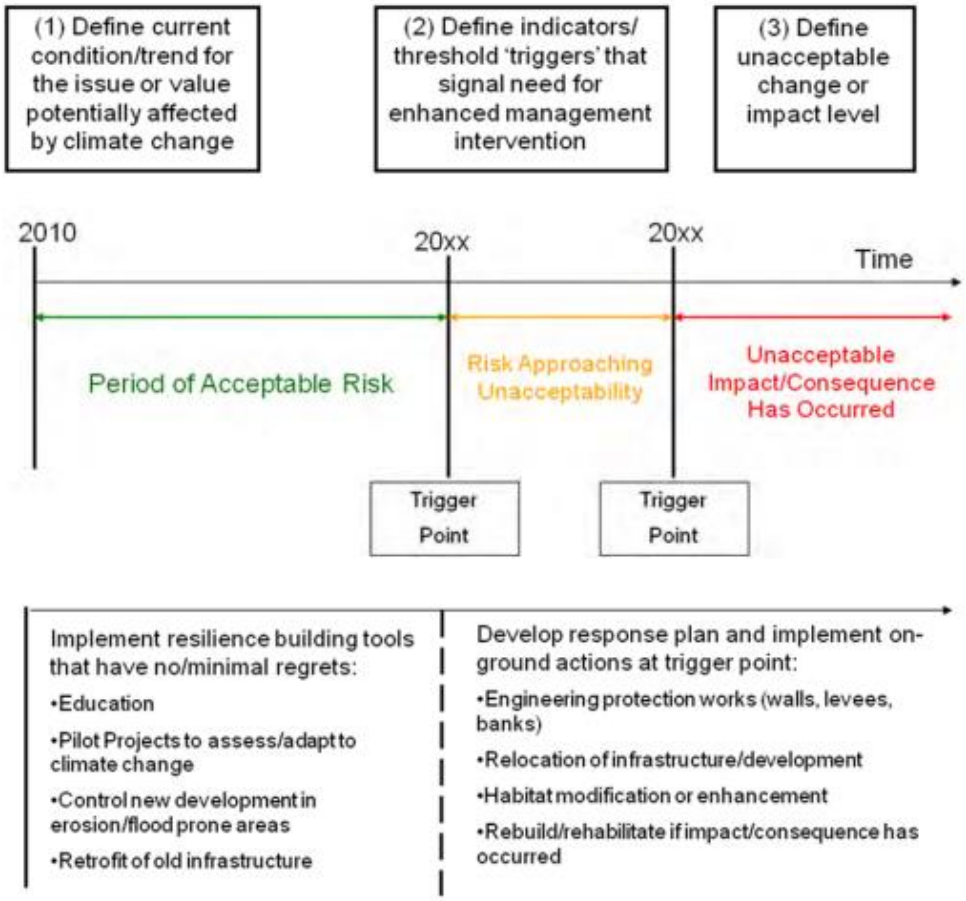


Figure 4-1: Continuum 'Trigger' Model for Coastal Adaptation Actions

4.2 Likelihood Scale for Coastal Hazards

The likelihood of the coastal hazards erosion and inundation scenarios (summarised previously in section 3.1.1 and section 3.1.2 respectively in accordance with the design event specified in Policy SPP2.6 Schedule 1) has been rated against the Shires' likelihood scale by considering the cumulative probability of each scenario over each planning timeframe.

4.2.1 *Hazard Likelihood Scale*

A likelihood scale applicable to the assets at risk in the coastal zone was developed (Table 4-1) consistent with the Australian Standard Risk Management Principles and Guidelines ISO 31000:2009 and existing enterprise risk frameworks already used by the Shire.

Table 4-1: Likelihood scale for coastal hazard (adapted from Shire of Esperance Measures of Likelihood)

Likelihood Rating (level)	Description	Frequency	Probability of occurrence over planning horizon (project life)
Almost Certain (5)	The event is expected to occur in most circumstances	More than once per year	Greater than 90% chance of occurrence
Likely (4)	The event will probably occur in most circumstances	At least once per year	60% - 90% chance of occurrence
Possible (3)	The event should occur at some time	At least once in 3 years	40% – 60% chance of occurrence
Unlikely (2)	The event could occur at some time	At least once in 10 years	10% - 40% chance of occurrence
Rare (1)	The event may only occur in exceptional circumstances	Less than once in 15 years	Less than 10% chance of occurrence

4.2.2 *Coastal Erosion Hazard Mapping*

Coastal Erosion Hazard Likelihood Rating

A scale of likelihood of occurrence for a hazard impact was developed for erosion (Table 4-2) for each of the planning timeframes, based on the Australian Standard for Risk Management (AS/NZS ISO 31000:2009) and its companion document (HB 436:2004).

The erosion likelihood rating was derived from the cumulative probability of occurrence of the acute storm erosion specified in the Policy SPP2.6. This approach is consistent with the one adopted by Rollason et al (2010).

Coastal Erosion Hazard Maps

Three erosion hazard areas have been mapped along Esperance Bay study area, as shown in Figure 4-2. They represent potential areas impacted by highly erosive coastal processes, resulting in significant alteration of the landscape.

The coastal erosion hazards areas shown are “partially mitigated” in places where protective structures exist. In particular, the presence of an adequately maintained seawall along the recently developed foreshore is considered to be an effective erosion control measure (within its design capacity) for up to 50 years horizon.

Each line effectively represents the anticipate shoreline position for three distinct time horizons (e.g. present day, year 2060 and year 2100) under relevant coastal processes and climate variability, including storm event and sea level rise allowance, and the applicable coastal planning policy.

Local effects, such as existing protective structures, have been included; however, future coastal zone management strategies are not reflected in these illustrations. Over time, the transition between each line is not expected to be a smooth process, but a combination of gradual erosion and rapid shoreline retreat during extreme events.

Table 4-2: Likelihood scale for erosion hazard lines for each planning timeframe. The three scenarios highlighted in the table have been mapped in Figure 4-2

Exceedance probability over timeframe	Likelihood rating (Level)	1 years (2010 to 2010, 0m SLR)	50 years (2010 to 2060, +0.3m SLR)	100 years (2010 to 2110, +0.9m SLR)
> 90%	Almost Certain (5)	-	-	2010 1%AEP Storm Erosion
60% - 90%	Likely (4)	-	-	-
40% - 60%	Possible (3)	-	2010 1%AEP Storm Erosion	2060 1%AEP Storm Erosion
10% - 40%	Unlikely (2)	-	-	-
≤ 10%	Rare (1)	2010 1%AEP Storm Erosion	2060 1%AEP Storm Erosion	2110 1%AEP Storm Erosion

(-) not used.

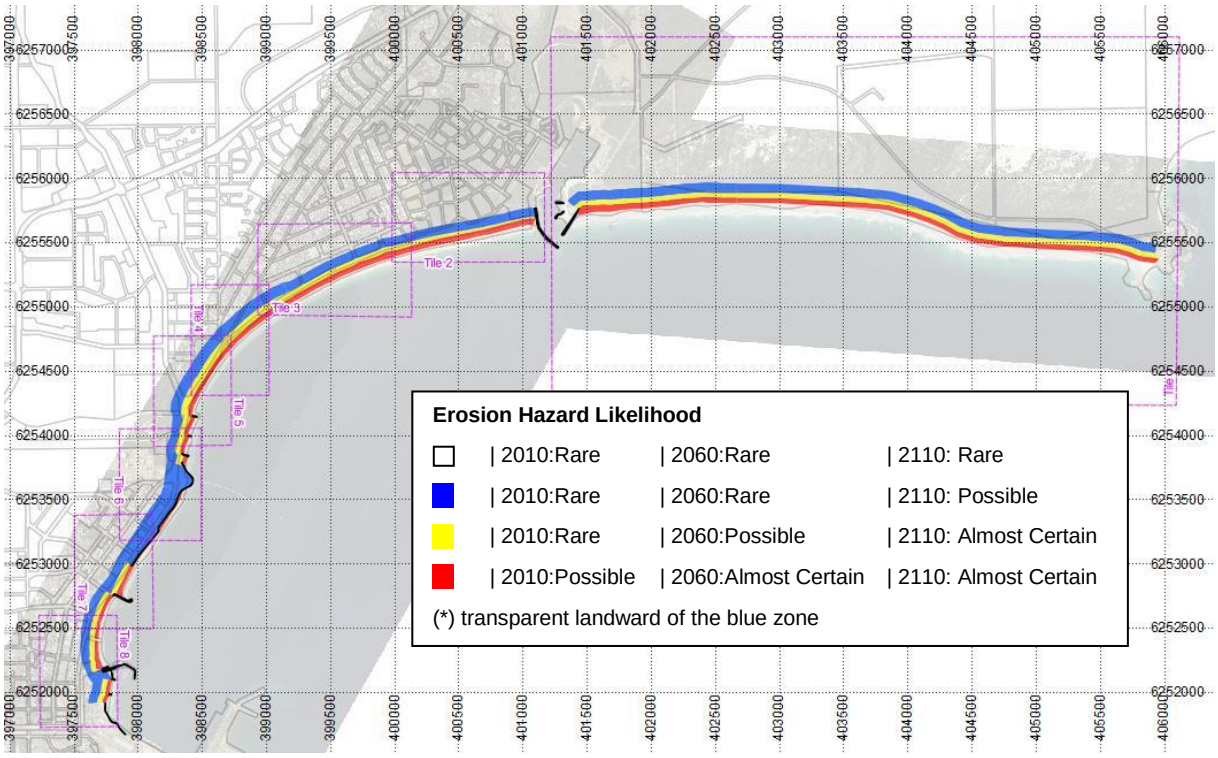


Figure 4-2: Erosion Hazard Zones Map. The zones delineated on the map correspond to a limited number of scenarios modelled which have been categorised within the likelihood scale (Table 4-2). Accordingly, the likelihood of erosion may vary rapidly within these limited number of hazard zones. Following the precautionary principle, a highest likelihood have been assigned to a given hazard zone.

4.2.3 *Coastal Inundation Hazard Mapping*

Coastal Inundation Hazard Likelihood Rating

A scale of likelihood of occurrence for a hazard impact was developed for inundation (Table 4-3) for each of the planning timeframes, based on the Australian Standard for Risk Management (AS/NZS ISO 31000:2009) and its companion document (HB 436:2004).

The inundation likelihood rating was derived from the cumulative probability of exceedance of the extreme water level specified in the Policy SPP2.6. Calculations are provided in Appendix B.

Coastal Inundation Hazards Maps

Three inundation hazard areas have been mapped along Esperance Bay study area, as shown in Figure 4-3. They represent potential areas impacted by storm surge flooding processes, resulting in temporary inundation of the landscape.

The coastal inundation hazards areas shown are “partially mitigated” in places where protective structures exist. In particular, the presence of an adequately maintained seawall along the recently developed foreshore is considered to be an effective inundation control measure (within is design capacity) for up to 50 years horizon.

Each area effectively represents the anticipate inundation extent for three distinct time horizons (e.g. present day, year 2060 and year 2100) under relevant coastal processes and climate variability, including storm event and sea level rise allowance, and the applicable coastal planning policy. No allowance for ground water connectivity was made.

Lower areas behind dunes have been identified in the coastal inundation maps, where:

- A dune is breached according the SPP2.6 criteria; this is the case between Landfill Rd and Wylie Creek, where dune breach may lead to local lowland inundation over an extent limited by hydraulic connectivity and the quantity of water available through wave overtopping.
- An ocean outfall enables direct hydraulic connection between the ocean side and the lower area on the land side; this is case in Castletown, the Irvine St ocean outfall.

The inundated areas may be exacerbated by additional rainfall based flooding and shoreline retreat following erosion event. These are not reflected in the inundation maps.

Table 4-3: Likelihood scale for inundation hazard zones for each time horizons (Taylor Street to Norseman Road). The four scenarios highlighted in the table have been mapped in Figure 4-3

Exceedance probability over timeframe	Likelihood rating (level)	1 years (2010 to 2010, 0m SLR)	50 years (2010 to 2060, +0.3m SLR)	100 years (2010 to 2110, +0.9m SLR)
> 90%	Almost Certain	-	**[<1.90mAHD]**	**[<2.35mAHD]** 2010 1% AEP Storm Inundation [2.0mAHD] 2010 0.2% AEP Storm Inundation [2.3mAHD]
60% - 90%	Likely	-	**[1.90mAHD to 2.05mAHD]** 2010 1% AEP Storm Inundation [2.0mAHD]	**[2.35mAHDto 2.55mAHD]**
40% - 60%	Possible	-	**[2.05mAHD to 2.20mAHD]**	**[2.55mAHDto 2.70mAHD]** 2060 0.2% AEP Storm Inundation [2.6mAHD]
10% - 40%	Unlikely	-	**[2.20mAHD to 2.50mAHD]** 2010 0.2% AEP Storm Inundation [2.3mAHD]	**[2.70mAHDto 3.10mAHD]**
≤ 10%	Rare	**[>1.57mAHD]** 2010 1% AEP Storm Inundation [2.0mAHD] 2010 0.2% AEP Storm Inundation [2.3mAHD] 2060 0.2% AEP Storm Inundation [2.6mAHD] 2110 0.2% AEP Storm Inundation [3.2mAHD]	**[>2.50mAHD]** 2060 0.2% AEP Storm Inundation [2.6mAHD] 2110 0.2% AEP Storm Inundation [3.2mAHD]	**[>3.10mAHD]** 2110 0.2% AEP Storm Inundation [3.2mAHD]

(-) not used

Table 4-4: Likelihood scale for inundation hazard zones for each time horizons (Goldfields Road to Castletown Quays). The four scenarios highlighted in the table have been mapped in Figure 4-3.

Exceedance probability over timeframe	Likelihood rating (level)	1 years (2010 to 2010, 0m SLR)	50 years (2010 to 2060, +0.3m SLR)	100 years (2010 to 2110, +0.9m SLR)
> 90%	Almost Certain	-	**[<2.0mAHD]**	**[<2.40mAHD]** 2010 1% AEP Storm Inundation [2.2mAHD]
60% - 90%	Likely	-	**[2.21mAHD to 2.0mAHD]** 2010 1% AEP Storm Inundation [2.2mAHD]	**[2.75mAHD to 2.40mAHD]** 2010 0.2% AEP Storm Inundation [2.6mAHD]
40% - 60%	Possible	-	**[2.4mAHD to 2.21mAHD]**	**[2.9mAHD to 2.75mAHD]** 2060 0.2% AEP Storm Inundation [2.9mAHD]
10% - 40%	Unlikely	-	**[2.8mAHD to 2.4mAHD]** 2010 0.2% AEP Storm Inundation [2.6mAHD]	**[3.4mAHD to 2.9mAHD]**
≤ 10%	Rare	**[>1.63mAHD]** 2010 1% AEP Storm Inundation [2.2mAHD] 2010 0.2% AEP Storm Inundation [2.6mAHD] 2060 0.2% AEP Storm Inundation [2.9mAHD] 2110 0.2% AEP Storm Inundation [3.5mAHD]	**[>2.8mAHD]** 2060 0.2% AEP Storm Inundation [2.9mAHD] 2110 0.2% AEP Storm Inundation [3.5mAHD]	**[>3.4mAHD]** 2110 0.2% AEP Storm Inundation [3.5mAHD]

(-) not used

Table 4-5: Likelihood scale for inundation hazard zones for each time horizons (Ormonde Street to Bandy Creek). The four scenarios highlighted in the table have been mapped in Figure 4-3.

Exceedance probability over timeframe	Likelihood rating (level)	1 years (2010 to 2010, 0m SLR)	50 years (2010 to 2060, +0.3m SLR)	100 years (2010 to 2110, +0.9m SLR)
> 90%	Almost Certain	-	**[<2.10mAHD]**	**[<2.80mAHD]** 2010 1% AEP Storm Inundation [2.7mAHD]
60% - 90%	Likely	-	**[2.10mAHD to 2.60mAHD]**	**[2.80mAHD to 3.20mAHD]**
40% - 60%	Possible	-	**[2.60mAHD to 2.90mAHD]** 2010 1% AEP Storm Inundation [2.7mAHD]	**[3.20mAHD to 4.10mAHD]** 2010 0.2% AEP Storm Inundation [3.3mAHD]
10% - 40%	Unlikely	-	**[2.90mAHD to 3.45mAHD]** 2010 0.2% AEP Storm Inundation [3.3mAHD]	**[3.45mAHD to 4.10mAHD]** 2060 0.2% AEP Storm Inundation [3.6mAHD]
≤ 10%	Rare	**[>1.84mAHD]** 2010 1% AEP Storm Inundation [2.7mAHD] 2010 0.2% AEP Storm Inundation [3.3mAHD] 2060 0.2% AEP Storm Inundation [3.6mAHD] 2110 0.2% AEP Storm Inundation [4.2mAHD]	**[>3.45mAHD]** 2060 0.2% AEP Storm Inundation [3.6mAHD] 2110 0.2% AEP Storm Inundation [4.2mAHD]	**[>4.10mAHD]** 2110 0.2% AEP Storm Inundation [4.2mAHD]

(-) not used

Table 4-6: Likelihood scale for inundation hazard zones for each time horizons (Bandy Creek to Wylie Head)

Exceedance probability over timeframe	Likelihood rating (level)	1 years (2010 to 2010, 0m SLR)	50 years (2010 to 2060, +0.3m SLR)	100 years (2010 to 2110, +0.9m SLR)
> 90%	Almost Certain	-	**[<2.10mAHD]**	**[<2.70mAHD]** 2010 1% AEP Storm Inundation [2.6mAHD]
60% - 90%	Likely	-	**[2.10mAHD to 2.50mAHD]**	**[2.70mAHD to 3.10mAHD]**
40% - 60%	Possible	-	**[2.50mAHD to 2.80mAHD]** 2010 1% AEP Storm Inundation [2.6mAHD]	**[3.10mAHD to 3.35mAHD]** 2010 0.2% AEP Storm Inundation [3.2mAHD]
10% - 40%	Unlikely	-	**[2.80mAHD to 3.35mAHD]** 2010 0.2% AEP Storm Inundation [3.2mAHD]	**[3.35mAHD to 4.00mAHD]** 2060 0.2% AEP Storm Inundation [3.5mAHD]
≤ 10%	Rare	**[>1.74mAHD]** 2010 1% AEP Storm Inundation [2.6mAHD] 2010 0.2% AEP Storm Inundation [3.2mAHD] 2060 0.2% AEP Storm Inundation [3.5mAHD] 2110 0.2% AEP Storm Inundation [4.1mAHD]	**[>3.35mAHD]** 2060 0.2% AEP Storm Inundation [3.5mAHD] 2110 0.2% AEP Storm Inundation [4.1mAHD]	**[>4.00mAHD]** 2110 0.2% AEP Storm Inundation [4.1mAHD]

(-) not used

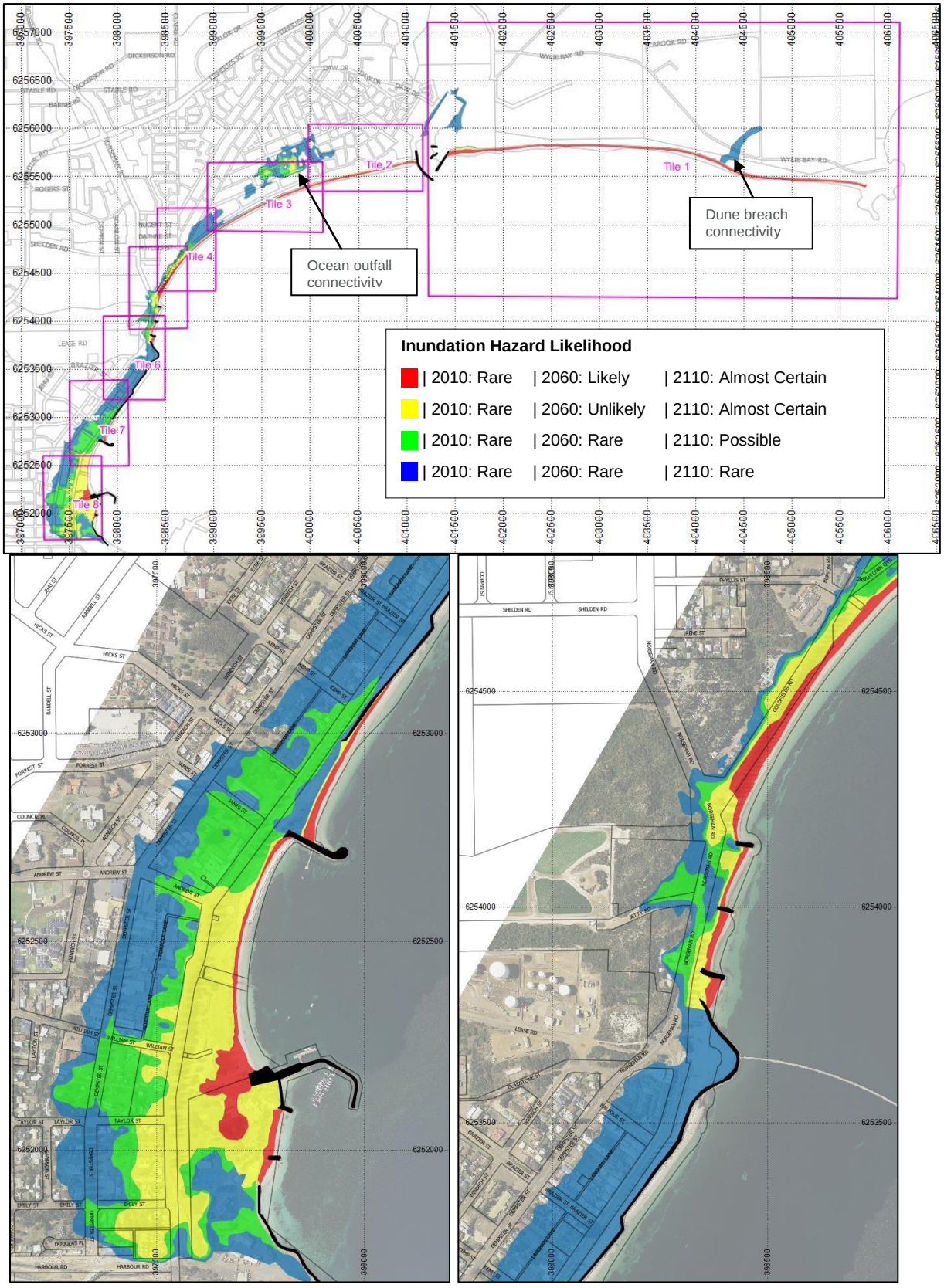


Figure 4-3: Inundation Hazard Zones Map – All Tiles (top), Tile 8-7 (left), Tile 6-5 (right)

4.3 Summary of Coastal Hazard Zones

The combined coastal hazard zones are shown in Figure 4-3 and Figure 4-4. The landward edge of the zones corresponds to the extreme event scenarios based on the SPP2.6 Policy. The probability of occurrence of such scenarios varies overtime depending on the timeframe considered. The landward edge of the hazard zone corresponds to a rare event for the baseline year indicated on the figure.

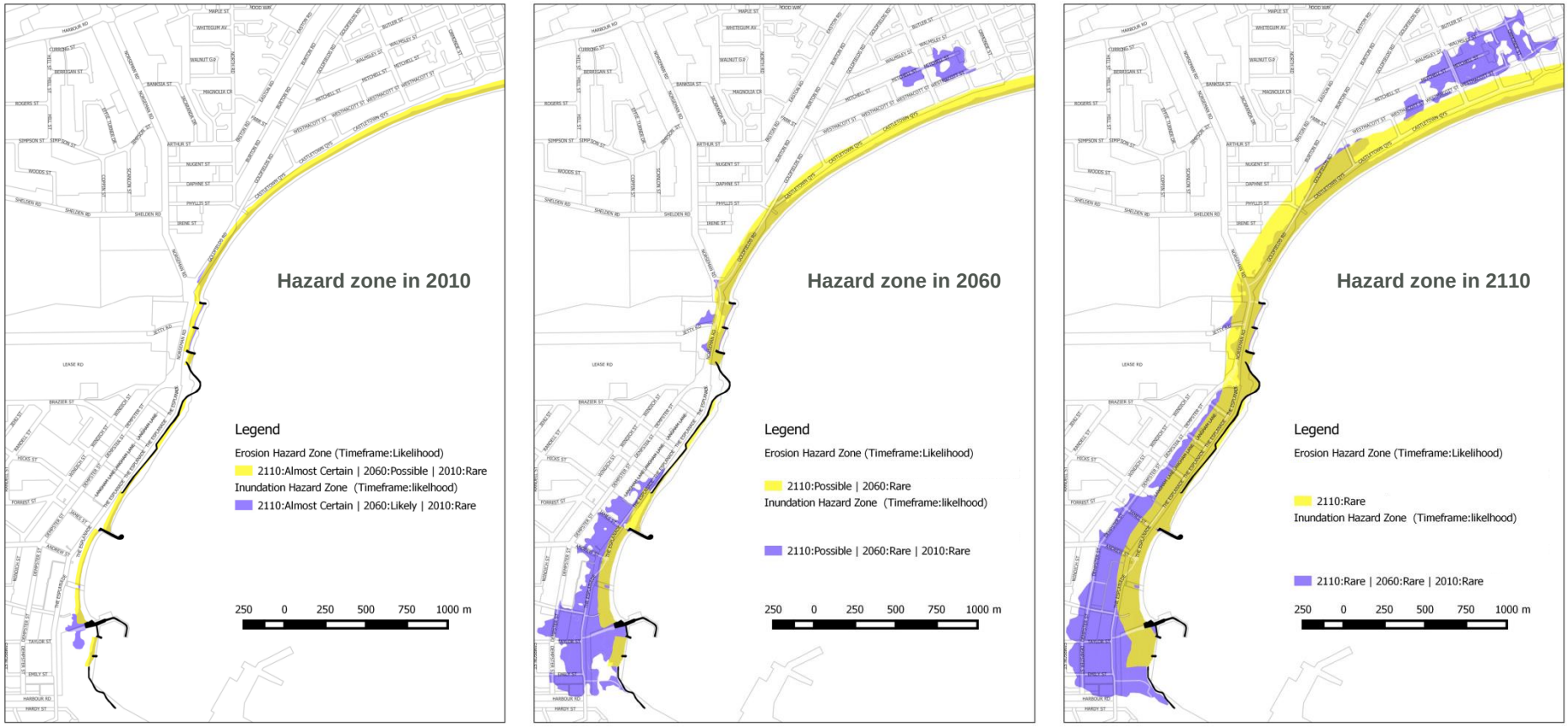


Figure 4-4: Combined erosion (yellow) and inundation (blue) hazard zones over three timeframes: 1 year from now (left), 50 years to 2060 (middle) and 100 years to 2110 (right).

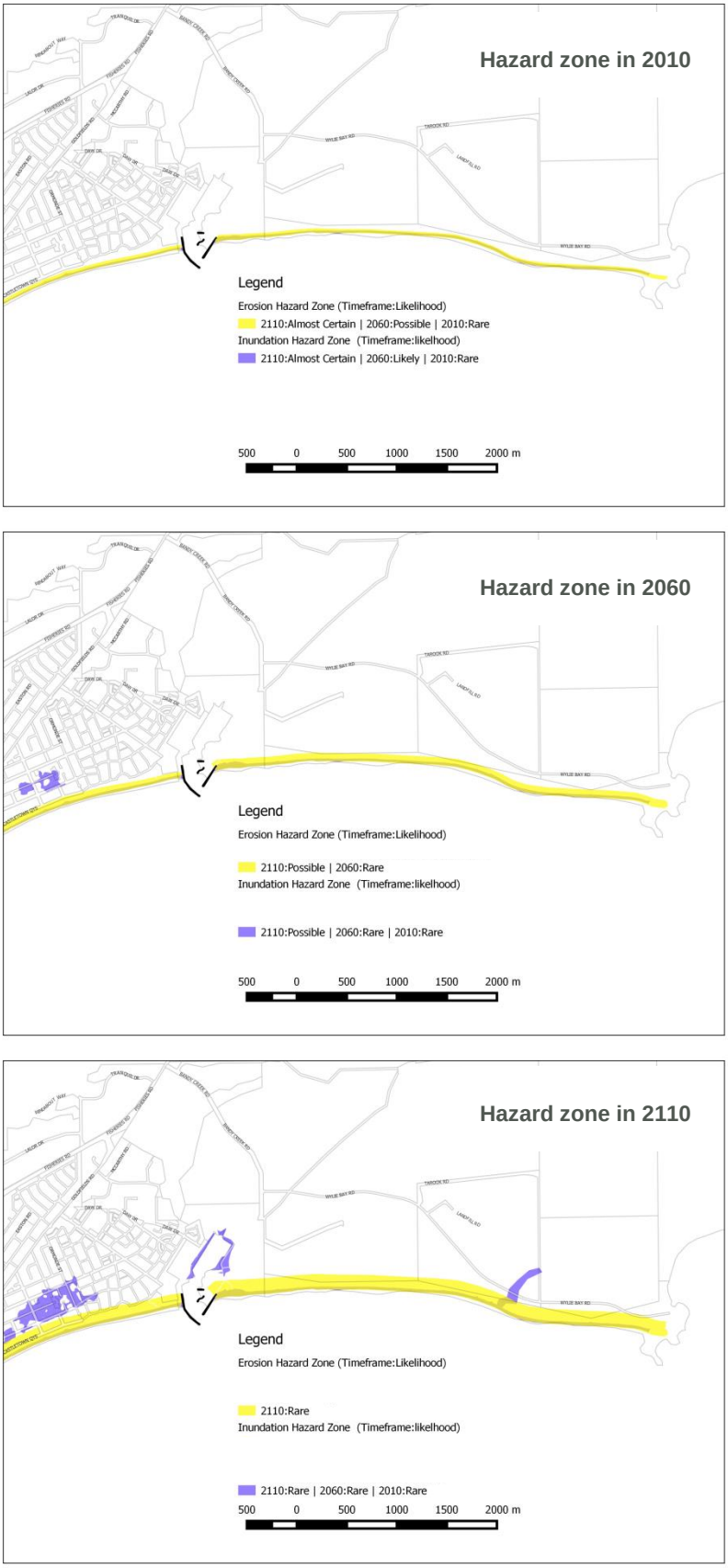


Figure 4-5: cont. Combined erosion (yellow) and inundation (blue) hazard zones over three timeframes: 1 year from now (top), 50 years to 2060 (middle) and 100 years to 2110 (bottom).

4.4 Consequences Scale for Values at Risk

The consequence of coastal erosion and inundation hazards depends largely on the value of the asset impacted.

4.4.1 *Coastal Erosion Hazards Impacts*

In a coastal erosion hazard zone, permanent erosion is expected during extreme events. As a result, excepted conditions in these areas are characterised by:

- Very dangerous and damaging surges of water
- Rapid changes in water depth, fast flowing water and waves potentially laden with debris
- Area should be completely evacuated
- Very dangerous to people and vehicles
- Will cause significant structural damage and/or destruction of buildings not designed to sustain the extreme event.

4.4.2 *Coastal Inundation Hazards Impacts*

In a coastal inundation hazards zone, temporary inundation is expected during extreme events. As a result, excepted conditions in these areas are characterised by:

- Area will be continuously inundated, generally by standing or slow moving water
- Depth will vary depending on location, and may be dangerous and damaging in some locations
- Areas should be evacuated
- Buildings (not designed to sustain the extreme event) may be damaged but are unlikely to be completely destroyed.

4.4.3 *Measures of Consequence*

A consequence scale for economic, social and environmental values applicable to the assets at risk in the coastal zone was developed (Table 4-7) consistent with the Australian Standard Risk Management Principles and Guidelines ISO 31000:2009 and existing enterprise risk frameworks already used by the Shire. The grades were appropriately weighted to ensure equivalence in impact severity across the economic, social and environmental categories. The consequence scale was designed such that it is appropriate to consider management actions for each asset as designated by the highest grade of consequence.

4.4.4 *Consequence Scale for Assets Exposed to Coastal Hazards*

The assigned consequence of the coastal hazard on the identified assets was included in Table 4-8. Distinct levels of consequence are shown depending on the type of hazards. The consequence of erosion is usually more server than the consequence of inundation due to the intensity of the coastal processes at play.

The rating of the coastal assets within the Shires' measures of consequence framework was confirmed by the Shire on behalf of the community and stakeholders.

Table 4-7: Shire of Esperance Measures of Consequence

Consequence Rating (Level)	Social			Economical			Environmental
	Safety / Health (Physical)	Safety / Health (Psychological)	Services	Financial	Compliance	Reputational	Environment
Insignificant (1)	Negligible injuries/ First aid injuries	Temporary, no leave taken, short term with full recovery	No material service interruption	Less than $5,000	No noticeable regulatory or statutory impact	Unsubstantiated, low impact, low profile or 'no news' item	Contained, reversible impact managed by on site response
Minor (2)	Medical type injuries (</= 9 days lost time)	Sick leave, short term impact, recovery 1-3 weeks	Short term temporary interruption – backlog cleared < 1 day	$5,001 - $50,000	Some temporary non compliances	Substantiated, low impact, low news item	Contained, reversible impact managed by internal response
Moderate (3)	Medical type injuries (10 days - 3 months lost time)	Significant non-permanent, longer term illness, recovery 1-6 months	Medium term temporary interruption – backlog cleared by additional resources < 1 week	Up to $500,000	Short term non-compliance but with significant regulatory requirements imposed	Substantiated, public embarrassment, moderate impact, moderate news profile	Contained, reversible impact managed by external agencies
Major (4)	Medical type injuries (> 3 months lost time)	Longer term illness, severe trauma, extended incapacity	Prolonged interruption of services – additional resources; performance affected < 1 month	Up to $1.5M	Non-compliance results in termination of services or imposed penalties	Substantiated, public embarrassment, high impact, high news profile, third party actions	Uncontained, reversible impact managed by a coordinated response from external agencies
Catastrophic (5)	Fatality, permanent disability	Death, permanent severely disabling illness, e.g. Post-Traumatic Stress Disorder	Indeterminate prolonged interruption of services – non-performance > 1 month	More than $1.5M	Non-compliance results in litigation, criminal charges or significant damages or penalties	Substantiated, public embarrassment, very high multiple impacts, high widespread multiple news profile, third party actions	Uncontained, irreversible impact

Table 4-8: Consequence scale to coastal hazard applicable to identified coastal asset

		Consequence Rating		Comments
Category		Erosion	Inundation	
Beaches[i]	Emily St to Norseman Rd	4-Major	1-Insignificant	
Beaches	Norseman Rd to Bandy Creek	3-Moderate	1-Insignificant	
Beaches	Bandy Creek to Wylie Head	1-Insignificant	1-Insignificant	
Boating Facilities	Yacht Club Facilities	3-Moderate	1-Insignificant	
Coastal Assets		5-Catastrophic	3-Moderate	
Coastal Protections		4-Major	1-Insignificant	
Esperance Waterfront		5-Catastrophic	5-Catastrophic	
Essential Services Facilities and corridors	Aged Care	5-Catastrophic	5-Catastrophic	None identified at risk
Essential Services Facilities and corridors	Emergency access corridors	5-Catastrophic	5-Catastrophic	
Essential Services Facilities and corridors	Hospital	5-Catastrophic	5-Catastrophic	None identified at risk
Essential Services Facilities and corridors	School	5-Catastrophic	5-Catastrophic	None identified at risk
Footpaths & Cycleways		3-Moderate	2-Minor	
Heritage		5-Catastrophic	2-Minor	
Infrastructure	Communication	5-Catastrophic	5-Catastrophic	
Infrastructure	Gas	5-Catastrophic	5-Catastrophic	
Infrastructure	Hazardous Product and Material	5-Catastrophic	5-Catastrophic	None identified at risk
Infrastructure	Petroleum	5-Catastrophic	5-Catastrophic	
Infrastructure	Power	5-Catastrophic	5-Catastrophic	
Infrastructure	Water	5-Catastrophic	4-Major	
Infrastructure	Drainage	5-Catastrophic	3-Moderate	
Infrastructure	Roads	5-Catastrophic	2-Minor	
Reserves	Bandy Creek Reserve	2-Minor	1-Insignificant	
Reserves	Esperance Bay foreshore Reserves	2-Minor	1-Insignificant	
Reserves	Wylie Bay foreshore Reserves	2-Minor	1-Insignificant	
Shire of Esperance Buildings		5-Catastrophic	5-Catastrophic	
Zoning	Central Area	5-Catastrophic	5-Catastrophic	
Zoning	Future Residential	5-Catastrophic	5-Catastrophic	
Zoning	Residential	5-Catastrophic	5-Catastrophic	
Zoning	Tourist residential	5-Catastrophic	5-Catastrophic	
Zoning	Tourist Zone	5-Catastrophic	5-Catastrophic	
Zoning	Agriculture - general	5-Catastrophic	2-Minor	
Zoning	Local Road	5-Catastrophic	2-Minor	
Zoning	Regional Road	5-Catastrophic	2-Minor	
Zoning	Public purpose	5-Catastrophic	5-Catastrophic	
Zoning	Railway and Port Installation	5-Catastrophic	5-Catastrophic	
Zoning	Park, Recreation and Conservation	2-Minor	1-Insignificant	

[i] Beach erosion consequence is rated against the general loss of beach area. It excludes the consequence of shoreline retreat which may impact other asset class. The consequence rating of beach erosion was downgraded the further from Esperance town centre to reflect the vulnerability of each beach section to Wylie Head. A beach section is more vulnerable to erosion, and requires a higher consequence rating, where the potential loss of sand is not balanced by sufficient potential sand supply. This is the case between Emily Street and Norseman Road, where the back of the beach and dune is low, and in front of the seawall. In contrast, between Norseman Road and Wylie Head, there is an increasing amount of sand stored in the back beach and high dune system which could contribute to naturally replenish the beach as the shoreline retreats.

5 COASTAL HAZARDS RISK EVALUATION

Evaluation of the risk is about prioritising risk management and adaptation actions. It is an important part of the CHRMAP process as it may not be possible or necessary to treat every risk. Comparison of the results of the risk analysis is undertaken to determine the acceptability/tolerability, unacceptability/intolerability of the risks, according to the risk measures (scale) applicable for the project.

5.1 Risk Scale and Responsibilities

A risk scale applicable to the assets exposed to coastal hazards was developed (Table 5-1) consistent with the Australian Standard Risk Management Principles and Guidelines ISO 31000:2009 and existing enterprise risk frameworks already used by the Shire. The grades were appropriately weighted to take into consideration the combination of likelihood and consequence of coastal hazards on a given asset. Appropriate management actions requirements are also proposed in response to the risk level identified (Table 5-2).

Table 5-1: Risk scale

		Risk Scale				
Consequence Scale	Catastrophic (5)	Extreme	Extreme	High	High	Moderate
	Major (4)	Extreme	High	High	Moderate	Low
	Moderate (3)	High	High	Moderate	Moderate	Low
	Minor (2)	High	Moderate	Moderate	Low	Low
	Insignificant (1)	Moderate	Low	Low	Low	Low
		Almost Certain (5)	Likely (4)	Possible (3)	Unlikely (2)	Rare (1)
		Likelihood Scale				

Table 5-2: Risk management responsibility

Risk Level	Tolerance Level	Performance measure	Monitoring, review and testing frequency	Team Responsible
Extreme	Unacceptable	• Implement risk reduction strategy • Control measures – Fully in place – Well addressed / complied with – Subject to ongoing maintenance • All treatment plans to be – Explored – Implemented where possible	Continuously	Council, CEO
High	Urgent attention required	• Develop risk reduction strategy • Control measures – Fully in place – Well addressed / complied with – Subject to ongoing maintenance	Monthly	CEO / Director
Moderate	Monitor	• Monitor risk enhancing trigger • Control measures – In place – Addressed / complied with	Semi-annually	Operational Manager
Low	Acceptable	• Monitor risk enhancing trigger • Control measures – In place – Addressed / complied with	Annually	Operational Manager

5.2 Characterisation of Coastal Erosion Risks

According to the adopted risk framework introduced before, the first key dimension of the erosion risk pertains to the erosion hazard likelihood (as introduced in section 4.2), while the second key dimension of the erosion risk pertains to the consequence of a coastal asset being subject to erosion (as introduced in section 4.3). In the following sections, we provide some further insight into the characterisation of these dimensions, as they relate to specific sector in the study area.

5.2.1 *Erosion Hazard Summary*

A summary breakdown of the erosion allowance in the study area for the three timeframes is shown in Figure 5-1.

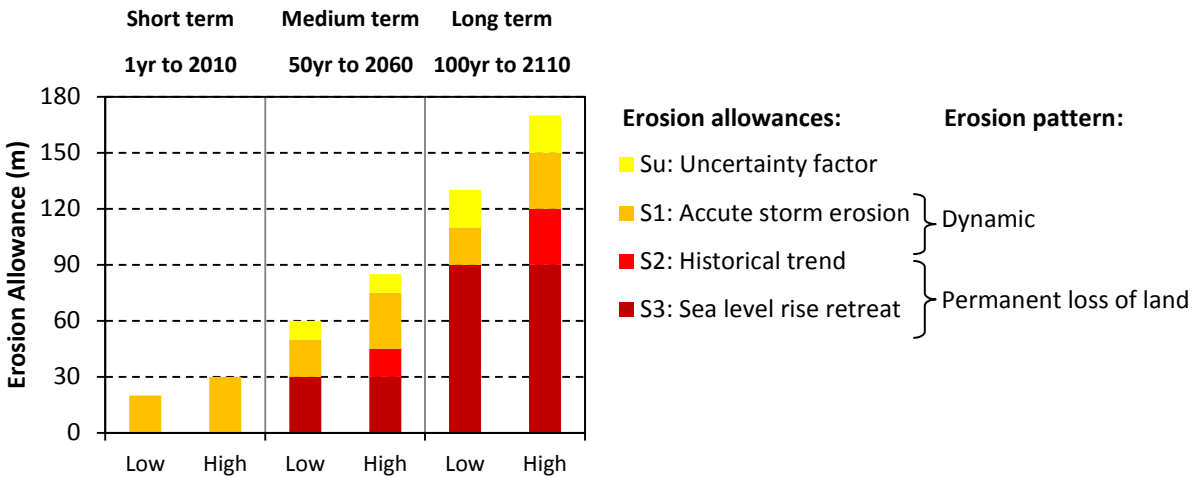


Figure 5-1: Erosion allowance breakdown for the 3 timeframes. Data shown correspond to the smallest (Low) and largest (High) allowance in the study area (referred to as Emily St Frontage and Goldfields Rd Frontage respectively in Table 3-2).

The cross-shore erosion allowance in the study area is characterised as follow:

- In the short term (within 1 year in the present), the 20-30m erosion allowance is apportioned to various components as follow:
  - 100% acute storm erosion (S1) “storm bight”;
- In the medium term (within 50 years by 2060), the 60-85m erosion allowance is apportioned to various components as follow:
  - 45% acute storm erosion (S1);
  - 45% shoreline recession due to sea level rise (S3); and
  - 10% “uncertainty factor” (SPP2.6)
- In the long term (within 100 years by 2110), the 130-170m erosion allowance is apportioned to various components as follow:
  - 65% shoreline recession due to sea level rise (S3); and
  - 20% acute storm erosion (S1); and
  - 15% “uncertainty factor” (Su).

This shows that over the medium to long term, the erosion allowance becomes significantly influenced by the shoreline retreat component attributed to the impact of sea level rise alone.

The “sea level rise“ hazard zone is characterised by permanent loss of land due to the erosion forces at play. Beyond this zone, the shoreline movement may be more dynamic and episodic, subject to cycles of acute storm erosion and accretionary periods.

The erosion hazard zones (shown on Figure 5-9 and Figure 5-10) have been subdivided according to their likelihood in accordance with the above interpretation of the cross-shore erosion allowance. The erosion hazard zones are delineated on the landward boundary by the 1% AEP Storm erosion scenario for a given timeframe. By definition this boundary line has a very low probability of occurrence. Seaward of this line, the probability of occurrence

of erosion rises rapidly as the processes at work within the hazard zone, such as sea level rise retreat, are occurring with increased frequency. It was assumed that the retreat due to sea level rise alone was a certainty. Therefore, as the sea level rises over time, erosion become *Almost Certain* (shown in red) in the zone affected by it; and between this zone and the landward boundary line the probability of erosion was considered to be *Possible* (shown in yellow).

The along shore erosion pattern, characterised by the width of the erosion hazard zone, is relatively uniform along the coast from Emily Street to Wylie Head (as shown in Figure 5-9 and Figure 5-10). A small longshore variation can be noticed along Goldfields Road frontage, where the erosion allowance peaks due to a marked historical trend in addition to the other coastal processes. At the scale of the study, the local effect of hard points (e.g. breakwaters) was not considered to influence the risk assessment results.

5.2.2 *Erosion Consequence Rating Summary*

Erosion consequence is characterised by significant change in land form, including permanent loss of land. As a result, the consequence rating of erosion across most asset category is *Catastrophic*. Assets classes such as Beaches, Boat facilities and Footpaths and Cycleways attract a lower consequence rating. Reserves (e.g. Park, Recreation and Conservation) have a *Minor* erosion consequence rating[ii]. The consequence rating of erosion for various assets is detailed in Table 4-7 and illustrated in Figure 5-8.

5.2.3 *Existing Erosion Controls and Effectiveness*

The following erosion controls have been implemented by the Shire and are currently in place:

<u>Coastal Protection Scheme</u>

- Seawall - The erosion hazard can be temporarily reduced in the presence of effective protective structures. Despite the progressive loss of frontal beach, protective structures, such as seawalls, may affect erosion hazard zones by reducing the erosion allowance and reducing the likelihood of erosion. It is the case along a 900m long section of the coast in the Esperance Waterfront area, where a brand new seawall (built in 2014, Figure 5-2) offers erosion protection in the medium term to 2060. Beyond this timeframe, it has been assumed that the erosion hazard will follow the regional pattern. That is, in the absence of further erosion mitigation measures, such as increasing the seawall useful life or upgrading to control overtopping with increased sea level.

[ii] Unless developed for nodal activation, in recessionary scenario, the foreshore reserve is considered a sacrificial buffer to be utilised until progressively lost.

Figure 5-2: Esperance Waterfront seawall.

- Groyne field - The erosion allowance was not modified by the presence of a groynes field (Figure 5-4), which were not designed to offer significant erosion protection due to sea level rise and acute storm erosion. Groynes reduce longshore transport by trapping beach material on the up drift side and causing the beach orientation to change relative to the dominant wave directions. During higher energy wave or current conditions, sand is carried in temporary suspension and will therefore tend to be carried over or around these cross-shore structures.

Figure 5-3: Groyne field at Norseman Road frontage.

- Landscape edge walls - The erosion allowance was not modified by the presence of landscape edge walls (Figure 5-4), which were not designed to offer significant erosion protection. The feature wall provides an elegant retaining function that minimises trimming and maintenance of the edge between the grassed area and the sandy beach. However, with the projected erosion, these will increasingly be impacted by storm waves and decision to protect or abandon these will have to be addressed in the future.

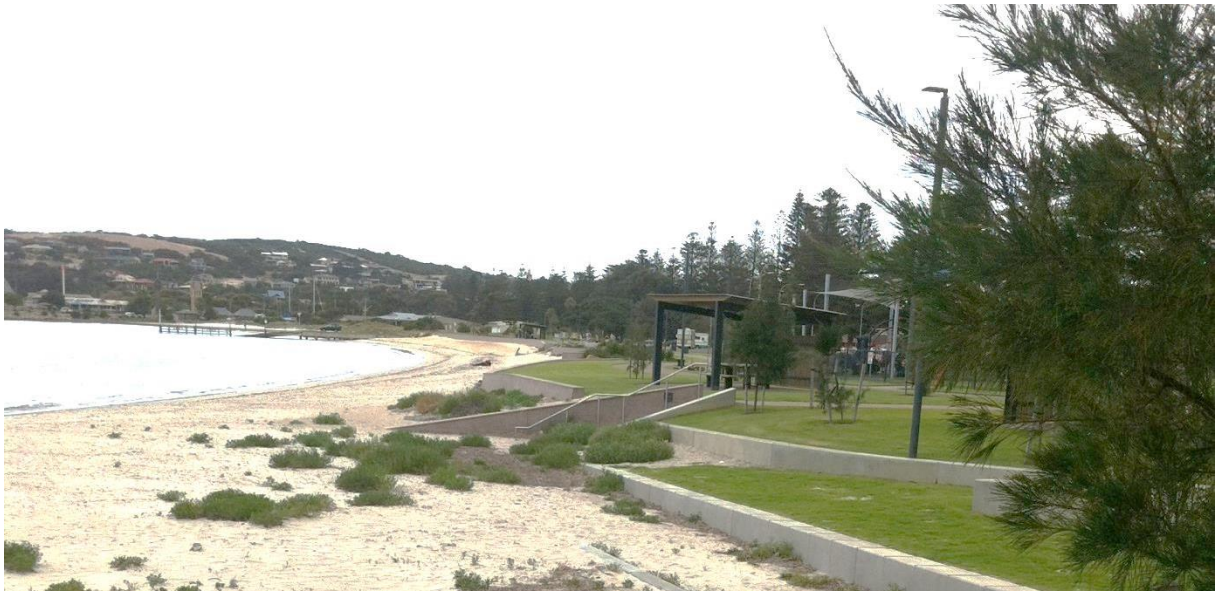


Figure 5-4: Landscape edge walls north of James Street Groyne.

- Beach nourishment - The erosion allowance was not modified by the presence of beach nourishment actions along the coast. It is understood that The Shire is actively managing the Goldfields Road frontage (Figure 5-5), where recurrent erosion issues have prompted the implementation of a beach nourishment program. Sand is currently trucked to the location and pushed over the fore dune scarp along this section a rate in the order of 10,000m^3 per annum.

Figure 5-5: Dune scarp along Goldfields Road foreshore following the beach nourishment program.

Planning Scheme

- Special Control Areas, such as Coastal Erosion and Inundation Risk Special Control Area 9 (SCA9, Local Planning Scheme No. 23 - Amendment No. 19), provide guidance for land use and development within the potential coastal erosion and inundation risk area based on the latest risk mapping. This control triggers the need for:
  - A notification to be placed on the Certificate of Title warning of potential inundation risk
  - A planning permit for some types of buildings and works
- Foreshore Reserves - The erosion allowance was not modified by the presence of foreshore reserves. Foreshore reserves can be used to contain erosion risk by offering a buffer zone within which the consequence level of erosion is capped. The effectiveness of the existing foreshore reserves to contain the risk of erosion in the study area is discussed in section 5.2.8.

Figure 5-6: Foreshore reserves at Goldfields Road looking east (top) and at Ormonde Street looking west (bottom).

5.2.4 *Erosion Risk Register*

In order to provide clarity and distinctions in the risk evaluation, a risk register has been developed which identifies values at risk in the erosion hazard zones. A detailed risk evaluation has been undertaken by overlaying the GIS layers for each hazard zones and asset class, as provided by the Shire. Where an asset intersect a hazard likelihood category, a line item for the asset at risk has been created and risk profile characterised, including scale, key risk descriptors, key controls in place, likelihood index, consequence index and resulting risk for the three evaluation timeframes.

5.2.5 *Erosion Risk Aggregate Trend*

The erosion risk profile has been aggregated over all the asset classes and its evolution over the three timeframes is presented in Table 5-3. The migration of the current erosion risk profile toward the higher end of the risk spectrum is evident in the table. In the present day, 5% of the values identified are found to be at High risk and 85% are found to be at Moderate risk. By 2050, 5% of the values identified are found to be at Extreme risk, 25% are found to be at High risk and 66% are found to be at Moderate risk. By 2100, 28% of the values identified are found to be at Extreme risk, 68% are found to be at High risk and 4% are found to be at Moderate risk.

Table 5-3: Erosion risk table summary

Asset at Risk - to Present	**Likelihood**					
Consequence	Almost Certain (5)	Likely (4)	Possible (3)	Unlikely (2)	Rare (1)	**Grand Total**
Catastrophic (5)	-	-	4%	-	80%	84%
Major (4)	-	-	1%	-	1%	3%
Moderate (3)	-	-	2%	-	4%	6%
Minor (2)	-	-	3%	-	4%	7%
Insignificant (1)	-	-	-	-	-	-
Grand Total	**-**	**-**	**10%**	**-**	**90%**	**100%**
Asset at Risk - to 2060	**Likelihood**					
Consequence	Almost Certain (5)	Likely (4)	Possible (3)	Unlikely (2)	Rare (1)	**Grand Total**
Catastrophic (5)	4%	-	19%	-	62%	84%
Major (4)	1%	-	1%	-	-	3%
Moderate (3)	2%	-	2%	-	2%	6%
Minor (2)	3%	-	2%	-	2%	7%
Insignificant (1)	-	-	-	-	-	-
Grand Total	**10%**	**-**	**24%**	**-**	**66%**	**100%**
Asset at Risk - to 2110	**Likelihood**					
Consequence	Almost Certain (5)	Likely (4)	Possible (3)	Unlikely (2)	Rare (1)	**Grand Total**
Catastrophic (5)	25%	-	59%	-	-	84%
Major (4)	3%	-	-	-	-	3%
Moderate (3)	4%	-	2%	-	-	6%
Minor (2)	5%	-	2%	-	-	7%
Insignificant (1)	-	-	-	-	-	-
Grand Total	**37%**	**-**	**63%**	**-**	**-**	**100%**
Risk scale: Extreme, High, Moderate, Low						

In the aggregate, the spatial extend of the erosion risk rapidly increases over time, with approximately 1,000m of coastline is at *High* risk in the short term, increasing 3,200m at *High*

risk (including 500m at Extreme risk) in the medium term and reaching 9,000m at *High* risk (including 3,000m at Extreme risk) in the long term. This trend is illustrated in Figure 5-7.

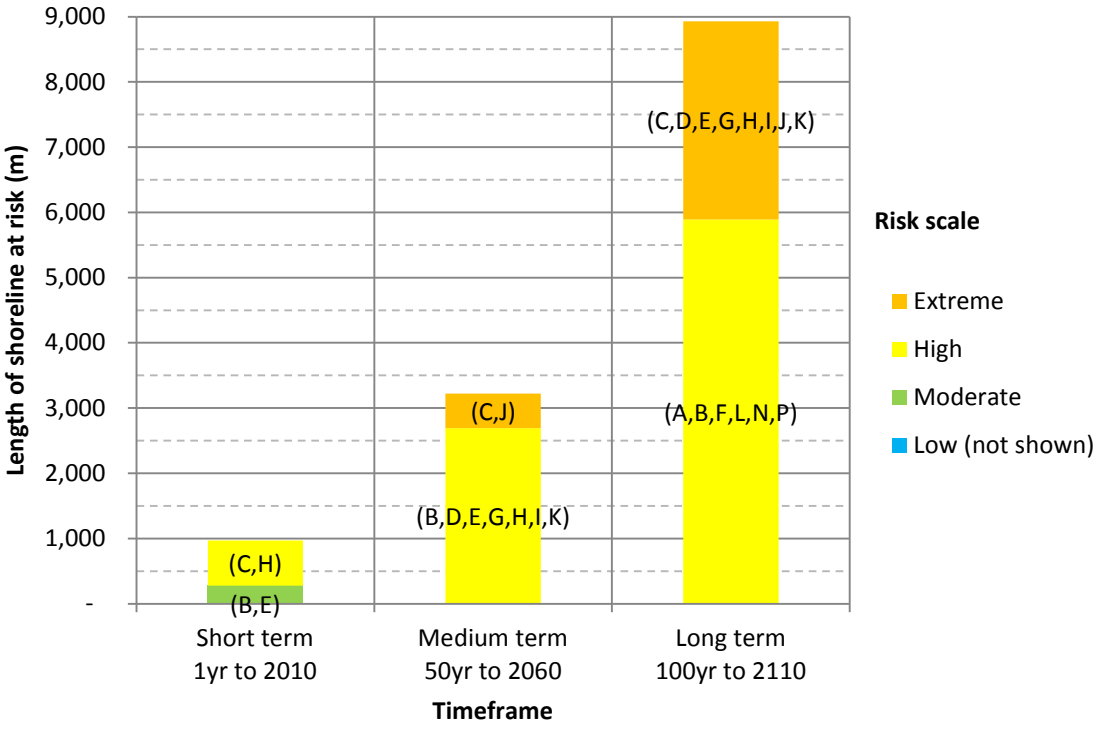


Figure 5-7: Length of shoreline at risk of erosion over the three timeframes considered. The length of shoreline assessed is approximately 9,560m, excluding Bandy Creek Reserve and Railway and Port Installation. The erosion management unit name is provided in parentheses (Figure 5-14).

5.2.6 *Erosion Risk Segmentation*

Considering the geographical location of the assets at risk of erosion in study area, the coastline has been subdivided into 16 segments, each representing a potential management unit with its own erosion risk rating for a given timeframe. This segmentation is illustrated in Figure 5-14 and is referred to in the rest of the document. The pattern of erosion risk is characterised as follow:

- In the short term, segments C, H, and J are at *High* risk of erosion and segments B and E are at *Moderate* risk of erosion. Assets impacted are mostly infrastructures.
- In the medium term, segments C and J become at *Extreme* risk. The *High* risk segments have increased, including B, D, E, G, H, I and K. Assets impacted are mostly infrastructures.
- In the long term, the whole coastline in the study area is at risk. Segment C,D, E, G,H,I,J and K become at *Extreme* risk. The remaining segments B, F, L, N, P become at *High* risk. Assets impacted include infrastructures and zoning.

5.2.7 *Erosion Risk Hot Spots*

Priorities areas have been identified by sorting items in the risk register according to the aggregated risk index over the three timeframes. We observe that this aggregated risk classification is consistent with a classification based on the risk index for the present timeframe, thereby strongly reflecting the increased erosion risk over time in areas already under pressure due to erosion processes.

The coastal assets summarised in Table 5-4 are considered as "hot spots". They are ranking equally high risk, with a High (3) to Extreme (4) risk over the planning time frame, due to their location within the erosion hazard zone likelihood Possible (3) and elevated consequence index High (4) and Extreme (5).

Table 5-4: Erosion risk hotspots by asset class

Asset Class	Scale	Location (Management Unit)
Beach	Approx. 2,200m	– Emily St to Tanker jetty (A-F) – Tanker jetty to Norseman Rd (A-I)
Infrastructure – Power	Approx.15m	– 100m south of Phyllis St off Goldfields Rd (J)
Infrastructure - Water - Marine Outfalls	Approx. 110m	– William St (A) – Phyllis St (K) – Chaplin St (K) – Irvin St (K)
Infrastructure - Water - Rising Main	Approx. 575m	– Between Andrew St and James Street (C) – Goldfields Rd (J)
Infrastructure – Petroleum - Pipeline	Approx. 65m	– South of James St (C)
Boat ramp	1 structure	– Between William St and Andrew St (B)
Carpark & Water pump Station	Approx. 223m^2	– Phyllis St (K)
Regional Road	Approx. 9,300m^2	– Goldfields Rd (J)

5.2.8 *Erosion Risk Breakdown for Key Asset Classes*

The erosion risk to key asset classes, including existing zoning and infrastructure, is detailed hereafter and illustrated in Figure 5-11, Figure 5-12 and Figure 5-13. The erosion management unit name is provided in parentheses (Figure 5-14).

Zones and Reserves

- Foreshore reserves (i.e. parks, recreation and conservation areas) are present all along the coast from Taylor St to Wylie Head. They are relatively effective erosion control instruments, as they cap the upward risk level to *High*, even under erosion hazard scenarios that are highly likely (e.g. *Almost Certain,* which has more than 90% probability of occurrence over the timeframe considered). Within foreshore reserve zones affected by coastal hazards, the risk level will therefore be *High* in the areas potentially impacted by permanent loss of land, but it will be *Moderate* landward of these areas. In the study area, the risk to foreshore reserve zones is *Moderate* in the short term, and increases to *High* in the medium to long term. The erosion risk to foreshore reserve is characterised as follow:
  - In the short term, reserves are offering some degree of protection against erosion
  - In the medium and long term, the protection buffer is reducing, potentially exposing other assets to higher level of erosion risk in the medium and long term (A-P).
- Road reserves are more sensitive to erosion than foreshore reserves and tend to attract a higher risk rating when exposed to a similar probability of erosion. The erosion risk to road reserves is characterised as follow:
  - In the short term, the Goldfields Road frontage south of Phyllis Street (J) is at *High* risk of erosion over a 500m section.
  - In the medium term, the risk to Goldfields Road frontage (J) will escalate to an *Extreme* level, while the adjacent Norseman Road frontage (G,H,I) become at *High* risk of erosion over a 500m section, and the contiguous Castletown Quays (K) become at *Moderate* risk of erosion over a 3,500m section. In addition, approximately 500m of The Esplanade centered on James Street (C,D) will also be at *High* risk.
  - In the long term, the risk to Goldfields Road frontage (J) will remain to an *Extreme* level, while the adjacent Norseman Road (G,H,I) frontage will escalate to *Extreme* risk of erosion over a 500m section, and the contiguous Castletown Quays (K) will also escalate to *Extreme* risk of erosion over a 3,500m section. In addition, approximately 500m of The Esplanade centered on James Street (C,D) will escalate to *Extreme* risk, while the complement of the Esplanade from William Street to Norseman Road (A,B,C,D,E,F,G) (approximately 1,300m) will be at *High* Risk.
- Residential and tourist zones are the most sensitive zones to erosion risk (with a similar consequence rating as road reserves). The erosion risk to residential and tourist zones is characterised as follow:
  - In the short term, residential and tourist zones are not impacted by erosion risk.
  - In the medium term, there is a *High* risk of erosion to residential and tourist zones within 30-40m of Goldfields Road and Castletown Quays frontages south of Straker Street (K). This corresponds to an area approximately 30,000m^2.
  - In the long term, the 30,000m^2 *High* risk area identified previously for the medium term will become an *Extreme* risk area. In addition, there will be a *High* risk of erosion to residential and tourist zones within 60-110m of Norseman Road, Goldfields Road and Castletown Quays frontages south of Ormond Street (K). This corresponds

to an additional area approximately 160,000m^2. In addition, in the absence of a sustain protection from the Esperance Waterfront seawall, there will be a *High* risk of erosion to residential and tourist zones North of Kemp Street within approximately 130m from the shoreline (F). This corresponds to an additional area approximately 44,000m^2. A further 36,000m^2 will also be similarly impacted from Kemp Street to Taylor Street (A,B,C,D,E).

- Public Purpose zone are sensitive zones to erosion risk. They are characterised as follow:
  - In the short term, there is a *High* risk of erosion at Phyllis Street water pump station.
  - In the medium term, there is a *High* risk of erosion at Phyllis Street water pump station.
  - In the long term, there is an *Extreme* risk of erosion at Phyllis Street water pump station. There is also a *High* risk of erosion at William Street drain, Andrew Street water pump station, James Street museum, Langham Lane water pump station and Norseman Road Hall.
- Beaches in the study area are all subject to erosion hazard over time, however, the presence or absence of sand supply influence the overall risk rating obtained for various section of the coast between *Low* and *High* depending on the location and time frame considered. The erosion risk to road reserve is characterised as follow:
  - In the short term, beaches to the south of Goldfields Road (A,B,C,D,E,F,G,H,I) are at *High* risk of erosion, while to the north they are at increasingly lower risk, i.e. *Moderate* risk up to Bandy Creek (J,K,L) and *Low* risk from Bandy Creek to Wylie Head (M,N,O,P).
  - In the medium and long term, there is an *Extreme* risk of erosion to beaches to the south of Goldfields Road (A,B,C,D,E,F,G,H,I). The risk to beaches to the north of Goldfields Road (J,K,L) increases to *High* up to Bandy Creek and *Moderate* risk from Bandy Creek to Wylie Head (M,N,O,P).

Infrastructure

Apart from the zones and reserves assets at risk discussed before, there also exists a number of infrastructure assets at risk. These assets include infrastructure such as road, water, petroleum, power, gas, outfall, boat ramp, footpath, carparks, toilet blocks and coastal access. Water pump stations located in public purpose zones were addressed above in the Zone and Reserve section and indirectly covered in the following Roads and Utilities section.

- Roads and Utilities (water, gas, and power) are at an increasing risk of erosion over time. There is a strong correlation between the erosion risk for Road reserves and the erosion risk for utilities listed above because they often share similar corridors. The erosion risk to existing roads and utilities is characterised as follow:
  - In the short term, the Goldfields Road frontage south of Phyllis Street (J) is at *High* risk of erosion over a 500m section. There is also a 100m section at *High* risk on the Norseman Road frontage south of Jetty Road (H) and an additional 100m section at *High* risk on the Esplanade frontage between James Street and Andrew Street (C).
  - In the medium term, the risk to Goldfields Road frontage (J) will escalate to an *Extreme* level, while the adjacent Norseman Road frontage (G,H,I) will become at

High risk of erosion over a 500m section, and the contiguous Castletown Quays (K) become at *Moderate* risk of erosion over a 3,500m section. In addition, approximately 500m of The Esplanade centered on James Street (C,D) will also be at *High* risk.

- In the long term, the risk to Goldfields Road frontage (J) will remain to an *Extreme* level, while the adjacent Norseman Road frontage (G,H,I) will escalate to *Extreme* risk of erosion over a 500m section, and the contiguous Castletown Quays (K) will also escalate to *Extreme* risk of erosion over a 3,500m section. In addition, approximately 500m of The Esplanade centered on James Street (C,D) will escalate to *Extreme* risk, while the complement of the Esplanade from William Street to Norseman Road (A,B,E,F) (approximately 1,300m) will be at *High* Risk.

- Petroleum infrastructure linking the port and the tank farm is at risk of erosion north of William Street and South of Kemp Street. The erosion risk to existing petroleum asset is characterised as follow:
  - In the short term, there is a 65m section of the pipeline at *High* risk south of James Street groyne (C).
  - In the medium term, there is a 600m section of the pipeline at *High* risk south of Kemp Street (D,E), including a 65m section at *Extreme* risk south of James Street groyne (C).
  - In the long term, there is a 875m section of the pipeline at *High* risk south of Kemp Street down to William Street (A,B,C,D,E), including a 600m section at *Extreme* risk south of James Street groyne (C,D,E).
- Carparks on the waterfront are at risk of erosion near Andrew Street and at the northern end of the seawall off Norseman Road. The erosion risk to existing carpark is characterised as follow:
  - In the short term, there is approximately 500m^2 of carpark are *Moderate* risk of erosion, including 330m^2 at Andrew St (B) and 170m^2 off Norseman Road (G).
  - In the medium term, there is approximately 6,800m^2 of carpark are *Moderate* risk of erosion, including the above (B,G) 500m^2 area become at *High* risk.
  - In the long term, there is approximately 12,000m^2 of carpark are *Moderate* risk of erosion, including the above (B,G) 6,800m^2 area become at *High* risk.
- Marine outfalls and Boat ramp are at risk of erosion near William Street (A), Phyllis Street (K) and along Castletown Quays (K). The erosion risk to identified outfalls is characterised as follow:
  - In the short term, there is approximately 110m of outfall and 35m of the boat ramp at *High* risk of erosion and approximately 600m of outfall are *Moderate* risk of erosion.
  - In the medium term, there is approximately 110m of outfall and 35m of the boat ramp at *Extreme* risk of erosion and approximately 600m of outfall are at *Moderate* risk of erosion, including 300m of outfall *High* risk.
  - In the long term, there is approximately 425m of outfall and 50m of the boat ramp at *Extreme* risk of erosion and approximately 300m of outfall *High* risk.

- Beach access and toilet block at Chaplin Street (K) are at increasing risk of erosion over time, as follow:
  - In the short term, the toilet block and approximately 15m of beach access are at *Moderate* risk of erosion.
  - In the medium term, the risk to the toilet block and approximately 15m of beach access increases to *High* risk of erosion and an additional 15m of beach access becomes at *Moderate* risk of erosion
  - In the long term, the toilet block is at *Extreme* risk and there is approximately 30m of beach access are at *High* risk of erosion.

Heritage Places and Buildings

There are a number of buildings and heritage places along the study area which will be at risk of erosion, as follow:

- In the short term, none of the buildings and heritage places identified are at risk of erosion.
- In the medium term, the Esperance Fish Cannery (fmr) (H) is partially at *High* risk of erosion.
- In the long term, the Esperance Fish Cannery (fmr) (H) is at *Extreme* risk of erosion, while the other buildings and heritage places, including Yacht Club (A), Railway Goods Shed (fmr) (D), Tanker Jetty (F), Cannery Waterhole (I), Old Pad (Bandy Creek) (L), become at *High* risk of erosion.

Figure 5-8: Erosion consequence for zoning (left) and infrastructure (right).

Figure 5-9: Erosion hazard zones over three timeframes: 1 year from now (left), 50 years to 2060 (middle) and 100 years to 2110 (right). Landward edge of the zone based on the 1%AEP Strom Erosion and associated erosion allowances (as per SPP2.6) for the 3 timeframes.

Figure 5-10: Erosion hazard zones over three timeframes: 1 year from now (left), 50 years to 2060 (middle) and 100 years to 2110 (right). Landward edge of the zone based on the 1%AEP Strom Erosion and associated erosion allowances (as per SPP2.6) for the 3 timeframes.

Figure 5-11: Erosion risk to zoning over three timeframes: 1 year from now (left), 50 years to 2060 (middle) and 100 years to 2110 (right). The risk level was allocated in accordance with the likelihood, consequence and risk scales. Zoning highlighted includes Central Area, Residential, Agriculture, Road, Public Purpose, Park, Recreation and Conservation. Beaches are also included (light shaded o). Railway and Port Installation (hatched) was excluded from the assessment.

Figure 5-12: Erosion risk to Zoning over three timeframes: 1 year from now (left), 50 years to 2060 (middle) and 100 years to 2110 (right). The risk level was allocated in accordance with the likelihood, consequence and risk scales. Zoning highlighted includes Central Area, Residential, Agriculture, Road, Public Purpose, Park, Recreation and Conservation. Beaches are also included (light shaded o). Bandy Creek Reserve (hatched) was excluded from the assessment.

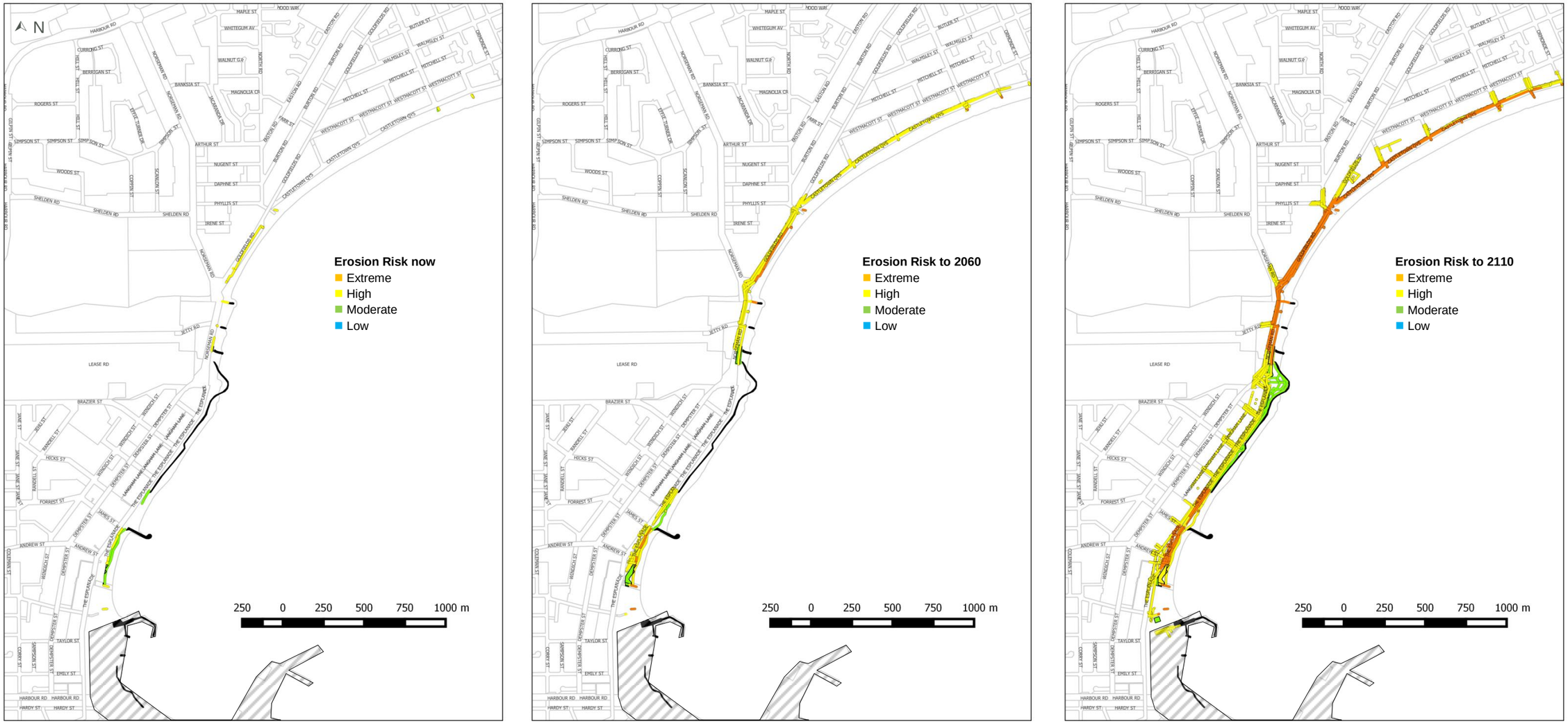


Figure 5-13: Erosion risk to Infrastructures over three timeframes: 1 year from now (left), 50 years to 2060 (middle) and 100 years to 2110 (right). The risk level was allocated in accordance with the likelihood, consequence and risk scales. Infrastructures highlighted include Road, Water, Petroleum, Gas, Power, Beach Access, Carpark and Boat Ramp. Railway and Port Installation (hatched) was excluded from the assessment

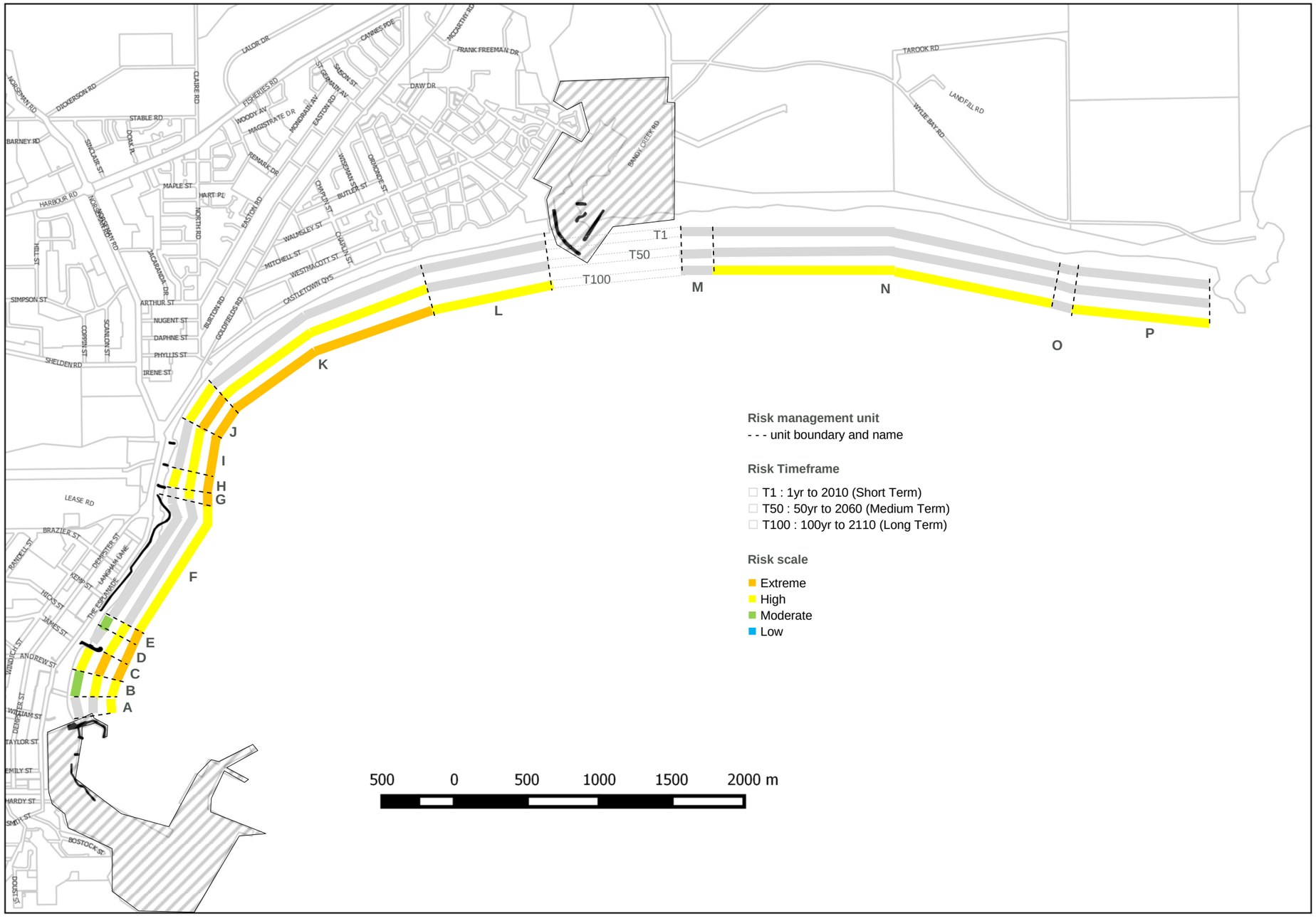


Figure 5-14: Summary of erosion risk over the three timeframes and proposed erosion management units considered. Exclude risk to foreshore reserves and beaches. Bandy Creek Reserve and Railway and Port Installation (hatched) were excluded from the assessment.

5.3 Characterisation of Coastal Inundation Risks

According to the adopted risk framework introduced before, the first key dimension of the inundation risk pertains to the inundation hazard likelihood (as introduced in section 4.2), while the second key dimension of the inundation risk pertains to the consequence of a coastal asset (or value) being subject to inundation (as introduced in section 4.3). In the following sections, we provide some further insight into the characterisation of these dimensions, as they relate to specific sector in the study area.

5.3.1 *Inundation Hazard Summary*

A summary breakdown of the inundation water levels scenarios in the study area for the three timeframes is shown in Figure 5-15.

The inundation allowance adopted under the SPP2.6 policy corresponds to the scenario *1:500 ARI Wave Run-up Level*. Accordingly, the inundated area of this defined coastal inundation event should be used as the area over which controls on land use and development need to recognise the impacts of coastal inundation.

The *1:500 ARI Wave Run-up Level* scenario however has an extremely low probability of occurrence over the planning timeframe, as discussed in Appendix B, therefore alternative inundation water levels were established to better reflect the actual likelihood of acceptable extreme event.

The *1:100 ARI WL equivalent* scenario is consistent with the widely adopted flood management guideline under the SPP3.4 policy. Accordingly, this 100 year average recurrence interval inundation was also used as the defined inundation event, which sets the minimum floor level for all habitable, commercial and industrial buildings. This level was defined as a function of its *equivalent* cumulative probability of occurrence over a given timeframe, as discussed in Appendix B, so that it is adequately adjusted for the effect the anticipated rising sea level trend.

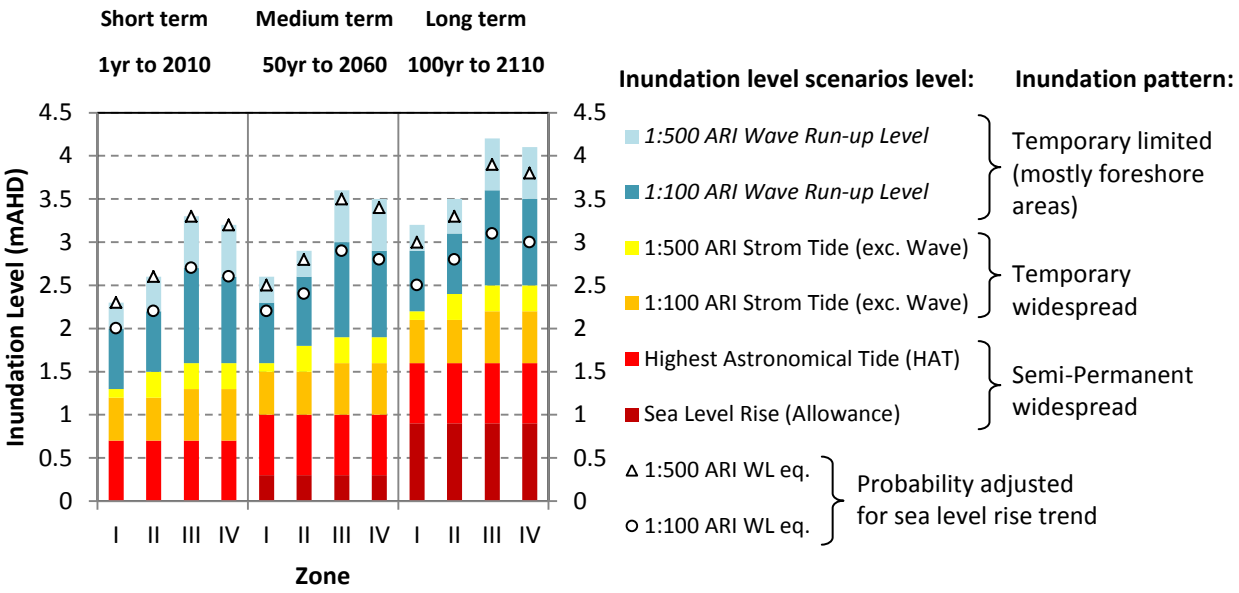


Figure 5-15: Inundation level scenarios breakdown for the three timeframes for the zones defined in Table 3-1, I: Emily St - Norseman Rd; II: Goldfields Rd - Ormonde St; III: Ormonde St – Bandy Creek; IV: Bandy Creek – Wylie Head)

The inundation allowance takes into account multiple oceanic and coastal processes, including rising global sea level, astronomical tide fluctuation, and extreme storm surge and wave run-up (Figure 5-15). Each factor contributes to the inundation pattern in a different way, as follow:

- The combined effect of sea level rise and tide can be described as semi-permanent and widespread. The mean sea level is expected to rise by +0.3m by 2060 and +0.9m by 2010. The highest astronomical tide level is in the order of 0.7m above mean sea level. The resulting combined water level is uniform in the study area.
- The effect of an extreme storm surge tide can be described as temporary and widespread. The storm surge water level component is in the order of 0.5-1.0m. It is slightly higher (+0.3m) in the zone with a south facing shoreline (Zone III and IV) than in the zone with a west facing shoreline (Zone I and II).
- The effect of an extreme wave run-up can be described as temporary and limited to the foreshore areas and may contribute to dune overtopping and breaching. Behind these foreshore run-up areas, the water level is expected to drop as the wave kinetic energy is dissipated. The run-up water level component is in the order of 0.7m. It is higher (+0.3m) in the zone with a south facing shoreline (Zone III and IV) than in the zone with a west facing shoreline (Zone I and II).
- The occurrence of breaching may be compounded by the potential change in the dune topography and in particular the reduction of its cross-sectional area under the action of erosive forces. The breaching inundation scenario presented here is based on the present day geometry of the dune and does not consider its combined effect with erosion scenarios.

- The inundation allowance is also sensitive to the design event probability of occurrence. The sea level rise trend and tidal fluctuation are considered to be certain. The probability of extreme event considered are 1% AEP for the 1:100 ARI event and 0.2% AEP[iii] for the 1:500 ARI event. This difference in extreme event probability translates into a water level difference in the order of 0.3m in the zone with a west facing shoreline (Zone I and II) and 0.5m in the zone with a south facing shoreline (Zone III and IV).
- Also, considering the actual cumulative probability of exceedance of extreme events over the planning horizon in the presence of sea level rise, the increase in design water level only reflect the full sea level rise allowance only for extremely rare events. In the case of the 1:100 ARI event, the increased water level above present day level is only +0.2m by 2060 and +0.5m by 2110. In the case of the 1:500 ARI event, the increased water level above present day level is only +0.2m by 2060 and +0.7m by 2110.

This shows that the inundation allowance in the coastal zone is sensitive to the processes at play and to the defined inundation events over the planning horizon. Although the inundation hazard is expected to rise over time, the rise of the defined inundation level does not mirror in full the adopted sea level rise allowance, especially over the long term.

Various extreme water levels scenarios were used to illustrate the inundation pattern over the existing topography in the study area (Figure 4-3, Figure 4-4 and Figure 5-15). The inundation footprints were overlayed with cadastral data to determine the potential effects of those elevated water levels on land and infrastructure. Information on inundation depth was also provided to increase the capability of coastal inundation studies and helps with decision making.

The inundation hazard zones (shown on Figure 5-20) have been subdivided according to their likelihood in accordance with the Shire's likelihood scale (Table 4-1). The inundation hazard zones are delineated on the landward boundary by the 0.2% AEP Storm erosion scenario for a given timeframe. By definition this boundary line has a very low probability of occurrence. Seaward of this line, the probability of occurrence of inundation rises rapidly and follows the irregularity the terrain. As the sea level rises over time, inundation become *Almost Certain* (shown in red) in the zone affected by the additional effect of tide, surge and waves; while the probability of inundation declines the further away from the low lying foreshore ground areas.

The inundation pattern varies rapidly spatially and over time. The inundation hazard surface area is expected to increase from approximately 160,000m^2 in the present day to 540,000m^2 by 2060 and to 1,200,000m^2 by 2110. The hazard zone surface area with likelihood greater than 60% (i.e. *Likely* and *Almost Certain*) increases 3-fold in 50 years to 2060 and an additional 3-fold subsequently to 2110.

Three keys regions (excluding beach areas) are prone to inundation, including: Town Center and Foreshore (south of Esperance Jetty landing), Tourist Nodes (along Norseman Rd and Goldfields Rd) and West Castletown (between Walmsley St and Westmacott St), as follow:

- In the short term, only a small portion of the Town Center and Foreshore (14,000m^2) and the Tourist Nodes (7,000m^2) areas are concerned with rare inundation events.

[iii] Annual Exceedance Probability

- In the medium term, the inundation surface area rapidly expends by 20 fold, where the Town Center and Foreshore (320,000m^2), the Tourist Nodes (70,000m^2) areas and West Castletown (70,000m^2) are concerned with inundation events of increasing likelihood.
- In the long term, the inundation surface area keeps expending slowly by 2 fold, where the Town Center and Foreshore (630,000m^2), the Tourist Nodes (200,000m^2) areas and West Castletown (250,000m^2) are concerned with inundation events of increasing likelihood.

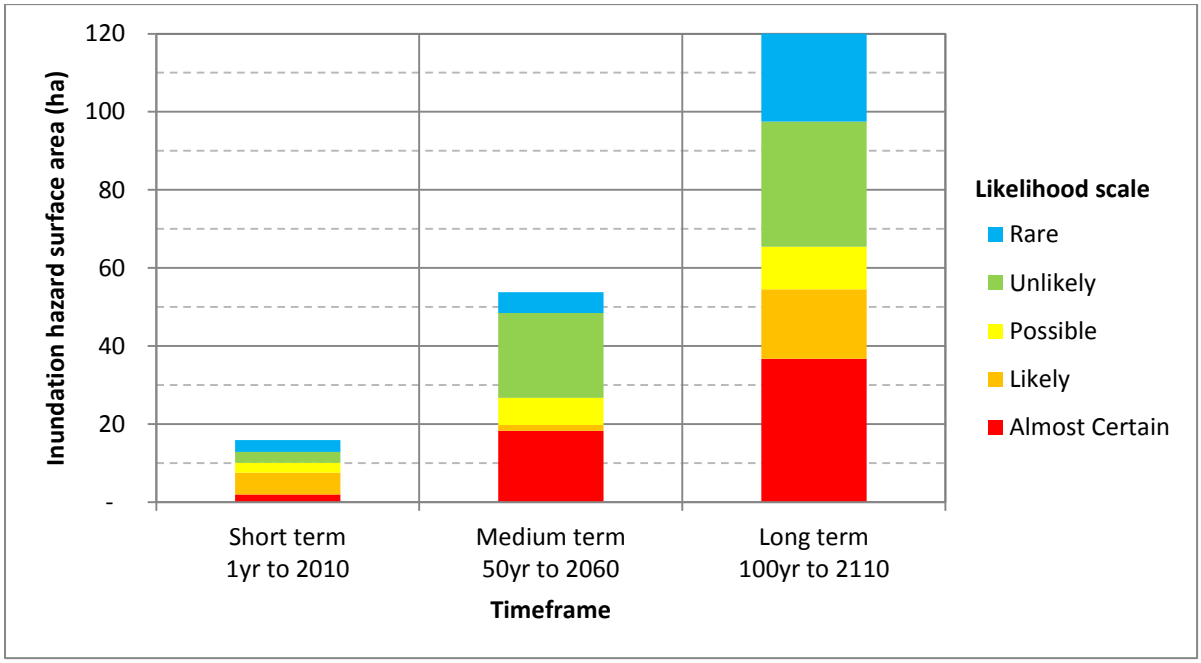


Figure 5-16: Inundation hazard surface area over the three timeframes considered.

5.3.2 *Inundation Consequence Summary*

Inundation consequence is characterised by significant flooding of the landscape, including temporary or permanent elevated water level. As a result, the consequence rating of inundation across many asset categories is *Catastrophic*. Assets classes such as Beaches, Reserves and Roads have a *Insignificant* to *Minor* inundation rating. The consequence rating of inundation for various assets is detailed in Table 4-7 and illustrated in Figure 5-19.

Climate change impacts on infrastructure are expected to include accelerated degradation of materials and foundations of buildings and facilities, mainly due to rising sea levels, increased ground movement, changes in ground water affecting the chemical structure of foundations and fatigue of structures from extreme storm events. Inundation impacts on infrastructure in the coastal zone will have broader consequences for the community

Roads

Social and economic value of roads is significant to local communities, as well as often key emergency routes. Foundation integrity may be potentially subject to damage from flooding, in addition to disruption to accessibility.

Water and Wastewater

Water and wastewater infrastructure can have an effective operational life of many decades. Stormwater pipes and drainage assets exposed to the impacts of rising sea levels and may not be adequate to accommodate future changes in extreme rainfall and storm surge. Increasing maintenance and renewal costs of drainage assets. Saltwater may increasingly enter because of factors such as cracks in pipes caused by ageing or movement, and the presence of seawater reduces system capacity and increases operational costs.

Electrical Components

Electrical components are particularly vulnerable to corrosion from saltwater, even with pressure cleaning immediately after a flood exposed equipment will have to be replaced sooner than would otherwise be the case.

Residential and Commercial Buildings

In coastal areas, a building can be considered a success only if it is capable of resisting damage from coastal hazards and coastal processes over a period of decades. This statement does not imply that a coastal residential building will remain undamaged over its intended lifetime. It means that the damage following impact of a design-level inundation will be limited (Figure 5-17).

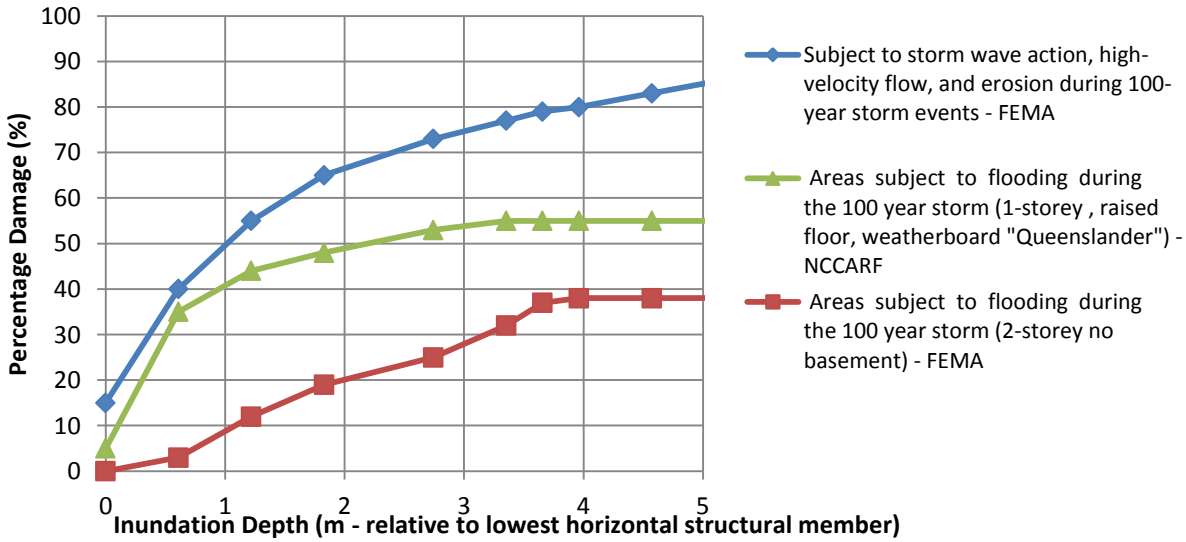


Figure 5-17: Inundation depth versus building damage curves (after FEMA[iv] and NCCARF[v]).

5.3.3 *Existing Inundation Controls and Effectiveness*

The following inundation controls have been implemented by the Shire and are currently in place:

[iv] Home Builder's Guide to Coastal Construction, Technical Fact Sheet Series, FEMA P-499 / December 2010
[v] Analysis of damage to buildings following the 2010–11 Eastern Australia floods

Planning Scheme

- Foreshore Reserves - The inundation allowance was not modified by the presence of foreshore reserves. Foreshore reserves can be used to contain inundation risk by offering a buffer zone within which the consequence level of inundation is capped. The effectiveness of the existing foreshore reserves to contain the risk of inundation in the study area over the planning timeframe is adequate in sections of the coast with high dunes and elevated lands, such as Castletown and further west. In the town-site area characterized small dunes and low lying lands, the effectiveness of the existing foreshore reserves is limited to the short term timeframe only.
- Special Control Areas, such as Coastal Erosion and Inundation Risk Special Control Area 9 (The Shire of Esperance, Local Planning Scheme No. 23 - Amendment No. 19, SCA9), provide guidance for land use and development within the potential coastal erosion and inundation risk area based on the latest risk mapping. This control triggers the need for
  - a notification to be placed on the Certificate of Title warning of potential inundation risk; and
  - a planning permit for some types of buildings and works.
- Special Building Controls that sets appropriate conditions and floor levels to address any flood risk to developments and trigger the need for a planning permit for some types of buildings and works may not be fully in place in the coastal hazard zone. According to the Regulation Impact Statement regarding Proposals to address the risk of floods to new residential buildings (Australian Government, State and Territory Governments, Nov 2012):
  - The general approach of the States and Territories in addressing the risk of floods is to require the minimum floor height of new residential buildings (in flood hazard areas) to be above the expected flood level. WA specify in planning legislation that minimum floor levels are required for these buildings. Local governments provide planning approval on this basis.
  - Responsibility for determining the location of flood hazard areas sits with planning authorities, in most cases. This determination is normally based on the 1% AEP, with authorities typically avoiding any risk exposure above this level.
  - Local governments typically incorporate provisions into their Town Planning Schemes. Local governments have the power to not issue approvals in areas at risk of flooding and may consult with State authorities to determine specific requirements for construction in those areas.

Coastal Protection Scheme

- Esperance waterfront seawall stretches along the Esperance town-site foreshore and a headland around the base of the Tanker Jetty. Although, the primary purpose of the seawall and headland is the protection of new and existing infrastructure from coastal erosion, this coastal structure also offer some degree of protection against inundation. The effectiveness of such inundation control is compromised as soon as flood pathways are activated around the structure. These adverse conditions are anticipated beyond the medium term.

Drainage schemes

They are used to plan the infrastructure for new urban developments. They guide the standards needed to meet for flood protection, water quality and waterway health.

5.3.4 *Inundation Risk Aggregate Trend*

The inundation risk profile has been aggregated over the Zones and Reserves asset classes and its evolution over the three timeframes is presented inTable 5-5. The migration of the current inundation risk profile toward the higher end of the risk spectrum is evident in the table. In the present day, 12% of the values identified are found to be at Moderate risk and 88% are found to be at Low risk. By 2050, 14% of the values identified are found to be at High risk, 41% are found to be at Moderate risk and 45% are found to be at Low risk. By 2100, 12% of the values identified are found to be at Extreme risk, 17% are found to be at High risk, 37% are found to be at Moderate risk and 34% are found to be at Low risk.

Table 5-5: Inundation risk to zoning table summary

Asset at Risk - to Present	**Likelihood**					
Consequence	Almost Certain (5)	Likely (4)	Possible (3)	Unlikely (2)	Rare (1)	**Grand Total**
Catastrophic (5)	-	-	-	-	-	-
Major (4)	-	-	-	-	-	-
Moderate (3)	-	-	-	-	-	-
Minor (2)	-	-	-	1%	6%	7%
Insignificant (1)	12%	34%	15%	16%	16%	93%
Grand Total	**12%**	**34%**	**15%**	**17%**	**21%**	**100%**
Asset at Risk - to 2060	**Likelihood**					
Consequence	Almost Certain (5)	Likely (4)	Possible (3)	Unlikely (2)	Rare (1)	**Grand Total**
Catastrophic (5)	-	-	2%	11%	4%	17%
Major (4)	-	-	-	-	-	-
Moderate (3)	-	-	-	-	-	-
Minor (2)	1%	-	4%	14%	3%	23%
Insignificant (1)	33%	3%	6%	15%	3%	60%
Grand Total	**34%**	**3%**	**13%**	**40%**	**10%**	**100%**
Asset at Risk - to 2110	**Likelihood**					
Consequence	Almost Certain (5)	Likely (4)	Possible (3)	Unlikely (2)	Rare (1)	**Grand Total**
Catastrophic (5)	4%	8%	4%	9%	7%	32%
Major (4)	-	-	-	-	-	-
Moderate (3)	-	-	-	-	-	-
Minor (2)	4%	8%	4%	8%	6%	29%
Insignificant (1)	19%	5%	3%	6%	7%	39%
Grand Total	**27%**	**20%**	**11%**	**22%**	**20%**	**100%**
Risk scale : Extreme, High, Moderate, Low						

In the aggregate, the spatial extend of the inundation risk rapidly increases over time, with less than 2ha of the coastal zone is at *Moderate* and higher risk in the short term, increasing to 30ha at *Moderate* and higher risk (including 7.6ha at *High* risk) in the medium term and reaching 78ha at *Moderate* and higher risk (including 25ha at *High* risk and 9ha at *Extreme* risk) in the long term. This trend is illustrated in Figure 5-18.

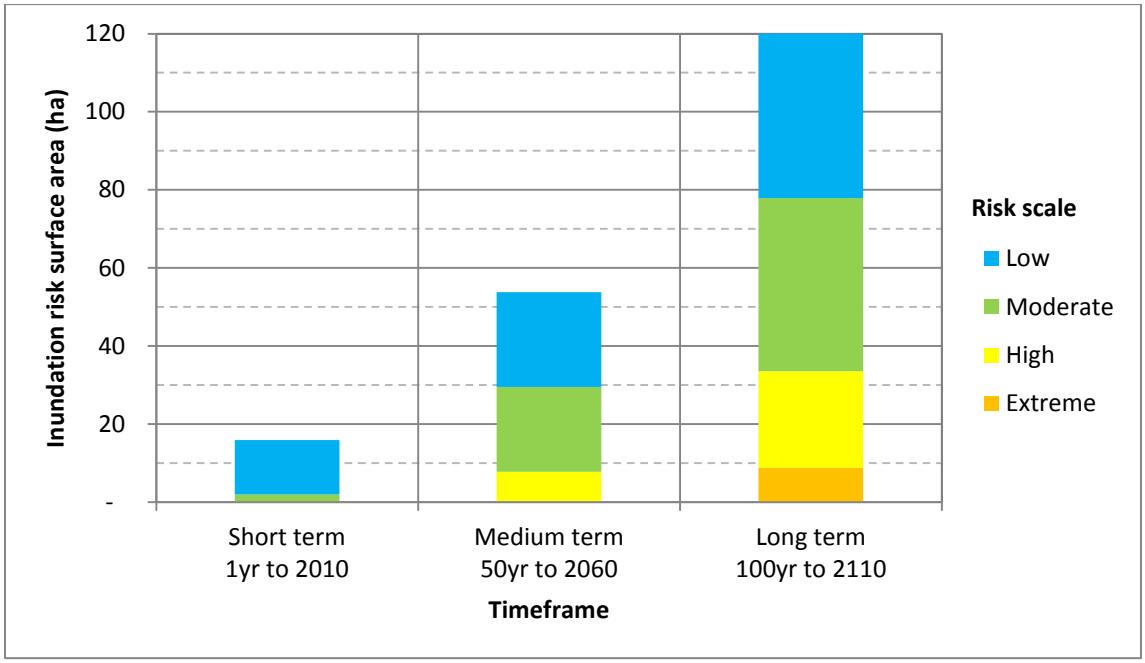


Figure 5-18: Inundation risk to zoning surface area over the three timeframes considered.

5.3.5 *Inundation Risk Subdivision*

Considering the geographical location of the zoning assets at risk of inundation in the study area, the inundation pattern can be simplified and split into 14 subdivisions, each representing a potential management unit with its own inundation risk rating for a given timeframe. These subdivisions are illustrated in Figure 5-22 and are referred to in the rest of the document. The pattern of inundation risk to zoning is characterised as follow:

- In the short term, subdivisions iA and iB are at *Low* risk of inundation. The zoning assets impacted are mostly beaches and foreshore reserves.
- In the medium term, subdivisions iA and iB become at *Moderate* risk and increase in surface to include subdivisions iD and iE. The zoning assets impacted are mostly beaches, foreshore reserves and roads. Subdivisions iC and iF present a *High* risk of inundation. The zoning assets impacted have a higher consequence rating, being residential and commercial zones. Subdivisions iD highlight a *Moderate* to *High* risk of inundation in the Castletown residential area.
- In the long term, south of the Esperance foreshore headland, the *Moderate* risk of inundation in subdivisions iA and iD extends to adjacent subdivisions iH and iJ. The *Moderate* risk of inundation in subdivisions B and E extends to adjacent subdivisions iL and iM. The *High* risk of inundation in subdivision iC escalates to *Extreme* risk. The *High* risk of inundation zone also extends to subdivision iI, with an *Extreme* risk in subdivision iK. North of the Esperance foreshore headland, the *Moderate* risk of inundation in

subdivisions iB and iE extends to adjacent subdivisions iL and iM. The *High* risk of inundation in subdivision iF and iG escalates to *Extreme* risk. The *Moderate* risk of inundation in the Castletown residential area also extends to subdivisions iN and escalates to *High* risk.

5.3.6 *Inundation Risk Breakdown for Key Asset Classes*

The inundation risk to key asset classes, including existing zoning and infrastructure, is detailed hereafter and illustrated in Figure 5-21 and Figure 5-23. The inundation subdivision name is provided in parentheses (Figure 5-22).

Zones and Reserves

- Foreshore reserves (i.e. parks, recreation and conservation areas) are present all along the coast from Taylor St to Wylie Head. They are relatively effective inundation control instruments, as they cap the upward risk level to *Moderate*, even under inundation hazard scenarios that are highly likely (e.g. *Almost Certain,* which has more than 90% probability of occurrence over the timeframe considered). Within foreshore reserve zones affected by coastal hazards, the risk level will therefore be *Moderate* in the areas potentially impacted by temporary or permanent flooding of existing land. Landward of these areas the risk level may rise rapidly. In the study area, the risk to foreshore reserve zones is *Low* in the short term, and increases to *Moderate* in the medium to long term. The erosion risk to foreshore reserve is characterised as follow:
  - In the short term, reserves are offering some degree of protection against inundation;
  - In the medium and long term, the protection buffer is diminishing, potentially exposing other assets to higher level of inundation risk (iA and iD).
- Road reserves are more sensitive to inundation than foreshore reserves and attract a higher risk rating when exposed to a similar probability of inundation. The inundation risk to road reserves is characterised as follow:
  - In the short term, the Goldfields Road frontage south of Phyllis Street (iB) is at *Low* risk of inundation over a 400m section.
  - In the medium term, the risk to Goldfields Road extends to Norseman Road over a 600m section (iB and iE) and remains *Low* in most parts with some areas at *Moderate* risk. The Esplanade becomes at *Moderate* to *High* risk over a 1,500m section between Harbour Road and Brazier Street (iD). A smaller section (250m) of Dempster Street is also at *Moderate* risk of inundation on both sides of William Street. Similarly, the parallels to William Street between Harbour Road and James Street are at *Low* to *Moderate* risk (iC). In Castletown, approximately 600m of streets are at low risk of inundation (iG).
  - In the long term, the risk to Norseman Road (iE) and Goldfields Road (iB) extends further south (iL) and west to Castletown Quays, Goldfields Road and La Page Street (iM), for a total of 2,250m at *Moderate* to *High* risk. In the Town Centre, 4,800m of roads and streets between Dempster Street (south of Hicks Stree) and the Esplanade are at *Moderate* to *High* risk (iC, iD, I, L, iJ, iK). In Castletown, 2,400m of streets are *Moderate* risk of inundation.

- Residential, commercial and tourist zones are the most sensitive zones to inundation risk. They are characterised as follow:
  - In the short term, residential, commercial and tourist zones are not impacted by inundation risk.
  - In the medium term, there is a *High* risk of inundation to residential, commercial and tourist zones within 100m landward of the Esplanade south of James Street and extending 100m either side of Dempster Street between Taylor and William Street (iC). This zone corresponds to an area approximately 10ha. In the tourist zone along the Goldfields Road frontage, there is an area of 0.5ha at *High* risk (iF). In Castletown, there is an area of 1ha at *High* risk (iG).
  - In the long term, there is an *Extreme* risk of inundation to residential, commercial and tourist zones within 100m landward of the Esplanade south of James Street and extending 100m either side of Dempster Street between Taylor and William Street (iC, iK). Between Dempster Street and the Esplanade, there is an additional 12ha at *High* risk (iL) and 2.5ha at Low risk (iJ). This zone corresponds to an area approximately 10ha. In the tourist zone along the Goldfields Road frontage, there is an area of 0.5ha at *High* risk (iF) and some *Extreme* risk hot spots between Goldfield road and Castletown Quays (iM). In Castletown, there is an area of 5ha at *High* risk (iN) with some *Extreme* risk hot spots.
- Public Purpose zone are sensitive zones to inundation risk. They are characterised as follow:
  - In the short term, public purpose areas are not impacted by inundation risk.
  - In the medium term, there is an *Extreme* risk of inundation at James Street museum. There is also a *High* risk of inundation at William Street drain and Phyllis Street water pump station.
  - In the long term, there is an *Extreme* risk of inundation at William Street drain, James Street museum, Langham Lane water pump station and Phyllis Street water pump station. There is also a *High* risk of inundation at Andrew Street water pump station, and Norseman Road Hall.
- Beaches in the study area are all subject to inundation hazard over time, however, these zones are considered as *Low* risk.

Infrastructure

Beyond the zones and reserves assets at risk discussed before, there also exist a number of infrastructure assets at risk. These assets include infrastructure such as road, water, petroleum, power, gas, outfall, boat ramp, footpath, carparks, toilet blocks and coastal access. Water pump stations located in public purpose zones were addressed above in the Zone and Reserve section.

- Roads have been assessed in the Road reserves section.
- Utilities (water, gas, and power) and Roads are at an increasing risk of inundation over time. There is a strong correlation between the inundation risk for road reserves and the inundation risk for utilities listed above because they often share similar corridors;

however utilities are more sensitive to flooding than road, as a result, utilities corridor will attract a higher risk. The inundation risk to existing utilities is characterised as follow:

- In the short term, there is a *Low* to *Moderate* risk of inundation over short sections[vi] (50 to 200m) of the gas and water infrastructure in the Town Centre near Taylor Street (iA) and over short sections of the power and water infrastructure in the Tourist Zone on Goldfields Road (iB).
- In the medium term, there are some *Extreme* risk hot spots over short sections (400m in the aggregate) of the power infrastructure in the Town Centre along the Esplanade, south of Andrew Street. There are also some *Extreme* risk hot spots over short sections (60m in the aggregate) of the power infrastructure in the Tourist Zone along Goldfields Road. In Castletown, there is a *Moderate* to *High* risk of inundation over short sections (500m in the aggregate) of the power and water infrastructure (iG). There is a *Moderate* to *High* risk of inundation over long sections (up to 1.5km) of the gas and water infrastructure in the Town Centre, to the west of Dempster Street from Harbour Road to Brazier Street Taylor Street (iC, iD) and over long sections (up to1km) of the power and water infrastructure in the Tourist Zone along Norseman Road and Goldfields Road (iE).
- In the long term, there is a *High* risk of inundation over long sections (1.5km in the aggregate) of the gas and power infrastructure in the Town Centre, to the west of Dempster Street from Emily Road to Brazier Street Taylor Street (iC); over long sections (750m in the aggregate) of the power infrastructure in the Tourist Zone along Norseman Road and Goldfields Road (iE) and over short sections (90m in the aggregate) of the power infrastructure in Castletown (iN). There is a *Moderate* to *High* risk of inundation over long sections (8km in the aggregate) of the gas, water and power infrastructure in the Town Centre

- Petroleum infrastructure linking the port and the tank farm is at risk of inundation, in the medium and long term, north of Harbour Road and Norseman Road. The inundation risk to existing petroleum asset is characterised as follow:
  - In the short term, there is not risk of inundation of the pipeline identified.
  - In the medium term, there is a 1,500m section of the pipeline at *Moderate* to *High* risk south of Kemp Street (iD), including a sections at *Extreme* risk along the Esplanade south of Emily Street (210m) and north William Street (85m).
  - In the long term, there is a 2,200m section of the pipeline at *High to Extreme* risk (iD, iI, iJ), including a 1,000m section at *Extreme* risk south of Andrew Street and a further 300m section north of James Street.
- Carparks on the waterfront are at risk of inundation near Andrew Street and at the northern end of the seawall off Norseman Road. The inundation risk to existing carpark is characterised as follow:
  - In the short term, there is no risk of inundation of the carparks identified.

[vi] There may be multiple infrastructures along some sections; therefore the total length of infrastructure at risk may be greater than the aggregate section length.

  - In the medium term, there is approximately 5,000m^2 of carpark are *Low* risk of inundation.
  - In the long term, there is approximately 7,500m^2 of carpark are *Moderate* to High risk of inundation.
- Marine outfalls and Boat ramp are at *Low* risk of inundation near William Street, Phyllis Street and along Castletown Quays.
- Beach access and toilet block at Chaplin Street (K) are at no to *Low* risk of inundation risk over time.

Heritage Places and Buildings

There are a number of buildings and heritage places along the study area which will be at risk of inundation, as follow:

  - In the short term, none of the buildings and heritage places identified are at risk of inundation.
  - In the medium term, the Esperance RSL carpark is at *Low* risk of inundation, a fraction of the Cannery Waterhole is at *High* risk of inundation.
  - In the long term, a fraction (1,800m^2) of the Demster Homestead (fmr) block is at Moderate to *High* risk of inundation, the Bijou Theater is at *Low* risk of inundation, the Esperance RSL is at *Low* risk of inundation and its carpark is at *High* risk of inundation, the Railway Goods Shed (fmr) is at *High* risk of inundation, and half of the Cannery Waterhole is at *High* risk of inundation.

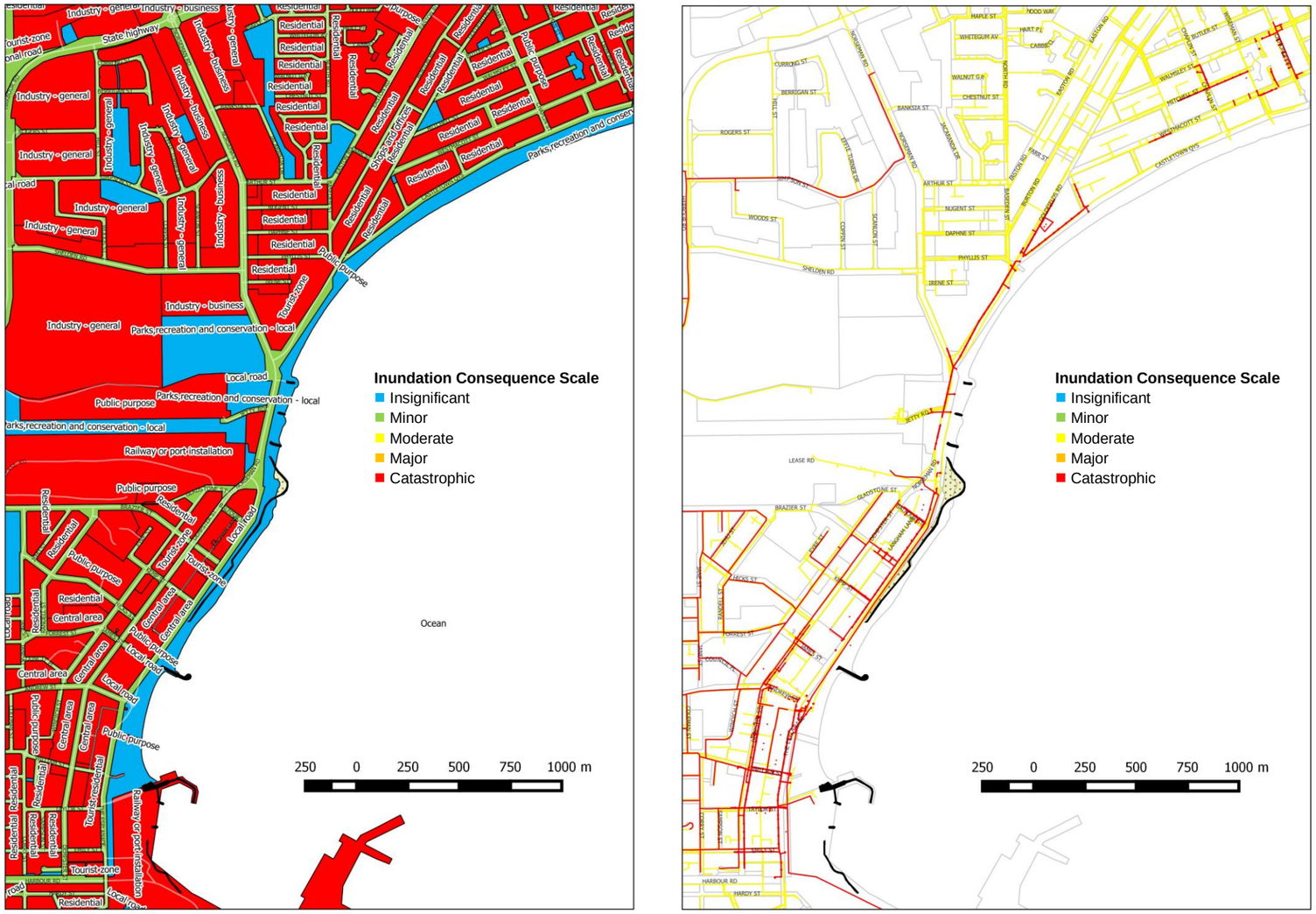


Figure 5-19: Inundation consequence for zoning (left) and infrastructure (right).

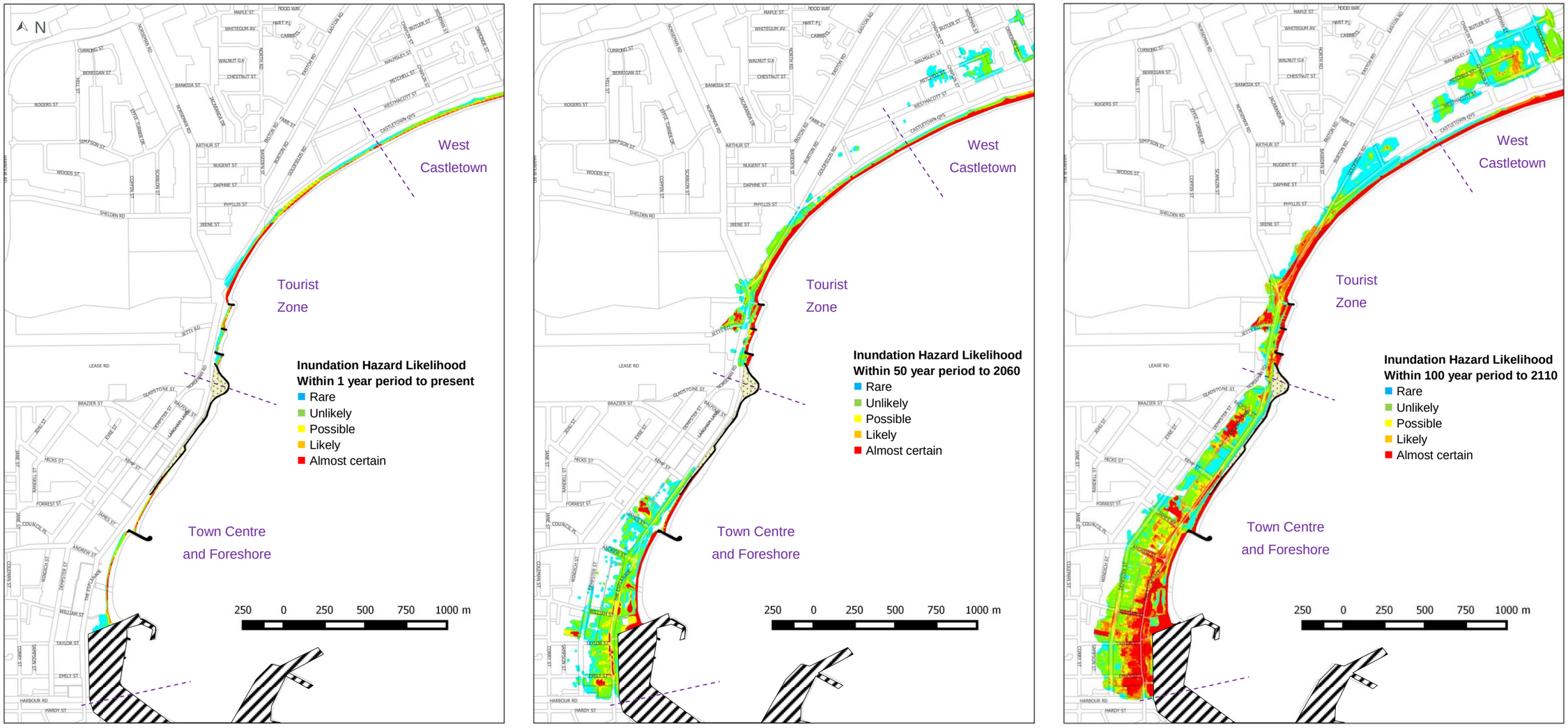


Figure 5-20: Inundation hazard zones over three timeframes: 1 year from now (left), 50 years to 2060 (middle) and 100 years to 2110 (right). Landward edge of the zone based on the 0.2%AEP Strom Inundation and associated inundation allowances (as per SPP2.6) for the 3 timeframes.

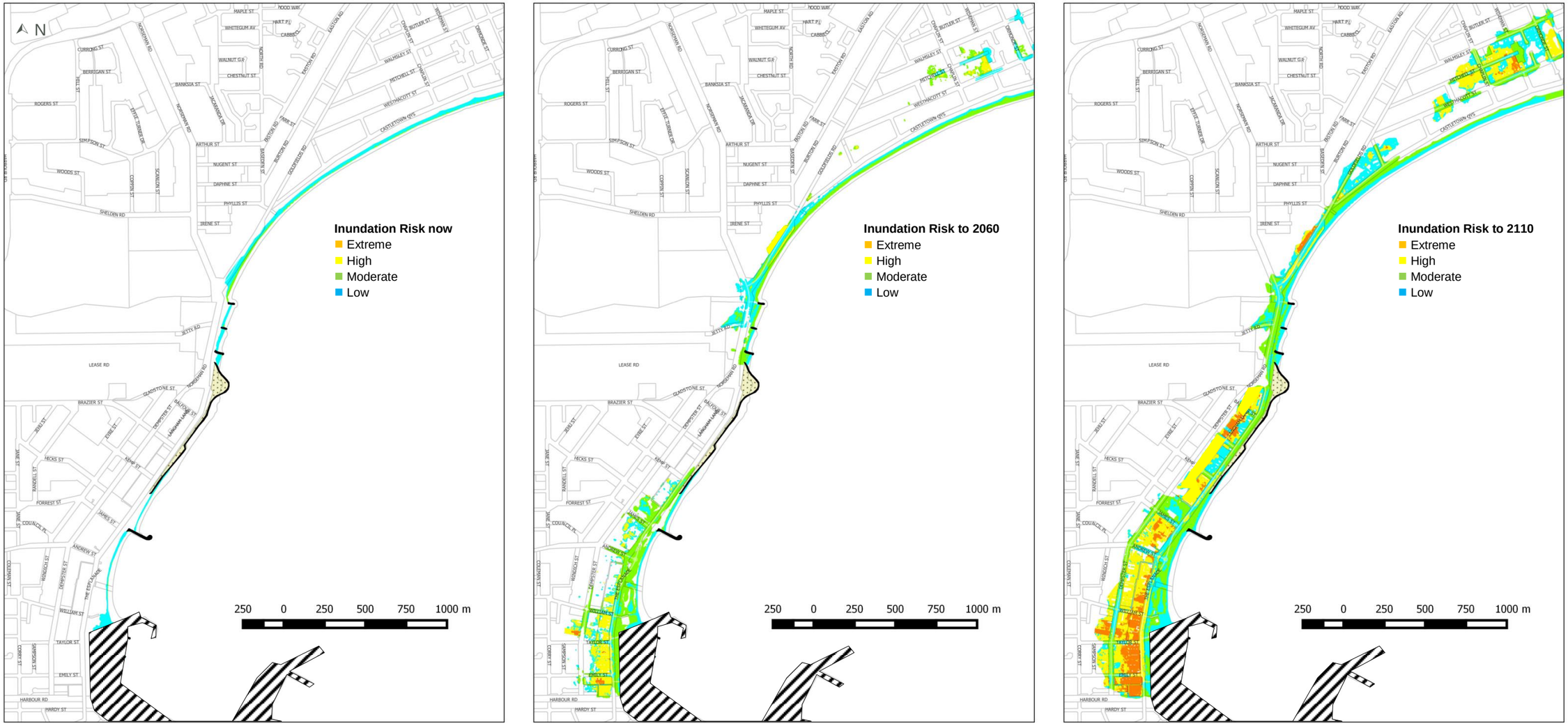


Figure 5-21: Inundation risk to zoning over three timeframes: 1 year from now (left), 50 years to 2060 (middle) and 100 years to 2110 (right). The risk level was allocated in accordance with the likelihood, consequence and risk scales. Zoning highlighted includes Central area, Local road, Parks, recreation and conservation – local, Public purpose, Railway or port installation, Regional road, Residential, State highway, Tourist residential, Tourist zone, Industry – business, Industry – general, Future residential. Railway and Port Installation (hatched) was excluded from the assessment.

Figure 5-22: Simplified inundation risk to zoning over three timeframes: 1 year from now (left), 50 years to 2060 (middle) and 100 years to 2110 (right). The risk level was allocated in accordance with the likelihood, consequence and risk scales. Zoning highlighted includes Central area, Local road, Parks, recreation and conservation – local, Public purpose, Railway or port installation, Regional road, Residential, State highway, Tourist residential, Tourist zone, Industry – business, Industry – general, Future residential. Railway and Port Installation (hatched) was excluded from the assessment. Colour shades used to distinguish zones at risk in previous timeframe.

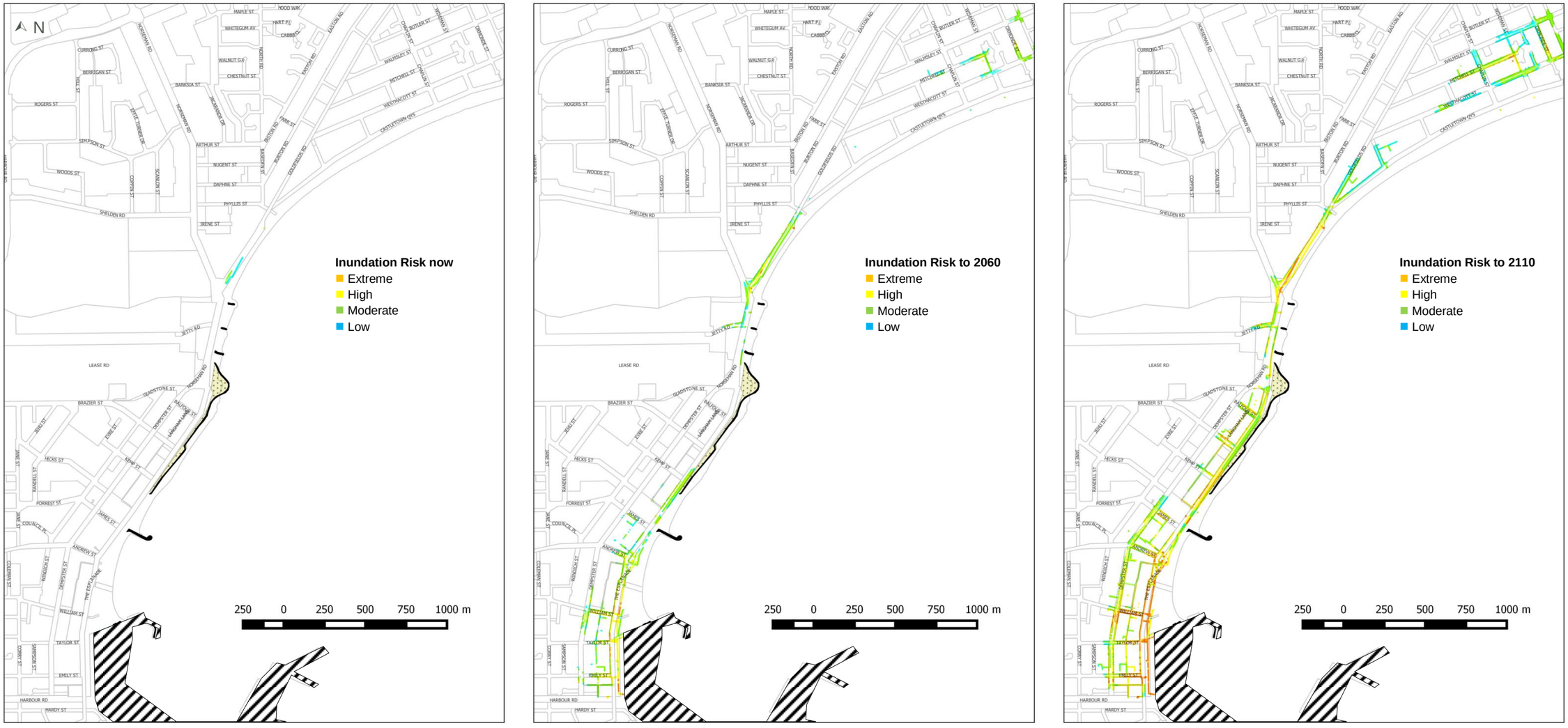


Figure 5-23: Inundation risk to infrastructures (utilities) over three timeframes: 1 year from now (left), 50 years to 2060 (middle) and 100 years to 2110 (right). The risk level was allocated in accordance with the likelihood, consequence and risk scales. Infrastructures highlighted include Drainage, Petroleum, Gas and Power. Roads were included in the zoning map (Figure 5-21).

Figure 5-24: Overlay of Inundation risk to infrastructures and simplified inundation risk to zoning.

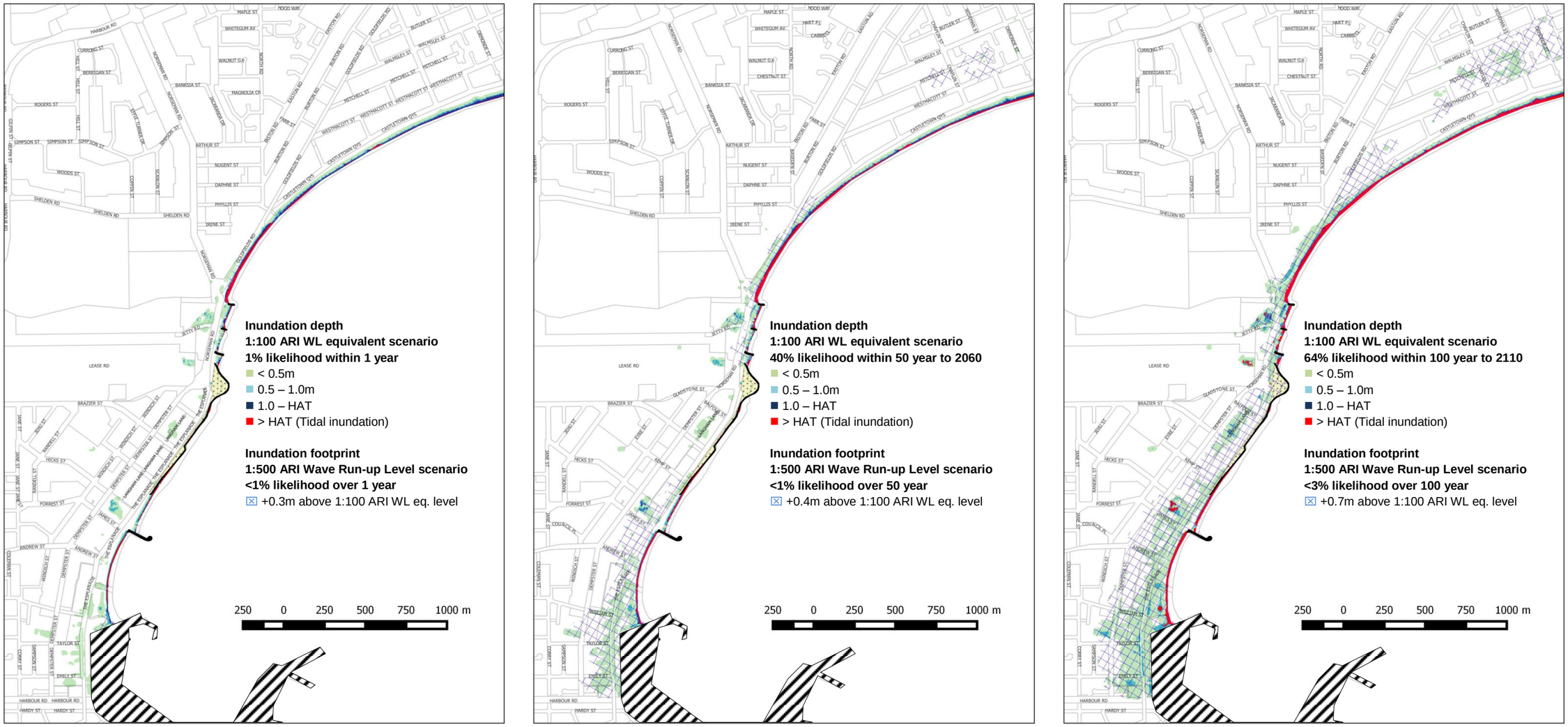


Figure 5-25: Water depth within the inundation hazard zones over three timeframes: 1 year from now (left), 50 years to 2060 (middle) and 100 years to 2110 (right). Cumulative probability (% likelihood) is provided for the edge of the inundation zone. The inundation footprint for the 1:500 ARI Wave Run-up Level scenario takes into account dune breaching in accordance with SPP2.6. The inundation depth pattern for the 1:100 ARI WL equivalent scenario assuming complete hydraulic connectivity (e.g. surface flow, drainage network, ground permeability) between the inundated areas.

6 COASTAL HAZARD RISK ADAPTATION PLANNING

An integrated approach to land use planning provides a means of improving risk reduction[vii] while addressing requirements for community safety and sustainability. The approach links strategic and statutory planning as part of a wider approach that embraces risk management and the setting of strategic directions in establishing a strategic land use plan.

The first stage of the planning process is contingent to the:

- Review of risk and impact on the planning strategy
- Review of coastal erosion and/or erosion hazard risk treatment options
- Review of risk management implementation mechanisms.

The second stage considers the following element for each management units:

- Appraisal of adaptation pathways in consultation with key stakeholders
- Review the preferred adaptation pathways
- Recommend a strategic course of actions.

These elements contain the tools used to implement the strategic land use and development plan. They set out specific methods to be used and ensure that all the actions and programs of the responsible authority are directed towards achieving the desired outcomes.

They enable different departments, sections or organisations working towards shared goals and objectives to create programs and requirements that complement and support each other.

The plan itself constitutes a risk reduction measure and also facilitates response and recovery in the relation to the emergency risk management.

6.1 Review of Coastal Hazard Risks and their Impact on the Planning Strategy

6.1.1 *Summary of Coastal Hazard Risks*

Coastal hazard risks can be divided into[viii]:

- Existing risk – where developments and use of land in vulnerable coastal area is subject to erosion and/or inundation risk
- Future risk – where developments and use of land may occur in vulnerable coastal area subject to erosion and/or inundation risk
- Residual risk – the risk associated with erosion and/or inundation hazard exceeds management measures

[vii] It must be noted that risk reduction here means reducing risk to community safety. This process may not reduce corporate risk or reduce consent authorities exposure to liability.

[viii] Adapted from Australian Government Attorney-General's Department 2013, Managing the floodplain: a guide to best practice in flood risk management in Australia, Australian Emergency Management Handbook Series, Australian Emergency Management Institute.

- Infrastructure risk – where the performance of the infrastructure function, during and after a coastal erosion or inundation event, enable the community to respond to and recover from the impacts of such event.

6.1.2 *Summary of Coastal Hazard Impact on the Shire of Esperance Local Planning Strategy*

A number of values are at risk in strategic coastal areas over the planning timeframe to 2110, as demonstrated in the previous sections. Table 6-1 summarises 25 instances of coastal hazard impacts categorised within 11 key assets (values) and five strategic coastal areas, including:

- Strategic coastal areas
  - Town Centre & Foreshore
  - Castletown
  - Flinders
  - Bandy Creek & Surrounds
  - Wylie Head
- Key assets at risk
  - Agricultural – general
  - Central area
  - Future residential
  - Local road
  - Parks, recreation and conservation – local
  - Public purpose
  - Regional road
  - Residential
  - Tourist residential
  - Tourist Zone
  - Infrastructures (Utilities)

Table 6-1 also makes distinctions between erosion risk and inundation risk for the three timeframes considered, including:

- Short term: 1 year present
- Medium term: 50 years to 2060
- Long term: 100years to 2110

Overall, the risk exposure and risk level rapidly increase over time. Erosion is posing a level of risk sooner and higher than inundation does, as follow:

- In the short term, a *High* risk of erosion exists for three instances; and a *Moderate* risk of erosion exists for five instances

- In the medium term, an *Extreme* risk of erosion exists for three instances; a *High* risk of erosion exists for eight instances; a *Moderate* risk of erosion exists for two instances; an *Extreme* risk of inundation exists for one instance; a *High* risk of inundation exists for seven instances; a *Moderate* risk of inundation exists for six instances.
- In the long term, an *Extreme* risk of erosion exists for 6 instances; a *High* risk of erosion exists for 19 instances; an *Extreme* risk of inundation exists for six instances; a *High* risk of inundation exists for three instances; a *Moderate* risk of inundation exists for ten instance

Across the strategic coastal areas, the Town Centre & Foreshore and Castletown are the most exposed, with an elevated (*High* and *Extreme*) and rising risk of erosion at all timeframes and a *Low* risk of inundation in the short term rapidly increasing (*High* and *Extreme*) in the medium and long term.

Across the key assets (values), Infrastructures (Utilities), Regional Road, Tourist Zone and Residential are the most critically exposed , with an elevated (*High* and *Extreme*) and rising risk of erosion at all timeframes and a *Low* risk of inundation in the short term rapidly increasing (*High* and *Extreme*) in the medium and long term.

6.1.3 *Risk-Adjusted Priorities*

Considering the summary of risks provided in Table 6-1, the following instances were ranked in descending order of priority on a risk-adjusted basis:

- 1st priority (□□□ :*High, Extreme, Extreme* risk in the short, medium, long term respectively)
  - Town centre & Foreshore
    - [1] infrastructures (utilities) at risk of erosion
  - Castletown
    - [1] Infrastructures (utilities) at risk of erosion
    - [2] Regional road at risk of erosion
- 2nd priority (□□□ : *Not, Extreme, Extreme* risk in the short, medium, long term respectively)
  - Town centre & Foreshore
    - [1] Residential at risk of inundation
    - [2] Public Purpose at risk of inundation
- 3rd priority (□□□: *Not, High, Extreme* risk in the short, medium, long term respectively)
  - Town Centre & Foreshore
    - [1] Regional road at risk of erosion
    - [2] Central area at risk of inundation
    - [3] Tourist residential at risk of inundation
    - [4] Infrastructures (utilities) at risk of inundation
  - Castletown
    - [1] Tourist zone at risk of erosion & inundation

[2] Infrastructures (utilities) at risk of inundation

- 4th priority (□□□: *Moderate, High, High* risk in the short, medium, long term respectively)
  - Throughout all coastal areas
    [1] Parks, recreation and conservation – local at risk of erosion
- 5th priority (□□□: *Moderate, High, High* risk in the short, medium, long term respectively)
  - Town Centre & Foreshore
    [1] Regional road at risk of inundation
  - Castletown
    [1] Residential at risk of erosion & inundation

Table 6-1: Summary of Coastal Hazard Risk

	Strategic Coastal Area											
Key Asset at Risk	**Town Centre & Foreshore**		**Castletown**		**Flinders**		**Bandy Creek & Surrounds**		**Wylie Head**		**Total**	
Agricultural – general									Erosion □□□	Inundation □□□	Erosion □□□	Inundation □□□
Central area	Erosion □□□	Inundation □□□									Erosion □□□	Inundation □□□
Future residential							Erosion □□□	Inundation □□□			Erosion □□□	Inundation □□□
Local road	Erosion □□□	Inundation □□□	Erosion □□□	Inundation □□□					Erosion □□□	Inundation □□□	Erosion □□□ □□□ □□□	Inundation □□□ □□□ □□□
Parks, recreation and conservation – local	Erosion □□□	Inundation □□□	Erosion □□□	Inundation □□□	Erosion □□□	Inundation □□□	Erosion □□□	Inundation □□□	Erosion □□□	Inundation □□□	Erosion □□□ □□□ □□□ □□□ □□□	Inundation □□□ □□□ □□□ □□□ □□□
Public purpose	Erosion □□□*	Inundation □□□					Erosion □□□	Inundation □□□	Erosion □□□	Inundation □□□	Erosion □□□ □□□ □□□	Inundation □□□ □□□ □□□
Regional road	Erosion □□□	Inundation □□□	Erosion □□□	Inundation □□□							Erosion □□□ □□□	Inundation □□□ □□□
Residential	Erosion □□□	Inundation □□□	Erosion □□□	Inundation □□□	Erosion □□□	Inundation □□□	Erosion □□□	Inundation □□□			Erosion □□□ □□□ □□□ □□□	Inundation □□□ □□□ □□□ □□□
Tourist residential	Erosion □□□	Inundation □□□									Erosion □□□	Inundation □□□
Tourist zone	Erosion □□□	Inundation □□□	Erosion □□□	Inundation □□□							Erosion □□□ □□□	Inundation □□□ □□□
Infrastructures (utilities)	Erosion □□□	Inundation □□□	Erosion □□□	Inundation □□□							Erosion □□□ □□□	Inundation □□□ □□□
Total	Erosion □□□ □□□ □□□ □□□ □□□ □□□ □□□ □□□	Inundation □□□ □□□ □□□ □□□ □□□ □□□ □□□ □□□	Erosion □□□ □□□ □□□ □□□ □□□ □□□ □□□ □□□	Inundation □□□ □□□ □□□ □□□ □□□ □□□ □□□ □□□	Erosion □□□ □□□ □□□ □□□	Inundation □□□ □□□ □□□ □□□	Erosion □□□ □□□ □□□ □□□	Inundation □□□ □□□ □□□ □□□	Erosion □□□ □□□ □□□ □□□	Inundation □□□ □□□ □□□ □□□	Erosion □□□ □□□ □□□ □□□ □□□ □□□ □□□ □□□ □□□ □□□ □□□ □□□ □□□ □□□ □□□ □□□	Inundation □□□ □□□ □□□ □□□ □□□ □□□ □□□ □□□ □□□ □□□ □□□ □□□ □□□ □□□ □□□ □□□

(*) Excludes Phyllis Street Water Pump Station erosion risk (□□□), which was included with the broader Infrastructures category.

Legend:

Hazard type	**Timeframe**	**Risk level**	**Scope**
Erosion	□□□ 1 year (Present)	Low	Instance not applicable
Inundation	□□□ 50 years (to 2060)	Moderate	
	□□□ 100 years (to 2110)	High	
		Extreme	
		Not within hazard zone	

6.1.4 *Summary of Existing Options in Place and Their Effectiveness to Manage Risk*

The risk levels identified were based on the risk assessment process (reported in previous sections), which incorporated a number of control measures. The effectiveness of these control measures to treat the identified coastal risk is summarised in Table 6-2.

As shown in Table 6-2, the most effective measures in place to manage coastal hazard risk are through the following:

- Planning Scheme measures (i.e. Foreshore Reserves, Special Building Controls, Land-use zones and reserves), which tend to reduce the consequence rating of the asset at risk.
- Coastal Protection Scheme measures (i.e. Seawall and headland), which tend to reduce the likelihood rating of erosion or inundation hazard occurring in the area protected by the scheme for the design life of the scheme and subject to adequate maintenance.

Residual risk arises with hazards that exceed the management measures in place. Table 6-2 shows that the most effective measure to address residual risk is through the following:

- Planning Scheme measures (i.e. Land-use zones and reserves), by reducing the intensity of the land use at risk.

At this point, coastal hazards have been identified and are expected to impact the Shire local planning strategy with an elevated level of risk that is not acceptable. Therefore an adaptation strategy should be devised to treat coastal erosion and/or erosion hazard risk.

Table 6-2: Effectiveness of existing mitigation measures

Existing control in place		Effectiveness of mitigation measure			
		Mitigated likelihood	**Mitigated consequence**	**Mitigated risk**	**Residual risk**
Planning Scheme	Foreshore Reserves	Low – this measure does not reduce the likelihood rating of the defined erosion or inundation hazard event	High – this measure is effectively capping the consequence rating of the asset at risk	Medium / High - this measure can effectively cap the risk level in the area over the design life of the allowance	Low – this measure is not designed to sustained erosion or inundation hazard events in excess of the defined erosion or inundation hazard event
	Special Control Areas – Disclosure of coastal hazard	Low – this measure does not reduce the likelihood rating of the defined erosion or inundation hazard event	Low – this measure does not reduce the consequence rating of the asset impacted by the defined erosion or inundation hazard event	Low – although this measure promotes greater awareness of the erosion or inundation hazard and may act as a disincentive for future development, this measure is not effective in reducing the risk level to existing development	Low – by definition this measure is an overlay within the erosion or inundation hazard zone which does not deal effectively with erosion or inundation hazard events in excess of the defined erosion or inundation hazard event
	Special Building Controls	Low – this measure does not reduce the likelihood rating of the defined erosion or inundation hazard event	High – this measure can effectively reduce the consequence rating of the asset impacted by the defined erosion or inundation hazard event, by implementing appropriate design criteria	High - this measure can effectively cap the risk level of the asset impacted by increasing its capacity to sustain the defined erosion or inundation hazard event	Low – by definition this measure is an overlay within the erosion or inundation hazard zone which does not deal effectively with erosion or inundation hazard events in excess of the defined erosion or inundation hazard event

Existing control in place		Effectiveness of mitigation measure			
		Mitigated likelihood	**Mitigated consequence**	**Mitigated risk**	**Residual risk**
	Land-use zones and reserves	Low – this measure does not reduce the likelihood rating of the defined erosion or inundation hazard event	High – this measure can effectively reduce the consequence rating of the asset impacted by the defined erosion or inundation hazard event, by adjusting the land use classification	High - this measure can effectively cap the risk level of the asset impacted by lowering the land use intensity	High - this measure can effectively reduce the residual risk level of the asset impacted by reducing the intensity of the land use
Coastal Protection Scheme	Seawall	High – this measure can effectively reduce the likelihood rating of erosion or inundation hazard occurring in the area protected,	Low – this measure does not reduce the consequence rating of the asset impacted in the area protected	Medium / High - this measure can effectively cap the risk level in the area protected over the design life of the protection	Low – this measure is usually not designed to sustained erosion or inundation hazard events in excess of the defined erosion or inundation hazard event
	Headland	High – this measure can effectively reduce the likelihood rating of erosion or inundation hazard occurring in the area protected,	Low – this measure does not reduce the consequence rating of the asset impacted in the area protected	Medium / High - this measure can effectively cap the risk level in the area protected over the design life of the protection	Low – this measure is usually not designed to sustained erosion or inundation hazard events in excess of the defined erosion or inundation hazard event
	Groyne	Low – this measure does not reduce the likelihood rating of the defined erosion or inundation hazard event	Low – this measure does not reduce the consequence rating of the asset impacted in the area protected	Low – this measure is not reducing the risk level of the asset/area impacted	Low – this measure is not designed to sustained erosion or inundation hazard events in excess of the defined erosion or inundation hazard event

Existing control in place		Effectiveness of mitigation measure			
		Mitigated likelihood	**Mitigated consequence**	**Mitigated risk**	**Residual risk**
	Landscape edge walls	Low – this measure does not reduce the likelihood rating of the defined erosion or inundation hazard event	Low – this measure does not reduce the consequence rating of the asset impacted in the area protected	Low – this measure is not reducing the risk level of the asset/area impacted	Low – this measure is not designed to sustained erosion or inundation hazard events in excess of the defined erosion or inundation hazard event
	Beach nourishment	Low – this measure does not reduce the likelihood rating of the defined erosion or inundation hazard event	Low – this measure does not reduce the consequence rating of the asset impacted in the area protected	Low – this measure is not reducing the risk level of the asset/area impacted	Low – this measure is not designed to sustained erosion or inundation hazard events in excess of the defined erosion or inundation hazard event
Drainage schemes		Low – this measure does not reduce the likelihood rating of the defined erosion or inundation hazard event	Low – this measure does not reduce the consequence rating of the asset impacted in the area protected	Low – this measure is not reducing the risk level of the asset/area impacted	Low – this measure is not designed to sustained erosion or inundation hazard events in excess of the defined erosion or inundation hazard event

6.2 Review of Coastal Erosion and/or Inundation Hazard Risk Treatment Strategies

6.2.1 *Risk Treatment Strategies*

Risk treatment generally draws on one or more of the strategies of:

- Risk prevention or avoidance (limiting or negating exposure to the hazard);
- Risk reduction (by mitigating the likelihood and/or consequences of the hazard); and/or
- Risk acceptance (accepting the risk that exists).

It involves acknowledging that living on a vulnerable coastal area subject to coastal erosion and/or inundation hazard comes with an inherent risk and understanding what adverse impacts the community is prepared to accept in return for the benefits of living on this coastal area.

ISO 31000:2009 states that risk evaluation is a process of comparing the results of risk analysis with risk criteria to determine whether the risk and its magnitude are acceptable or tolerable. Decision makers often use the risk evaluation process to determine if further analysis is required to:

- Improve confidence in estimates or understanding of risk
- Decide if risks are either broadly acceptable or intolerable
- Decide if action is needed to treat the risk.

The need to treat risk will depend upon whether the current level of residual risk is acceptable to the community. What level of risk is acceptable will depend upon:

- Who is asked
- What their experience of coastal hazard has been
- When they are asked.

Accordingly, governments may make decisions in the ‘public interest’, yet remain mindful of the general need for a consistent standard. They may come to a decision in consultation with the community and in consideration of what may be considered reasonable general practice.

6.2.2 *Review of Potential Adaptation Pathways*

In accordance with the risk treatment strategies listed above and SPP2.6, where risk assessments identify a level of risk that is unacceptable to the affected community or proposed development, adaptation measures need to be prepared to reduce those risks down to acceptable or tolerable levels.

A hierarchy of adaptation pathways has been established to reflect the concept of maintaining future decision-making flexibility (Table 6-3).

As a result, four broad categories of potential adaptation options are available on a sequential and preferential basis - from the most resilient option (top) to the least resilient option (bottom), as shown in Figure 6-1.

Figure 6-1: Adaptation pathway hierarchy

In assessing potential risk adaptation options, it is important to consider the ability of future decision-makers to maintain future decision-making flexibility. This involves assessing the potential of a risk adaptation option to restrict future risk adaptation opportunities.

This hierarchy underpins the concept of maintaining future flexibility, as detailed in Table 6-3. The adaptation hierarchy sits within the CHRMAP framework as the adaptation options available at any given point in time. The preferred option shall be revised from time to time, when the option is no longer appropriate and with due consideration for changing coastal environments and uncertainties that arise from complex climatic and coastal systems over long timeframe.

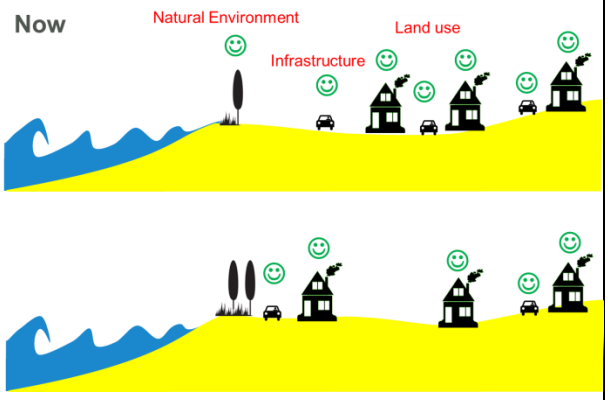
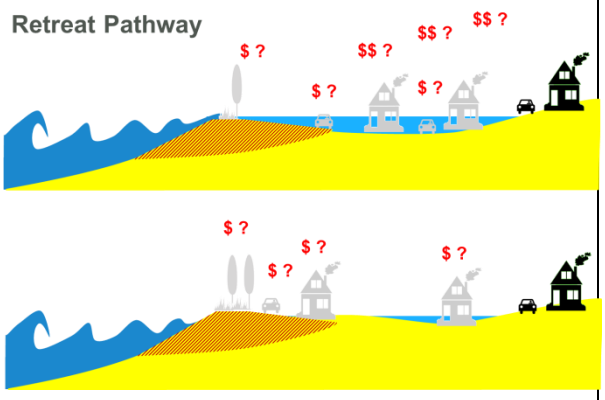
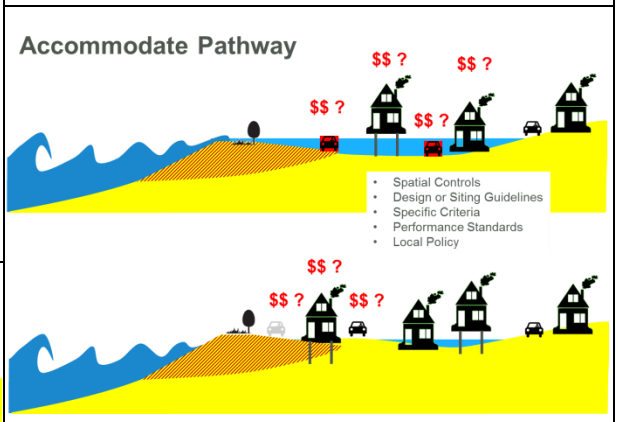
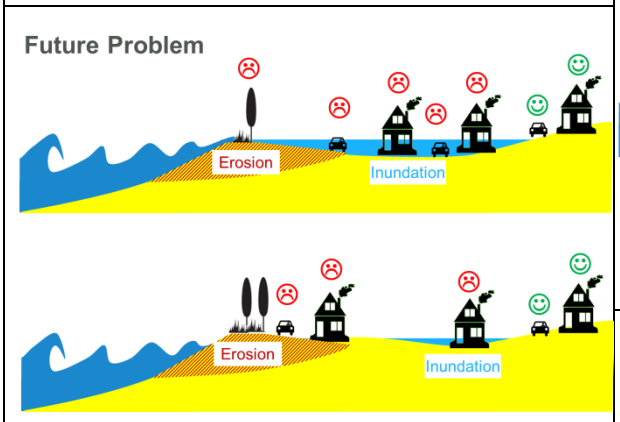
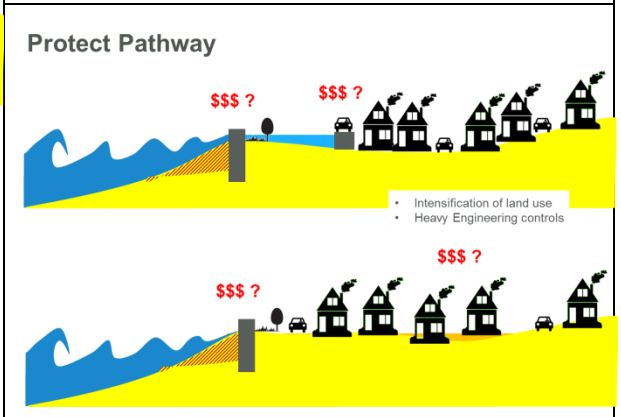
Illustration of the typical issues and adaptation pathways for the Town Centre & Foreshore and Castletown are summarised in Table 6-4.

Table 6-3: Typical* characteristics of adaptation pathway hierarchy (adapted from BMT Oceanica, 2014)

Characteristics	Avoid	Retreat (Planned / Managed)	Accommodate / Maintain	Protect / Intensify
Allow coastal processes to unfold naturally	Yes	Yes	No	No
Relocate foreshore community infrastructure	n/a	Yes	No	No
“Upgrade” existing development	n/a	No	Yes	Yes
“Upgrade” existing assets after end of life	n/a	No	Yes	Yes
“Upgrade” existing protective coastal structures	n/a	No	Yes	Yes
Allow new development	No	No	No	Yes
Allow new assets	No	No	Yes	Yes
Allow new coastal protective structures	No	No	Yes	Yes
Sandy beach amenity	Retreat	Retreat	Reduce	Loss
Reserve environmental value	Retreat	Retreat	Reduce	Loss
Land use intensity	n/a	Loss	Unchanged	Gain
Economic value	n/a	Loss	Reduce	Gain
Residual risk	Low	Medium	High	High

(*) The pathways envisaged under the adaptation pathway hierarchy (Figure 6-1) are not formally defined. Therefore, typical pathways characteristics have been summarized in Table 6-3 in an attempt to better define the expectations under each pathway and enable a like with like comparison. The pathway characteristics should be considered indicative only so that an adaptation strategy can be further developed on a case by case basis.

Table 6-4: Summary of typical issues and adaptation pathways. Sketches for Town Centre & Foreshore (upper panel) and Castletown (lower panel)

Issues	Adapation pathways
 Present day scenario showing developed areas and key values at low risk of coastal hazard impact in the short term.	 Long term retreat of key values impacted by coastal hazards involving downgrading of land use and removal of assets.
	 Long term accommodation of key values impacted by coastal hazards involving the predominant use of planning controls to maintain the level of land use.
 Future unmitigated risk scenario showing developed areas and key values at high risk of coastal hazard impact in the long term.	 Long term protection of key values impacted by coastal hazards involving the predominant use of engineering controls to intensify the level of land use.

6.2.3 *Review of Applicable Adaptation Options*

Potential options to consider within each pathway may fall in one of the following broad categories. It should be noted that comprehensive coastal hazard adaptation will only be achieved by combining options at the local scale. The typical applicability of management options within the adaptation pathway is shown in Table 6-5. Typical adaptation measures for the four adaptation pathways categories are described in Table 6-7.

Allow Coastal Processes to Unfold Naturally Option

This option is to avoid interacting with natural environmental flows so that nature takes it course with as little anthropogenic constraints as possible.

Relocate Foreshore Community Infrastructure Option

This option is to ensure continuity of the services provided to the community by vulnerable infrastructures.

Regenerative Options

Regenerative options are mimicking the natural environment to either improve or create coastal landforms (and ecosystems) which will provide immunity against coastal hazard risk. This may include options such as beaches nourishment and dunes construction and regeneration.

Coastal Engineering Options

Coastal engineering options involve the use of protective structures to control coastal erosion and storm surge inundation to defined design criteria (e.g. damage level and design life). This may include options such as artificial reefs, groynes and detached breakwaters, artificial headlands, sea dykes, seawalls.

Coastal Settlements Design Options

Coastal settlements design options involve the use of a combination of engineering design standard and materials to improve the resilience of current buildings and infrastructures. This may include options such as building retrofitting and improved design, flood-resilient public infrastructure, raise land levels.

Planning Options

Planning options involve the use of regional and local plans as statutory instruments to allow the responsible authority to control the use and development of resources. This may include options such as spatial controls, design guidelines, land negotiated acquisition (e.g. easement, buy-back, swap) and land-use change.

Emergency Response Planning Option

Emergency response planning is more of a requirement than an option as it deals with the risk associated with hazard events which exceed management measures in place. The plan covers the areas of prevention and mitigation, preparedness, response, recovery.

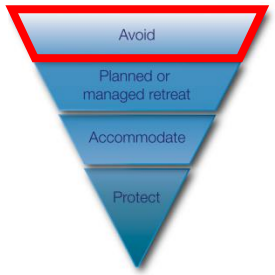
Table 6-5: Typical applicability of management options within adaptation pathway. Option applicability: ☺ High, 😐 Medium, ☹ Low, - not applicable.

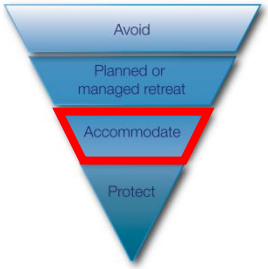
Options / Pathway		Avoid	Retreat (Planned / Managed)	Accommodate / Maintain	Protect / Intensify
Allow coastal processes to unfold naturally		☺	😐	☹	☹
Relocate foreshore community infrastructure		😐	☺	😐	☹
Regenerative options	Beaches nourishment	-	😐	☺	😐
	Dunes construction and regeneration	-	😐	☺	😐
Coastal engineering options	Artificial reefs	-	☺	😐	☹
	Groynes and Detached breakwaters	-	😐	☺	😐
	Artificial headlands	-	☹	😐	☺
	Sea dykes	-	☹	😐	☺
	Seawalls	-	☹	😐	☺
Coastal settlements design options	Building retrofitting and improved design	-	😐	☺	😐
	Flood-resilient public infrastructure	-	😐	☺	😐
	Raise land levels	-	☹	😐	☺
Planning options	Spatial controls, design guidelines	☺	☺	☺	😐
	Land negotiated acquisition (swap, buy-back)	😐	☺	😐	☹
	Land-use change	☺	☺	😐	☹
Emergency response planning option		☺	☺	☺	☺

Table 6-6: Typical effectiveness of management options to address risks. Option effectiveness: ☺ High, 😐 Medium, ☹ Low, 💣 Negative, - not applicable. Hazard type: Erosion (E), Inundation (I), both ( )

Adaptation Options		Likelihood	Consequence	Existing Development			Future Development		
				Existing Risk		Residual Risk	Existing Risk		Residual Risk
				Safety	Damage	Safety	Safety	Damage	Safety
Regenerative options	Beaches nourishment	E 😐 I ☹	E ☹ I ☹	E 😐 I ☹	E 😐 I ☹	E ☹ I ☹	E ☹ I ☹	E ☹ I ☹	E ☹ I ☹
	Dunes construction and regeneration	😐	☹	😐	😐	☹	☹	☹	☹
Coastal engineering options	Artificial reefs	☹	☹	☹	☹	☹	☹	☹	☹
	Groynes and Detached breakwaters	😐	☹	😐	😐	☹	☹	☹	☹
	Artificial headlands	☺	☹	😐	E 😐 I ☹	E ☹ I ☹	E ☹ I 😐	E ☹ I ☹	E ☹ I ☹
	Sea dykes	☺	☹	☺	☺	💣	☺	☺	💣
	Seawalls	☺	☹	☺	☺	☹	😐	😐	☹
Coastal settlements design options	Building retrofitting	☹	😐	E ☹ I 😐	E ☹ I 😐	☹	☹	☹	☹
	Improved design	☹	😐	😐	E 😐 I 😐	☹	☹	☹	☹
	Flood/erosion-resilient public infrastructure	☹	😐	😐	😐	☺	😐	😐	☺
	Raise land levels	☺	☹	☹	😐	💣	☹	☹	💣
Planning options	Spatial controls, design guidelines	☹	☺	☹	😐	☹	☺	☺	☹
	Land buy-back	☹	☺	☺	☺	☺	-	-	-
	Land swap	☺	☹	☺	☺	☺	-	-	-
	Land-use planning	☹	☺	😐	😐	☹	☺	☺	☹
Emergency response planning option		☹	☺	😐	☹	☺	😐	☹	☺

Table 6-7: Typical adaptation measures considered within each strategic pathway. Note that these measures may not always suitable and further investigations are required on a case-by-case basis.

Strategy	Considerations
	• Requirement for disclosure of hazards/vulnerability, e.g. Notification on title; • Rejecting the site and finding another; • Transferring development rights to another parcel better able to accommodate development; • Avoiding development within primary and fore dunes and low-lying coastal areas.
	• Requirement for disclosure of hazards/vulnerability, e.g. Notification on title; • Prevention of further development; • Leaving land and resources unprotected; • Demolition and removal of infrastructure as they become at risk by coastal hazards; • Applying easements or planning zones to allow for rolling change of land-use as it becomes affected by coastal hazards; • Prohibiting high value developments and infrastructure in at risk areas in favour of low cost activities (such as recreation, grazing etc.); • Locating major roads and key community infrastructure away from the coast with sacrificial connecting roads to vulnerable areas; and • Retaining public coastal land in public ownership.



- Requirement for disclosure of hazards/vulnerability e.g. Notification on title;
- Preparation of emergency evacuation plans to reduce the human consequences of coastal hazards;
- Applying easements or planning zones to allow for rolling change of land-use as it becomes affected by coastal hazards;
- Raised buildings and infrastructure in areas prone to inundation and flooding, for which:
  - Building foundations should remain intact and functional
  - Habitable rooms and/or floors should be sufficiently elevated to prevent floodwaters from entering the elevated building envelope during the design event
  - Utility connections (e.g. Electricity, water, sewer, natural gas) should remain intact or be easily restored
  - Buildings should be accessible and useable following a design-level event
  - Damage to enclosures below the design flood level should not result in damage to the foundation, the utility connections, or the elevated portion of the building;
- Locating development on the least hazardous portion of the site;
- Combining lots or parcels;
- Reducing the footprint of the proposed building, and shifting the footprint away from the hazard;
- Shifting the location of the building on the site by modifying or eliminating ancillary structures and development;
- Seeking variances to lot line setbacks along the landward and side property lines (in the case of development along a shoreline);
- Modifying the building design and site development to facilitate future relocation of the building;
- Altering the site to reduce its risk to coastal hazards;
- Only permit development of temporary or low value assets;
- Do not permit increases in development density (rezoning/ subdivisions);
- Do not permit development of high value assets (community centres, schools, hospitals);
- Reduce risk to defined acceptable levels for an estimated time period;
- Be designed to be durable and effective for the estimated time period and/or have reasonably well known maintenance and operating costs for the design period;
- Indicate the anticipated response at the end of the estimated extended period when risks again approach intolerable levels;
- Lower portions of structures are constructed of flood resistant materials and are designed to withstand water forces;
- For roads, alternative routes or other emergency contingency plans exist;
- Apply appropriate risk management strategies to vulnerable areas; and
- The design of temporary or relocatable structures, or structures that could be readily repaired or reinstated following the impacts of the likely coastal hazards.

	• Requirement for disclosure of hazards/vulnerability, e.g. Notification on title; • Implementation of a protection scheme; • Beach nourishment or replenishment; • Dune management; • Flood and sea walls; • Groynes; • Off-shore breakwaters or reefs; • There is likely to be long-term commitment to a high level of development in the area to justify the long-term costs; • The area will remain ultimately defendable; • There are compelling reasons why this area rather than a less vulnerable, higher elevation areas nearby should attract continued development and occupation; • Development is located and designed so that it can be appropriately protected from risks and impacts such as inundation and coastal erosion; • Construction of coastal protective structures, or allowing space for their future construction; • Emergency management; • Construction methods or materials that reduce the consequences of inundation and/or reduce the costs of relocation.

6.3 Review of Risk Management Implementation Mechanisms

6.3.1 *Regional Plans and Local Plans*

Regional and local plans have different roles in the implementation process, though they use similar tools. The framework for these plans is set by state and national policies and instruments. Regional and local plans are statutory instruments to allow the responsible authority to control the use and development of resources. They use planning tools to assist in risk reduction. Such tools include:

- **Spatial Controls** set limits to the type and extent of development that can happen in particular areas. These controls may take the form of:
  - Prescriptive zones (including reserves and easement)
  - Overlays with associated controls
  - Reference to resource documents.
- **Design or Siting Guidelines** are widely used by planning authorities throughout Australia and cover
  - Siting of buildings
  - Design and access to subdivisions
  - Environmental management requirements
  - Building codes in high risk areas
  - Construction criteria in areas of risk.
- **Specific Criteria** Planning instruments can also include criteria aimed at producing specific outcomes for particular developments, for example
  - Distance set-backs
  - Types of materials to use
  - Siting specifications in relation to hazards.
- **Performance Standards** In recent years there has been an increasing dependence on performance standards for design and siting. Here the intent is to
  - Specify a goal or objective to be met in development.
- **Local Policy** contributes to the framework for developing local plans within the context of regional and state or territory policies. It is intended to:
  - Reflect the aspirations of the community.

A combination of these tools should be used in planning instruments which govern the assessment of development proposals. Development proposals should:

- Respond to the site conditions, operating natural processes and the wider ecological, social and economic context;
- Show how the proposal can meet the objectives and desired outcomes for risk reduction while maintaining sustainability; and
- Demonstrate how the proposal is intended to be implemented.

6.3.2 *Implementation program*

The key throughout the implementation program is the integration between planning, statutory instruments and other regional or local strategic and management processes. The implementation program then links the application of the statutory planning instruments to specific mitigation works, as well as public and private sector development.

Program Requirements

Examples of desired outcomes that could influence an implementation program include:

- Certain development must not occur in areas of high or extreme risk;
- Development should not result in an increase in susceptibility or an increase in vulnerability to impacts from coastal hazards;
- Areas of high conservation value should not be adversely affected in order to reduce risk;
- No significant interference with natural processes should occur in order to reduce risk;
- No building, development or works should be allowed unless it can be shown that the potential risk from coastal hazards has been reduced to an acceptable level;
- In areas prone to hazard events, specified design and siting standards must be met in the construction of buildings in order to reduce risk; and
- Risk reduction should be incorporated into strategies using resources within the planning area.

It is important that any works program is approved through the statutory planning process so its impacts can be assessed in relation to the strategic plan and risks to the community.

Construction and Development

Appropriate techniques should be used for all works to ensure statutory and risk reduction requirements are met. Construction of protection works, creation of open spaces, development of artificial wetlands, use of appropriate construction techniques, and restoration and rehabilitation of areas or sites critical for risk reduction, can all be part of an authority's program for risk reduction derived from the strategic plan. Similar concepts should be applied to private sector development.

Assessment

All works and development programs should be assessed for their contribution to risk reduction and their potential to impact on community risk. Before implementation, works can be assessed using a risk analysis and evaluation approach; post-implementation works should be monitored continually. Inappropriate or unacceptable works which increase risk or do not contribute to risk reduction can be modified to ensure the risk reduction objectives of the strategic plan are satisfied. Management programs Public authorities can also implement a number of management programs to contribute to risk reduction. These can include the options listed below.

Ground Management

It is required to ensure that areas maintain their capacity to reduce risks, for example, maintenance of drainage channels, storm water systems and coastal protection schemes.

Education

Education of people in hazardous areas and training of staff and communities about the need for and the techniques of risk reduction helps to lower risks. This education should cover the design and siting of buildings, on-site management of vegetation on private property, building and structure maintenance, and training to deal with emergencies when they occur.

Enforcement Programs

Development proposals may be approved subject to certain risk reduction conditions being met. It is then essential that those conditions be enforced. Risk reduction measures that need to be implemented as part of a development, must be included on permit conditions. Furthermore, these works need to be inspected periodically to ensure they are being maintained in accordance with their permit requirements.

6.3.3 *Monitor & Review*

Another critical element in land use planning and risk reduction is monitoring and reviewing plans. Plans need to be living documents if they are to meet their goals and objectives. Monitoring should occur on a continual basis and can include the number of new housing permits issued, assessment of areas that are growing the fastest, and other trends in development which can have profound impacts on the community and natural hazard risks. The potential for cumulative effects should be reviewed on a regular basis. Two key questions to be addressed during the review are:

- In light of permitted development, is the strategic land use and development plan still valid?
- Has any cumulative impact started to occur as a result of permitted development?

There is a role for 'State of the Environment' reporting in this process.

Regular community meetings should be conducted to review plan goals, objectives and progress against the plan. Any revisions to the plan identified and agreed by the community and decision makers should be implemented.

A critical time for review of plans is during the response and recovery stages to an event. A quick land use planning process may need to be applied to situations such as temporary accommodation or re-settlement, particularly in remote areas. Furthermore the recovery phase offers the opportunity to re-address the whole land use planning issue.

6.4 Appraisal of Adaptation Pathways

As indicated by the risk profile of the strategic areas impacted by coastal hazards (Table 6-1), each area (i.e. Town Centre & Foreshore, Castletown, Flinders, Bandy Creek & Surrounds and Wylie Head) requires treatment to reduce the coastal hazard risk to an acceptable level. A structured framework was used to appraise the possible adaptation pathway and identify the preferred pathway, thereby clarifying the values and trade-off for each individual strategic area.

The key appraisal criteria included the following:

- Capital cost
- Recurrent cost

- Environmental and social benefit
- Community acceptability
- Reversibility / adaptability in the future
- Effectiveness over time
- Legal / Approval risk
- Technical viability

The 3-point scoring system included the following rating:

- Against, least preferred : ☹ (0 points)
- Neutral : 😐 (1 point)
- For, most preferred : ☺ (2 points)

This structured appraisal framework followed the aspects and ratings summarised in Table 6-8. This semi-quantitative analysis provides the similarities and dissimilarities between the strategic areas and the potential pathways. It also incorporates the perspective of key stakeholders.

Table 6-8: Aspects and ratings used in the structured appraisal framework

Aspects / Preference (score)	☺ (2 points)	😐 (1 point)	☹ (0 point)	BMT	Shire	Public
Capital cost	<$0.5M	$0.5M – 1.5M	More than $1.5M	☑	☐	☐
Recurrent cost per annum	<$0.5M	$0.5M – 1.5M	More than $1.5M	☑	☐	☐
Environmental and social impact	Beneficial	No net impact	Negative impact	☑	☐	☐
Community acceptability	>90% acceptance	<50% acceptance	<10% acceptance	☑	☐	☐
Reversibility / adaptability in the future	Flexible with many possible alternative	Reversible but at considerable cost	Irreversible with limited alternative in the future	☑	☐	☐
Effectiveness over time	Provide long-term solution (100 year)	Medium term solution (50 year)	Short Term solution (1 years)	☑	☐	☐
Legal / Approval risk	Minimal risk	Substantial requirements	Approval may not be granted	☑	☐	☐
Technical viability	Widely tested and proven technics	Limited national experience with technics	Limited international experience with technics	☑	☐	☐

6.4.1 *CHRMAP forum held on 8 March 2016*

A CHRMAP forum was held on 8 March 2016 during which the appraisal process facilitated the development of a unique and coherent reasoning behind the adoption of a preferred adaptation pathway. As part of the appraisal process, key stakeholder feedback was also captured during the CHRMAP forum.

For the first time since the inception the Esperance CHRMAP project, a presentation of the coastal hazard risk and a workshop centred on potential adaptation pathways were provided to Esperance councillors and stakeholders. The goals of the engagement were:

- To provide balanced, objective, accurate and consistent information to assist stakeholders to understand the problem, alternatives, opportunities and/or solutions.
- To work directly with stakeholders throughout the process to ensure that their concerns and needs are consistently understood and considered.
- To obtain feedback from stakeholders on analysis, alternatives and/or outcomes.

A session was held with the council in the morning, while an afternoon session was open to all stakeholders, including the general public. These sessions were advertised and planned by the Shire. The list of attendees included:

- All the Shire's councillors
- Some key Shire's officers, including CEO and planning and asset management directors,
- Two representatives from the Port Authority
- One representative from a local environmental consultancy

The presentation was jointly provided by BMT JFA Brad Saunders and Frederic Saint-Cast. The outline of the presentation is given hereafter:

- Background
  - Overview of the CHRMAP context, including planning framework, local planning strategy and sea level rise projections
  - Key coastal processes, including related erosion and inundation hazard
  - Historical events, trend and existing controls.
- Risk assessment
  - Assessment framework, in accordance with the Shire's own likelihood definitions and consequence rating of the costal hazards for key asset categories
  - Coastal hazards zones maps for the three planning horizons
  - Coastal hazard risk maps
  - Current hot spots and mitigation measures
  - Future high risk sections of the coastal zone
  - Summary characterisation of coastal risks.
- Coastal Hazard Risk Adaptation Pathways
  - Potential Pathways: Avoid, Retreat, Accommodate, Protect

  - Comparative definitions
  - Comparative illustrations
  - Key issues
- Risk profile score cards and adaptation pathway appraisal sheets for:
  - Town Centre & Foreshore (Table 6-12)
  - Castletown (Table 6-13)
  - Flinders (Table 6-14)
  - Bandy Creek & Surrounds (Table 6-15)
  - Wylie Head (Table 6-16)

During and after the presentation, questions from the floor were answered by the consultants. Attendee's perspective and issues were also noted and are summarised in Table 6-9, Table 6-10 and Table 6-11.

Table 6-9: Summary of attendee's perspective and issues: Town Centre & Foreshore

Stakeholder perspective: Town Centre & Foreshore	Issues
The existing seawall is an important erosion control measure which provides immunity to this section of the coast in the short and medium term and will need to be maintained adequately to remain effective over this period of time*.	Existing control effectiveness* *(*) This insight was provided by the specialist consultant in response to the attendees questions*
It is challenging to think strategically for "large" section of the coast. It is "easier" to deal with smaller scale tactical responses.	Decision making bias
A hydrological assessment will be required to evaluate the related inundation risk not cover in the CHRMAP scope of work.	Need more information
The issues are "exceptionally" complex consultants are requested to submit recommendations.	Decision making bias
There is a natural tendency to want to protect where the assets are.	Decision making bias
Downgrading zoning has a cost.	Trade off
Disclosure of coastal hazards may lead developer (e.g. shopping centre) out of town	Trade off
There may be a need to relocate some businesses (e.g. petrol station) away from the hazard areas	Trigger point
It is easier to see what is to be protected	Decision making bias
It may be preferable to accommodate inundation in the Town Centre until the	Trigger point

3rd events before reviewing, when insurance premium go up	
The cost of raising road should be based on volume infilled required	Need more information
There is no alternative to shift (retreat from) Town Centre	Preference
Decision should aim at protecting	Preference
Accommodate seems like “throwing good money after bad”	Preference
We don’t know what the town centre will look like in 50 – 100 years	Need more information
The port oil pipeline will be eventually removed and replaced by a trucking service. A retreat approach is considered for this asset.	Trigger point

Table 6-10: Summary of attendee’s perspective and issues: Castletown

Stakeholder perspective: Castletown	**Issues**
The existing sand dumping is an important erosion control measure which provides immunity to this section of the coast in the short term. The sustainability of the approach is questionable for medium to long term horizon*.	Existing control effectiveness* *(*) This insight was provided by the specialist consultant in response to the attendees questions*
Public would resent losing the beach but would Not accept losing the road	Preference
Continue seawall vs. longer term buy back	Trade off
Eventually the pine trees will disappear (e.g. fall in the water, salt water intrusion)	Trigger
Accommodate with sand nourishment for now then protect	Trigger
Lack of information to decide	Decision making bias
Accommodate pathway appears less costly than protect	Trade off
Cost of sand nourishment	Need more information

Table 6-11: Summary of attendee's perspective and issues: Flinders, Bandy Creek & Surrounds, Wylie Head

Stakeholder perspective: Flinders, Bandy Creek & Surrounds, Wylie Head	Issues
The existing setback is an important coastal hazard control measure which provides immunity to these sections of the coast in the short and medium term. The sustainability of the approach is confirmed subject to some minor alteration of the foreshore reserve boundary*.	Existing control effectiveness* *(*) This insight was provided by the specialist consultant in response to the attendees questions*
General agreement to avoid coastal hazard risk in theses undeveloped coastal zones.	Preference

In addition, during the workshop the following issues were raised:

- Competitive nature of funding for coastal protection
- Slow growth in regional centres
- Slow/low residential and commercial stock renewal
- Residual risk management is required for events over and above protection design events

The outcomes of the forum are in accordance with the expectations outlined in the stakeholders' engagement strategy. Specifically, the forum:

- Informed stakeholders about:
  - Coastal Planning Policy (SPP2.6)
  - Coastal process (Storm & Sea level rise)
  - Inundation and Erosion Hazard zone.
- Consulted stakeholders about:
  - Values at Risk (present and future)
  - Risk profile
  - Existing controls.
- Involve stakeholders about:
  - Adaptation pathways (avoid, planned retreat, accommodate, protect)
  - Adaptation options (Regenerative, Protective, Design, Land use).

In conclusion of the forum, distinct strategies were identified as preferred adaptation pathways for specific section of the coast as follow:

- Protect: Town Centre & Foreshore
- Accommodate: Castletown
- Avoid: Flinders, Bandy Creek & Surrounds, Wylie Head.

The Protect and Accommodate strategies were considered for the Town Centre & Foreshore and Castletown areas respectively. It was acknowledged that there is a great deal of uncertainty regarding the timing and impact of coastal hazards. Also, the natural tendency to wish to protect existing asset rich areas may not be implementable due to financing constraints. Therefore a staged approach seems more appropriate and trigger points were identified in order to mark significant events or thresholds beyond which the current course of action would be altered. The approach intend to maximise the use of existing controls as long as they remain effective in mitigating risk while minimising the outlay of large capital expenses.

The Avoid strategy was unanimously preferred in the other non-developed sections of the coast. This approach sits the highest on the risk management hierarchy and also scores the highest against all selection criteria in the cost and benefits analysis.

Table 6-12: Appraisal of adaptation pathways for Strategic Coastal Areas at risk: Town Centre & Foreshore

Profile	Risk summary	Erosion	Inundation	Key controls in place
Existing development 	Central area	□□□	□□□	Protection scheme
	Local road	□□□	□□□	Foreshore reserves
	Parks, recreation and conservation – local	□□□	□□□	Special Control Areas – Disclosure of coastal hazard
	Public purpose	□□□	□□□	
	Regional road	□□□	□□□	
	Residential	□□□	□□□	
	Tourist residential	□□□	□□□	
	Tourist zone	□□□	□□□	
	Infrastructures (utilities)	□□□	□□□	

Appraisal Criteria \ Pathway	Avoid	Retreat (Planned/Managed)	Accommodate / Maintain	Protect / Intensify
Capital cost	n/a	☹ (0 point)	☹ (0 point)	☹ (0 point)
Recurrent cost	n/a	☹ (0 point)	☹ (0 point)	😐 (1 point)
Environmental and social benefit	n/a	☹ (0 point)	😐 (1 point)	☺ (2 points)
Community acceptability	n/a	☹ (0 point)	😐 (1 point)	☺ (2 points)
Reversibility / adaptability in the future	n/a	☺ (2 points)	😐 (1 point)	☹ (0 point)
Effectiveness over time	n/a	☺ (2 points)	☹ (0 point)	☹ (0 point)
Legal / Approval risk	n/a	☹ (0 point)	☺ (2 points)	☺ (2 points)
Technical viability	n/a	☹ (0 point)	☺ (2 points)	☺ (2 points)
TOTAL SCORE (points)	**-**	**4**	**7**	**9**

Table 6-13: Appraisal of adaptation pathways for Strategic Coastal Areas at risk: Castletown

Profile	Risk summary	Erosion	Inundation	Key controls in place
Existing development 	Local road	□□□	□□□	Foreshore reserves Special Control Areas – Disclosure of coastal hazard
	Parks, recreation and conservation – local	□□□	□□□	
	Regional road	□□□	□□□	
	Residential	□□□	□□□	
	Tourist zone	□□□	□□□	
	Infrastructures (utilities)	□□□	□□□	

Appraisal Criteria \ Pathway	Avoid	Retreat (Planned/Managed)	Accommodate / Maintain	Protect / Intensify
Capital cost	n/a	😐 (1 point)	☹ (0 point)	☹ (0 point)
Recurrent cost per annum	n/a	😐 (1 point)	☹ (0 point)	😐 (1 point)
Environmental and social benefit	n/a	☹ (0 point)	☺ (2 points)	😐 (1 point)
Community acceptability	n/a	☹ (0 point)	☺ (2 points)	😐 (1 point)
Reversibility / adaptability in the future	n/a	☺ (2 points)	😐 (1 point)	☹ (0 point)
Effectiveness over time	n/a	☺ (2 points)	☹ (0 point)	☹ (0 point)
Legal / Approval risk	n/a	☹ (0 point)	☺ (2 points)	☺ (2 points)
Technical viability	n/a	☹ (0 point)	☺ (2 points)	☺ (2 points)
TOTAL SCORE (points)	**-**	**6**	**9**	**7**

Table 6-14: Appraisal of adaptation pathways for Strategic Coastal Areas at risk: Flinders

Profile	Risk summary	Erosion	Inundation	Key controls in place
New development 	Parks, recreation and conservation – local	□□□	□□□	
	Residential	□□□	□□□	Foreshore reserves
				Special Control Areas – Disclosure of coastal hazard

Criteria	Avoid	Retreat (Planned/Managed)	Accommodate / Maintain	Protect / Intensify
Capital cost	☺ (2 points)	n/a	n/a	n/a
Recurrent cost per annum	☺ (2 points)	n/a	n/a	n/a
Environmental and social benefit	☺ (2 points)	n/a	n/a	n/a
Community acceptability	☺ (2 points)	n/a	n/a	n/a
Reversibility / adaptability in the future	☺ (2 points)	n/a	n/a	n/a
Effectiveness over time	☺ (2 points)	n/a	n/a	n/a
Legal / Approval risk	☺ (2 points)	n/a	n/a	n/a
Technical viability	☺ (2 points)	n/a	n/a	n/a
TOTAL SCORE (points)	**16**	**-**	**-**	**-**

Table 6-15: Appraisal of adaptation pathways for Strategic Coastal Areas at risk: Bandy Creek & Surrounds

Profile	Risk summary	Erosion	Inundation	Key controls in place
New development 	Future residential	□□□	□□□	
	Parks, recreation and conservation – local	□□□	□□□	Foreshore reserves
	Public purpose	□□□	□□□	Special Control Areas – Disclosure of coastal hazard
	Residential	□□□	□□□	

Criteria	Avoid	Retreat (Planned/Managed)	Accommodate / Maintain	Protect / Intensify
Capital cost	☺ (2 points)	n/a	n/a	n/a
Recurrent cost per annum	☺ (2 points)	n/a	n/a	n/a
Environmental and social benefit	☺ (2 points)	n/a	n/a	n/a
Community acceptability	☺ (2 points)	n/a	n/a	n/a
Reversibility / adaptability in the future	☺ (2 points)	n/a	n/a	n/a
Effectiveness over time	☺ (2 points)	n/a	n/a	n/a
Legal / Approval risk	☺ (2 points)	n/a	n/a	n/a
Technical viability	☺ (2 points)	n/a	n/a	n/a
TOTAL SCORE (points)	**16**	**-**	**-**	**-**

Table 6-16: Appraisal of adaptation pathways for Strategic Coastal Areas at risk: Wylie Head

Profile	Risk summary	Erosion	Inundation	Key controls in place
New development 	Agricultural – general	□□□	□□□	Foreshore reserves Special Control Areas – Disclosure of coastal hazard Low intensity land use
	Local road	□□□	□□□	
	Parks, recreation and conservation – local	□□□	□□□	
	Public purpose	□□□	□□□	

Criteria	Avoid	Retreat (Planned/Managed)	Accommodate / Maintain	Protect / Intensify
Capital cost	☺ (2 points)			
Recurrent cost per annum	☺ (2 points)			
Environmental and social benefit	☺ (2 points)			
Community acceptability	☺ (2 points)			
Reversibility / adaptability in the future	☺ (2 points)			
Effectiveness over time	☺ (2 points)			
Legal / Approval risk	☺ (2 points)			
Technical viability	☺ (2 points)			
TOTAL SCORE (points)	**16**	**-**	**-**	**-**

7 Preferred Adaptation Strategies

The preferred adaptation strategies presented hereafter forms a response to the current circumstances and state of knowledge, with key characteristics and determinants that reflect the values and preferences of key stakeholders, as confirmed at the CHRMAP Forum held on 8 March 2016. The underpinnings of the preferred adaptation pathways adopted for each strategic area include:

- Key issues – summarising the outcome of the risk assessment
- Controls in place – outlining the effectiveness of current mitigation measures
- Hotspots – presenting risk adjusted priorities
- Preferred Strategy – depicting the aim of the strategy and its anticipated results and community acceptance
- Trade-offs – stressing key upsides and downsides of the strategy
- Adaptation measures – indicating the nature and timing of the risk treatment measures
- Trigger points – indicating conditional timing for implementation of adaptation measures
- Cost of Implementation – estimating the overall cost of the strategy
- Monitoring and review – providing key indicators that should trigger a specific course of action
- Five year plan - to lay down a preferred course of actions that address identified issues.

7.1 Town Centre & Foreshore: Protect

7.1.1 *Key issues*

Town Centre & Foreshore is a developed area with a broad range of values at present (including high intensity land use and infrastructure assets) that are at *High* to *Extreme* risk of erosion and inundation in the near, medium and long term.

In the long term, coastal hazards could potentially lead to:

- Permanent loss of land following erosion, with a possibility of retreat of the shoreline from its current position in the order of:
  - 90m, as a near certainty (over 100 years)
  - 130m, as rare possibility (over 100 years)
- Temporary widespread inundation of the area, with water depth in the order of:
  - Less than 0.5m in most of the hazard zone, with a 64% chance (over 100 years)
  - Less than 1.3m in all of the hazard zone, with a 3% chance (over 100 years)

7.1.2 *Controls in Place*

Control measures in place (e.g. seawall, foreshore reserve) in some segments of the area are highly effective to treat risk in the near to medium term. The effectiveness of these controls should not be taken for granted over the long term.

7.1.3 *Hotspots*

The risk adjusted hotspots have been summarised in Table 6-16.

Table 7-1: Risk adjusted priority hotspots: Town Centre & Foreshore

Risk	Short term	Medium term	Long term
Extreme	-	Erosion of: • Infrastructures (utilities) Inundation of: • Residential areas • Public purpose	Erosion of: • Infrastructures (utilities) • Regional road • Protective structure (seawall) Inundation of: • Residential areas • Central area • Tourist residential • Infrastructures (utilities)
High	Erosion of: • Infrastructures (utilities)	Erosion of: • Regional road • Parks, recreation and conservation – local • Protective structure (seawall) Inundation of: • Central area • Tourist residential • Infrastructures (utilities) • Public purpose	Erosion of: • Parks, recreation and conservation – local
Scale of impact	Erosion of the order of: • 0.3km (South of James St)	Erosion of the order of • 0.6km (South of Kemp St) • 0.4km (Norseman Rd) Exhaustion of protection • 1.7km (Foreshore reserve) • Seawall Inundation in the order of • 11.9ha over 1km (South of James St)	Erosion of the order of • 1.7km (The Esplanade) • 0.4km (Norseman Rd) Exhausted protection • 1.7km (Foreshore reserve) • Seawall Inundation in the order of • 24.4ha over 1km (South of James St) • 4.2ha over 1km (North of James St)
Cost to Protect*	Seawall erosion control: • $3M + $30kpa	Seawall erosion control: • $10M + $100kpa Levee inundation control: • $0.6M + $6kpa	Seawall erosion control: • $21M + $210kpa Levee inundation control: • $1.8M + $18kpa
(*) Protection cost based on the scale of impact and on the order of magnitude cost estimate for construction ($10,000/m seawall, $500/m levee) + maintenance (1% of construction cost per annum assuming 40 year life)			

7.1.4 *Preferred Strategy*

The aim of the protect pathway is to defend existing core strategic assets and enable intensification of the land use.

Community acceptance of this strategy is strong despite the progressive loss of natural beach amenity.

Risk reduction and net positive environmental and social benefits are being sought through adequate planning and development of the foreshore.

7.1.5 *Trade-offs*

Key upsides of the protect strategy are to:

- Enable the intensification of the area
- Increase the economic and social value of the area.

Key downsides of the protect strategy are to:

- Require substantial capital investment into protective structures
- Rely on the effectiveness of controls to maintain adequate performance criteria
- Increase demand on residual risk management especially in the long term.

7.1.6 *Adaptation Measures*

The Protect pathway is illustrated in the sketch Figure 7-1.

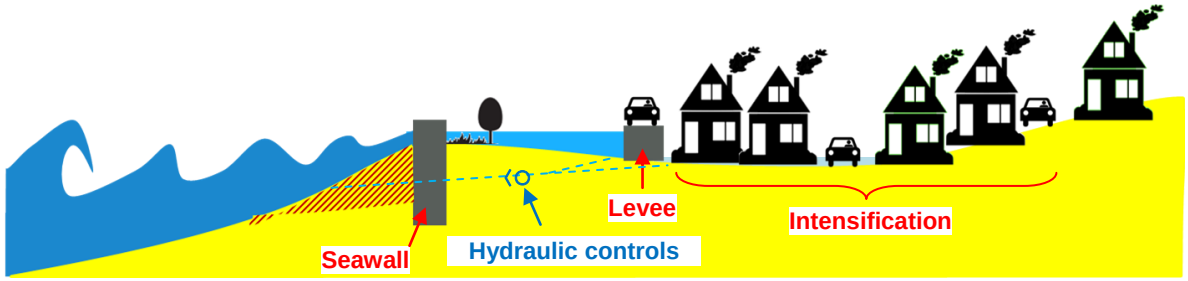


Figure 7-1: Protect pathway sketch

Risk treatment measures, in addition to existing controls in place, will be required to protect against the coastal hazard risks, by drawing on a combination of:

- Significant engineering coastal protections, with a scheme combining seawalls, levees and hydraulic controls
- Planning measures supporting the development of the protection scheme.

It is envisaged that the protection scheme is developed holistically and implemented in successive stages in response to the results for the monitoring of trigger points. The protection scheme staging is illustrated in Figure 7-2, with stages reflecting the risk adjusted priorities. Each element of the protection scheme will require adequate maintenance to fulfill its role effectively as erosion and inundation control measure. This means that regular upgrades and repair interventions are expected on an ongoing basis. This is true for the existing seawall (C1) and subsequent stages of the scheme, including the segment south of James Street groyne (C2), the segment north of James Street groyne (C3), the segment

north of the seawall along Norseman Rd groyne field (C4), and the segment south of Andrew St (C5), as shown in in Figure 7-2.

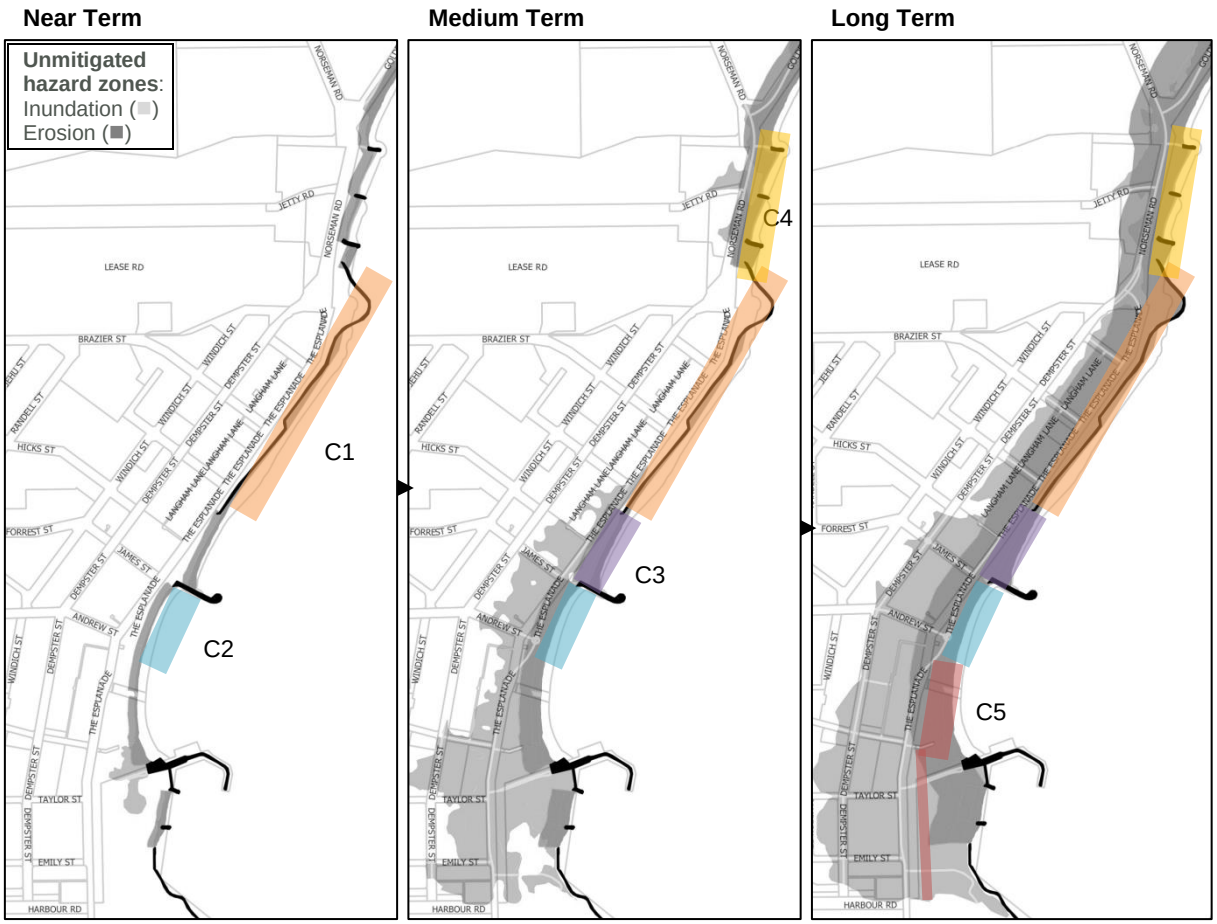


Figure 7-2: Protection scheme stages: C1: Construction of (existing) Esperance Seawall, C2: construction phase 2, C3: construction phase 3, C4: construction phase 4, C5: construction phase 5.

7.1.7 *Trigger Points*

Trigger points for the implementation of the protection scheme key expenditures are shown in Figure 7-3 and detailed below:

- T1 : undermining of beach amenities (footpath and carpark) near Andrew St round about
- T2 : undermining of beach amenities (footpath) along the Esplanade south of Kemp St
- T3 : undermining of beach amenities (carpark) along the Norseman Rd
- T4 : undermining of Esperance Seawall function
- T5 : undermining of beach amenities (Sailing Club and Car park) at William St.

Subsequent interventions should be carried out in order to maintain an acceptable level of functionality.

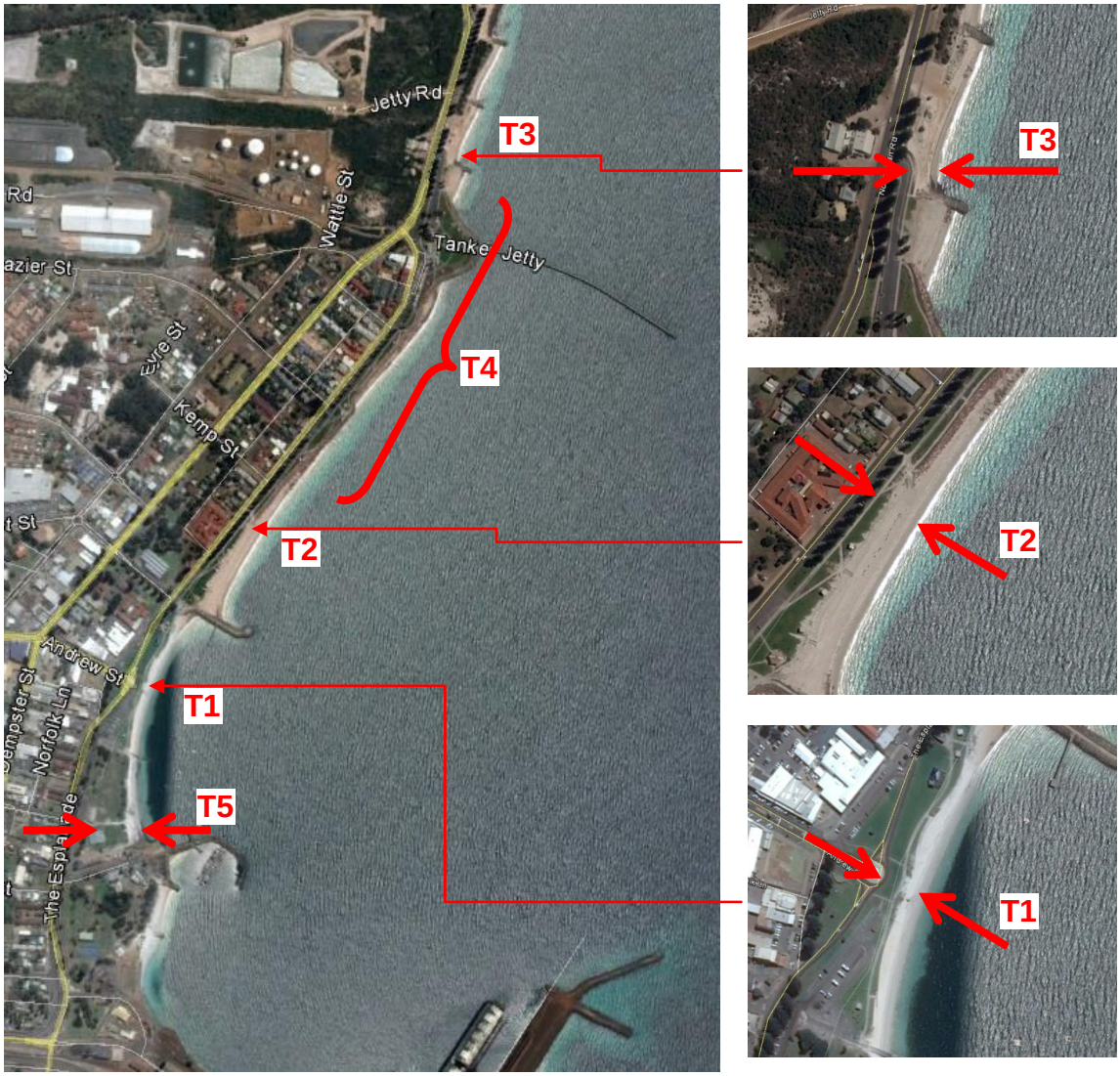


Figure 7-3: Trigger points for Town Centre & Foreshore: Protect Strategy

7.1.8 *Cost of Implementation*

The anticipated cost of the strategy is in the order of $300kpa over the planning period (Figure 7-4). This is based on the averaging of capital expenditures and upkeep cost required to achieve an acceptable level of functionality of the structure over time. The cash flow requirement will vary significantly depending on the phase of implementation (i.e. planning, design, construction, maintenance) with higher demand placed during major capital upgrade.

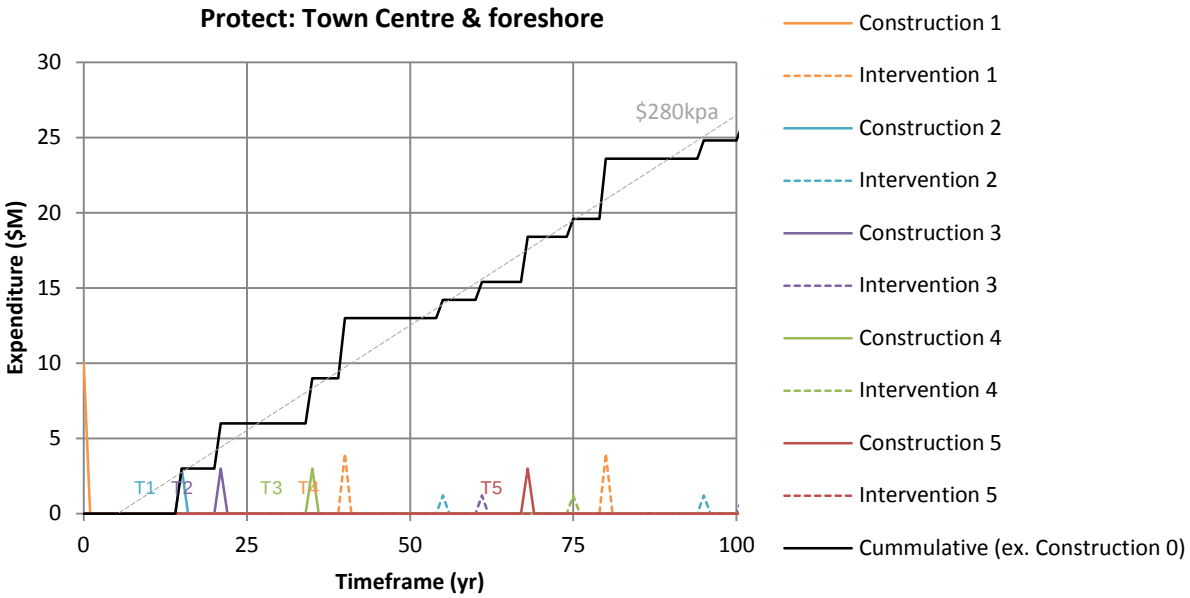


Figure 7-4: Example of key expenditure program for the coastal protection strategy. Construction 1 (i.e. Esperance seawall) works are included for comparative purpose. "Construction" corresponds to the anticipated expenditure requirement for the implementation of major works. "Intervention" corresponds to the anticipated expenditure requirement to maintain major works. Expenditure timing is subject to trigger points, with respect to construction of protection works and subsequent interventions required to keep an acceptable level of functionality. In this example, interventions occur after 40 years and assume deployment of sinking fund accumulated at an annual rate of 1% of initial construction cost.

7.1.9 *Monitoring and Review*

Monitoring of the trigger points is required to ensure timely implementation of the protection scheme. This shall include:

- Seasonal (summer and winter) surveys of beach cross sections (at T1, T2, T3, T5) to track changes in beach profile
- Post-storm visual assessment of the seawall (T4) to establish a high level condition assessment rating based on standard methods, such as the US army Corps of Engineers Repair, Evaluate, Maintain and Rehabilitate (USACE-REMR) technique for assessing coastal structures.

In addition, key indicators that should prompt the review of the strategy are:

- Deterioration of the foreshore reserve to a level undermining its effectiveness as a buffer against coastal processes hazards
- Deterioration of the economic and social values of the area to a level undermining the viability of intensification of land use scenario
- Requirement for capital expenditures and upkeep of protection requirements exceed fund available.

7.1.10 *Five Year Plan*

The Protect strategy is making allowances to "defend the line" continuously by implementing a well though-through protection scheme. It is therefore recommended to fully consider the implications of the strategy so that commitment to the decision is achieved and adequate allocation of resources is sustained over time.

Although in the short term, no significant capital expenditure is anticipated, the presence of hotspots stresses the importance for the Shire to develop, strengthen and maintain its capacity to respond promptly and effectively to coastal hazard risks.

Key actions are focused on the following three main endeavours:

- Insight - to identify issues that need addressing by monitoring trigger points
- Plan – to lay down a preferred course of actions that address identified issues by planning, designing and funding of a holistic protection scheme, including its integration with the drainage management scheme
- Implementation – to manage the execution of the adopted plan seamlessly, i.e. works.

The resulting implementation plan (Table 7-2) addresses the first two elements (Insight and Plan) with a focus on tasks to be completed within the 1-5 year timeframe. When these tasks are completed. The Shire will be in a position to take immediate, corrective actions in accordance with the adopted Protect strategy thereby avoiding the serious consequences of not acting quickly enough and/or misallocating resources in the long run.

Table 7-2: Five year adaptation plan 2016 - Town Centre & Foreshore: Protect Strategy

ID	Category	Expected Benefit(s)	Task(s) including [Predecessors]	Performance measure	Reporting and monitoring	Responsibility
1	Asset Management services - guide maintenance and upgrades of infrastructures	• Update asset risk profile • Consider asset life cycle in decision-making • Coordinated coastal hazard risk mitigation response	a) Flag assets at risk in asset register b) Establish anticipated maintenance strategy for assets at risk [1a] c) Update risk register in asset management plan [1b]	• Asset Management services are consulted during the development of the protection scheme • *Asset Management plan* is updated, as required	• *Asset Management Plan*	Services Manager
2	Engineering services - guide development and construction of infrastructures	• Refine protection cost estimate • Refine protected footprint • Refine staging of works • Control erosion risk • Control inundation risk	a) Develop concept designs suitable to address erosion and inundation risk in multiple stages reflecting the use of protective measures (including offshore) and inundation proofing measures and integrated with the drainage scheme [1b] b) Develop detailed design of preferred option c) Develop triggers monitoring plan d) Monitor triggers, including beach surveys and seawall condition assessment [d2]	• Engineering services are consulted during the development of the protection scheme • The protection scheme is effectively reducing coastal erosion and inundation risks • *Detailed design and cost estimate* of the protection scheme is developed • *Monitoring plan* is developed • *Monitoring reports* of triggers points are issued systematically at scheduled intervals	• *Concept Design* • *Preliminary Cost Estimate* • *Detailed Design* • *Specifications* • *Cost Estimate* • *Monitoring Plan* • *Monitoring Reports*	Services Manager
3	Planning services - guide all development and land uses	• Awareness of staged development constraints and opportunities • Lower risk profile using engineered protection and planning controls • Net triple bottom line benefits	a) Develop an appreciation of staged development constraints and opportunities [2a] b) Develop planning control measures as per 6.3.1 [1a] c) Update regional plans and local plans as required [3b] d) Update CHRMAP (controls in place, values at risk, risk profile) as required [1,3]	• Planning services are consulted during the development of the protection scheme • A planning strategy is developed to reflect the constraints and opportunities presented by the protection scheme • *Planning instruments* are updated, as required	• *Planning Strategy* • *Planning Scheme* • *Foreshore Master Plan* • *Local Plans* • *Precinct Design Guidelines* • *CHRMAP*	Services Manager
4	Environmental services - guide protection, rehabilitation, enhancement and management of the social and environment values	• Enhance environmental and social values	a) Develop landscaping options [2a] b) Develop detailed landscaping option [2b] c) Update coastal management plan [2c]	• Environmental services are consulted during the development of the protection scheme • Environmental and social value enhancement opportunities are identified • *Coastal management plan* is updated, as required	• *Coastal Management Plan*	Services Manager
5	Emergency response services	• Prevention and mitigation • Preparedness • Response • Recovery	a) Present CHRMAP and preferred protection concept to management authorities [3a] b) Update procedures as required [5a] c) Review plan [2c]	• Emergency response services are consulted during the development of the protection scheme • *Emergency response plan* is updated, as required	• *Emergency Response Plan*	Services Manager
6	Corporate Finance services – guide allocation of resources	• Establish and grow dedicated reserve • Deal with sources of funding • Appropriate financing	a) Review budgets and fund allocation [3a] b) Develop financing strategy for protection scheme construction, maintenance and damage repair [6a]	• Corporate Finance services are consulted during the development of the protection scheme • *Financial plan* is updated, as required	• *Financial Plan*	Services Manager

7.2 Castletown: Accommodate / Maintain

7.2.1 *Key issues*

Castletown is a developed area with a broad range of values at present (including medium intensity land use and infrastructure assets) that are at *High* to *Extreme* risk of erosion and inundation in the near, medium and long term.

In the long term, coastal hazards could potentially lead to:

- Permanent loss of land following erosion, with a possibility of retreat of the shoreline from its current position in the order of:
  - 90m, as a near certainty
  - 170m, as rare possibility
- Temporary spatially limited inundation of the land, with water depth in the order of:
  - Less than 0.5m in most of the hazard zone, with a 64% chance (over 100 years)
  - Less than 1.3m in all of the hazard zone, with a 3% chance (over 100 years)

7.2.2 *Controls in Place*

Control measures in place (e.g. sand nourishment, foreshore reserve) are effective to treat risk in the near term. The effectiveness of these controls should not be taken for granted over the long term.

7.2.3 *Hotspots*

The risk adjusted hotspots have been are summarised in Table 7-3.

Table 7-3: Risk adjusted priority hotspots: Castletown

Risk	Short term	Medium term	Long term
Extreme	-	Erosion of: • Infrastructures (utilities) • Regional road	Erosion of: • Infrastructures (utilities) • Regional road • Tourist zone Inundation of: • Tourist zone • Infrastructures (utilities)
High	Erosion of: • Infrastructures (utilities) • Regional road • Protective measure (sand nourishment)	Erosion of: • Tourist zone • Residential areas • Parks, recreation and conservation – local Inundation of: • Tourist zone • Residential areas • Infrastructures (utilities)	Erosion of: • Tourist zone • Residential areas • Parks, recreation and conservation – local Inundation of: • Tourist zone • Residential areas • Infrastructures (utilities)
Scale of impact	Erosion of the order of • 0.1km (South of Jetty Road) • 0.4km (South of Phyllis Street) Encroachment of protection: • Sand nourishment	Erosion of the order of • 2.6km (Castleton Quays) Exhaustion of protection: • 2.6km (Foreshore reserve) Inundation in the order of • 0.5ha over 250m (Quays) • 0.2ha over 50m (Chaplin St)	Erosion of the order of • 2.6km (Castleton Quays) Exhausted protection: • 2.6km (Foreshore reserve) Inundation in the order of • 0.5ha over 250m (Quays) • 4ha over 1km (Chaplin St)
Cost to Protect*#	Seawall erosion control: • $5M + $50kpa	Seawall erosion control: • $26M + $260kpa Levee inundation control: • $150k + $2kpa	Seawall erosion control: • $26M + $260kpa Levee inundation control: • $625k + $6kpa

(*) Protection cost based on the scale of impact and on the order of magnitude cost estimate for construction ($10,000/m seawall, $500/m levee) + maintenance (1% of construction cost per annum assuming 40 year life)

(#) Although the Accommodate / Maintain pathway does not primarily focus on protection measures, it does not exclude them completely. Therefore order of magnitude costs were included for information.

7.2.4 *Preferred Strategy*

The aim of the accommodate pathway is to preserve key infrastructure corridors and maintain the land use level.

Community acceptance of this strategy is neutral in anticipation of the progressive reduction in environmental and social values locally.

Risk reduction is being sought through adequate planning and management of the foreshore.

Additional risk treatment measures will be required to accommodate the coastal hazard risks, by drawing on a combination of

- Planning measures
- Limited engineering coastal protections.

7.2.5 *Trade-Offs*

Key upsides of the accommodate strategy are to:

- Maintain the status quo in the area
- Limit the outlay of capital expenditure for hard engineering protections.

Key downsides of the accommodate strategy are to:

- Require substantial operational expenditures in the aggregate to “defend the line”
- Rely on the ongoing management of the existing controls to maintain adequate performance criteria
- Increase demand on residual risk management especially in the long term.

7.2.6 *Adaptation Measures*

The Accommodate / Maintain pathway is illustrated in the sketch Figure 7-5.

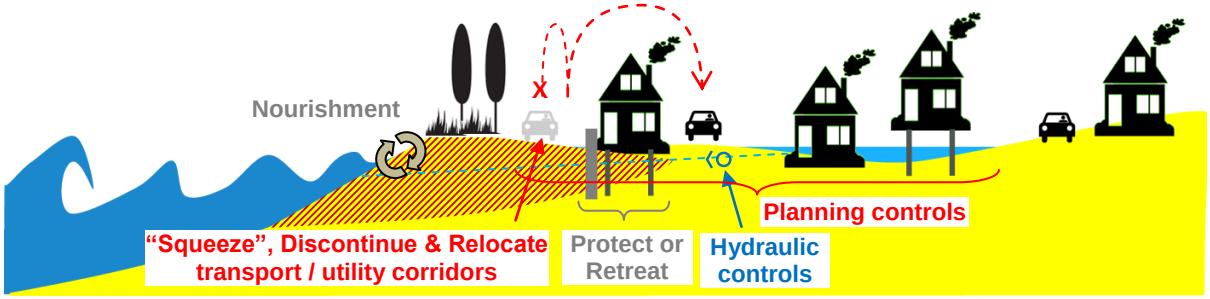


Figure 7-5: Accommodate / Maintain pathway sketch

Risk treatment measures, in addition to existing controls in place, will be required to protect against the coastal hazard risks, by drawing mainly on:

- Planning measures, in accordance with the statutes governing the administration of land in Western Australia (including the *Land Administration Act 1997*).
- Engineering measures supporting the strategy.

It is envisaged that the Accommodate scheme is developed holistically and implemented in successive stages in response to the results for the monitoring of trigger points. The Accommodate scheme staging is illustrated in Figure 7-6, with stages reflecting the risk adjusted priorities. Each element of the strategy scheme will require timely implementation to fulfill its role effectively as erosion and inundation control measure. This means that a number of amendments to planning instruments and revisions of engineering treatments are expected over time. This is true for the review of beach nourishment measures (N1) and the

deployment of planning controls (P1) supporting the use easements to "squeeze" public infrastructure away from the hazard zone (S1,S2) and relocate transport and utility corridor (R2,R3) so as to service fringing properties from the "back".

While the Accommodate approach is effective at managing risk in the near to medium term, the anticipated shoreline retreat over the long term will continue to apply pressure on the first row of properties along the foreshore. Therefore, further considerations should be given to shifting to one of the following alternative pathways:

- Managed Retreat Strategy (R3), as shown in Figure 7-2 (long term top), which it intends to "not over capitalise" in areas at risk where no economies of scales can be achieved by a collective protection scheme. In this case, it is expected that the supply of services and the access to properties within the hazard zone be gradually discontinued and assets be progressively removed at the end of their useful life before safety issues arise.
- Protect Strategy (P3), as shown in Figure 7-2 (long term bottom), which intends to "defend the line", as detailed previously for the Town Centre & Foreshore area. This strategy relies heavily on adequate financing over the life of the protection scheme.

Both pathways have the potential to effectively reduce risk in the coastal hazard zone.

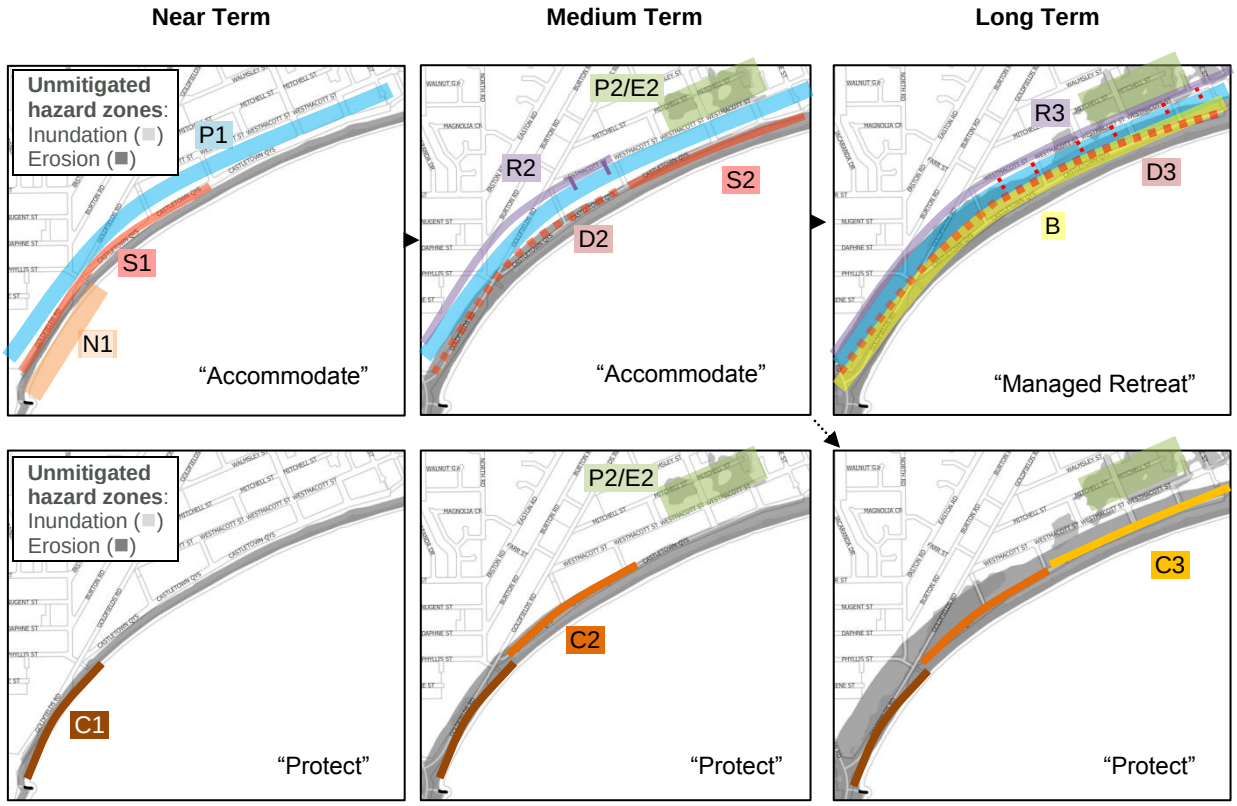


Figure 7-6: Accommodate / Maintain strategy stages (top): N1: Beach Nourishment, P1: Planning Controls, S1: Squeeze, R2: "Relocated" Transport/Utility corridor, P2/E2: Planning/Engineering Controls, R2: "Relocated" Transport/Utility corridor, D2: Discontinued Transport/Utility corridor, R3: "Relocate" Transport/Utility corridor, D3: Discontinued Transport/Utility, B Abandoned assets/Natural processes enfold. Alternative Protect pathway strategy stages (bottom): C1: construction phase 1, C2: construction phase 2, C3: construction phase 3, P2/E2: Planning/Engineering Controls.

7.2.7 *Trigger Points*

Trigger points for the implementation of the Accommodate / Maintain strategy key steps are shown in Figure 7-7 and detailed below:

- T1 : undermining of beach amenities (footpath, Norfolk Pines) at YHA
- T2 : undermining of beach amenities (footpath, Norfolk Pines) at Lapage St
- T3 : undermining of beach amenities (footpath, Norfolk Pines) at Chaplin St.

Figure 7-7: Trigger points for Castletown: Accommodate / Maintain Strategy

7.2.8 *Cost of Implementation*

The anticipated cost of the strategy using protective measures is in the order of $385kpa over the planning period (Figure 7-8). This is based on the averaging of capital expenditures and upkeep cost required to achieve an acceptable level of functionality of the structure over time. The cash flow requirement will vary significantly depending on the phase of

implementation (i.e. planning, design, construction, maintenance) with higher demand placed during major capital upgrade.

The protection cost is provided as a baseline to compare against the preferred Accommodate/Maintain strategy, which relies more heavily on the use of planning instruments, such as creation and closure of roads, reserves, easements and special control areas.

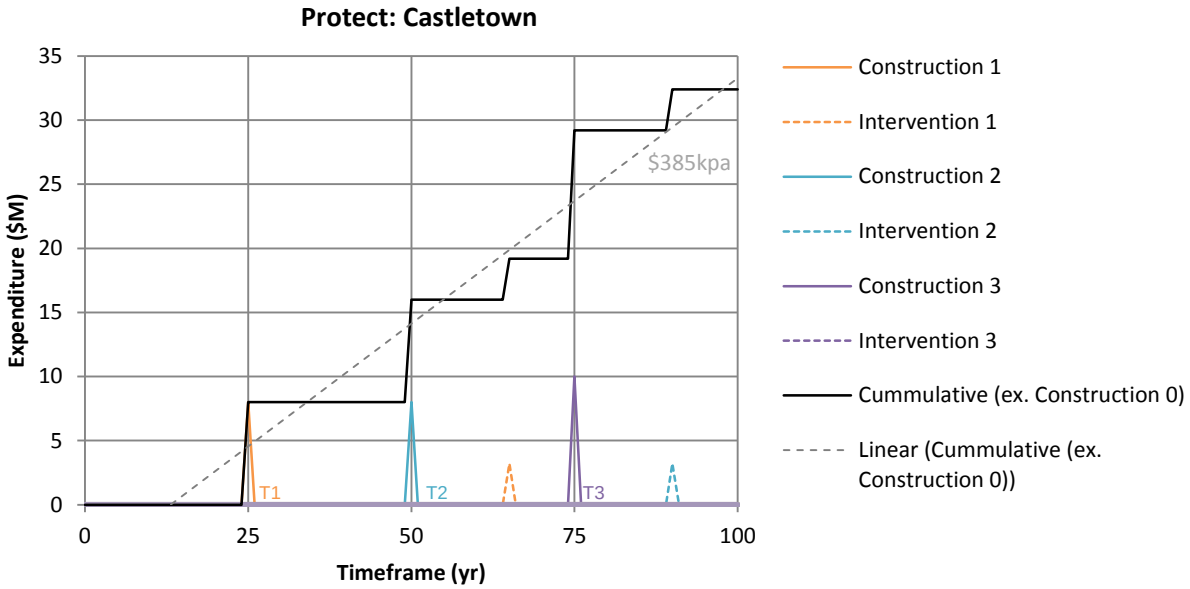


Figure 7-8: Example of key expenditure program for a coastal protection strategy for Castletown. "Construction" corresponds to the anticipated expenditure requirement for the implementation of major works. "Intervention" corresponds to the anticipated expenditure requirement to maintain major works. Expenditure timing is subject to trigger points, with respect to construction of protection works and subsequent interventions required to keep an acceptable level of functionality. In this example, interventions occur after 40 years and assume deployment of sinking fund accumulated at an annual rate of 1% of initial construction cost.

7.2.9 *Monitoring and Review*

Monitoring of the trigger points is required to ensure timely implementation of the protection scheme. This shall include:

- Seasonal (summer and winter) surveys of beach cross section at T1, T2, T3 to track changes in beach profile.

In addition, key indicators that should prompt reconsidering the strategy are:

- Operational expenditure requirement for sand nourishment (at Norseman Rd) exceed fund available or an alternative management approach has higher a net present value
- Deterioration of the foreshore reserve to a level undermining its effectiveness as a buffer against coastal processes hazards.

7.2.10 *Five Year Plan*

The Accommodate/Maintain strategy is making allowances to preserve key infrastructure corridors and maintain the land use level continuously by taking advantage of existing control measures in place (i.e. foreshore reserves, beach nourishment) while implementing cost effective solutions which can be supported in the absence of intensification of the land use. However, the protective capacity of existing controls will eventually run out or become prohibitive. It is anticipated that in the medium to long term, the accommodate pathway will need to be reviewed and further consideration should be given to alternative ones such as "Managed Retreat" or "Protect". In any case, it is recommended to fully consider the implications of the strategy so that commitment to the decision is achieved and adequate strategic planning is undertaken and/or allocation of resources is sustained over time.

Although in the short term, no significant capital expenditure is anticipated, the presence of hotspots stresses the importance for the Shire to develop, strengthen and maintain its capacity to respond promptly and effectively to coastal hazard risks.

Key actions are focused on the following three main endeavours:

- Insight - to identify issues that need addressing by monitoring trigger points and better understanding the Shire's liabilities with respect to the managed retreat pathway bifurcation
- Plan – to lay down a preferred course of actions that address identified issues by planning, designing and funding of the adopted strategy
- Implementation – to manage the execution of the adopted plan seamlessly, i.e. engineering works and amendment to planning instruments.

The resulting implementation plan (Table 7-4) addresses the first two elements (Insight and Plan) with a focus on tasks to be completed within the 1-5 year timeframe. It has similarities with the adaptation plan for the Town Centre & Foreshore, as far has coastal protection is concerned. However, the adaptation plan for Castletown has unique requirements to develop a better appreciation of the Shire's cost of pursuing a Managed Retreat pathway in the medium to long term should the Protection pathway proven to be financial unstainable.

When these tasks are completed, the Shire will be in a position to take immediate, corrective actions in accordance with the adopted Accommodate strategy thereby avoiding the serious consequences of not acting quickly enough, misleading stakeholders and/or misallocating resources in the long run.

Table 7-4: Five year adaptation plan 2016 - Castletown: Accommodate/Maintain Strategy

ID	Category	Expected Benefit(s)	Task(s) including [Predecessors]	Performance measure	Reporting and monitoring	Responsibility
1	Asset Management services - guide maintenance and upgrades of infrastructures	• Update asset risk profile • Consider asset life cycle in decision-making • Coordinated coastal hazard risk mitigation response	a) Flag assets at risk in asset register b) Establish anticipated maintenance strategy for assets at risk [1a] c) Update risk register in asset management plan [1b]	• Asset Management services are consulted during the development of the accommodation/maintenance scheme • *Asset Management plan* is updated, as required	• *Asset Management Plan*	Services Manager
2	Engineering services - guide development and construction of infrastructures	• Refine protection cost estimate • Refine protected footprint • Refine staging of works • Control erosion risk • Control inundation risk	a) Develop concept designs suitable to address erosion and inundation risk in multiple stages reflecting the use of protective measures and inundation proofing measures and integrated with the drainage scheme [1b] b) Develop detailed design of preferred option c) Develop triggers monitoring plan d) Monitor triggers, including beach surveys and seawall condition assessment [d2]	• Engineering services are consulted during the development of the accommodation/maintenance scheme • The protection scheme is effectively reducing coastal erosion and inundation risks • *Detailed design and cost estimate* of the protection scheme is developed • *Monitoring plan* is developed • *Monitoring reports* of triggers points are issued systematically at scheduled intervals	• *Concept Design* • *Preliminary Cost Estimate* • *Detailed Design* • *Specifications* • *Cost Estimate* • *Monitoring Plan* • *Monitoring Reports*	Services Manager
3	Planning services - guide all development and land uses	• Awareness of staged development constraints and opportunities • Lower risk profile by using engineered protection and planning controls • Net triple bottom line benefits	a) Develop an appreciation of staged development constraints and opportunities [2a] b) Develop an enhanced Cost-Benefit Analysis of the Protect vs Managed Retreat pathway [3e] c) Develop planning control measures as per 6.3.1 [1a] d) Update regional plans and local plans as required [3b] e) Update CHRMAP (controls in place, values at risk, risk profile) as required [1,3]	• Planning services are consulted during the development of the accommodation/maintenance scheme • A planning strategy is developed to reflect the constraints and opportunities presented by the accommodation/maintenance scheme • *Planning instruments* are updated, as required	• *Planning Strategy* • *Planning Scheme* • *Foreshore Master Plan* • *Local Plans* • *Precinct Design Guidelines* • *CHRMAP*	Services Manager
4	Environmental services - guide protection, rehabilitation, enhancement and management of the social and environment values	• Enhance environmental and social values	a) Develop landscaping options [2a] b) Develop detailed landscaping option [2b] c) Update coastal management plan [2c]	• Environmental services are consulted during the development of the accommodation/maintenance scheme • Environmental and social value enhancement opportunities are identified • *Coastal management plan* is updated, as required	• *Coastal Management Plan*	Services Manager
5	Emergency response services	• Prevention and mitigation • Preparedness • Response • Recovery	a) Present CHRMAP and preferred protection concept to management authorities [3a] b) Update procedures as required [5a] c) Review plan [2c]	• Emergency response services are consulted during the development of the accommodation/maintenance scheme • *Emergency response plan* is updated, as required	• *Emergency Response Plan*	Services Manager
6	Corporate Finance services – guide allocation of resources	• Establish and grow dedicated reserve • Deal with sources of funding • Appropriate financing	a) Review budgets and fund allocation [3a] b) Develop financing strategy for accommodation/maintenance scheme construction, maintenance and damage repair [6a]	• Corporate Finance services are consulted during the development of the accommodation/maintenance scheme • *Financial plan* is updated, as required	• *Financial Plan*	Services Manager

7.3 Flinders, Bandy Creek & Surrounds and Wylie Head: Avoid

7.3.1 *Issues*

Flinders, Bandy Creek & Surrounds and Wylie Head are undeveloped areas with a limited range of values at present (including future medium intensity and present low intensity land use) that are at *Moderate* to *High* risk of erosion and inundation (to a lesser extend) in the near, medium and long term.

In the long term, coastal hazards could potentially lead to:

- Permanent loss of land following erosion, with a possibility of retreat of the shoreline from its current position in the order of:
  - 90m, as a near certainty
  - 130m, as rare possibility
- Temporary limited inundation of the land, with water depth in the order of:
  - No inundation, with a 64% chance (over 100 years)
  - Less than 1.5m within the dune breaching inundation hazard zone, with a 3% chance (over 100 years)

7.3.2 *Controls in Place*

The control measure in place (e.g. foreshore reserve) in most segments of the area, is highly effective to treat risk in the near to medium term. The effectiveness of these controls should not be taken for granted over the long term.

7.3.3 *Hotpots*

The risk adjusted hotspots have been summarised in Table 7-5.

Table 7-5: Risk adjusted priority hotspots: Flinders, Bandy Creek & Surrounds and Wylie Head

Risk	□□□ Short term	□□□ Medium term	□□□ Long term
□ Extreme	-	-	-
□ High	-	Erosion of: • Parks, recreation and conservation – local	Erosion of: • Residential (Future) • Public Purpose • Agriculture – General • Local road • Parks, recreation and conservation – local
Scale of impact	-	Encroachment of protection: • 5km (Foreshore reserve)	Erosion of the order of: • 1km (Flinders) • 3.5km (Wylie Head) Exhausted protection of: • 5km (Foreshore reserve)

7.3.4 *Preferred Strategy*

The aim of the avoid pathway is not to allow the presence of significant assets (other than foreshore reserves) within the hazard zone.

Community acceptance of the strategy is strong.

Risk reduction is being sought through adequate planning and management of the foreshore reserve.

Risk treatment measures will be required to avoid coastal hazard risks, by drawing on:

- Planning measures

7.3.5 *Trade-Offs*

Key upsides of the avoid strategy are to:

- Enable the future development of the area outside the identified coastal hazard zone
- Economical and effective use of planning instruments
- Reduced demand on residual risk management.

Key downsides of the protect strategy are to:

- Rely on the effectiveness of controls to maintain adequate performance criteria.

7.3.6 *Adaptation Measures*

The Avoid pathway is illustrated in the sketch Figure 7-1.

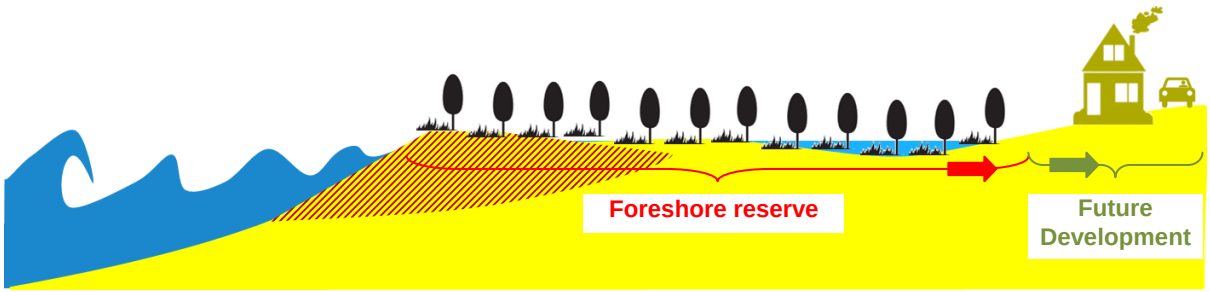


Figure 7-9: Protect pathway sketch

Risk treatment measures, in addition to existing controls in place, will be required to avoid the coastal hazard risks, by drawing on:

- Planning measures supporting the delineation of adequate foreshore reserve.

It is envisaged that the avoid pathway is developed as soon as practicable to eliminate the overlap between future development areas (and low intensity land use areas) and adequate coastal setback at a number of trigger points. The segments of the coastal reserve that need to be revised are illustrated in Figure 7-2. Once setbacks and land use boundaries have been adjusted the revised spatial control areas is anticipated to fulfill its role effectively as erosion and inundation control measure for the planning horizon, in accordance with the State planning policy SPP2.6.

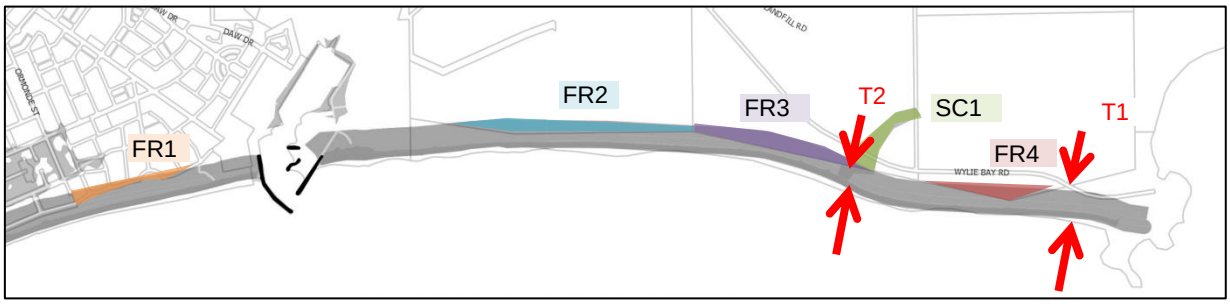


Figure 7-10: Avoid strategy stages: Adjust foreshore reserve/development boundaries at FR1-FR4, incorporate spatial inundation control at SC1, Monitor erosion at M1. Unmitigated hazard zones: inundation (light grey) and erosion (dark grey).

7.3.7 *Trigger Points*

The hotspots in the Flinders, Bandy Creek & Surrounds and Wylie Head are only present in the long term horizon and can mainly be addressed by adjusting existing planning control (i.e. foreshore reserve). This is anticipated to be carried out swiftly and no trigger points have been created in this case.

The only trigger points established here are shown in Figure 7-10 as detailed below:

- T1 – undermining of the local road at the end of Wylie Bay Rd
- T2 – undermining of the barrier dune at SC1.

7.3.8 *Cost of Implementation*

The cost of implementation is anticipated to be relatively modest due to the nature of the mitigation measure, i.e. amendment to the boundaries of existing low intensity land use in accordance with the SPP2.6.

7.3.9 *Monitoring and Review*

Monitoring of the only trigger point is required to ensure timely mitigation of potential erosion risk to the local road (end of Wylie Bay Rd) toward the end of the planning period.

Taking into account the nature of the avoid strategy and the generous protection offered by the existing and revised foreshore reserves, only a long term monitoring program is envisaged in the area. This shall include:

- Five-yearly surveys of beach cross section along the area at Flinders, and Wylie Head (SC1 and T1) to track changes in beach profile.

In addition, a key indicator that should prompt the review of the strategy is:

- Deterioration of the foreshore reserve to a level undermining its effectiveness as a buffer against coastal processes hazards.

7.3.10 *Five Year Plan*

The Avoid strategy is making allowances not to allow the presence of significant assets (other than foreshore reserves) within the hazard zone. In other word, it is a strict implementation of SPP2.6 Schedule one in order to delineate the minimum coastal foreshore reserve width, so that the created buffer is sufficient to mitigate the impact of coastal erosion and inundation hazards by allowing nature to take its course.

Key actions are focused on the following three main endeavours:

- Insight - to identify issues that need addressing by monitoring trigger points
- Plan – to lay down a preferred course of actions that address identified issues by planning adequate foreshore reserves
- Implementation – to manage the execution of the adopted plan seamlessly, i.e. amending planning instruments.

The resulting implementation plan (Table 7-2) addresses the first two elements (Insight and Plan) with a focus on tasks to be completed within the 1-5 year timeframe. When these tasks are completed, the Shire will be in a position to take immediate, corrective actions in accordance with the adopted Avoid strategy thereby avoiding the development of asset in a risky area over the planning horizon.

Table 7-6: Five year adaptation plan 2016 - Flinders, Bandy Creek & Surrounds and Wylie Head: Avoid Strategy

ID	Category	Expected Benefit(s)	Task(s) including [Predecessors]	Performance measure	Reporting and monitoring	Responsibility
1	Engineering services - guide development and construction of infrastructures	• Control erosion risk • Control inundation risk	a) Develop triggers monitoring plan b) Monitor triggers, including beach surveys [1a]	• *Monitoring plan* is developed • *Monitoring reports* of triggers points are issued systematically at scheduled intervals	• *Monitoring Plan* • *Monitoring Reports*	Services Manager
2	Planning services - guide all development and land uses	• Lower risk profile by using planning controls • Net triple bottom line benefits	a) Develop planning control measures in accordance with reported hazard zones, as per 6.3.1 b) Update regional plans and local plans as required [2b] c) Update CHRMAP (controls in place, values at risk, risk profile) as required [1,2]	• A planning strategy is developed to reflect the constraints and opportunities presented by the Avoid strategy • *Planning instruments* are updated, as required	• *Planning Strategy* • *Planning Scheme* • *Foreshore Master Plan* • *Local Plans* • *Precinct Design Guidelines* • *CHRMAP*	Services Manager

7.4 Funding the Adaptation

Effective adaptation will rest on adequate governance and funding mechanism. There is a need for:

- Timely and coordinated management response to coastal hazard risk
- Equitable funding of the adaptation measures.

The recurring cost of implementing protection measures from the Town Centre to Castletown was estimated to be in the order of $700k per annum. However, the net value created (or lost) with the implementation of various management approaches and their timing also needs to be reflected in the equity of the owner and the user of the coastal asset(s) at risk, for example by adjusting for changes in:

- the value of foreshore reserve getting eroded (literally) as it absorbs the impact of erosion and inundation events over time
- the value of coastal protection increasing (or decrease) depending on the degree of intensification of land use realised in the area that it protects
- the value of an asset decreasing within special control areas designated at potential risk of coastal hazard
- the value of an asset over the remaining of its economic life.

Therefore, the burden associated with the cost of coastal hazard risk adaptation management may be offset by the creation of value in the coastal zone and the adoption of sensible funding policies that make a clear distinction between stakeholders' vested interests. Special rates and levies are among possible the possible instruments that could apply to raise funds for adaption.

In addition, sources of funding to support the ongoing CHRMAP activities are listed in Table 7-7.

Table 7-7: Sources of Funding

ID	Funding	Reference	Type of Projects
1	Internal	Shire of Esperance	All type of projects can be fully or partially funded
2	Coastal Management Plan Assistance Program (CMPAP) grants	Department of Planning (www.planning.wa.gov.au/CMPAP)	• Coastal strategy • Coastal management plan • Coastal hazard risk management and adaptation plan.
3	Coastwest	Department of Planning (www.planning.wa.gov.au/coastwest)	• On-ground actions • Site or local area planning • Identification and monitoring • Capacity-building
4	Coastal Adaptation and Protection (CAP) grants	Department of Transport (http://www.transport.wa.gov.au/imarine/coastal-adaption-and-protection-cap-grants.asp)	• Coastal monitoring. • Adaptation planning. • Asset management. • Coastal adaptation. • Maintenance works.
5	Recreational Boating Facilities Scheme (RBFS) grants	Department of Transport (http://www.transport.wa.gov.au/imarine/recreational-boating-facilities-scheme-rbfs-grants.asp)	• Planning new public recreational boating facilities. • Building new public recreational boating facilities. • Upgrading existing public recreational boating facilities.
6	Royalties for Regions	Department of Regional Development (http://www.drd.wa.gov.au/rfr/Pages/default.aspx)	• Building capacity in regional communities • Retaining benefits in regional communities • Improving services to regional communities • Attaining sustainability • Expanding opportunity • Growing prosperity

8 Monitoring and Review

Monitoring and review is an important part of managing costal hazard risk, and completes the risk management framework.

The preferred adaptation strategies presented in the previous section may be reviewed from time to time, in order to evaluate its success and to propose changes (as required) that would reflect changing circumstances supported by the review of:

- Risk profiles subject to external environmental factors and implemented controls
- Implemented measures effectiveness, including strengths and weaknesses
- Adaptation capabilities subject to shire internal resources and external funding sources
- Stakeholders preferences.

These steps ensure that assumptions, methods, data sources, results and reasons for decisions are subject to regular checks. These checks should consider changes in:

- Our understanding of coastal hazard;
- Its impacts or its management;
- Lessons learnt from inundation and erosion events; and
- Trends in changes of exposure or vulnerability or stakeholder's preference.

Such checks keep the overall understanding of coastal hazard risk and management measures relevant and up to date.

Establishing key performance indicators (KPIs) can help with reporting and more importantly assess progress toward understanding and managing coastal hazard risk. KPIs will differ depending upon the roles and responsibilities in managing coastal hazard risk. In relation to the overall performance of the CHRMAP, it is recommended to include the KPI listed in Table 8-1.

The agreed processes and outputs of monitoring and review should be recorded and reported. They form an important part of the review cycle for the risk management framework. The Shire should develop systems to monitor risk and management gaps so that these can be prioritised and addressed.

Monitoring and review should help provide up-to-date advice to decision makers and others on the effectiveness of coastal hazard risk management, and where implementation may be impeded. Any hindrances with successful implementation may mean the management plans need to be reviewed to see if the obstacles can be overcome or whether other options may be viable and require further investigation.

The procedure outlined in this report should be seen within the context of strategic decision making at local government level. Ultimately, coastal development should be further assessed at a smaller scale (e.g. district, locality) and undertaken responsibly, not only with due consideration given to the economically optimal pathway but also to the preservation of key environmental features at the site and its vicinity to ensure that ecosystem services are not compromised by excessive development.

Table 8-1: Key performance indicators for Shire of Esperance CHAS

KPI	CHAS Review Year :		Score
	Strategy: ☐ **Avoid** ☐ **Managed retreat** ☐ **Accommodate/Maintain** ☐ **Protect**	**Area:** ☐ **Town Centre & Foreshore** ☐ **Castletown** ☐ **Flinders, Bandy Creek & Surrounds and Wylie Head**	
1	Percentage of area that is zoned for development within the coastal hazard zone where information is available for strategic land-use planning and to the community		
2	Percentage of developed area in the coastal hazard zone supported by emergency management plans		
3	Percentage of properties that have experienced above-floor coastal inundation in key storm events		
4	Percentage of properties that have experienced coastal erosion in key storm events		
5	Number of high-priority treatments identified in management plans, and the percentage implemented		
6	Number of properties that are protected by control measures and the level of protection provided.		
7	Level of stakeholder support by for the current strategy		
8	Funding sustainability		

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APPENDIX A:
INUNDATION LIKELIHOOD RATING

INUNDATION LIKELIHOOD RATING

This appendix presents the process that has been followed to estimate the cumulative probability of each inundation hazard scenarios in order to assign them an adequate likelihood rating against the Shire's likelihood scale. In particular, the cumulative probability for the inundation scenario is determined in a way that accounts for the effect of sea-level rise on the water level exceedance threshold defined by the design event S4 specified in the Policy.

Extreme Event Annual Probability Constant Over Time

Where the annual probability of an extreme event is constant over time, the cumulative probability of such event to be exceeded over a given time frame can be readily calculated.

Figure A-1 illustrates the probability of occurrence for natural hazard events with recurrence intervals ranging from 1 to 1,000 years and for length of period of 1, 10, 20, 40, 50, 70 and 100 year. The percentages shown represent the probabilities of one or more occurrences of an event of a given magnitude or larger within the specified period. The formula for determining these probabilities is $P_n = 1-(1-P_a)^n$, where P_a= the annual probability and n = the length of the period.

Table A-1 probability wheels illustrates a sub sample of the above probability set with recurrence intervals of 100 and 500 years and for length of period of 1, 50 and 100 year.

For example, there is 18% chance for a 0.2% AEP event (i.e. 500 year ARI event) to be exceeded in any given 100 year period. Note that the probability of exceedance of such an inundation level significantly increases when sea level rise is considered over the planning horizon.

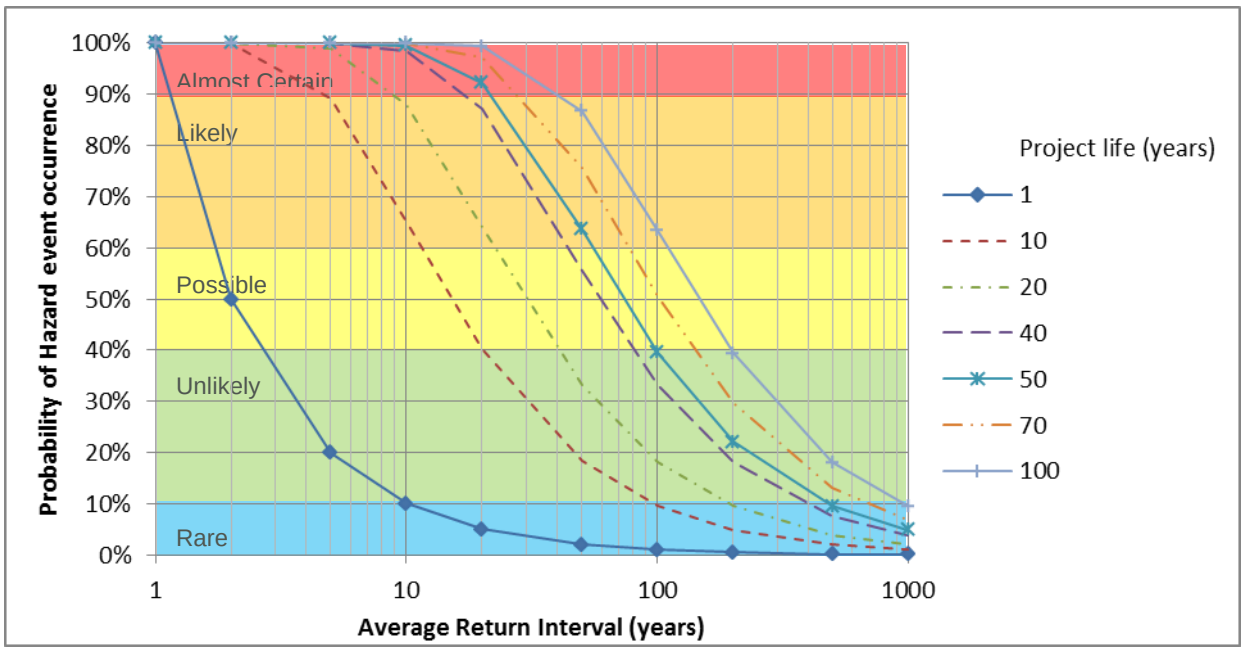
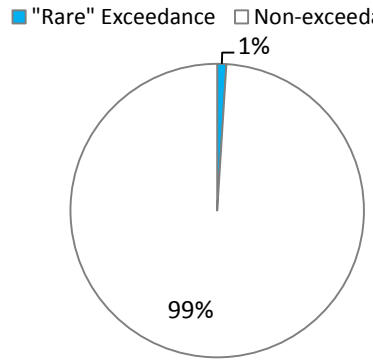
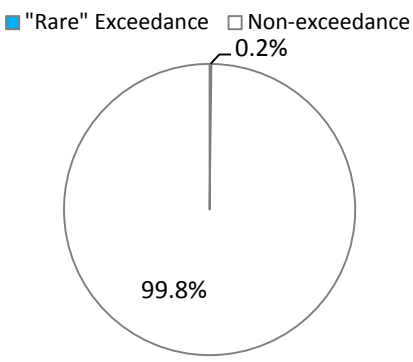
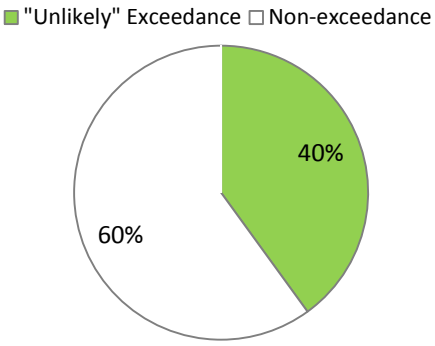
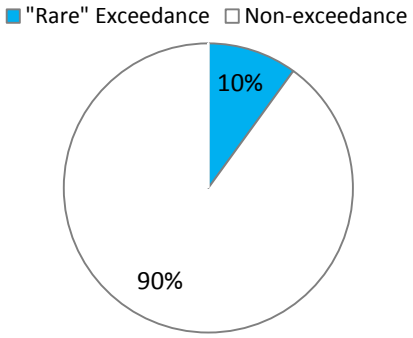
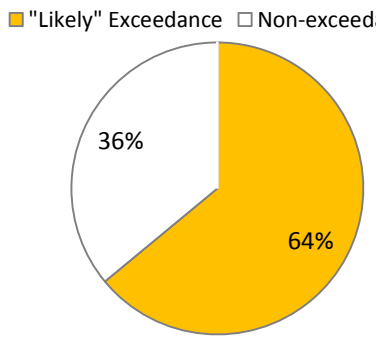
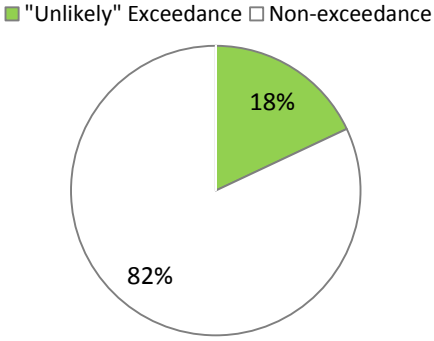


Figure A-1: Probability of occurrence for natural hazard events with recurrence intervals ranging from 1 to 1,000 years for length of period of 1, 10, 20, 40, 50, 70 and 100 year. Shaded areas indicate the Shire of Esperance likelihood scale.

Table A-1: Probability wheels of hazard exceedance over the planning period

Exceedance Probability		Coastal Hazard Scenario	
		Erosion event (100 year ARI)*	Inundation event (500 year ARI)
Planning timeframe	1 year		
	50 years		
	100 years		

(*) In the case of the erosion hazard scenario, it should be recognised that the probability of occurrence of 3 successive events is lower that the probability of one event in isolation.

Extreme Event Annual Probability Varying Over Time

In the case of inundation events, sea level rise will mean that the annual probability of a given extreme water level varies over time. For example, a 0.2% AEP (500 year ARI) event water level in 2010 may well be as frequent as a 10% AEP (10 year ARI) event in 2110.

This means that the cumulative probability of such an extreme water level event being exceeded over this time frame cannot be obtained readily by applying the formulation applicable to constant AEP. Therefore, the cumulative probability over a given timeframe must be determined on a case by case basis, so as to take into account the site specific response to sea level rise.

Here, the extreme water level distributions over time, between 2010 and 2110, was definedbased on the lin-log interpolation of the 1% AEP and 0.2% AEP extreme events and

the added sea level rise allowance (Figure A-2). Water level exceedance probability over three timeframes (i.e. 1 year to 2010, 50 year to 2060 and 100 year to 2110) were derived from the integration of the time dependent extreme water level distributions (Figure A-3) using a Monte-Carlo type simulation.

Results are shown in Figure A-4. For example, over the 100 year planning timeframe in the area between Taylor Street and Norseman Road, a 2.3m AHD storm surge level is expected to be almost certain (>90% chance of occurrence), whilst a 3.1m AHD storm surge level is expected to be a rare event (< 10% chance of occurrence).

Accordingly, it is possible to define the water level corresponding to a 100 year inundation event, which is equivalent to:

- 1% probability of occurrence over 1 years;
- 40% probability of occurrence over 50 years; and
- 64% probability of occurrence over 100 years.

Similarly it is possible to define the water level corresponding to a 500 year inundation event, which is equivalent to:

- 0.2% probability of occurrence over 1 years;
- 10% probability of occurrence over 50 years; and
- 18% probability of occurrence over 100 years.

The resulting water levels for the *100 year equivalent* and the *500 year equivalent* inundation levels are shown in Table A-2.

This method was implemented to establish the relationship between the likelihood scale and the inundation hazard zones for each time horizons, as detailed in Table 4-2, Table 4-3, Table 4-4, Table 4-5 and Table 4-6.

Conclusion

By adopting this approach the likelihood rating for the inundation scenarios defined by the design event S4 specified in the Policy was determined more accurately along the likelihood scale adopted by the Shire. Furthermore, alternative approaches that do not take into accounts the effect of sea-level rise on the water level exceedance probability may overestimate the depth of inundation or the extent of the inundation hazard zone or the likelihood implied by the design inundation event.

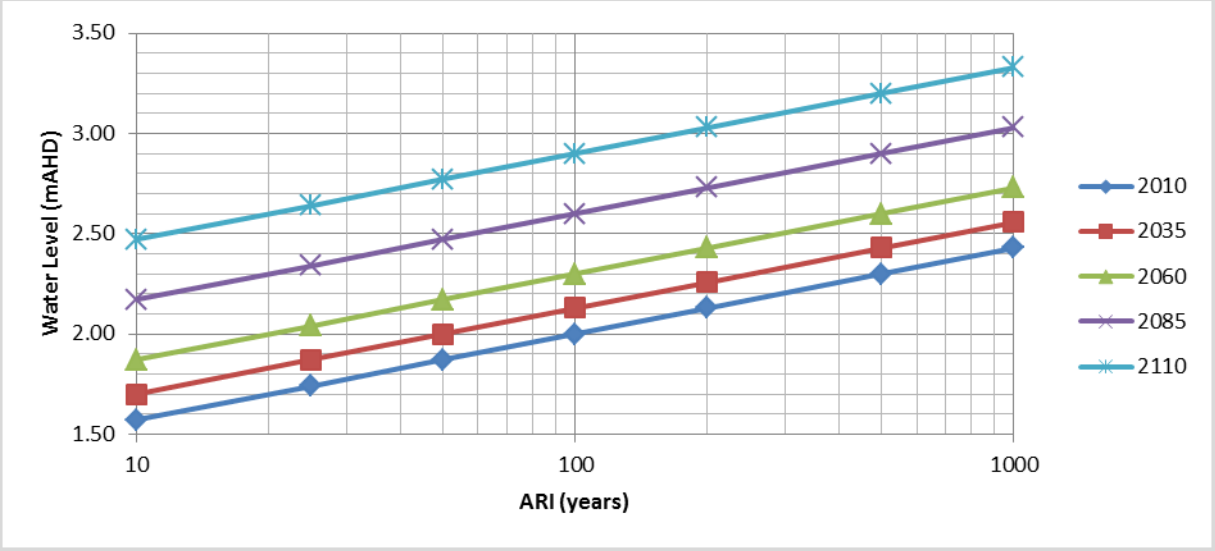


Figure A-2: Extreme water level distributions between 2010 and 2110 (Taylor Street to Norseman)

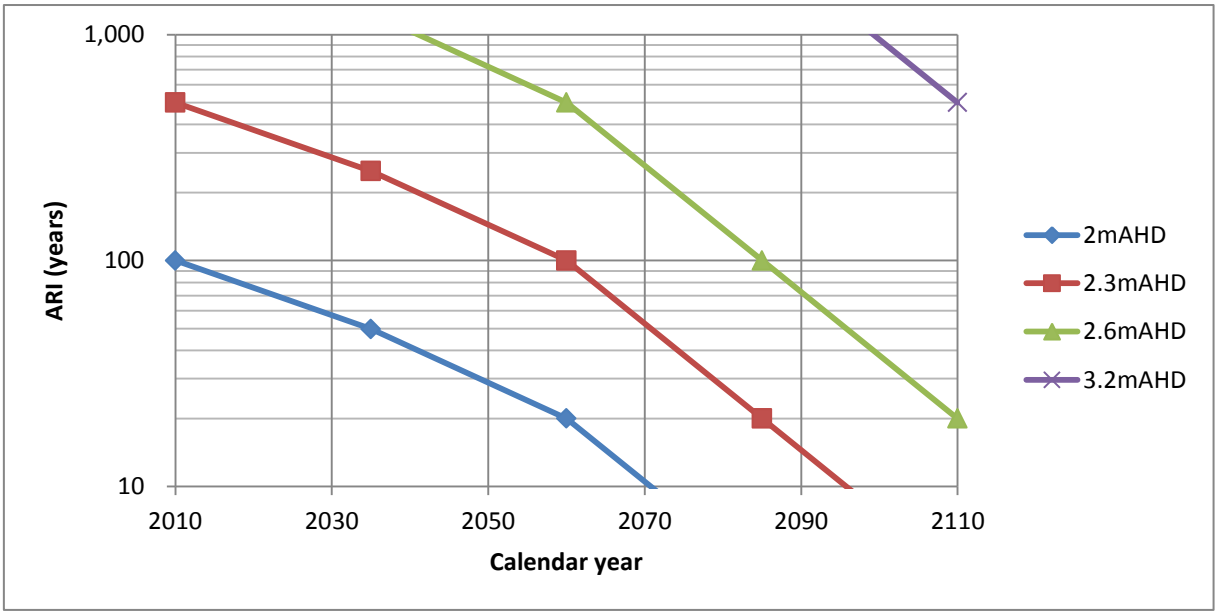
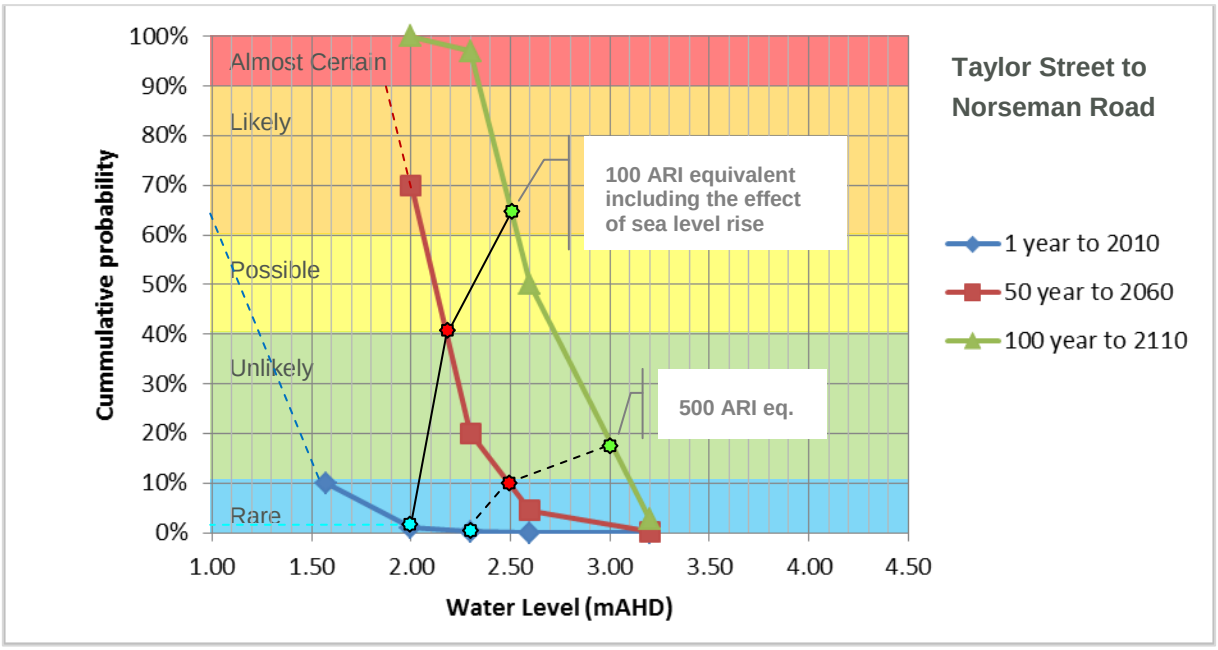


Figure A-3: Extreme event variability between 2010 and 2110 2110 (Taylor Street to Norseman)



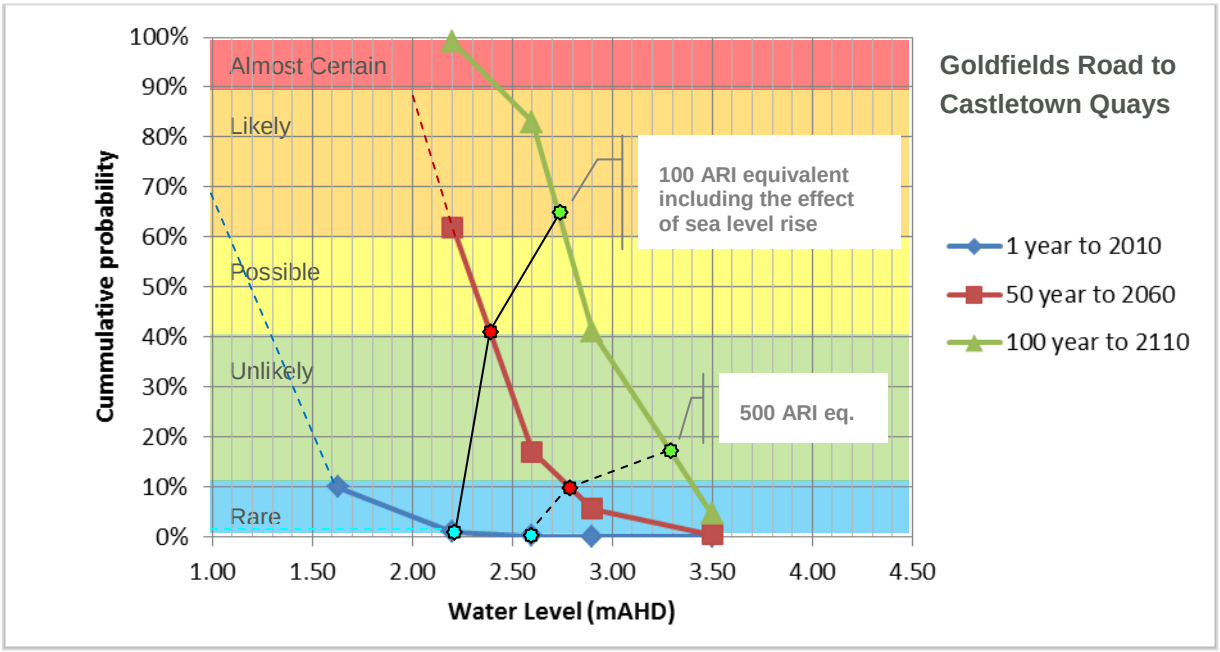
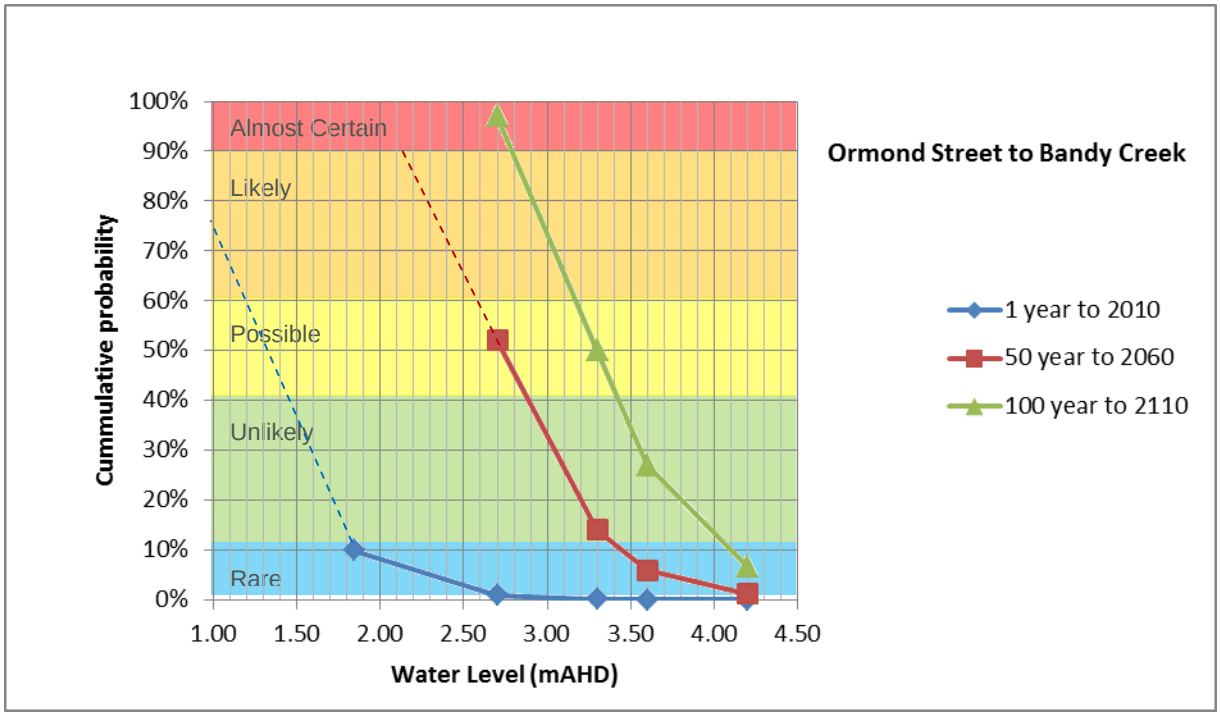


Figure A-4: Probability of occurrence for inundation hazard events for length of period of 1, 50 and 100 year. Shades areas indicate the Shire of Esperance corresponding likelihood rating. Red dash lines extrapolation from plain red line. Blue dash line interpolation to 0.7mAHD (HAT) considered to be almost certain.



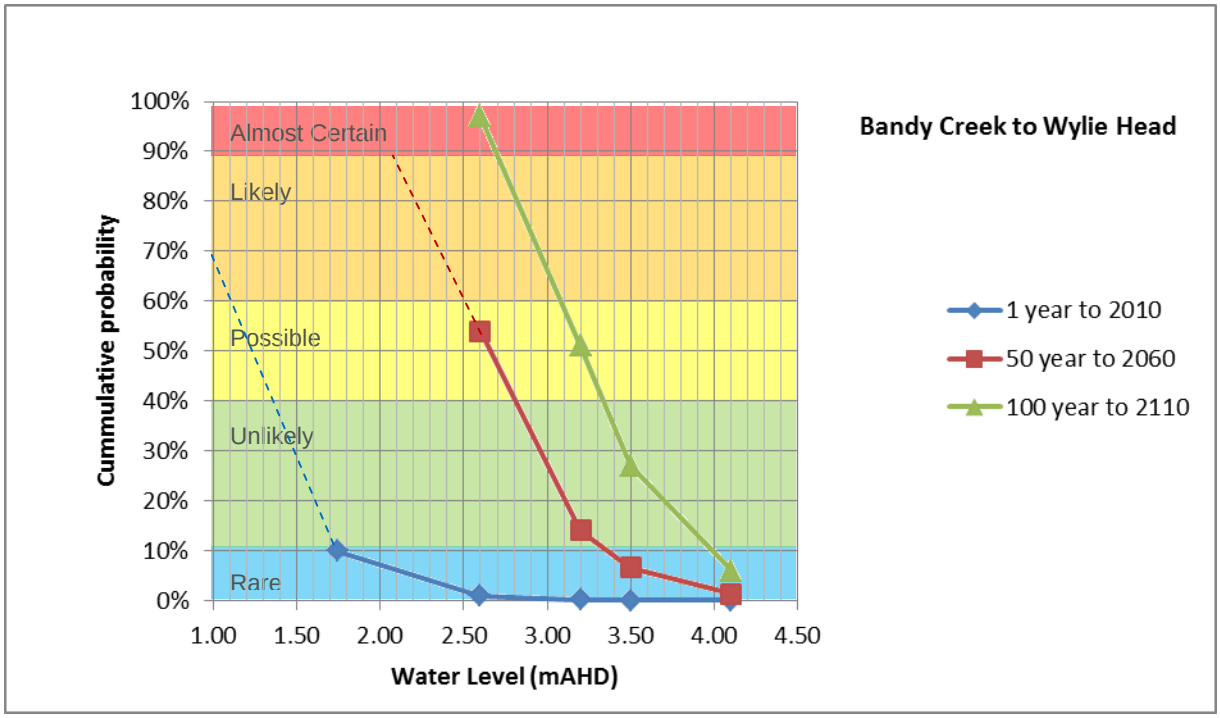


Figure A-4 cont.

Table A-2: Comparison of extreme water levels for the 100 year and 500 year events, including basic inundation hazard scenarios and equivalent events as defined by their cumulative probability of occurrence over a given timeframe (after Figure A-4). Zone: I: Emily St - Norseman Rd, II: Goldfields Rd - Ormonde St, III: Ormonde St – Bandy Creek, IV: Bandy Creek – Wylie Head.

	Planning horizon	2010				2060				2100			
	Water Level (mAHD) for zone	I	II	III	IV	I	II	III	IV	I	II	III	IV
A	1:500 ARI Wave Run-up Level scenario	2.3	2.6	3.3	3.2	2.6	2.9	3.6	3.5	3.2	3.5	4.2	4.1
B	***500 year WL equivalent***	***2.3***	***2.6***	***3.3***	***3.2***	***2.5***	***2.8***	***3.5***	***3.4***	***3.0***	***3.3***	***3.9***	***3.8***
C	1:100 ARI Wave Run-up Level scenario	2.0	2.2	2.7	2.6	2.3	2.6	3.0	2.9	2.9	3.1	3.6	3.5
D	***100 year WL equivalent***	***2.0***	***2.2***	***2.7***	***2.6***	***2.2***	***2.4***	***2.9***	***2.8***	***2.5***	***2.8***	***3.1***	***3.0***
E	A-B	0	0	0	0	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.3
F	A-D	0.3	0.4	0.6	0.6	0.4	0.5	0.7	0.7	0.7	0.7	0.9	1.1
G	B-D	0.3	0.4	0.6	0.6	0.3	0.4	0.6	0.6	0.5	0.5	0.8	0.8