Appendix B
Coastal Hazard Risk Management and Adaption Plan 2017 (CHRMAP)

Broome Townsite

Coastal Hazard Risk Management and Adaptation Plan

16 August 2017 | 12518.101.R2.Rev0

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Broome Townsite

Coastal Hazard Risk Management and Adaptation Plan

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Executive Summary

The Shire of Broome (The Shire) has undertaken development of a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) to provide strategic guidance on coordinated, integrated and sustainable management of coastal areas identified as being at risk of coastal erosion and inundation in current and future planning periods. The Broome townsite CHRMAP has been developed for the Shire based on the Western Australian Planning Commission CHRMAP guideline document (WAPC 2014), which provides a risk management approach to dealing with forecast impacts from coastal hazard in future planning periods.

Under projected climate change and sea level rise scenarios, coastal hazard as a result of storm surge inundation and the erosion of the shoreline are forecast to increase for the coastal areas of Broome. The Broome Coastal Vulnerability Study (CVS, Cardno 2015) was completed for the Shire to identify coastal hazard for the Broome townsite and is a key document that underpins the CHRMAP process. Completed under the guidelines of the Western Australian Planning Commission State Planning Policy No. 2.6 - State Coastal Planning Policy (SPP2.6, WAPC 2013) the CVS determined coastal hazards as a result of either coastal erosion or storm surge inundation affecting Broome currently and in future planning periods 2040, 2070 and 2110.

To deliver the CHRMAP, Baird Australia led a consultant team comprised of subject specialists in coastal engineering, planning, economics and community consultation. The team maintained a strong involvement with the Shire throughout the project, supported by an extensive community and stakeholder engagement process, which sought input from the Broome community and key stakeholders to shape the CHRMAP outcomes (Appendix A). A steering committee led by the Shire and involving key stakeholders was established to oversee the project and its delivery. Specialist advice and review was provided through the Department of Transport Coastal Management Group and the Department of Planning during the CHRMAP development.

The project assessed approximately 30km of the Broome shoreline within nine coastal compartments as shown on Figure E.1. Coastal compartments were as follows:

1. Cable Beach
2. Gantheaume Cliffs
3. Reddell Beach
4. Entrance Point Beach
5. Simpsons Beach
6. Town Beach
7. Broome Town Centre
8. Dampier Creek Inner
9. Dampier Creek East

Figure E.1: Coastal Compartments for CHRMAP

The CHRMAP process was supported by an extensive community and stakeholder engagement process, which was designed to firstly inform the community of the coastal hazard risk to the coastal areas around the townsite, and secondly seek their input into the risk management process. In structured CHRMAP workshops with community and stakeholders (reported in Appendix A), a series of tasks designed to inform the risk management process were undertaken to:

- identify key coastal infrastructure/assets within each of the coastal compartments that hold economic, social and environmental value;
- discuss consequence scales for the identified coastal hazards;
- define risk tolerances to the identified coastal hazard risks; and
- discuss adaptation options that could address the risks.

The workshops were used to understand community use of the coastal areas and to have the community define coastal assets broadly categorised into Economic, Social and Environmental categories. For each of the assets the community and stakeholders provided a statement to explain their function, service or value. Coastal hazard as a result of erosion or inundation were considered in terms of their likelihood and consequence to develop a risk rating, calculated for future planning periods 2040, 2070 and 2110.

The risk analysis and evaluation process was completed based on the guidance presented in AS5334-2013 and WAPC2014 and is presented in this report in Section 5. The evaluation undertakes risk analysis for the identified coastal assets and works through prioritising risk management and adaptation strategies. The outcomes from the community engagement (Appendix A) and coastal hazard mapping developed for the CHRMAP (Appendix B) are combined. Within each of the coastal compartments the foreshore areas and the identified assets within are reported in terms of likelihood and consequence and combined in a risk matrix to determine a level of risk on a scale of low, medium, high or extreme. A risk tolerance scale describing actions required to be undertaken to mitigate the highest levels of risk was established based on the community and stakeholder engagement.

In Section 6 of the CHRMAP report the coastal adaptation strategies to manage coastal hazard risk are determined, incorporating both planning solutions and engineering alternatives. The risk management and adaptation hierarchy (WAPC2014) provides a platform for considering risk management through a tiered approach that aims to build coastal resilience and maintain flexibility for future decision makers in coastal areas. The hierarchy is presented on Figure E-2.

Figure E.2: Risk Management and Adaptation Hierarchy (WAPC 2014)

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

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

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

The coastal hazard identified within each of the coastal compartments of Broome has been considered within the risk management and adaptation hierarchy through a process that has involved the application of WAPC and SPP2.6 requirements, and which has been guided from discussions with stakeholders and the community in the community engagement workshops. Adaptation responses can vary within coastal compartments, and in many instances a range of complementary adaptation responses that mitigate the coastal risk are recommended.

In key compartments, Cable Beach, Town Beach and Broome Town Centre, the risk management and adaptation options have been evaluated in the most detail and economic evaluation of adaptation options including cost benefit analysis of alternatives (CBA) is reported. The key findings for these coastal compartments is summarised here:

- The value of Cable Beach and associated tourism infrastructure to Broome's economy and community supports the need for a **Protect** option to be adopted for the main tourist hub of Cable Beach. Further studies on a coastal protection option for up to 500m of the main foreshore area is recommended by the CHRMAP. This will require a detailed erodibility study to determine the underlying geotechnical properties of the foreshore beneath the dune;
- For Town Beach, the large local residential population adjoining its shoreline, coupled with the mix of short term accommodation options in the area including the Roebuck Bay caravan park place a high value on the beach and its foreshore areas, which attracts significant tourist numbers particularly during viewing of the 'staircase to the moon' phenomenon. The need for coastal protection along the eroding pindan cliff north of old jetty area has been acknowledged by the Shire and construction of a coastal revetment is planned for 2018-19. The **Protect** option in this location is fully supported by the CHRMAP;
- The mitigation of the identified coastal inundation risk and erosion risk for the Chinatown peninsula was the focus of the CHRMAP in workshops held with community and stakeholders, a process which

ultimately led to a coastal adaptation recommendation of **Protect** for the Chinatown peninsula. To protect Chinatown a coastal protection structure that can mitigate coastal flooding from storm tide as well as provide erosion protection is required around the Chinatown peninsula. The format of this structural solution and the critical considerations for the timing of its construction has been reported in the CHRMAP, with concept designs and costings assessed through CBA; and

- Chinatown is Broome's commercial business hub and is susceptible to inundation as a result of storm tide inundation, due to its low lying topography. At present the land level of the Chinatown peninsula is able to hold back storm tide level to withstand approximately a 1 in 100yr event. Under projected sea level rise, this level of storm tide risk increases rapidly and by 2070 the Chinatown area of the peninsula would flood under the general tide regime and would need to have a coastal protection structure in place to provide protection against flooding from the general tides alone. The outcomes of the CBA presented in this report indicate that the coastal protection structure could deliver a net benefit within 20 years (2037) depending on the assumed construction costs.

The adaptation approaches are summarised for all coastal compartments on Table E.1.

Table E.1: CHRMAP Adaptation Strategy by Coastal Compartment

Coastal Compartment	Adaptation Strategy Recommendations
	For areas north and south of central tourist area Planning Approach • **Avoid**. Any future planning approaches will need to be sited landward of the identified 2110 planning period coastal erosion hazard. For central section (Surf Club, Zanders café, Amphitheatre etc) Recommendations • Further studies on a coastal protection option for up to 500m of the main foreshore area is recommended and supported through the CHRMAP with a view to adopting a **Protect** strategy for this section of coast. Will require a detailed erodibility study to determine the underlying geotechnical properties of the foreshore beneath the dune. Following the erodibility assessment, requirement for concept engineering, consultation with community / stakeholders and further economic analysis of option/s.
Cable Beach	Planning Approach (general) • **Avoid** further development of vacant land within the identified coastal erosion hazard area for areas north and south of the central tourist hub; • **Planned / Managed Retreat** Existing assets located on land prone to coastal erosion within the 2110 planning timeframe for land not proposed to be protected by a seawall; and • **Accommodate** Land uses exempted by Part 7 of SPP2.6 Schedule 1 eg Community use of foreshore. Planning Approach **f**or areas behind a coastal protection structure (type of coastal protection, alignment and timing to be confirmed in future studies) • **Protect** Existing assets through a coastal protection structure. Shire Structures • **Managed Retreat** for current structures and properties within the erosion hazard area.

Gantheaume Cliffs	Planning Approach • **Avoid** further development within the identified 2110 coastal erosion hazard on vacant land; and • **Accommodate, Managed Retreat** for existing assets located on land prone to coastal erosion within the 2110 planning timeframe (eg Broome Turf Club). Shire Structures in foreshore areas • **Managed Retreat** for coastal structures and roads.
Reddell Beach	Planning Approach • **Avoid** further development within the identified 2110 coastal erosion hazard on vacant land; and • **Accommodate, Managed Retreat** for existing assets located on land prone to coastal erosion within the 2110 planning timeframe. Shire Structures in foreshore areas • **Managed Retreat** for coastal structures and roads.
Entrance Point	Recommendations • Recommended the Kimberley Port Authority undertake a detailed erodibility study to determine the underlying geotechnical properties of the foreshore area. Planning Approach • **Avoid** further development within the identified 2110 coastal erosion hazard on vacant land; and • **Accommodate, Managed Retreat** for existing assets located on land prone to coastal erosion within the 2110 planning timeframe. Shire Structures in foreshore areas • **Managed Retreat** for coastal structures and roads.
Simpsons Beach	Planning Approach • **Avoid** further development within the identified 2110 coastal erosion hazard on vacant land; and • **Accommodate, Managed Retreat** for existing assets located on land prone to coastal erosion within the 2110 planning timeframe. Shire Structures in foreshore areas • **Managed Retreat** for coastal structures.
Town Beach	Recommendations • Further studies on construction of the Town Beach revetment (engineering, environmental and local stakeholder issues); • Develop an appropriate Emergency Response Plan for the Roebuck Bay caravan park; • Undertake a foreshore management plan; and • Investigate remediation of the dune in front of the properties in Demco Drive. Planning Approach • **Accommodate** developable land located on land prone to coastal erosion within the 2110 planning timeframe; • **Accommodate** Land uses exempted by Part 7 of SPP2.6 Schedule 1 eg Community use of foreshore; and

	• **Protect** Existing assets through a coastal protection structure for areas landward of the planned revetment / seawall north of old jetty area. Shire Structures in foreshore areas • **Managed Retreat** for minor structures within the erosion hazard area; • **Accommodate** for minor structures in the defined storm surge inundation area; and • **Protect** Shire assets covered by the revetment / seawall at the eroding Pindan Cliff north of Old Jetty Groyne (Pioneer Cemetery, foreshore area in Town Beach Reserve).
Broome Central	Recommendations • A coastal protection structure to **Protect** Chinatown peninsula providing storm surge immunity and coastal erosion protection is supported through CHRMAP. Further studies required to determine type, alignment and timing. At latest the structure is assumed to be constructed for the 2070 planning period; and Planning Approach • **Accommodate** developable land located on land prone to coastal erosion within the 2110 planning timeframe; • **Accommodate** land prone to storm surge flooding through Special Control Area and specific requirements for planning approval of properties within the defined storm surge inundation area; and • **Accommodate** Land uses exempted by Part 7 of SPP2.6 Schedule 1 eg Community use of foreshore. For areas within the Chinatown peninsula • **Protect** Existing assets. Shire Structures in foreshore areas • **Managed Retreat** for minor structures within the erosion hazard area; and • **Accommodate** for minor structures in the defined storm surge inundation area.
Dampier Creek Inner	Planning Approach • **Avoid** further development within the identified 2110 coastal erosion hazard on vacant land; and • **Accommodate** land prone to storm surge flooding, through Special Control Area and specific requirements for planning approval of properties within. Shire Structures in foreshore areas • **Managed Retreat** for minor structures and properties within the erosion hazard area; and • **Accommodate** for minor structures in the defined storm surge inundation area.
Dampier Creek East	Planning Approach • **Avoid** further development within the identified 2110 coastal erosion hazard on vacant land; and • **Avoid** land prone to storm surge flooding. Shire Structures in foreshore areas • **Managed Retreat** for minor structures and properties within the erosion hazard area; and • **Accommodate** for minor structures in the defined storm surge inundation area.

A Scheme Amendment to insert a Special Control Area (SCA) covering all properties impacted by coastal hazards to the year 2110 (as defined through the CVS) is currently under consideration from the West Australian Planning Commission (WAPC). The CHRMAP supports the SCA by providing detailed assessment of the coastal hazard risk for properties within the SCA extents.

For properties identified as being at risk of coastal erosion in the SCA, the CHRMAP adaptation responses are summarised by coastal compartment in Table E.1 and discussed in detail in Section 6 of the main report with the following noted:

- In approving development on land identified as prone to coastal processes within the planning timeframe, the Shire may be inclined to impose conditions on the planning approval seeking the applicant indemnify the Shire against future actions, claims, demands or costs. For accommodation of erosion, Section 70A notifications are recommended to be placed on the titles of all lots at risk of coastal processes as a condition of planning approval, and this is an accepted practice recognised within SPP 2.6. Planning instruments that can be used for indemnification are discussed in Section 2.13 of this report; and
- As part of adaptation approaches, the right for individual landowners to construct coastal defences is discussed in Section 2.12. It is recommended that the Shire develop a local planning policy relating to the construction of private seawalls, that would address matters relating to ongoing maintenance responsibilities, liability, public access and safety and ongoing monitoring requirements.

Properties identified as being at risk of storm surge inundation in the SCA are located in coastal compartments 6 to 9 incorporating the areas Town Beach, Broome Central (Chinatown) and Dampier Creek. Mitigation of storm surge risk in these areas is detailed in the CHRMAP and will be controlled through planning measures detailed in Section 6.10 under an accommodate approach.

For properties identified as affected by coastal inundation in the SCA there are two general categories of inundation response.

- Tier 1: Properties within the SCA and with a lot level less than 7m AHD
  - Highest category of risk. Lot levels are below the SPP2.6, 500yr ARI storm tide peak for 2110
- Tier 2: Properties within the SCA with a lot level greater than 7m AHD
  - Lower category of risk. Lot levels are above the SPP2.6, 500yr ARI storm tide peak for 2110

Tier 1 affected properties would be informed of the storm surge inundation flood height that would occur in the design 500yr ARI storm surge scenario. Depending on the depth of flooding on the property a range of adaptation measures to accommodate the risk would apply for development as outlined on Table E.2.

Properties identified as Tier 2 are at risk of secondary inundation from catchment based rainfall that is held up by storm tide level in Dampier Creek. For planning considerations, it is recommended that local drainage adopt the 2110 storm tide level (7m AHD) as a tail water condition in runoff considerations. Development must consider the management of runoff such that increased flooding to surrounding areas under the assumed tail water condition is minimised.

Table E.2: Planning response for property identified at risk of storm tide inundation hazard

Height of Storm Surge Above Natural Ground Level of Property	Design Response
0-500mm	• Raise the height of the finished floor level for all habitable rooms (dwellings) or net lettable area for commercial / retail / community buildings 500mm above the identified storm surge level[1] through either: ◦ Filling of the land; or ◦ Structural / building design response (i.e Elevated 'Queenslander' style housing); or ◦ A combination of fill/retaining and stilt construction.
500mm – 1 metre	• Raise the height of the finished floor level for all habitable rooms (dwellings) or net lettable area for commercial / retail / community buildings 500mm above the identified storm surge level[1] through either: ◦ Filling of the land[2]; or ◦ Structural / building design response (i.e Elevated 'Queenslander' style housing); or ◦ A combination of fill/retaining (to a maximum of 0.5m) and stilt construction.
1 metre – 2 metre +	• Raise the height of the finished floor level for all habitable rooms (dwellings) or net lettable area for commercial / retail / community buildings 500mm above the identified storm surge level[1] through a structural / building design response (i.e. Elevated 'Queenslander' style housing); or • A combination of fill / retaining (to a maximum of 0.5m) and stilt construction.

Notes
1. 500mm allowance recommended based on DoW 2016.
2. Filling of the site between 500mm and 1 metre above natural ground level would need to be considered on a case-by-case basis. Developers would need to demonstrate that this approach would not have a detrimental impact on the amenity of adjoining properties or the amenity of the locality generally.

Further information on design flood levels and building design examples are presented in Section 6.10 of the CHRMAP to demonstrate design considerations for buildings and preferred construction materials to be used in flood prone areas.

The implementation of the CHRMAP is outlined in Section 7 of the CHRMAP report. Implementation will be the responsibility of the Shire of Broome, with support from Yawuru and the Department of Parks and Wildlife in regards to monitoring activities within the Yawuru Conservation Estate.

The CHRMAP is to be supported by a monitoring program that has been presented in Section 8 with a nominal commencement date of 2018. The monitoring program and potential sources of funding have been outlined. The focus of the monitoring will be to support the CHRMAP objectives and build the understanding of Broome's coastal areas to inform future revisions of the CHRMAP document. This would

look to build on the data developed in the CVS and regularly assess the changes to the dunes, mangroves and pindan shorelines to track the rate of future shoreline erosion. The key locations of interest include Cable Beach, Reddell Beach, Town Beach and Chinatown Peninsula.

The CHRMAP process is supported by the Department of Transport and the Department of Planning and these agencies can provide technical advice to Shire on current policy. It is important to note the CHRMAP is an ongoing process that will be reviewed approximately every five years, over which time any updates to the understanding of coastal hazard risk for Broome or changes to planning policies in Western Australia would need to be considered. Where new information or methods become available that significantly modify the understanding of the coastal hazards, then adaptation approaches within coastal compartments would need to be reviewed through the CHRMAP hierarchy, as part of the ongoing monitoring and review process.

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1 Introduction

The Shire of Broome (The Shire) has undertaken development of a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) to provide strategic guidance on coordinated, integrated and sustainable management of coastal areas identified as being at risk of coastal erosion and inundation in current and future planning periods. The Broome townsite CHRMAP has been developed for the Shire based on the Western Australian Planning Commission CHRMAP guideline document (WAPC 2014), which provides a risk management approach to dealing with forecast impacts from coastal hazard in future planning periods.

The Shire recently completed a Coastal Vulnerability Study (CVS) for the Broome townsite (Cardno, 2015). The CVS is a key document that underpins the CHRMAP process and was completed under the guidelines of the WAPC State Planning Policy No. 2.6 - State Coastal Planning Policy (SPP2.6, WAPC 2013). Coastal hazard from shoreline erosion and storm surge inundation was examined in the CVS to develop an understanding of how these are likely to impact the Broome town site and coastal areas in future planning periods.

Under projected climate change and sea level rise scenarios, coastal hazard as a result of storm surge inundation and the erosion of the shoreline are forecast to increase for the coastal areas of Broome. Broome experiences coastal hazards typically as a result of tropical cyclones that can impact on the Kimberley coastline in the wet season (November to April) bringing extreme water levels and waves. The Western Australian planning policy recommendation for future sea level rise is for an increase in ocean level of 0.9m by 2110 (DoT 2010).

Approximately 30 km of coastline surrounding the Broome townsite is assessed in the CHRMAP. Nine individual coastal compartments are used to assess risk to the natural and built assets in foreshore areas over a range of future planning periods - present day, 2040, 2070 and 2110. Community and stakeholder engagement has played an important role in defining the community's use of the coast and developing the understanding of the consequence of coastal hazard impact for these values and assets.

The goal of the CHRMAP is to provide the Shire direction for management of its coastal areas and infrastructure in future planning periods based on a considered examination of coastal hazard through a risk management process. It is recognised that there is considerable uncertainty in both the extent and timing of future climate change and how these may impact the Broome coastal areas, and in recognition of this it is noted that CHRMAP is a continual process which will be reviewed and updated over time as this is further understood. This CHRMAP document provides Shire with a clear direction on long term planning and adaptation strategies for its coastal areas, with the focus on the short to medium term measures that will be required to treat coastal risk in the next 25 years (2040).

The format of the CHRMAP document follows the WAPC guideline format with sections as follows:

- Section 2: Establishing the Context
- Section 3: Identify
- Section 4: Analyse
- Section 5: Evaluate
- Section 6: Risk Management and Adaptation
- Section 7: Implementation Plan

- Section 8: Monitoring and Review
- Section 9: Conclusions and Recommendations

2 Establishing the Context

2.1 Purpose

The Shire of Broome is undertaking coastal hazard risk management and adaptation planning (CHRMAP) to provide strategic guidance on coordinated, integrated and sustainable management of coastal areas identified as being at risk of coastal hazard through erosion and storm surge inundation.

With a resident population of approximately 15,000 and up to 60,000 visitors annually the coastal regions are critically important as both a lifestyle and recreation focus, whilst for local businesses the coastal areas provide economic benefits that are both direct and indirect. Management of the coastal areas and foreshore reserves that surround the town, and the mitigation of the coastal hazard risk posed to the community is integral to Broome's ongoing and future success.

The Shire has recently completed a coastal vulnerability study (CVS) for the Broome town site, which identified the coastal hazard affecting the town in the present day and for future planning periods out to 2110. The CHRMAP process applies the findings of the CVS, and examines the coastal areas likely to be affected by coastal erosion and inundation, to identify areas that require management and adaptation strategies for mitigation of coastal hazard risk in future planning periods.

2.2 Objectives

A number of objectives for the CHRMAP were outlined by the Shire of Broome at the commencement of the study, which were further developed through the community engagement process:

- Inform key stakeholders and the Broome community about the coastal hazard risks identified in the CVS.
- Undertake a widespread stakeholder and community engagement program that will identify the values of various coastal assets, inform the tolerance of the identified coastal hazard risks, identify potential adaptation options to address the risks and indicate the level of support for these options;
- Ensure stakeholders and the community are included in the planning and decision-making process
- Produce a Broome Townsite CHRMAP in accordance with the Western Australian Planning Commission's (WAPC's) CHRMAP Guidelines to be adopted by Council.
- identify community and cultural values and the social value of environmental assets as well as key coastal infrastructure and assets
- provide a clear pathway for the Shire of Broome and partners to address coastal hazard risks over time
- guide investment decisions by the Shire in terms of the location and maintenance of coastal infrastructure
- provide guidance for the development of statutory planning controls.

2.3 Scope

The CHRMAP is focussed on the near shore and foreshore area that may be influenced by coastal processes (SPP2.6) within the planning period to 2110. It is limited to the assessment of coastal processes and does not include assessment of possible impacts or adaptation strategies outside the coastal zone. Catchment flooding from rainfall is not specifically assessed, though consideration of this is included where flooding interacts with storm surge in the coastal zone. Land based flooding as a result of rainfall, and stormwater management is not considered in CHRMAP.

The CHRMAP is specifically designed to address potential adverse impacts from erosion and inundation hazards (in particular where they will be amplified by climate change and sea level rise) upon assets in the coastal zone. For Broome the CHRMAP provides guidance on long term planning and adaptation strategies for its coastal areas, with the focus on the short to medium term management and adaptation measures that will treat coastal risk identified as unacceptable/intolerable in the next 25 years (2040).

2.4 Study Area

The CHRMAP study extent covers approximately 30km of coast as shown on Figure 2.1. The CHRMAP extent is based on the Broome town site area that was assessed in the CVS (Cardno, 2015).

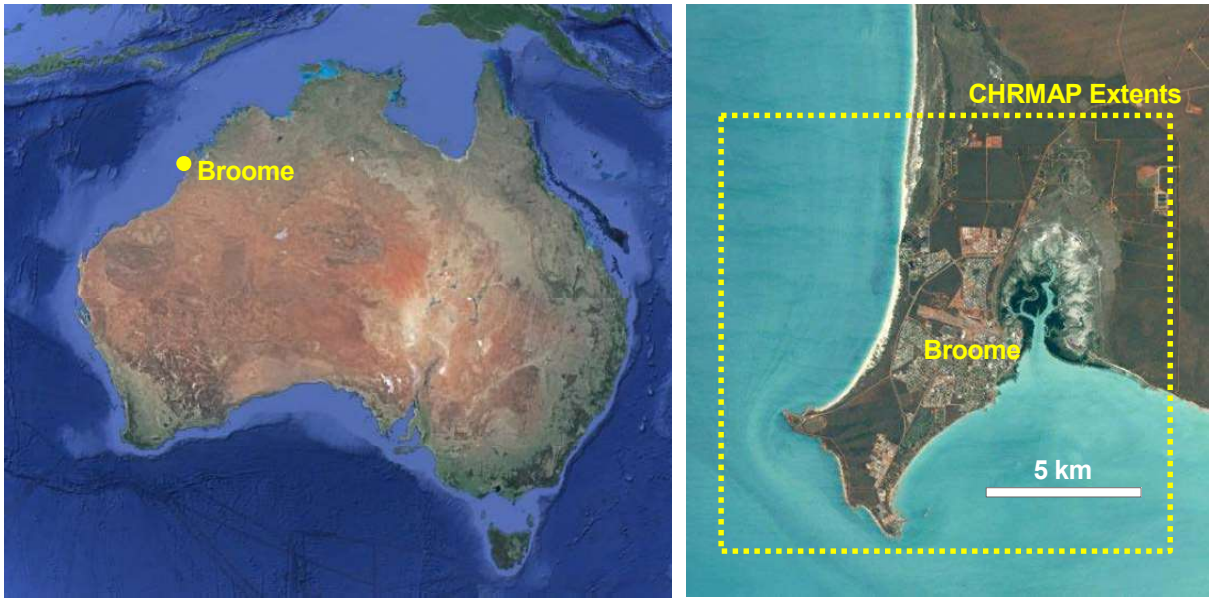


Figure 2.1: Study Location and extent of CHRMAP (Google Earth

The study area is assessed within a number of coastal compartments. Coastal areas on the western open coast include Cable Beach, Gantheaume Point, Reddell Beach and Entrance Point. On the south side of the town in Roebuck Bay the coastal areas of Simpsons Beach and Town Beach are covered. Within Dampier Creek the Broome central area of Chinatown and the estuarine foreshore areas within are covered, and foreshore area on the eastern side of Dampier Creek entrance fronting Roebuck Bay is also included. Coastal compartments are discussed further in Section 4.

2.5 Community and Stakeholder Engagement

The community engagement process developed to support the CHRMAP project was led by The Planning Group (TPG). At the inception of the project TPG developed a Community Engagement Strategy which was agreed with the Shire and the project steering committee and structured to comply with the Shire's Community Engagement Policy and Community Engagement Framework (TPG 2016a). The Shire's Community Engagement Framework draws from the International Association for Public Participation (IAP2) framework and establishes five levels of engagement, including:

- Inform – to provide the public with balanced and objective information to assist them in understanding the problem, alternatives, opportunities and/or solutions;
- Consult – to obtain public feedback on analysis, alternatives and/or decisions;
- Involve – to work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered;
- Collaborate – to partner with the public in each aspect of the decision including the development of alternatives and the identification of the preferred solution; and
- Empower – to place final decision making in the hands of the public

Stakeholders identified in the strategy were broadly grouped as follows:

- Shire of Broome Council and Staff;
- Project Steering Committee;
- Government departments and service authorities;
- Affected landowners and lessees;
- Yawuru Prescribed Body Corporate (PBC) and other Aboriginal organisations;
- Community interest groups; and
- Local residents and the broader community.

A key part of the project delivery was two community engagement workshops scheduled in July and August 2016. The first of these was an information forum, and the second a CHRMAP workshop.

The Shire employed the following methods to promote the Project, the Information Forums and Workshops online:

- A dedicated CHRMAP webpage was established on the Shire's website with relevant project information. Community members could use links to download the CVS document and there was a Frequently Asked Questions handout developed for the CHRMAP. A contact name and number for a Shire representative who could be contacted to discuss the project was provided.
- The information sessions and workshops were promoted under the 'Latest News' section on the front page of the Shire website and in the 'Have my Say' tab which is used to inform the community about matters where public input is sought.
- The information sessions and workshops were publicised on the Shire's Facebook page on 5 July, 14 July, 20 July, 5 August, 15 August, and 16 August 2016 (including photos from the first session).

Other information used to promote the Information Forums and Workshops was circulated by the following methods:

- Letters of invitation including a FAQ Sheet were sent to 319 landowners with property identified as being at risk of coastal hazard in the CHRMAP and 17 organisations identified as being key stakeholders in the Broome Community (determined in the Community Engagement Strategy).
- A Media Release was distributed on 4 July 2016.
- The information sessions and workshops were promoted in the 'Shire News' July and August 2016 editions. The 'Shire News' is included as a full page in the Broome Advertiser and distributed via an email list.
- The Shire's Director Development Services was interviewed on ABC Radio on 8 July 2016.
- A poster with details of the Information Forums was displayed in the Broome Public Library and on the notice board at the front of the Shire Administration Office.

2.5.1 Information Forums

The Information Forums were held on Wednesday 20th July 2016 and were scheduled at times that would allow a broad cross-section of the community to attend (between 1–3pm and 6-8pm respectively). These sessions were an opportunity to provide an:

- Overview of Coastal Planning Policies in Western Australia;
- Overview of the Broome Coastal Vulnerability Study (CVS);
- Overview of the Broome CHRMAP process;
- Outline on how community members can be involved in the CHRMAP process; and
- Opportunity for community and stakeholders to ask questions.

A total of 19 community members and stakeholders attended the day sessions and a total of 12 attended the night session. During the Information Forum the Shire, Baird Australia and TPG presented key information and answered questions from the community or alternatively attendees were encouraged to meet with Shire staff to discuss their issues further.

2.5.2 CHRMAP Workshops

The Workshops were held on Tuesday 16th August 2016 and were scheduled at times that would allow a broad cross-section of the community to attend (between 12:30-3:30pm and 5:30- 8:30pm respectively). The workshops were structured to ensure the viewpoints and values of the community could be considered in the CHRMAP. A series of tasks designed to inform the risk management process were undertaken with community members, providing the opportunity to:

- identify key coastal infrastructure/assets that hold economic, social and environmental value;
- discuss consequence scales for the identified coastal hazards;
- define risk tolerances to the identified coastal hazard risks; and
- discuss adaptation options that could address the risks

A total of 15 community and stakeholders attended the day sessions and a total of 2 attended the night session. During the Workshop the Shire, Baird Australia and TPG presented key information and guided participants through a series of table-based exercises.

The outcomes of the workshop exercises were used to define the coastal assets in each of the coastal compartments and the consequence for the stakeholders and community of coastal hazard impacting on

them in future planning periods. The Community Engagement Report (TPG 2016) is included in **Appendix A**

2.5.3 Identified Assets

Assets identified through the stakeholder and community workshops were broadly categorised into Economic, Social and Environmental categories. For each of the assets the community and stakeholders provided a statement to explain their function, service or value. The complete asset list is presented in tables in **Appendix A** by Coastal Compartment (discussed further in Section 4).

2.5.4 Internal Engagement

The project team maintained a strong involvement with the Shire throughout the project to obtain all relevant information for input into the CHRMAP. Specialist advice and review from the Department of Transport Coastal Management Group and the Department of Planning was required during the CHRMAP development.

The CHRMAP Community and Stakeholder Engagement Strategy was developed to provide structure to the internal engagement mechanism and ensure that the community and stakeholders were informed and actively and effectively engaged throughout the project. Its purpose was to:

- Provide an understanding of the purpose and intent of the CHRMAP;
- Define the project structure, key roles and responsibilities of the Consultant Team and the Shire along with communication protocols;
- Establish guiding communication and engagement objectives;
- Identify key project stakeholders;
- Establish an appropriate community engagement approach, tools and techniques;
- Outline the engagement and communications schedule;
- Acknowledge political sensitivities and provide an approach to dealing with user group conflict; and
- Establish a feedback mechanism.

As well as the workshops with community and stakeholders previously discussed, the project team conducted an internal workshop with Shire staff on 21 September 2016. The full day workshop involved representatives from Development, Engineering, Infrastructure, Planning, Parks and Assets and was a forum to promote understanding and support of the CHRMAP process, as well as share insights from the people who operate in key areas that the CHRMAP will apply to going forward.

2.6 Existing Planning Controls

This section was provided to the Steering group as an earlier project deliverable detailing Planning Issues (Baird 2016a). It is reproduced in full here as background to the CHRMAP.

A summary of the Broome township planning setting based on community, economic, census and environmental profile data sources is presented. Following this, a review of the Shire's Statutory and Strategic Planning documents is presented, with a particular focus on coastal planning and management and identification of the key issues in the context of the CHRMAP process. The following documents are included in this review:

- Shire of Broome Community Profile
- Shire of Broome Economic Profile
- Shire of Broome Environmental Profile
- Shire of Broome Strategic Community Plan
- Shire of Broome Corporate Business Plan 2015 – 2019
- Planning and Development (Local Planning Schemes) Regulations 2015
- State Planning Policy 2.6: State Coastal Planning Policy (WAPC)
- State Planning Policy 3.4: Natural Hazards and Disasters (WAPC)
- Shire of Broome Local Planning Strategy (2014)
- Shire of Broome Chinatown Development Strategy (2012)
- Shire of Broome Local Planning Scheme No. 6
- Shire of Broome Old Broome Development Strategy (2014)
- Shire of Broome Cable Beach Development Strategy (2016)

2.7 Profile of Broome

2.7.1 Broome Community Profile

The following information and data has been derived from the Shire of Broome's draft Community Profile (AEC 2012a).

2.7.1.1 Population

Broome had an estimated population of 16,031 at the 2011 Census. Based on a modest growth rate of an average annual increase of 2.1% based on WA Tomorrow's medium population projection estimates (WAPC 2005), Broome's population will grow to approximately 24,442 by 2031. In higher growth scenarios, the population is predicted to grow to greater than 35,000 persons by 2031. Broome's Community Profile prepared by AECgroup therefore recommends that future planning of the Broome townsite should cater for a total population of 45,000 people.

Broome services a much larger population than just its permanent residents due to Broome also being a major service centre and attraction for tourists and transient workers alike. The seasonality of the tourism industry also means that there are significant fluctuations between the number of visitors in Broome during the peak season and the low season. This fluctuation translates to an additional 2,617 visitors in Broome every day during peak season, on top of the average annual number of 3,488 daily visitors, thereby increasing pressure on existing infrastructure and the coastline.

The nature of Broome as a service centre and tourist attraction means that there is significant community value and resultant development and infrastructure pressure placed on the Broome coastline.

2.7.1.2 Dwelling Projections

It has been estimated that Broome will require a total of 9,200 dwellings to accommodate its future permanent residential population. The population will require approximately 1,723 new permanent dwellings between 2011 and 2021 (to a total of approximately 6,771 total dwellings), up to approximately 3,207 new permanent dwellings by 2031 (approximately 9,300 total dwellings). This increase in dwellings is

in response to the permanent residential population growth Broome is expected to experience over the coming 20 years.

2.7.1.3 Community Infrastructure

AECgroup conclude that Broome has an undersupply of community infrastructure to service its existing permanent resident population. This combined with the influx of tourist and transient workers, puts additional pressures on this infrastructure. Lack of infrastructure and impediments to the provision of infrastructure can impact on future growth. Infrastructure in proximity to the coast will need to be carefully planned in line with the adaptation recommendations contained within the CHRMAP.

2.7.2 Broome Economic Profile

The following information and data has been derived from the Shire of Broome's draft Economic Profile prepared by AECgroup in November 2012.

Broome has historically been reliant on the tourism industry and the spinoff economic benefits of this industry relating to construction and transport industries. Other industries related to the coast include fishing (including pearl fishing) and offshore mining. Commercial industries are also established within the Broome Town Centre area and Chinatown, which is located in close proximity to the coast. All of these industries have the potential to be impacted by coastal processes due to Broome's location on the coast, being susceptible to both storm surge and coastal erosion processes.

Therefore, while economic growth and diversification should be encouraged for Broome, careful planning needs to be undertaken into the future location of development with respect to areas that are sensitive to coastal processes.

2.7.3 Broome Environmental Profile

Essential Environmental were engaged by the Shire of Broome in 2012 to prepare an Environmental profile to inform the preparation of the Shire's Local Planning Strategy. A summary of this document and its relevance to the preparation of a CHRMAP for the Broome townsite is provided below.

2.7.3.1 Climate

The climate of Broome is characterised by two primary seasons, the wet season and the dry season, with two shorter transitional periods in between. The dry season occurs from May to October and is typified by sunny days and cooler nights. The 'tropical summer' is characterised as a wet and hot season and extends from November through to April. Almost 90% of the district's annual rainfall falls within this period and stormwater flooding and drainage issues are most likely to be prevalent within this season. Tropical cyclones can occur during the wet season months. Since 1910, there have been a reported 22 cyclones that have caused gale force winds at Broome. On average, this equates to one every four years.

2.7.3.2 Biodiversity

The coastline around Broome including areas of Roebuck Bay is known as the Yawuru Conservation Estate (YCE) and is Crown Reserve jointly vested in the Yawuru RNTBC and, in areas within the Broome townsite, the Shire of Broome. The YCE protects areas of important vegetation including the mangroves within Roebuck Bay and the vegetated dune system.

The coastal marine environment of Broome provides an important habitat for many marine and bird wildlife, including whales and turtles and many migratory birds which are afforded protection under the Environment Protection and Biodiversity Conservation Act (EPBC Act, 1999).

There are two wetlands within the Shire that are of international significance and afforded protection under the EPBC Act. They are Eighty Mile Beach and Roebuck Bay. These wetlands provide critical habitat to the region's fauna, including many species of migratory birds. The Roebuck Bay site is south of the Broome town site study area and is a RAMSAR site, recognised by the International Convention that focuses on the conservation and wise use of internationally important wetlands (Figure 2.2).

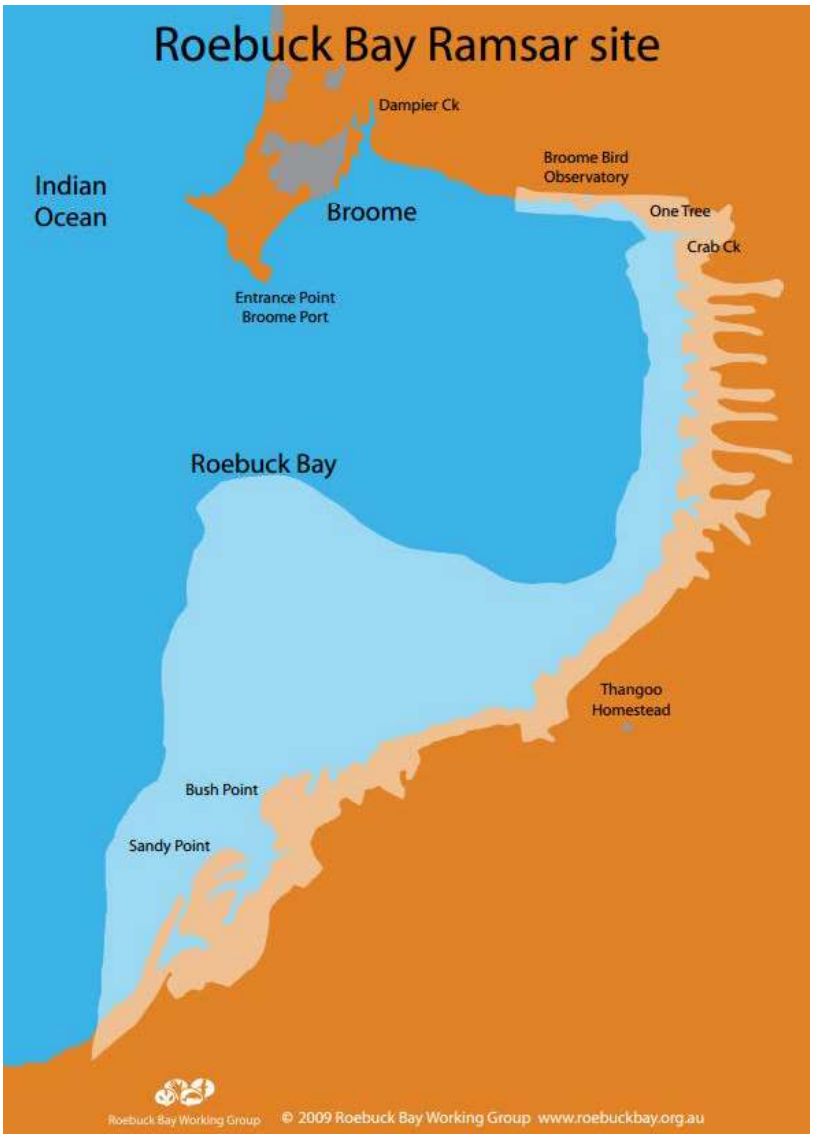


Figure 2.2: Roebuck Bay RAMSAR site (Source: Roebuck Bay Working Group 2009).

2.7.3.3 Surface Water Drainage

The management of stormwater within the townsite of Broome is a key consideration due to the high rainfall events in the wet season and the sensitive nature of the surrounding environment.

The seasonal high volume of rainfall runoff either flows to the west towards the dune system along Cable Beach, or towards Dampier Creek mangroves in the east.

Other issues associated with stormwater runoff is the potential impact for nutrient exportation into the surrounding sensitive water environment, including the potential to contribute to algal blooms within Roebuck Bay.

2.8 Corporate Governance Framework

2.8.1 Strategic Community Plan

The Shire of Broome Strategic Community Plan (SCP) is the overarching strategic plan providing guidance for the governance of the Shire for a ten year period. The Strategic Community Plan has been informed by the Broome 2040 community visioning / community engagement program facilitated by the Shire. The SCP informs the preparation of a Corporate Business Plan which allocates priorities over a four year period, and through this, the annual budget guiding expenditure on different strategies within the municipality. It is therefore an important consideration in the preparation of a CHRMAP for the District.

The Vision identified for the Shire of Broome is:

"A thriving and friendly community that recognises our history and embraces cultural diversity and economic opportunity, whilst nurturing our unique natural and built environment."

This vision is supported by four goals, including the following goal relating to the environment and cultural heritage:

"Help to protect the natural and built environment and cultural heritage."

Of note, the SCP includes outcomes of a community survey, where the community nominated 'beaches and coastline' as the second most valued characteristic for living in Broome after 'Lifestyle'.

The SCP also identifies the next big projects that the community wish to see happen over the next ten years. Projects relevant to the CHRMAP development include:

- Chinatown redevelopment;
- Construction of a safe boat launching facility;
- Marina development;
- Jetty to jetty boardwalk and foreshore redevelopment;
- Enhancement of the Cable Beach precinct;
- Redevelopment the Town Beach precinct; and
- Upgrading and relocating the airport.

The document notes the need to protect, manage and enhance the Shire's coastal environment as a significant asset and key attractor to the region.

2.8.2 Corporate Business Plan 2017 – 2021

The Shire of Broome Corporate Business Plan (CBP) has been prepared to implement the strategies contained in the Shire's Strategic Community Plan. The plan incorporates a capital expenditure program for implementation of different projects through to the 2020-21 financial year and includes the following projects of note:

- Implement jetty to jetty revetment project ($4.2m in 2017-18);
- Boating Facilities – Upgrades to Entrance and Gantheaume Point ($100k in 2017-18); and

The CBP is currently under review.

2.9 Summary of Existing Planning Framework

2.9.1 Planning and Development (Local Planning Schemes) Regulations 2015

The Planning and Development (Local Planning Schemes) Regulations 2015 (the Regulations) were introduced by the State government to ensure a consistent structure, format and approach to local planning schemes across the state of Western Australia.

The Regulations contain 'deemed provisions' being Schedule 2 of the Regulations and these provisions automatically apply to all local government planning schemes throughout the State and supersede corresponding provisions of these schemes. The deemed provisions were formally incorporated into the Shire's Local Planning Scheme No. 6 (LPS6) through a basic amendment which came into force in August 2016.

Schedule 2 of the Regulations contain provisions relating to various planning mechanisms which have varying degrees of application to implementing adaptation approaches for coastal processes. The planning mechanisms available in the Regulations are examined below.

2.9.1.1 Local Planning Policy

Division 2 of the deemed provisions relates to the preparation of local planning policies. A local planning policy may apply generally to the Scheme area or deal with a specific class or classes of matters.

In making a determination under the scheme, the Shire of Broome must have regard to each relevant local planning policy, to the extent that the policy is consistent with the scheme. In addition to introducing new policy measures to be considered within the Shire, a local planning policy may also vary existing deemed-to-comply provisions of the Residential Design Codes, where it is considered appropriate. In the context of coastal hazard and risk planning, a local planning policy could introduce additional design requirements for development, such as elevated habitable floor levels, additional setback requirements and other relevant matters to ensure coastal hazard issues are appropriately responded to within the planning framework.

2.9.1.2 Structure Plans and Activity Centre Plans

Part 4 of the deemed provisions relates to the preparation of structure plans while Part 5 relates to the preparation of Activity Centre Plans. A structure plan (or Activity Centre Plan) may be prepared for a specific area if:

(a) the area is:

i. all or part within a zone that is identified by the scheme as being suitable for urban or industrial development; and

ii. identified in this Scheme as an area requiring a structure plan to be prepared before any future subdivision or development is undertaken; or

(b) a State Planning Policy requires a structure plan to be prepared for the area; or

(c) the Commission considers that a structure plan for the area is required for the purposes of orderly and proper planning.

The relevant decision maker of subdivision and development applications within a structure plan area must have due regard to but is not bound by a structure plan. A structure plan therefore does not have the full force and effect of the scheme. Once adopted, a structure plan which identifies zoning and land use permissibility, would need to be normalised within a scheme by way of a scheme amendment, if the zoning and land use permissibility is to have statutory weight.

2.9.1.3 Local Development Plans

Regulation 47 of the Regulations provides for the preparation of local development plans (LDP), which states:

'A local development plan in respect of an area of land in the Scheme area may be prepared if –

(a) the Commission has identified the preparation of a local development plan as a condition of approval of a plan of subdivision of the area; or

(b) a structure plan requires a local development plan to be prepared for the area; or

(c) an activity centre plan requires a local development plan to be prepared for the area; or

(d) the Commission and the local government considers that a local development plan is required for the purposes of orderly and proper planning.'

2.9.1.4 Special Control Areas

Special control areas (SCA) may be established within Part 5 of the model scheme provisions. SCAs are typically put in place to establish special provisions to target a single issue or related set of issues often overlapping zone and reserve boundaries. The provisions of an SCA would establish the purposes and objectives of the SCA, specific development requirements and, if relevant, referral requirements to relevant agencies. A SCA could therefore be established within a scheme to comprehensively address the specific development issues associated with land prone to coastal hazard and risk issues.

A SCA would be delineated on the scheme maps by way of line work, which could follow the extent of mapped areas known to be prone to storm surge and or coastal physical processes (erosion, sea level rise allowance).

2.9.1.5 General Development Provisions

Part 4 (Clause 32) of the model scheme has provisions for the establishment of additional site and development requirements in addition to those set out in the R-Codes, activity centre plans, local development plans or State and local planning policies. General development provisions could technically

set out general development requirements relating to areas subject to coastal flooding and / or coastal processes. However, it is considered that given the specific nature of coastal issues, including the varied locational extent to which it may affect land within a district, specific development requirements would more appropriately be established within a special control area as opposed to general development provisions within the scheme.

2.9.1.6 Exemptions from planning approval

Regulation 61 of the Regulations specifies works and land uses that are exempt from requiring planning approval.

The following outlines development for which development approval is not required pursuant to this regulation:

- the carrying out of works that are wholly located on an area identified as a regional reserve under a region planning scheme (not applicable to the Shire of Broome);
- the carrying out of internal building work which does not materially affect the external appearance of the building, provided that the building is not afforded statutory heritage protection;
- the erection or extension of a single house provided that the single house is not afforded statutory heritage protection;
- the erection of extension of an ancillary dwelling, outbuilding, external fixture, boundary wall or fence, patio, pergola, veranda, garage, carport or swimming pool on the same lot as a single house or a grouped dwelling if the R-Codes are applicable provided that the development is not located in a place that is afforded statutory protection;
- the demolition of a single house, ancillary dwelling, outbuilding, external fixture, boundary wall or fence, patio, pergola, veranda, garage, carport or swimming pool provided that the single house or other structure is not located in a place that is afforded statutory heritage protection;
- temporary works which are in existence for less than 48 hours, or a longer period agreed by the local government, in any 12-month period;
- the temporary erection or installation of an advertisement in specific circumstances;
- the erection or installation of a sign in specific circumstances;
- the carrying out of any other works specified in a local planning policy or local development plan that applies to the development as works that do not require development approval;
- the carrying out of works of a type identified elsewhere in this Scheme as works that do not require development approval.

This is a consideration of the CHRMAP process, as it has the implication that certain development may be established within an area affected by storm surge or coastal processes without the requirement to obtain planning approval. However, there are ways of controlling this issue to some extent. For instance, a local planning policy or local development plan could vary the deemed-to-comply requirements of the R-Codes to put in place additional design requirements that may trigger the requirement for planning approval. Secondly, a Special Control Area could be established over land affected by coastal processes or storm surge, which would trigger the requirement for the prior planning approval to be obtained from the Shire of Broome, including the requirement for the prior planning approval to be obtained for exempted development.

2.9.1.7 Summary of options

The statutory planning mechanisms available to address coastal hazard in Broome are summarised in Table 2.1.

Table 2.1: Statutory planning mechanisms available to address coastal hazard in Broome

Statutory Measure	Advantages	Disadvantages
Structure Plan	Can address location specific issues i.e. identification of coastal physical setbacks and areas affected by storm surge.	Does not have the force and effect of the Scheme. Decision makers to have due regard only. Cannot specify / enforce built form requirements. Location specific only and therefore cannot address coastal hazard issues on a broad scale. Generally requires the land to be appropriately zoned to require the preparation of a structure plan.
Local Development Plan	Can specify built form requirements to address location specific coastal hazard issues i.e. increased setbacks, minimum habitable floor levels etc. Has statutory weight of the local planning scheme. Can vary 'deemed-to-comply' development requirements.	Location specific only and therefore cannot address coastal hazard issues on a broad scale.
Local Planning Policy	Can address coastal hazard and risk issues at a district (broad) level and/or at a location specific level. Can include mapping of coastal hazard issues with flexibility to update mapping as and when amendments are required to be undertaken. Has statutory weight of the local planning scheme. Can vary 'deemed-to-comply' development requirements.	
Special Control Area	SCAs may establish specific provisions to address a specific issue such as storm surge and or coastal processes. SCAs can broadly address unique issues that extend across multiple zones and / or reserves.	A scheme amendment would potentially need to be progressed every time mapping of the coastal issue is amended and/or updated.

	Has statutory weight of the local planning scheme. Can delineate a line on the map that corresponds with the extent of the identified coastal issue/s.	
General Development Provisions	May establish development provisions relating to coastal hazard and risk issues.	Due to the unique nature of coastal hazard and risk issues and the varied locational extent of the issues, it is considered that development provisions would more effectively be dealt with by way of a SCA as opposed to a general development provision of the scheme.

Of the mechanisms listed in Table 2.1, a Local Planning Policy and/or special control area (SCA) are considered the most suitable to address coastal hazard within the planning framework.

The Shire of Broome is in the process of implementing a Scheme Amendment to insert a Special Control Area (SCA) covering all properties impacted by coastal hazards to the year 2110 (as defined through the CVS). The SCA was supported by Council and publicly advertised in November 2016.

The CHRMAP supports the SCA by providing detailed assessment of the coastal hazard risk for properties within the SCA extents. It also outlines the preferred coastal adaptation strategy for the coastal compartments around Broome and makes recommendations for mitigating coastal hazard risk in future planning periods. Coastal adaptation recommendations determined through the CHRMAP will be included in a Local Planning Policy to function alongside the SCA.

2.9.2 State Planning Policy 2.6: State Coastal Planning Policy

State Planning Policy 2.6 – State Coastal Planning Policy (SPP 2.6) and associated guidelines have been prepared to guide decision making and policy in relation to planning along the State's coastline.

SPP2.6, provides policy on the determination of an appropriate foreshore reserve, which acts as a coastal buffer to accommodate coastal processes as a result of coastal erosion and risk or storm surge inundation in future planning periods.

SPP2.6 seeks to ensure coastal hazard risk management and adaptation planning is established to guide the location and form of development along the coast. The policy establishes a hierarchy for undertaking coastal hazard and risk adaptation planning. The adaptation measures of Avoid, Planned or Managed Retreat, Accommodate and Protect are to operate on a sequential and preferential basis starting with avoid as part of the coastal hazard risk management adaptation planning process.

The State Coastal Planning Policy guidelines were introduced to support draft SPP 2.6. These guidelines identify a range of ongoing risk management and adaptation planning measures that may be considered in the assessment of development proposals located within an area known to be subject to storm surge risk or coastal erosion hazard. The guidelines establish a process for undertaking CHRMAP, as follows:

1. Establish the context;
2. Undertake a risk vulnerability assessment;

3. Determine the likelihood of the hazard occurring;
4. Determine the consequences;
5. Evaluate the risks;
6. Set in place adaptation management measures; and
7. Undertake monitoring and review.

This process is shown on Figure 2.3

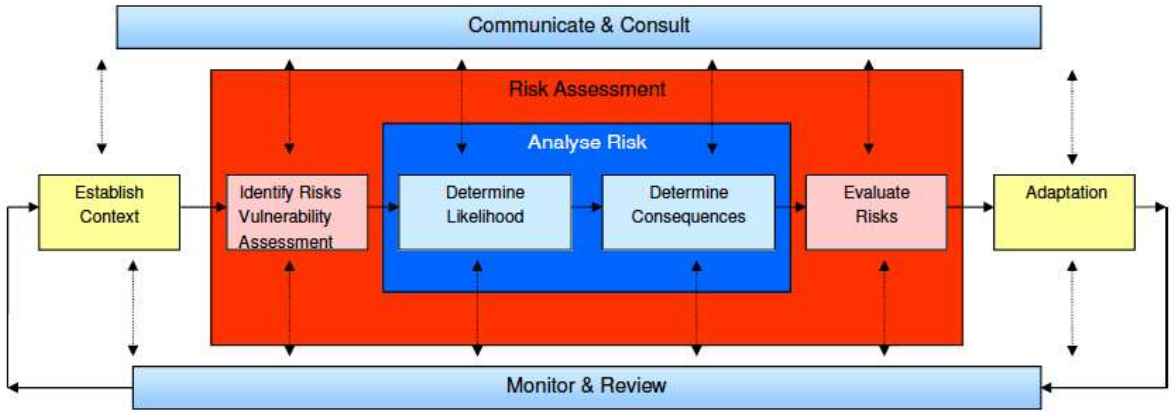


Figure 2.3: Risk Management and Adaptation Process Flowchart (Source WAPC 2013)

Section 77 of the Planning and Development Act 2005 requires that local governments when preparing or amending a local planning scheme, to have due regard to relevant State policies and guidelines such as SPP2.6 and its associated guidelines and State Planning Policy 3.4.

2.9.3 State Planning Policy 3.4: Natural Hazards and Disasters

State Planning Policy 3.4 – Natural Hazards and Disasters (SPP 3.4) was prepared to ensure that land use planning appropriately considers the risk of natural hazards and disasters. It addresses storm surge as well as a range of other hazards, including overland flooding. With respect to overland flooding events, SPP 3.4 requires that:

- the 100-year average recurrence interval overland flood event be used as the defined flood event in relation to the assessment of proposals.

While SPP3.4 identifies a 100-year ARI event for storm surge, the policy also references SPP2.6, which requires regard to be given to a 500 year ARI storm surge event.

With respect to storm surge, SPP 3.4 further states with respect to cyclonic activity and 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.

For coastal matters SPP2.6 is to be viewed as the higher order and prevailing policy, and the inundation extent associated with the 500-yr ARI event for storm surge is required for future planning purposes.

It is noted that the Department of Planning has programmed to review SPP3.4 as a priority.

2.9.4 Shire of Broome Local Planning Strategy (2014)

The Shire of Broome Local Planning Strategy (LPS) sets out the medium to long term planning direction for the Shire district over a 10 to 15-year period.

One of the principal objectives of the LPS is to facilitate the development of the Broome townsite as the principal centre in the Kimberley, with a view to it developing into a liveable regional city of between 25,000 and 35,000 permanent residents by 2031. In delivering this objective, the following strategies are relevant to this study:

- Cluster retail, employment, recreational and other activities within the townsite to minimise the need to travel.
- Undertake a Biodiversity Strategy and Coastal Vulnerability Study.
- Specific to Chinatown, the LPS identifies the following strategies to support the development of retail and commercial activity within the Broome townsite:
- Revitalise Chinatown as the primary centre with a focus on retail, commercial and entertainment uses, as considered in the Chinatown Development Strategy.
- Promote and encourage a mix of commercial/office, tourism and residential development south of Frederick Street and east of Herbert Street to provide a supporting role to Chinatown.
- Expand the town centre west of Hamersley Street to accommodate existing office, residential and entertainment uses.
- Promote and encourage development along the north side of Frederick Street as showrooms and bulky goods retail.

2.9.5 Shire of Broome Local Planning Scheme No. 6

2.9.5.1 Overview

The Shire of Broome Local Planning Scheme No. 6 (LPS 6) is the principal statutory planning document which imposes requirements in relation to land use and development within the Shire. The conversion of LPS 6 to conform with the recently introduced model scheme provisions within the Planning and Development (Local Planning Scheme) Regulations 2015 was published in the Government Gazette and came into effect on 5 August 2016.

LPS 6 addresses the issue of overland flooding by definition of a special control area, specifically Special Control Area 4 – Flood Prone Areas (SCA 4). The objective of SCA 4 is to 'minimise flood damage, ensure off-site impacts on adjoining land and receiving water bodies is limited, and to manage drainage for development.'

Specifically, SCA 4 is applicable to the following areas:

(a) Chinatown and areas immediately west of Broome Road;

(b) Billingurr – Lots north of Pearl Coast Road on Lullfitz Drive and Sands St;

(c) Port Drive – lots in the southern portion of the Industry Zone; and

(d) Any land below 6.0m A.H.D.

Clause 6.2.4.3 of the LPS 6 states that the local government may impose conditions in granting planning approval for development and land use on land within SCA 4 relating to any of the following matters:

(a) building floor and fill levels (absolute minimum fill level to be 5.3m AHD and minimum floor level of 5.7m AHD;

(b) fill or drainage requirements and financial contribution to drainage works;

(c) limitations / restrictions on filling in areas required to hold stormwater;

(d) location, construction style and/or orientation of buildings on site;

(e) density and site cover;

(f) landscaping and open space;

(g) location and style of fencing;

(h) lot access requirements; and

(i) the type and location of on-site effluent disposal systems.

LPS 6 does not contain any other provisions relating to storm surge or coastal physical setbacks. However, the Shire of Broome is in the process of implementing a scheme amendment which seeks to introduce a new special control area (SCA) relating to areas within the district that are either affected by storm surge and / or coastal processes such as erosion. The purpose of the SCA is to act as a trigger to indicate to Shire decision makers and development proponents that the area is considered to be at risk of coastal processes and hence that coastal hazard risk management and adaptation is required in accordance with SPP2.6.

Clause 5.12 of LPS 6 relates to the encouragement of Broome-style architecture within the Town Centre, Local Centre, Mixed Use, Tourist, Service Commercial and Residential zones. This architectural style promotes low scale buildings, however does not specifically discuss the requirement for raised habitable floor levels to deal with the local flooding or storm surge conditions. The Broome-style architectural requirements may in part be non-compatible from the need to protect habitable buildings from the impacts of flooding and storm surge, particularly in the Broome Town Centre precinct, most prone to flooding.

2.9.6 Chinatown Development Strategy (2012)

The Chinatown Development Strategy (CDS) was prepared by Hassell for the Shire of Broome in June 2012. The CDS establishes a vision and development strategy to provide a non-statutory framework to guide future decision making with respect to the ongoing development of Chinatown. Key considerations identified in the CDS that are relevant to the CHRMAP include:

- Chinatown's ongoing role as the central business district for Broome is challenged due to its fringe location on the shore of Roebuck Bay. Access is only possible from the west, which leads to congestion during peak periods. Chinatown is also no longer central to the growing population of

Broome and its location on the edge of Roebuck Bay creates challenges for outward growth of the Centre.

- Heritage and building height restrictions (due to the current location of the Broome International Airport) also limit the future growth potential of Chinatown.
- The CDS acknowledges that Chinatown is prone to flooding, due to its location on a peninsula and being surrounding by tidal flats on three sides. It notes that flooding of Chinatown is tidally influenced, with key risks being associated with storm surges or major stormwater events coinciding with high tides.
- The flooding of key access roads into Chinatown is raised as a significant issue by the CDS.
- The CDS recommends that "planning policy needs to support Chinatown as the preferred location for high order activities such as corporate regional headquarters, destination retail, specialist retail and services, and entertainment functions."
- The CDS identifies the core retail precinct for Chinatown being the street block bound by Short Street, Dampier Terrace, Napier Terrace and Carnarvon Street. Additional retail surrounds this street block with mixed use precincts, short stay accommodation and open space forming the remainder of the Chinatown development area.
- The CDS acknowledges the challenge of achieving activation of streetscapes within Chinatown while also requiring higher finished floor levels of tenancies to protect against flooding.
- Some of the actions in the Concept Plan included as part of the CDS are now taking place after the Shire received $10 million from Royalties for Regions to revitalise Chinatown.

With respect to natural resource and environment management the document identifies the requirement to prepare a Coastal Hazard Risk Management Adaptation Plan to identify measures to address possible risks to the environment from climate change impacts.

2.9.7 Old Broome Development Strategy (2014)

2.9.7.1 Overview

The Old Broome Development Strategy was prepared in response to a strategy within the Shire's Local Planning Strategy which recommends development strategies be prepared for specific precincts within Broome. The Old Broome precinct is identified as precinct 2 within the LPS. The Old Broome Development Strategy sets out medium to long term planning direction for Old Broome over at 10 to 15-year period.

The primary objective for the Old Broome precinct is to 'establish it as a mixed use area with an open form of development that recognises the historic character of the area. It is intended that there be diversity in the land use provided within the precinct to include residential, offices, community services, tourist development and limited retail and that the cultural heritage, recreational and tourism values of the area be maintained.'

The Strategy includes a Concept Plan for Town Beach and the Conti Foreshore which covers the land and foreshore south of Frederick Street to Demco Drive. This section of the coast, is captured within CHRMAP coastal compartment 'Town Beach' (Section 3.2.6) and the dominant coastal hazard for future planning periods is coastal erosion. The foreshore area incorporates land extending south of Moonlight Bay Apartments, down to Catalina's, Bedford Park, the Roebuck Bay Caravan Park Site, the Lions Pioneer Park and Apex Park.

The Strategy cites a number of environmental management concerns that are relevant for CHRMAP process and recommends the following actions:

1. Upgrade to the drainage network and the treatment of the stormwater before it is released into Roebuck Bay in line with Better Urban Water Management Principles and the Shire's Stormwater Management Policy;
2. Introduce erosion protection and control measures at vulnerable locations along the length of the foreshore, including the cliffs located along the caravan park site;
3. Construct a revetment to prevent further erosion of the pindan cliffs on the north side of the old jetty, which could incorporate tiers in the form of an amphitheatre that could be used as seating for viewing Staircase to the Moon; and
4. Remediate the dunal swale between the beach and housing on Demco Drive in consultation with Yawuru.

2.9.7.2 Key Issues / Recommendations

1. CHRMAP to identify appropriate adaptation measures to respond to the identified risk of coastal erosion processes within the Old Broome precinct.
2. Review appropriateness of concept plan for Town Beach and Conti Foreshore in the context of the findings of the CHRMAP with specific focus on recommendations relating to infrastructure and infill development.

2.9.8 Cable Beach Development Strategy (2016)

2.9.8.1 Overview

The Cable Beach Development Strategy (the strategy) was adopted by Council in July 2016. The intent of the strategy is to inform future reviews for the Shire's Strategic Community Plan and Corporate Business Plan. The strategy shall also be given due regard by decision makers in assessing development within the Cable Beach precinct by way of Clause 4.42.1 of the Shire's LPS6, which states with respect to the Tourist zone that 'development shall be consistent with any relevant endorsed development strategy and any relevant design guidelines'.

The strategy provides guidance with respect to the location of land use, built form requirements, the movement network and the public realm. The issues and implications of the strategy in relation to the CHRMAP study are discussed in further detail below.

2.9.8.2 Land Use

The strategy provides further guidance with respect to locating specific land uses within the precinct, which is primarily zoned 'Tourist' under the Shire's LPS6. In identifying preferred land uses, the strategy seeks to activate priority street frontages along Sanctuary Road and Cable Beach Road West.

Following review of the Coastal Vulnerability Study, it is noted that portions of the Cable Beach Precinct that are zoned for Tourist land uses have been identified as being impacted by coastal erosion over the planning timeframe.

2.9.8.3 Built Form

The strategy includes built form provisions to guide the form of development within the precinct. These provisions primarily deal with promoting high quality tourist accommodation with the ability to establish

appropriate permanent residential accommodation in a way that does not jeopardize the primary tourism function of the precinct.

The Strategy notes that coastal hazard risks are present and that future development must be planned in accordance with the recommendations of the Broome Townsite CHRMAP.

2.9.8.4 Movement Network

The precinct is currently serviced by Cable Beach Road West in the south and via Sanctuary Road in the north. The Strategy identifies that these roads would continue to operate as the primary movement network to and from the precinct. The strategy also flags the potential to establish new road connections between the Precinct and Chinatown once the Broome International Airport relocates to a site out of town.

It is noted that investigation into the reconfiguration of the car parking at the end of Cable Beach Road west is considered as part of the strategy. However, this car parking area has also been identified within the CVS as being prone to coastal erosion processes. The Strategy acknowledges this and recommends a detailed Foreshore Master Plan be prepared, which will consider the feasibility of all concepts and align with the CHRMAP outcomes.

2.9.8.5 Public Realm

The 'public realm' focuses primarily on Public Open Space and community buildings and facilities. The Strategy identifies that the Surf Life Saving Club is one of Broome's most popular and well attended sporting facilities and considers the potential for the aging club infrastructure to be replaced and redeveloped.

The Strategy also identifies the need to improve drainage infrastructure to manage periodic inundation from storm water runoff.

Additional facilities have also been identified by the community as a priority for the foreshore, such as shade, tables, seating, water fountains and barbecues.

2.9.8.6 Coastal Hazard Risk

The strategy does acknowledge that there is a need to manage coastal hazard and risk within the precinct, with the current and future erosion of the cliffs along the Cable Beach Foreshore the primary concern (discussed in detail in Section 3.2.1). Coastal protection works are likely to be required to stabilise these cliffs should it be identified that existing assets at risk are to be protected. The document acknowledges that the CHRMAP process will identify and prioritise methods to mitigate or adapt to coastal hazards within the precinct, and influence how development proceeds in affected areas.

2.9.8.7 Key Issues / Recommendations

1. The CVS identified that portions of the Cable Beach foreshore area are at risk of inundation as a result of catchment based flooding associated with severe cyclone events. The strategy identifies the need to improve drainage infrastructure to deal with inundation as a result of rainfall runoff.
2. The CVS also identifies that portions of the precinct will be subject to coastal erosion processes, including portions of the precinct zoned for Tourism land uses and also areas identified for community and recreation uses, including the existing car parking area at the end of Cable Beach Road West, the Surf Lifesaving Club (mooted for redevelopment) and Zanders café/restaurant (refer Section 3.2.1).

3. The Strategy identifies the need for the CHRMAP to provide guidance with respect to adaptation strategies for the precinct.

2.10 Key Elements (Assets)

The process for the identification of coastal assets in CHRMAP is defined as follows:

It is necessary to identify all relevant assets (social, economic, environment) together with their functions/services and value that will be assessed for the consequences of being impacted by the coastal hazards. It is important that once the assets have been identified, their function/service and values reflect the community and stakeholder viewpoint (WAPC2014).

During the community engagement workshops, a series of tasks were completed by the participants (community and stakeholders) to define the coastal assets around Broome in Economic, Social and Environmental categories. Community were asked to identify the assets within coastal compartments of the study area and for each provide a statement to explain their function, service or value. The outcomes were reported in the community engagement report (TPG 2016b) which is included in full in **Appendix A**. A list of the identified coastal assets is presented in **Appendix A** by Coastal compartment and further discussed in Section 4.

2.11 Success Criteria

The community engagement process highlighted the way that the community use the coastal areas of Broome. There was a particular focus on the connection that the community have to the coast and the values placed on these unique natural areas. The assets identified in the workshop sessions (Appendix A) and the value that people derived from them were articulated, setting a basis for how the CHRMAP can deliver adaptation responses that are in keeping with community expectations, as well as setting a basis for how future evaluation of the effectiveness of the CHRMAP can be determined.

The Broome 2040 community visioning project used surveys to identify the value of the beaches and coastline, lifestyle aspects of Broome for the community. The value of the beaches, coastline and natural areas that were identified in Broome 2040 and reinforced through the CHRMAP engagement process:

- The pristine or unspoilt nature of these areas and the diversity of flora and fauna.
- The easy access to beaches and the coastline and this includes being able to get to the beach in 5 minutes and also access in terms of being able to drive along beaches and the coastline, this relates to enjoying the natural environment and sense of isolation.
- The different qualities and the wide range of experiences possible and Cable Beach, Roebuck Bay and Gantheaume Point are commonly mentioned.
- Their central part of the way of life and lifestyle.
- The remote and wilderness qualities of the natural environment, the stunning beauty of the environment together with the remarkable colours of the landscape and ocean.

The coastal asset values and functions summarised in **Appendix A** and the values identified in Broome 2040 can be used to measure the success and effectiveness of the CHRMAP in meeting the communities needs in the future.

2.12 Consideration as to the use of private seawalls

This section examines the key issues and considerations relating to the use of private seawalls within the Shire.

From time to time, the Shire may receive applications from landowners proposing the construction of private seawalls on private property to protect assets from the risk of coastal processes. This may be necessary particularly in instances where the Shire is not proposing to construct a seawall within the coastal reserve, such as in sections of Town Beach.

Within Western Australia, it is rare for private property to have a boundary that directly abuts coastal waters, given it is standard practice to have a coastal foreshore reserve in public ownership. However, there are a number of instances within the Shire where private lots abut coastal waters directly, with no foreshore reserve in between. The Roebuck Bay caravan park and a number of properties north of Town Beach are examples of such properties.

Therefore, it may be possible that the need to build a seawall to protect private property arises within the Shire. The Shire should give consideration to the potential implications associated with the construction of private seawalls, including, but not limited to:

1. The potential for the seawall to impact on coastal processes on the wider coastline and adjacent properties, in particular, the potential for coastal erosion and/or accretion to be exacerbated on either side of the seawall;
2. The need to develop a coordinated plan to ensure consistency in seawall alignment, design and construction standards to protect numerous private property;
3. The need to maintain public access to the coastal foreshore where applicable;
4. Public liability issues where an individual seawall is constructed within the coastal foreshore reserve;
5. The need to establish legal mechanisms to ensure the proponent and future landowner/s are responsible for the ongoing repair, inspection, maintenance and insurance;
6. The potential for litigious action from private landowners if the private seawall fails to protect assets approved by the Shire; and
7. Expertise of local government staff in assessing the suitability of proposed structures and potential resource commitments associated with ongoing maintenance inspections of seawalls.

The Shire also needs to consider potential implications if it takes the position to refuse permitted development or the construction of seawalls on existing freehold and zoned land. A refusal of a development application may result in a costly process of defending the decision at the State Administrative Tribunal (SAT).

Given the implications associated with private seawalls identified above, it is recommended that the onus of justifying the suitability of a private seawall to protect existing or proposed assets, rests solely with the developer/landowner. An applicant proposing the construction of a seawall on private property should be required to prepare its own CHRMAP to ensure a process whereby the applicant appropriately assesses and accepts the level of risk associated with the proposal. In particular, the application should address matters detailed in Section 5.7 of SPP2.6 relating to coastal protection works.

From a management perspective, it is recommended that wherever possible, that a physical barrier such as a seawall be constructed on public property within an existing foreshore reserve rather than on private property. This will allow the local government (or other relevant body) to maintain control over the existence of the seawall, while the maintenance and management costs associated with the seawall would be the responsibility of the private landowner, through a licence agreement or similar mechanism. This is the approach taken by the Shire of Busselton for a number of properties along its coastline and is currently considered a best practice response to the issue of private seawalls by the Department of Planning.

In Section 6 of the CHRMAP as part of adaptation approaches the right for individual landowners to construct coastal defences is outlined. It is recommended that the Shire develop a local planning policy relating to the construction of private seawalls, that would address matters relating to ongoing maintenance responsibilities, liability, public access and safety to the beach and ongoing monitoring requirements.

2.13 Indemnification of local government

In approving development on land identified as prone to coastal processes within the planning timeframe, the Shire may be inclined to impose conditions on the planning approval seeking the applicant indemnify the Shire against future actions, claims, demands or costs.

There are a number of legal mechanisms which can theoretically achieve this outcome, however it is understood that currently insurance coverage is limited with respect to 'actions of the sea', such as coastal erosion. In fact, no insurance providers currently provide an insurance policy to cover damage as a result of sea level rise. Further legal advice should be sought with respect to whether indemnification can be sought where no insurance coverage is available to private landowners.

The Productivity Commission in its report titled *Barriers to Effective Climate Change Adaptation* (2012) recommended that in response to the lack of insurance coverage for coastal properties, government should not subsidise household or business property insurance, whether directly or be underwriting risks, as this would not remove the physical exposure to risks.

The National Strategy for Disaster Resilience (COAG 2011) identifies the primary role for local governments with respect to coastal processes, is in the areas of hazard mapping and data provision, community education and awareness raising, mitigation activities and providing emergency support services.

Notwithstanding, a summary of the legal instruments available to secure indemnification are summarised below. It would be necessary to use a suite of these instruments to secure appropriate and ongoing indemnification.

1. Deed of Covenant (indemnity)
   - This document would be registered on the certificate of title and run with the land. It would specify the terms of indemnity.
2. Subject to claim caveat
   - This document is used to prevent the registration of instruments in relation to the land except those that are expressed to be subject to the caveator's claim. It charges the property in question of its obligations under the deed of covenant to create a caveatable interest on the part of the Shire. It would permit the Shire to retain access to the deed of covenant.
3. Section 70A notification

- A Section 70A notification could be used to alert prospective purchasers to the risk of coastal processes on the property.

4. Condition of Planning Approval
- A condition of planning approval would run with the land and could potentially require the landowner to indemnify the local government.

5. Public Liability Insurance
- Public liability insurance may need to be maintained by a developer where a structure such as a seawall is proposed on public land, such as within the coastal foreshore reserve.

The Shire has been advised to seek legal advice as to whether indemnification can be adequately secured in relation to risk from coastal processes as this issue has not been adequately tested or resolved through the legal system.

In consideration of the lack of clarity around the legal position of indemnification of local governments in relation to coastal processes, the adaptation approaches taken in this document do not specifically require private landowner to indemnify the local government, however this will ultimately be left to the discretion of the Shire on a case by case basis.

In Section 6 of the CHRMAP as part of adaptation approaches, Section 70A notifications are recommended to be placed on the titles of all lots at risk of coastal processes as a condition of planning approval, and this is an accepted practice recognised within SPP 2.6. However, it is noted that the Section 70A notification will only alert prospective purchasers to the risk of coastal processes affecting the use and enjoyment of the land and will not indemnify local government on its own.

3 Identification of Coastal Hazard Risk

3.1 Vulnerability Assessment

The Broome Coastal Vulnerability Study (CVS, Cardno 2015) was completed for the Shire to identify coastal hazard for the Broome townsite. This is a key document that underpins the CHRMAP process and was completed under the guidelines of the Western Australian Planning Commission State Planning Policy No. 2.6 - State Coastal Planning Policy (SPP2.6, WAPC 2013).

SPP2.6, provides policy on the determination of an appropriate foreshore reserve, which acts as a coastal buffer to accommodate coastal processes as a result of coastal erosion and risk or storm surge inundation in future planning periods. The coastal buffer distance should be sufficient to ensure a coastal foreshore reserve is maintained should the physical processes be realised over the planning timeframe (Section 8 of SPP2.6). Physical processes acting on the coast are considered through the following:

- The coastal processes allowance is the sum of the current risk of storm erosion (S1), historical rate of shoreline change (S2), the allowance for erosion caused by future sea level rise (S3) and an uncertainty allowance of 0.2m/yr.
- Allowance for the risk of storm surge inundation (S4) based on ocean forces and coastal processes that have a 0.2 percent or one-in-five hundred probability of being equalled or exceeded in any given year (500-yr ARI). The current risk of inundation should be the maximum extent of storm inundation, defined as the peak steady water level plus wave run-up and include future sea level rise.

The CVS was managed by a steering committee with representatives from the Shire, Department of Transport (DoT), Department of Planning (DoP) and Department of Water (DoW), and was received by the Shire of Broome in June 2016.

The CVS provides a detailed assessment of the potential impacts to the Broome Township as a result of coastal erosion (immediate storm impact, long term recession / accretion and sea level rise) and inundation as a result of catchment flooding and storm surge (including assessment of nearshore processes such as wave setup and wave run-up).

Forecast impacts to Broome's coastal areas were assessed for a range of planning periods – present day, 2040, 2070 and 2110.

The CVS was comprised of a number of specialist studies as follows:

- Storm tide and coastal inundation assessment;
- Hydraulic Assessment;
- Hydro-geological assessment (not to be used in preparation of the CHRMAP); and
- Shoreline Stability assessment

The final outcomes of the CVS are summarised in mapping sets indicating projected coastal impacts for the present day, 2040, 2070 and 2110 showing:

- Coastal processes allowance to provide a suitable foreshore reserve for the risk of coastal erosion from:
  - S1: current storms;
  - S2: Historical shoreline movement; and
  - S3: Future sea level rise.
- Coastal inundation extents as a result of combined storm surge and catchment flooding (S4)

3.2 Planning Timeframe / Climate Change Scenarios

The planning timeframes that were investigated in the CVS and that will inform the CHRMAP are listed on Table 2.1. The adopted sea level rise values (DoT 2010), coastal erosion allowance factors and inundation scenarios provided in the CVS cases are provided for reference.

Table 3.1: CHRMAP Planning Scenarios

Planning Timeframe	Sea Level Rise (SLR)	Coastal Erosion Allowance (SPP 2.6 Recommendations)	Inundation Scenarios, Average Recurrence Interval (ARI)*
Current	0m	Sum of the Following: • S1: Storm Erosion • S2: Annual Change x Yrs Since 2010 • S3: SLR x 100 • 0.2m x Yrs Since 2010	10yr, 50yr, 100yr, 200yr, 500yr
2040	0.15m		
2070	0.4m		
2110	0.9m		

* Results are based on coupled catchment and ocean inundation cases. For example, the 100 year ARI inundation map is composed of the following two scenarios:

1. Coupled 100 year ARI catchment with 10 year ARI ocean inundation
2. Coupled 100 year ARI ocean inundation with 10 year ARI catchment inundation

Results from these two simulations are analysed in a GIS system and overlaid. At each grid point the higher of the two is identified and this becomes the '100 year inundation' level for that grid point.

3.3 Vulnerability Study Key Data Sets and Design Criteria

3.3.1 Survey Data

LiDAR was flown as part of the CVS at low tide on 24th August 2013. The LiDAR was applied in the numerical models, and described all land areas in the study region and the nearshore coastal areas to approximately -5m AHD as shown on Figure 3.1.

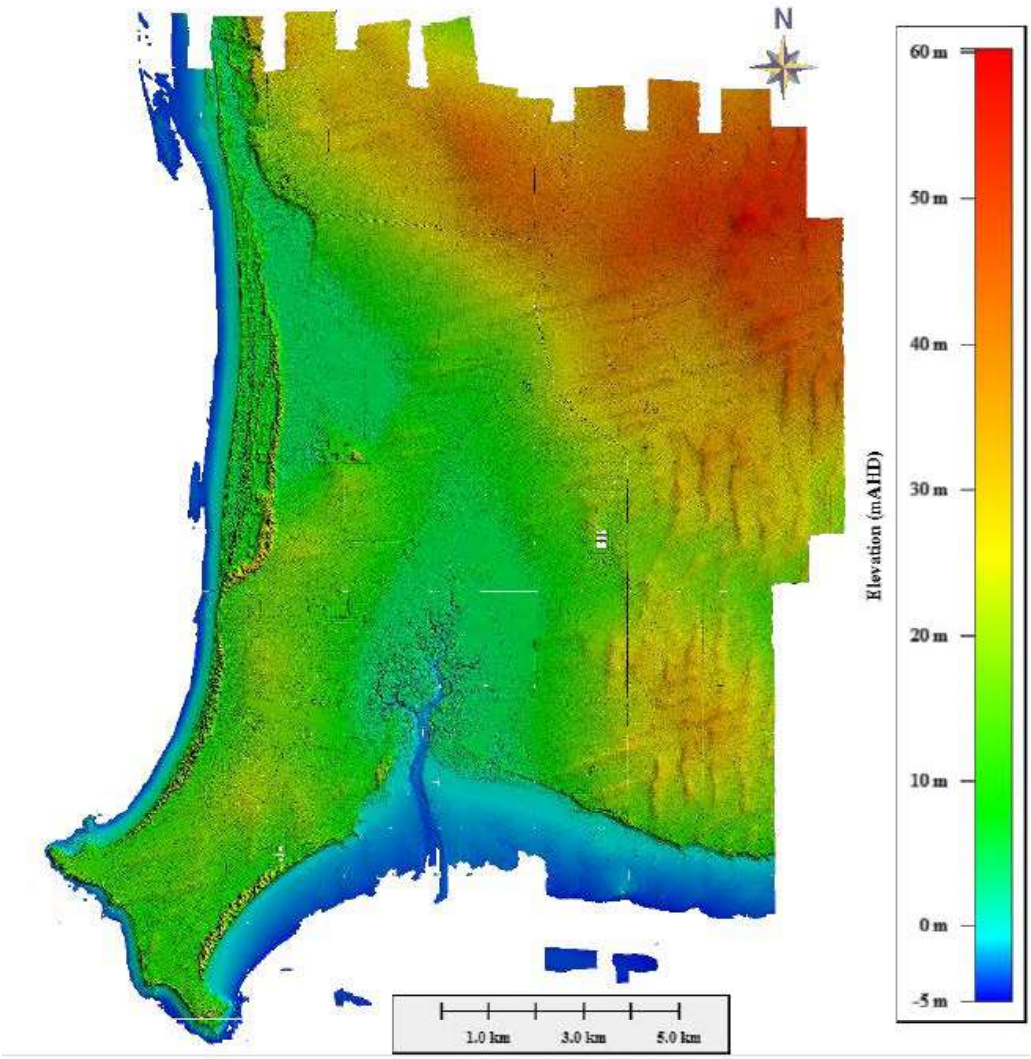


Figure 3.1: LiDAR Survey Data Collected for the Study Area

3.3.2 Climate and Oceanography

Broome's has a large tide range ('macrotidal') with a typical spring-tidal range of 8 m and a typical neap tidal range of 2 m. The largest spring tidal ranges can reach 9 m and the highest tides of each year can reach over 10 m LAT. Table 3.2 summarises the tidal planes at Broome. The tides are semidiurnal, with high tide occurring twice daily. Tides are a major factor in the coastal environment because they increase the range of shoreface affected by wave and current action. Significant tidal currents also affect the propagation, refraction and dissipation of waves within the coastal zone (Cardno, 2015).

Table 3.2: Tidal Planes For Broome

Tidal Level	Chart Datum (m CD)	Australian Height Datum (m AHD)
Highest Astronomical Tide (HAT)	10.56	5.24
Mean High Water Springs (MHWS)	9.28	3.96
Mean High Water Neaps (MHWN)	6.32	1.00
Mean Sea Level (MSL)	5.41	0.09
Australian Height Datum (AHD)	5.32	0.00
Mean Low Water Neaps (MLWN)	4.51	-0.81
Mean Low Water Springs (MLWS)	1.54	-3.84
Chart Datum (LAT)	0	-5.32

Broome experiences a tropical climate with a distinct wet and dry seasonality, with the wet season dominated by monsoon processes and tropical cyclones. Annual average rainfall is about 600 mm, occurring mostly between November and April. The majority of cyclones affecting the region pass to the north and west of Broome, with winds causing north-west and westerly swells to propagate to Cable Beach. Roebuck Bay is more exposed to less frequently occurring cyclones that pass to the east or south, causing winds and waves that approach from the south-west quadrant.

During most of the year, the Broome coast is subject to a refracted westerly swell that originates in the roaring 40's and the south-east trade wind belt of the Indian Ocean. In winter the swell is low to moderate and in summer it is low. During winter when south-east winds dominate, the south and east facing shores in Roebuck Bay are subjected to wave activity. In summer, under the influence of the north-west monsoons and occasional thunderstorms, waves from the north and northwest are more common and affect west and north facing shorelines.

3.3.3 Water Level

The CVS considered physical water level processes affecting the study area over the short, medium and long term as follows:

- Short Term (days): tides, cyclonic events, storm surge, wind driven currents and cyclonic waves
- Medium Term (months to years): seasonal and inter-annual water level variability due to southern hemisphere monsoons, tidal modulations and ENSO (El Nino Southern Oscillation)
- Long Term: Inter-decadal oscillations and long term trends in sea level (i.e., sea level rise)

Based on the current WAPC guidelines (WAPC 2013) and DoT recommendations (DoT 2010), the sea level rise adopted for planning periods in the CHRMAP are as shown in Table 3.3.

Table 3.3: Sea Level Rise for Planning Periods in CHRMAP

Scenario	2040	2070	2110
Sea Level Rise	0.15m	0.40m	0.90m

The CVS analysed the measured water levels from the Broome Wharf tide gauge to produce return period estimates of water level up to the 100 year ARI, with subsequent higher ARI values calculated based on Monte-Carlo modelling of synthetic storms. The water level design criteria determined in the CVS for Broome are summarised in Table 3.4.

Table 3.4: Design Water Level Criteria for Planning Periods in CHRMAP (CVS)

ARI	Water Level (m AHD) Present Day	Water Level (m AHD) 2040	Water Level (m AHD) 2070	Water Level (m AHD) 2110
1	5.04	5.19	5.44	5.94
10	5.26	5.41	5.66	6.16
50	5.36	5.51	5.76	6.26
100	5.39	5.57	5.86	6.39
200	5.41	5.61	5.95	6.51
500	5.48	5.70	6.05	6.63

For each scenario in Table 3.4, the allowance for wave setup at the shore should be added as shown in Table 3.5 depending on the shoreline location.

Table 3.5: Wave Setup Allowance (CVS)

ARI	Open Coast, Cable Beach	Roebuck Bay and Dampier Creek
1	0	0
10	0	0
50	0.1	0.1
100	0.3	0.2
200	0.35	0.3
500	0.4	0.4

3.3.4 Wind and Waves

Based on review of the potential future changes in cyclone climatology, cyclonic wind fields for planning periods in the CHRMAP have incorporated an increase in cyclone intensity (increase in wind speed compared with the present day condition) as shown in Table 3.6. Cyclone frequency was unchanged.

Table 3.6: Cyclone Intensity increase for Planning Periods in CHRMAP

Scenario	2040	2070	2110
Wind Speed Increase	3%	6%	10%

Wave conditions for the Broome study area were reported in the CVS at the 100-yr ARI level for two offshore locations - the exposed Cable Beach site and the relatively protected Roebuck Bay area. Offshore wave height, beach type and the resultant wave setup values for the design 100-yr ARI storm event are shown on Table 3.7 for Cable Beach and Roebuck Bay. Beach type is based on the Iribarren number and wave setup is based on empirical methods (Stockton et al 2006).

Table 3.7: Design Wave Conditions for Cable Beach and Roebuck Bay

Coastline Section	Beach Type	100-yr ARI Offshore Wave Height (H_{mo})	Wave Setup at the Shoreline (100-yr)
Cable Beach	Dissipative	7.32m	0.3m
Roebuck Bay	Intermediate	2.55m	0.2m

3.4 Exposure - Coastal Erosion Allowance Components

Coastal erosion allowances for the Broome shoreline were determined in the CVS based on the recommended approach from SPP2.6. The key components are discussed in this section.

3.4.1 Horizontal Setback Datum

The Horizontal Setback Datum (HSD) is used for coastal planning defining the point along the shoreline from which the coastal processes allowance is measured. The HSD is defined in SPP2.6 as “the seaward shoreline contour representing the peak steady water level under storm activity resulting from the one in one hundred year storm”.

The HSD incorporates an allowance for wave setup (as shown on Table 3.7) with the final contour level reported in the CVS as:

- 5.59 m AHD contour: Roebuck Bay beaches (Dampier Creek East, Town Beach)
- 5.69 m AHD contour: Entrance Point north through Cable Beach.

The Dampier Creek catchment will adopt the 5.59 m AHD contour.

3.4.2 Current Risk of Storm Erosion (S1)

The coastal erosion allowance from an extreme storm impacting the coast was assessed applying waves and water level conditions from a design storm consistent with the 100-yr ARI level, and adopting present sea level conditions, as recommended in SPP2.6. The numerical model SBEACH (Wise et al, 1995) was used to assess the beach and dune erosion under storm conditions.

3.4.3 Historical Changes to Shoreline Position (S2)

The historical rate of shoreline movement was assessed for the shoreline from available aerial data across the study area at roughly 10 year intervals from 1965 to 2012. Net shoreline movement and resultant annual average shoreline movement were calculated within each coastal compartment at transects spaced at approximately 50 m intervals along the shoreline of the study area.

3.4.4 Allowance for Sea Level Rise (S3)

Erosion caused by future sea level rise on a sandy coast is calculated at 100 times the adopted sea level rise value in the planning timeframe (Table 2.3). This approach takes no account of the landform and is considered conservative, with the CVS recommending a value in the range of 40 times the adopted sea level rise being more appropriate for Broome's macro-tidal environment and shoreline slope.

3.4.5 Allowance for Uncertainty

An uncertainty allowance of 0.2 m per year is factored into coastal processes allowances.

3.4.6 Summary: Coastal Processes Erosion Allowance

The summary coastal processes allowances for each of the coastal compartments assessed in the CVS are presented for the 2040, 2070 and 2110 planning periods in Table 3.8, Table 3.9 and Table 3.10.

The allowance is calculated under SPP2.6, and is a conservative estimate of the horizontal distance over which physical coastal processes could potentially impact the foreshore area in future planning periods. The coastal processes erosion allowance does not necessarily preclude future development. Areas identified as being at risk of coastal processes in future planning periods would need to consider coastal hazard risk through a CHRMAP process prior to new development being supported.

Table 3.8: Coastal Processes Erosion Allowance – 2040 Planning Period

Coastal Compartment	S1 (m)	S2 (m)	S3 (m)	Uncertainty (m)	Total 2040 (m)
Cable Beach (South)	47	0	15	6	**68**
Cable Beach (Central)	36	6	15	6	**63**
Cable Beach (North)	67	6	15	6	**94**
Gantheaume Cliffs	12	9	0	6	**27**
Reddell Beach	25	27	15	6	**73**
Entrance Point	21	9	15	6	**51**
Entrance Point (West of ramp)	21	12	15	6	**54**
Simpsons Beach (West)	9	5	15	6	**35**
Simpsons Beach (East)	14	5	15	6	**40**
Town Beach (South of Groyne)	7	0	15	6	**28**
Town Beach (North of Groyne)	30	9	15	6	**60**
Town Beach (North Pindan cliff)	9	9	15	6	**39**
Broome Central (Chinatown)[1]	5	9	15	6	**35**
Dampier Creek Inner[1]	5	9	15	6	**35**
Dampier Creek East	5	0	15	6	**26**

1. Calculated by Baird (Baird 2016a)

Table 3.9: Coastal Processes Erosion Allowance – 2070 Planning Period

Coastal Compartment	S1 (m)	S2 (m)	S3 (m)	Uncertainty (m)	Total 2070 (m)
Cable Beach (South)	47	0	40	12	**99**
Cable Beach (Central)	36	12	40	12	**100**
Cable Beach (North)	67	12	40	12	**131**
Gantheaume Cliffs	12	18	0	12	**42**
Reddell Beach	25	54	40	12	**131**
Entrance Point	21	18	40	12	**91**
Entrance Point (West of ramp)	21	24	40	12	**97**
Simpsons Beach (West)	9	10	40	12	**70**
Simpsons Beach (East)	14	10	40	12	**75**
Town Beach (South of Groyne)	7	0	40	12	**59**
Town Beach (North of Groyne)	30	18	40	12	**100**
Town Beach (North Pindan cliff)	9	18	40	12	**79**
Broome Central (Chinatown)[1]	5	18	40	12	**75**
Dampier Creek Inner[1]	5	18	40	12	**75**
Dampier Creek East	5	0	40	12	**57**

1. Calculated by Baird (Baird 2016a)

Table 3.10: Coastal Processes Erosion Allowance – 2110 Planning Period

Coastal Compartment	S1 (m)	S2 (m)	S3 (m)	Uncertainty (m)	Total 2110 (m)
Cable Beach (South)	47	0	90	20	**157**
Cable Beach (Central)	36	20	90	20	**166**
Cable Beach (North)	67	20	90	20	**197**
Gantheaume Cliffs	12	30	0	20	**62**
Reddell Beach	25	90	90	20	**225**
Entrance Point	21	30	90	20	**161**
Entrance Point (West of ramp)	21	40	90	20	**171**
Simpsons Beach (West)	9	15	90	20	**134**
Simpsons Beach (East)	14	15	90	20	**139**
Town Beach (South of Groyne)	7	0	90	20	**117**
Town Beach (North of Groyne)	30	30	90	20	**170**
Town Beach (North Pindan cliff)	9	30	90	20	**149**
Broome Central (Chinatown)[1]	5	30	90	20	**144**
Dampier Creek Inner[1]	5	30	90	20	**144**
Dampier Creek East	5	0	90	20	**115**

1. Calculated by Baird (Baird 2016a)

3.5 Exposure – Inundation

3.5.1 Inundation Model Grid Size

The coastal inundation model applied in the CVS to describe the extent of coastal and catchment flooding and covers the entire study area, with varying resolution across the land and ocean areas. For the land areas, the catchment based flooding is assessed on a 4 m grid size (ie 4m x 4m). For the Dampier Creek region, the model grid size is 8 m, whilst in the open coast and ocean areas the grid size is 24 m. The elevation and nearshore bathymetry levels in the numerical model were defined from the high resolution LiDAR data. An overview of the model grid size and topography is shown on Figure 3.2 from the CVS (Cardno 2015).

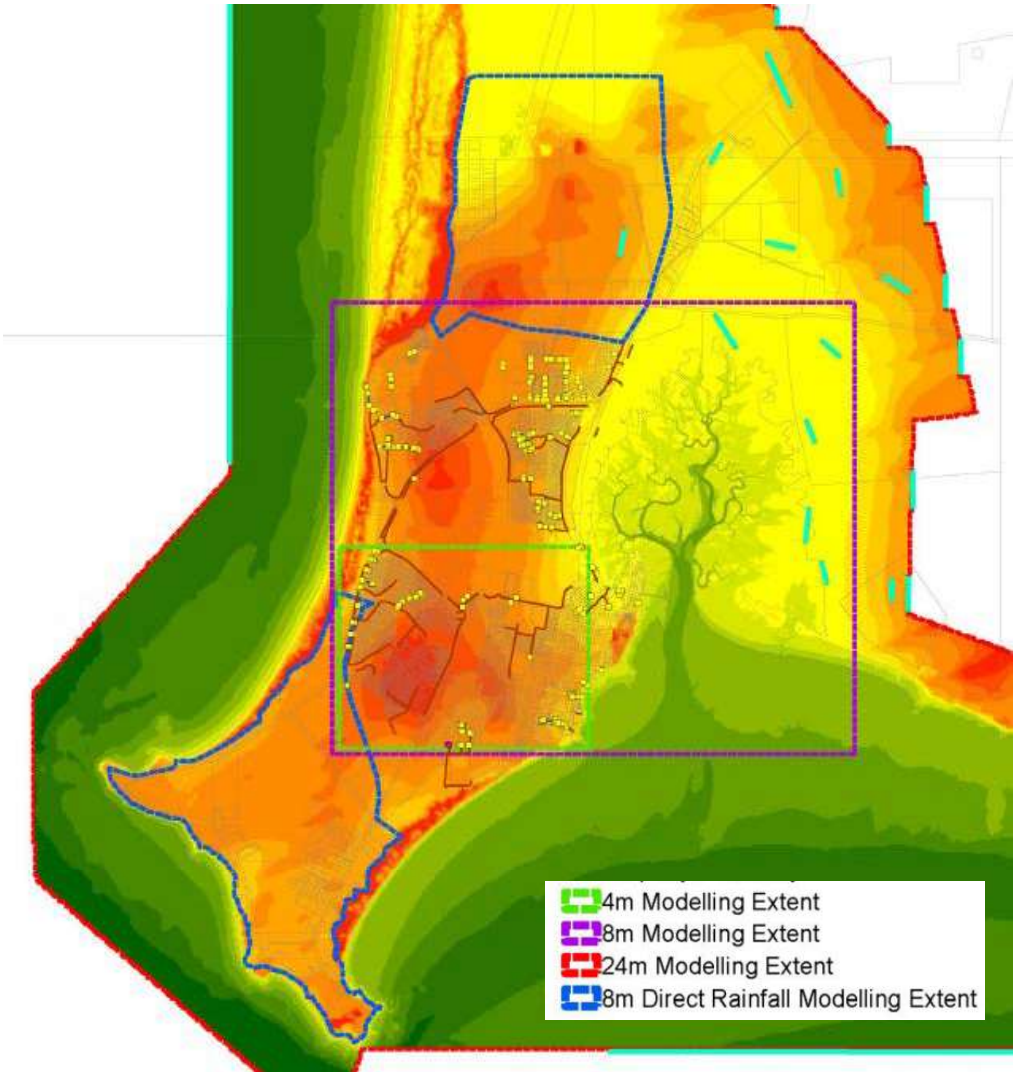


Figure 3.2: Numerical model grid size through the town site study area (Cardno 2015)

3.5.2 Numerical Model Cases

Cases are assessed with concurrent ocean inundation and catchment based flooding, with the peak storm surge inundation timed to coincide with peak catchment flows resulting from rainfall.

The mapping datasets have been provided from the CVS for application in the CHRMAP. The following model cases were provided for use in the CHRMAP:

- 10 yr, 50 yr, 100 yr, 200 yr, 500 yr ARI cases

The cases were made available for planning periods

- for present day, 2040, 2070, 2110

The mapping data represents the maximum inundation from either ocean or catchment flows explained by the following example (Cardno 2015):

"For the 100-year ARI inundation map as an example. It is composed of the following two scenarios:

1. *Coupled 100-year ARI catchment with 10 year ARI ocean inundation*
2. *Coupled 100-year ARI ocean inundation with 10 year ARI catchment inundation*

The results from these two simulations are brought into a GIS system and overlaid, at each grid point the higher of the two is identified and this becomes the 100-yr inundation level for that grid point ."

The maps include an allowance for wave setup (excluding runup) at the coast and this was applied to Dampier Creek. This is reasonable as it also allows for additional wind setup that may occur across Dampier Creek when fully inundated, a process which was not resolved by the hydraulic model (Cardno 2016).

The results of the Coastal Hazard Mapping are presented in Section 4.

3.6 Structures

3.6.1 Natural Defences

There are a number of *natural* defence mechanisms which are present in the Broome coastal areas:

- A barrier dune system provides a natural defence against coastal erosion for Cable Beach, Entrance Point, Simpsons Beach and parts of Town Beach. The dune is high enough to prevent coastal inundation of inland areas;
- The natural rock structure in the shoreline of Gantheaume Cliffs provides protection against coastal erosion and is high enough to prevent coastal inundation of inland areas;
- The extensive mangrove cover in the near shore areas of northern Town Beach and within Dampier Creek (Chinatown) play a vital role in attenuating storm surge and reducing the wave heights at the shoreline in extreme cyclonic events. Varying water depths and wave interaction with mangrove systems, and the additional friction provided by mangrove stands acts to attenuate waves, tidal water levels and storm surge water levels propagating through them (Baird 2015).
- Pindan cliffs at Reddell Beach, Town Beach and Entrance Point provide a degree of protection to the inland areas, however these are noted as significantly eroding in a number of locations (Cardno 2015)

3.6.2 Control Structures

3.6.2.1 Town Beach

At a number of locations along the Town Beach shoreline there are seawalls, groynes and rock placed in the coastal zone which do not fall under the control of the Shire. These have been noted:

- In front of Catalina's shoreline. Seawall engineered using quarry material, approximate construction date 1995 (Figure 3.3)
- In front of the Caravan Park (southern section) at the base of the cliff, there is rubble and rock material placed informally. A Groyne type structure has also been constructed in the shore from rock material (Figure 3.4)

These structures are not formally recognised in the SPP2.6 assessments for coastal erosion as they are not adopted council structures that the Shire has committed to maintaining in future planning periods. Based on discussions, the formalisation of these structures by the council is not supported at this time. It is recognised that these structures offer a degree of protection against erosion, however their future function is not assured over the planning period to 2110.

The old jetty area at Town Beach is a groyne structure which is all that remains of the towns original 19th century jetty structure. This groyne feature is composed of rubble material as shown on Figure 3.5.

3.6.2.2 Entrance Point

A number of structures around the port of Broome have been built for recreational and commercial purposes including:

- Two public boat ramps at entrance point
- On the Roebuck Bay side, rubble mound structures on either side of a boat launch ramp used by commercial vessels

3.6.2.3 Chinatown Structures

The Chinatown peninsula is surrounded on three sides by the mangrove lined foreshore of Dampier Creek. A number of hard structures are present in the eastern foreshore:

- A seawall / retaining wall structure in the section of shoreline adjacent Streeters Jetty is shown in Figure 3.6 and is severely degraded in a number of sections;
- To the south of Streeters Jetty, the seawall shown in Figure 3.7 built at the base of properties is in much better condition; and
- Further south in the foreshore, the seawall / retaining wall at the rear of Dampier Terrace properties is a retaining wall design in average condition. A number of drainage outlets are located in this section of the foreshore

At the rear of the Paspaley Shopping centre on the western side of the Chinatown peninsula the land has been reclaimed and the interface with Dampier Creek is shown on Figure 3.8.

Figure 3.3: Shoreline protection in front of Catalina's, Town Beach

Figure 3.4: Shoreline protection in front of Roebuck Bay Caravan Park, Town Beach. Upper left Mix of native and placed rock in the foreshore at base of cliff, Upper right and lower: groyne structure at midpoint of caravan park frontage made of old building material.

Figure 3.5: Old Broome Jetty Groyne Structure, Town Beach

Figure 3.6: Seawall / revetment in the Dampier Terrace shoreline north of Streeters Jetty

Figure 3.7: Seawall / revetment in the Dampier Terrace shoreline south of Streeters Jetty

Figure 3.8: Rear of Paspaley Shopping Centre, showing reclaimed land level at foreshore edge of Dampier creek

3.7 Sensitivity

The responsiveness of the natural defences around Broome to climate change has been examined in the CVS with the following highlighted:

- The low lying areas around Dampier Creek (eg Chinatown) are particularly vulnerable to sea level rise. This area is particularly susceptible to changes in ocean level and under a projected sea level rise scenario of 0.9m by 2110 the general tides would flood the Chinatown area.
- For the dune systems around the Broome coast, the increased ocean level as a result of sea level rise in future planning periods is projected to lead to an increased rate of erosion at the shoreline. This is addressed in SPP2.6 allowing a foreshore area of 90m over which coastal erosion may occur in the period to 2110. There is considerable uncertainty as to how the dune systems will respond to sea level rise and climate change factors, and this will require close monitoring to better understand this impact.

3.8 Adaptive Capacity

For the coastal areas, the natural defence mechanisms (dunes, mangroves, pindan cliffs) play a vital role in providing protection to the inland areas. The ability of these assets to respond to future pressures from external influences such as climate change is of key importance.

There is considerable uncertainty as to how climate change and sea level rise will affect the coastal dune systems, pindan cliffs and mangroves around Broome. Increasing the understanding of these areas and their response to climate change will be a key to building adaptive capacity for the future.

4 Coastal Hazard Mapping

4.1 Coastal Compartments

For the CHRMAP, the approximately 30 km of the Broome shoreline is assessed within nine coastal compartments which have been defined based on geomorphological characteristics, coastal processes and geographical locations of interest as follows:

1. Cable Beach
2. Gantheaume Cliffs
3. Reddell Beach
4. Entrance Point Beach
5. Simpsons Beach
6. Town Beach
7. Broome Town Centre
8. Dampier Creek Inner
9. Dampier Creek East

The coastal compartments are presented on Figure 4.1 and a brief outline of their characteristics is provided on Table 4.1.

Figure 4.1: Coastal Compartments for CHRMAP

Table 4.1: Characteristics of CHRMAP Coastal Compartments

Coastal Compartment	Coast Type	Shoreline Classification (SPP2.6)	Shoreline Description (CVS)
1. Cable Beach	Open Ocean	Sandy Coast	Sandy Coast. Wide beach backed by barrier dunes with topographic relief typically above 16 m AHD.
2. Gantheaume Cliffs	Open Ocean	Rock	Rock Cliffs. Composed of highly jointed and discontinuous rock cliffs, 12 to 14 m AHD overlain by Pindan sand.
3. Reddell Beach	Open Ocean	Mixed sandy and rocky	Fine sand overlaying outcrops of Broome sandstone. Backed by soft pindan cliffs interspersed with harder sandstone with topographic relief 12 to 14 m AHD.
4. Entrance Point	Open Ocean / Semi-Protected Embayment	Mixed sandy and rocky	Rocky promontory of resistant Broome formation overlain with Pindan sand. Topographic relief generally 12 to 14 m AHD.
5. Simpsons Beach	Semi-Protected Embayment	Mixed sandy and rocky	Pindan sand overlying harder cretaceous bedrock, backed by Pindan cliffs and vegetated sand dunes to 20 m AHD south and lowering to 12 m AHD on eastern side.
6. Town Beach	Semi-Protected Embayment	Mixed sandy and rocky.	Large rock groyne at crest level approximately 6 m AHD, divides the beach. South of groyne a gently sloping sandy beach is present, with development areas on fore dune. North of groyne, sand and silt shoreline, beach face above MHWS is steeply sloping Pindan sand cliffs at 6 m to 8 m AHD. At the northern limit, narrow sandy beach fronted by significant mangrove assemblages .
7. Broome Town Centre	Semi-Protected Embayment, Fully-Protected Mangrove	Coastal lowlands	High dune on embayment side leading north into extensive mangroves which front onto narrow steep beaches. Various forms of coastal and flooding protection present along shoreline.
8. Dampier Creek Inner	Fully-Protected Mangrove	Coastal lowlands	Estuarine area with mangrove cover and extensive tidal flats.
9. Dampier Creek East	Fully-Protected Mangrove, Semi-Protected Embayment	Coastal lowlands, Mixed sandy and rocky.	Mangrove areas on the west, moving through low lying beach barrier dunes fronting estuarine areas heading to the east, with well vegetated Pindan sand cliffs overlying occasional crops of Broome formation sandstone

4.2 Coastal Hazard Summary by Coastal Compartment

A brief overview of the key coastal issues (erosion and / or inundation) that will affect the coastal compartments over the planning period to 2110 is provided in the following sections based on the CVS.

4.2.1 Cable Beach

Overview

The Cable Beach compartment covers approximately 10 km of coastline on the western side of the Broome township. The wide and flat dissipative beach is backed by high barrier dunes and is the most exposed of Broome's beaches to coastal processes. Locally generated sea conditions occur predominantly through the wet season, whilst the dry season delivers long range swell originating from deep in the Southern Ocean. The section of coast is particularly susceptible to impact from waves generated by cyclones that track close to Broome, and was significantly impacted by erosion as a result of elevated water levels and waves generated during Cyclone Rosita in 2000. Cable Beach is a major focus for locals and tourists, with significant Shire infrastructure, community facilities, commercial and residential development.

Key Findings from CVS

Within the Cable Beach coastal compartment, three sections are considered based on the CVS outcomes: north, central and south. The Central section includes the main public access and parking facilities for Cable Beach, centred around commercial and community interests including the Cable Beach Club Resort, Zanders Café and the Surf Club. Within the Central section, there is significant development and infrastructure within the foreshore reserve. North and south of this central section, the extensive coastal foreshore area is essentially undeveloped dune system.

Findings from the CVS for the Cable Beach coastal compartment are summarised as

- The current risk of storm erosion identified in the CVS for the Cable Beach compartment was 67 m in the northern section, 36 m in the central section and 47 m in the south. It is noted that these outcomes are based on adopting a number of conservative assumptions including:
    1. The distances represent the highest impacts modelled from a total of 13 SBEACH transects through the entire coastal compartment, and vegetation is not included in the assessment which would offer a degree of protection in design events.
    2. The median sediment size adopted and modelled in SBEACH was 0.15 mm, which would lead to a more conservative (ie worse) outcome than adopting a coarser sediment size. A range of sediment sizes were reported for Cable Beach in the CVS, with median sediment size of 0.26 mm reported at the shore at the base of the dune near Zanders Café during sampling undertaken in the CVS
- The historical shoreline movement was assessed in the CVS through analysis of aerial imagery for Cable Beach over the period 1965 to 2012, supported by available literature and SPP2.6 methods. Based on the approximately 50 years of data, the study recommended the northern sector was effectively stable (0 m/yr), whilst for the central and southern sections of the compartment, erosion of 0.2 m/yr be adopted.

- Recovery of the dune system in the region of Zanders Café following significant erosion during Cyclone Rosita in 2000 has not occurred. Similar sections of the dunes to the north and south have shown measured accretion and recovery in the intervening years.
- For the Cable Beach coastal compartment, the threat from storm surge inundation as a result of the design 500-yr ARI event is negated by the high relief offered by the barrier dunes fronting the shoreline. The ability of the dune system to withstand the design storm (500 yr-ARI in 2110) was undertaken in the CVS based on SPP2.6 recommendations for cross sectional area above the design water level, and for the entire length of Cable Beach the system was reported to offer sufficient protection for the future.

Coastal Issues for CHRMAP

Coastal inundation as a result of storm surge will not impact the land areas within the Cable Beach compartment in current or future planning periods, as the high relief of the coastal dune system provides adequate protection from elevated water levels.

The key coastal risk for the Cable Beach coastal compartment will be from coastal erosion, with the Central section of the compartment the main area of this focus. Coastal processes allowances recommended in the CVS for future planning periods are presented graphically in Figure 4.2.

The Central section includes the main access point and focus of tourist activity for Cable Beach, which includes Zanders Café, the Cable Beach Club Resort, the Surf Club and significant Shire infrastructure including car parks, roads and beach access. Current and future risk from coastal erosion required through the CHRMAP is summarised as follows:

- The current risk posed from a 1 in 100-year storm impacting the coast is significant along the shoreline, with predicted coastal erosion associated with this event denoted by the 'Present Day Storm Erosion (2015)' line on Figure 4.2. This type of event could result in approximately 30 m of the coastal dune on which the present foreshore is sited being lost, with shoreline erosion back to the point of Zanders Café and the Surf Club. Shire infrastructure including beach access, coastal pathways, foreshore reserve and landscaping would all be severely impacted or lost in this event.
- For the 2040 planning period, with the inclusion of the sea level rise and historical rate of shoreline recession, the coastal processes allowance line moves a further 30 m landward. Under this scenario the potential for shoreline erosion is landward of Zanders Café and the Surf Club, and the present foreshore public open space areas. The main carpark would be partially at risk of erosion as would the beach access road.
- For the 2070 planning period, the coastal processes allowance line extends across most of the main carpark and is within the northwest boundary of the Cable Beach Club Resort.
- For 2110 the coastal processes line is 66m further landward predominantly due to sea level rise allowance. Under this scenario the potential for shoreline erosion encompasses the majority of the present day foreshore area, and extends to the main entrance of Cable Beach Club Resort.

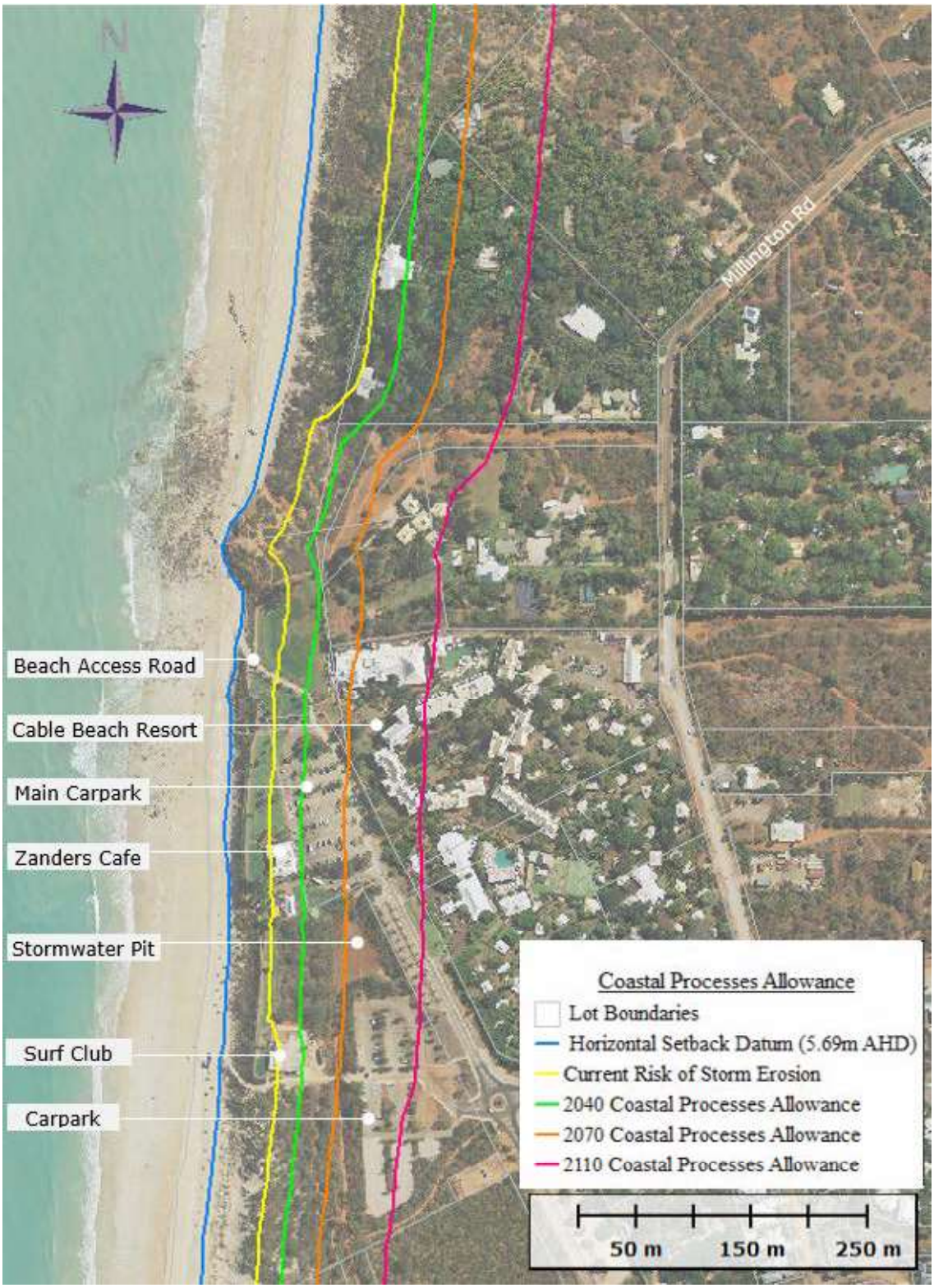


Figure 4.2: Cable Beach Coastal Compartment (Central) showing coastal processes erosion allowances recommended for future planning periods

For the northern area of the Cable Beach coastal unit shown on Figure 4.3, the foreshore reserve is sufficient to allow for the future coastal processes allowances to 2110. In this area, monitoring the stability of the dune system and shoreline erosion processes in the future will be important.

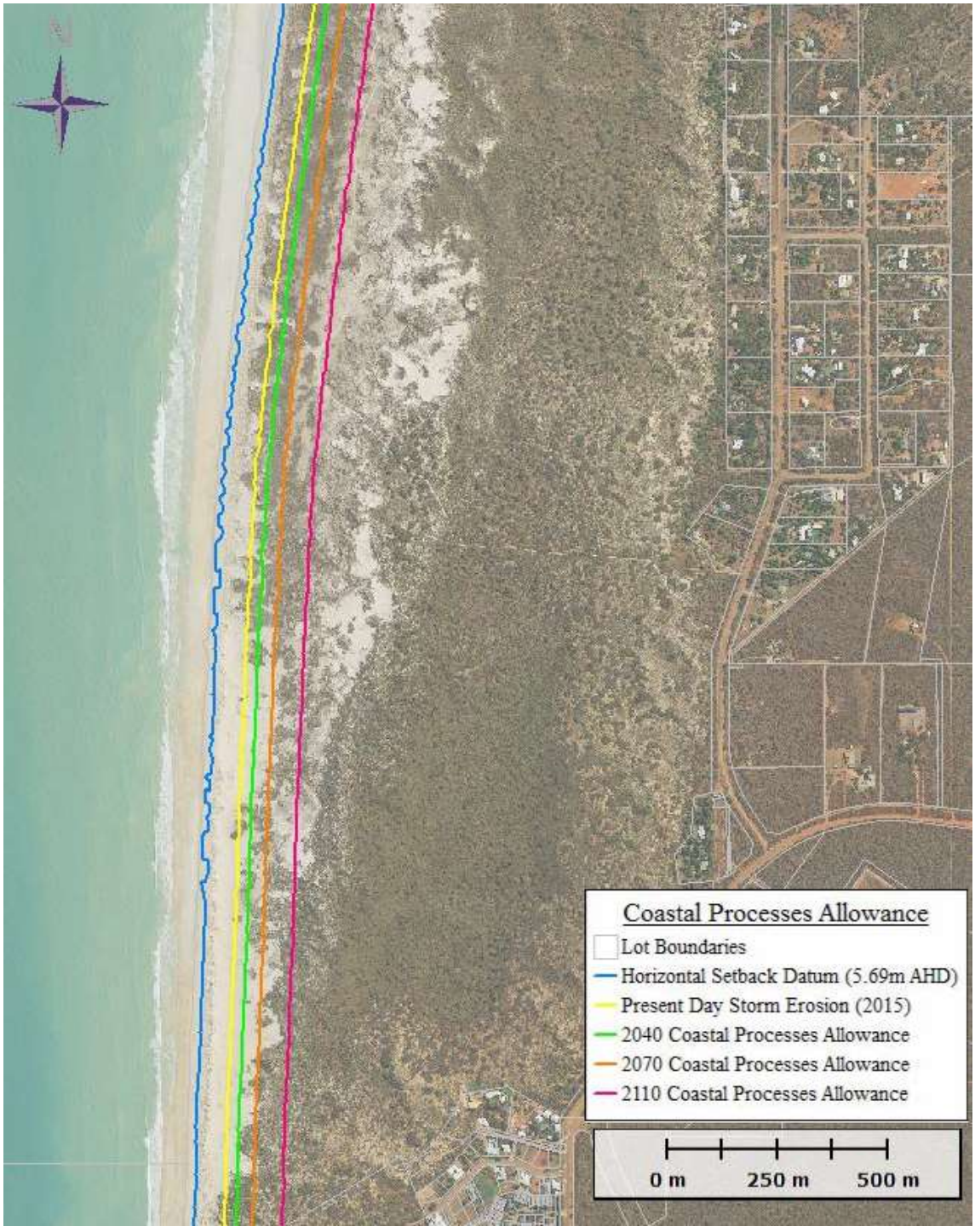


Figure 4.3: Cable Beach Coastal Compartment (North) showing coastal processes erosion allowances recommended for future planning periods

For the majority of the southern section of the Cable Beach coastal unit, the foreshore reserve is sufficient to allow for the future coastal processes to 2110. Figure 4.4 shows the largely undeveloped section of coast directly below the central Cable Beach section, with development areas and roads sited landward of coastal erosion processes forecast in future planning periods out to 2110.

Figure 4.4: Cable Beach Coastal Compartment (South, upper) showing coastal processes erosion allowances recommended for future planning periods

The southern end of the Cable Beach coastal compartment is shown on Figure 4.5. The coastal processes allowance line crosses Gantheaume Point Road in future planning periods from 2040 onwards. The 2110 line encroaches on the north-eastern edge of the Broome Turf Club racetrack.

Figure 4.5: Cable Beach Coastal Compartment (South, lower) showing coastal processes erosion allowances recommended for future planning periods

4.2.2 Gantheaume Cliffs

Overview

The Gantheaume Cliffs section of coast is unique in the CHRMAP study area as the only section of shoreline composed entirely of rock cliffs. The rock formations of the coastline are overlain by Pindan Sands with topography ranging from 12 m to 14 m AHD.

Key findings from CVS

The height of the rock around the Gantheaume Cliffs shoreline is sufficient to protect the coast from inundation as a result of storm surge associated with design storms in future planning periods. More

importantly, the rock provides a significant barrier to coastal erosion processes and is assessed with special consideration under SPP2.6 for current erosion risk (S1) and sea level rise (S3) components. This results in comparatively lower coastal processes allowances required for future planning periods when compared with other coastal compartments. The coastal processes allowances for the future planning periods are presented on Figure 4.6.

Coastal Issues for CHRMAP

The Broome turf club occupies much of the landward side of the coastal compartment, and is sited behind the coastal processes allowance lines for future planning periods to 2110. The lighthouse and cottage are behind the 2110 coastal processes line. The section of Kavite Road on the southern side of Gantheaume Point lies between the 2040 and 2070 coastal processes line.

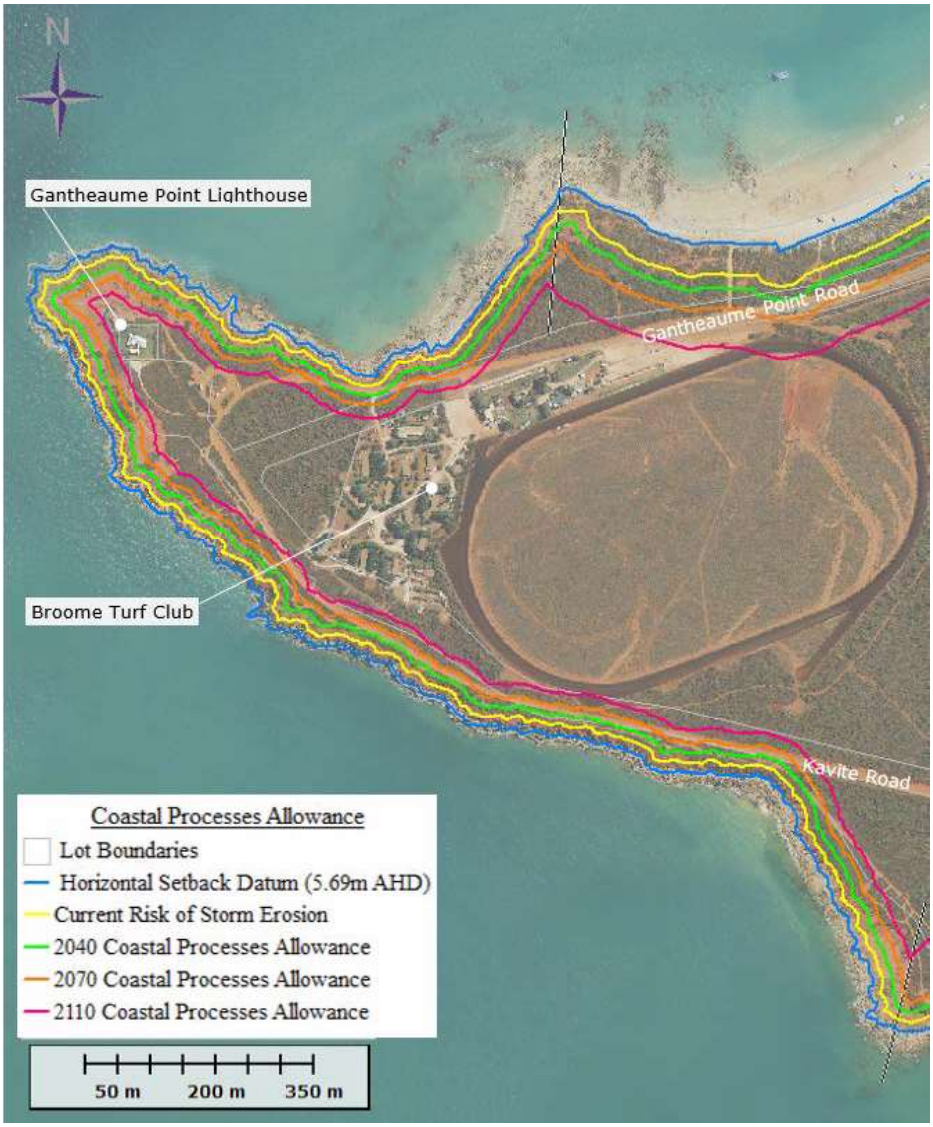


Figure 4.6: Gantheaume Cliffs Compartment showing coastal processes erosion allowances recommended for future planning periods

4.2.3 Reddell Beach

Overview

The Reddell Beach compartment is composed of steep Pindan cliffs fronting directly onto a flat and broad beach where marine sediments overlay outcrops of Broome sandstone. The westerly aspect of the beach makes it particularly susceptible to erosion during high water levels combined with westerly waves.

Key findings from CVS

The height of the Pindan cliffs is generally 12 m to 14 m AHD which is sufficient to protect the coast from inundation as a result of storm surge associated with design storms in future planning periods. The long term resilience of the Pindan cliffs is uncertain under higher water levels associated with cyclonic events and future sea level rise.

Analysis of the approximately 50 years of aerial imagery available from Reddell Beach, indicate an average rate of recession of the cliff face of 0.1 – 0.35 m annually. For the northern section of the compartment, the shoreline was found to have retreated 11 m between 2000 and 2012, (0.9 m/yr) and this section is recommended for reassessment in the next five years to determine if this accelerated rate continues to be observed. In keeping with SPP2.6 precautionary principle approach, the 0.9 m annual recession rate has been adopted for the entire compartment for future planning periods (S2 component). The coastal processes allowances for the future planning periods are presented on Figure 4.7.

Coastal Issues for CHRMAP

The properties located on the western side of Kavite Road are inside the coastal processes allowance for the present day to 2040. The southern section of Kavite Road in the Reddell Beach compartment is impacted by the coastal processes allowance between 2040 and 2070.

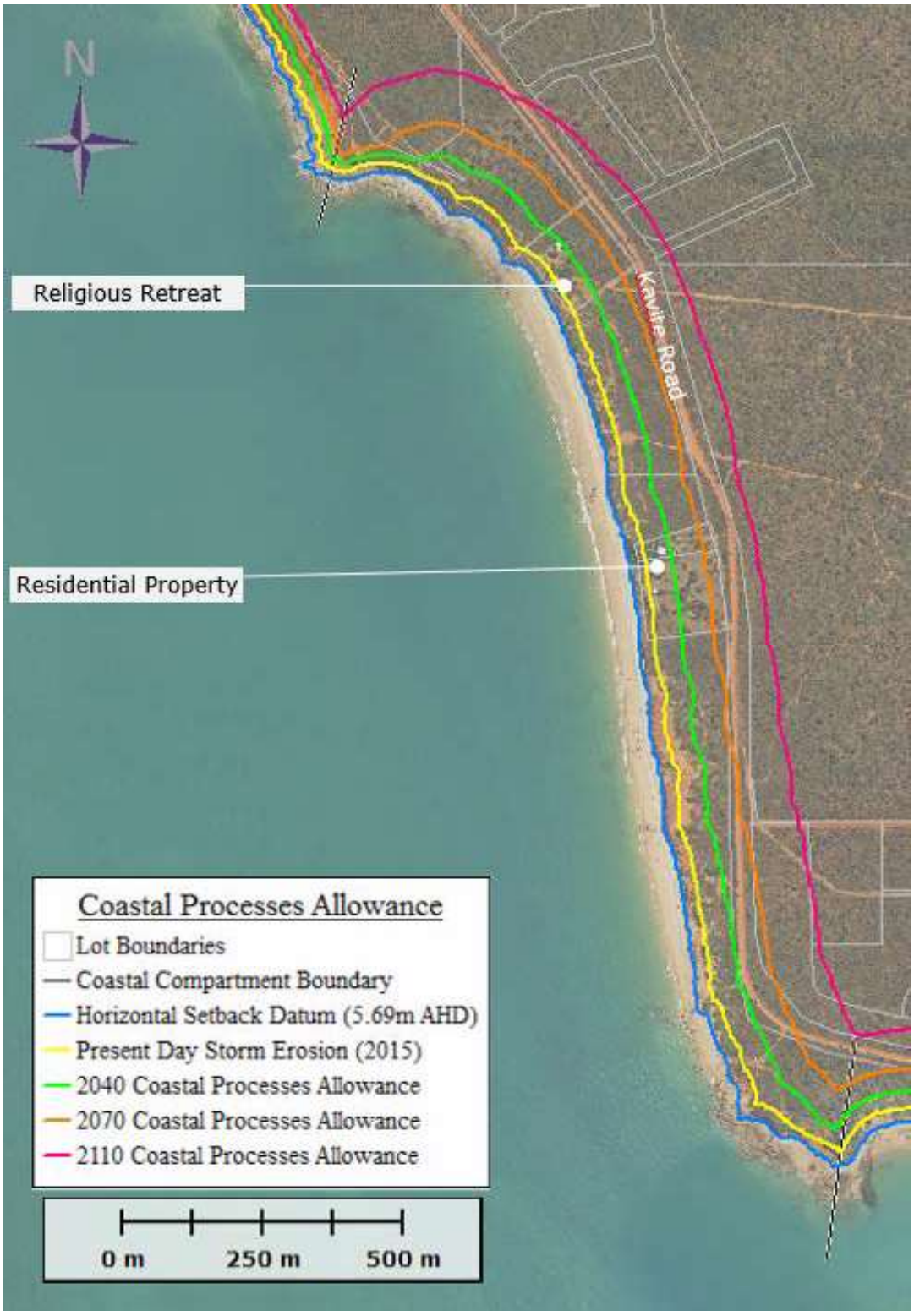


Figure 4.7: Reddell Beach Compartment showing coastal processes erosion allowances recommended for future planning periods

4.2.4 Entrance Point

Overview

The Entrance Point compartment covers a range of shoreline types around an elevated promontory which provides three differently aligned shorelines, southwest, southeast and northeast. The shorelines are generally sandy and backed by cliffs with topography in the range of 12 m to 14 m AHD. In the section of the shoreline from Entrance Point around to the northeast end of the compartment, a number of structures have been built to support the Broome Wharf, and two boat launching locations where associated facilities have been constructed.

Key findings from CVS

The height of the promontory on which the Entrance Point compartment is located is sufficient to protect the coast from inundation as a result of storm surge associated with design storms in future planning periods. The long term resilience of the Pindan cliffs is uncertain, under higher water levels associated with cyclonic events and future sea level rise and hence monitoring the future rate of erosion through this section of the coast is recommended.

Of note the current erosion allowance for the design storm (S1) component in the CVS has been determined based on an SBEACH profile on the western shoreline which resulted in 21 m erosion. The natural and man-made rock armouring of the shorelines on the southeast and northeast of the compartment has not been recognised in the assessment, and as such the adoption of 21 m applied throughout the compartment regardless of shoreline characteristics will be reviewed in the CHRMAP.

The historical rates of erosion are largely controlled by the mechanical resilience of the cliff face material, with average annual rates of erosion at 0.3 m/yr on the eastern side and 0.4 m on the western side of the boat ramp (S2). Modification of the shoreline as a result of construction and reclaimation has resulted in some localised erosion, as well as regions of newly created shore, and these were omitted from the overall long term shoreline assessment. The coastal processes allowances for the future planning periods are presented on Figure 4.8 for the western shoreline and on Figure 4.9 for the south-eastern and north-eastern shoreline.

Coastal Issues for CHRMAP

The coastal processes allowance for the shoreline on the western side of the Entrance Point compartment is located adjacent commercial properties in the 2070 to 2110 planning period. The section of Kavite Rd at the northwest of the compartment is located between the 2040 and 2070 coastal processes line.

The infrastructure along the coastline of the southeast facing section of the coastal compartment is highlighted as being at potential risk of coastal erosion in the immediate term to 2040. This section of the coast includes the Entrance Point boat ramps and carpark which lie seaward of the 2040 coastal processes line defined in the CVS. By 2070 coastal processes allowance is indicated landward of Kabbarli Road.

For the north-east facing section of the coastal compartment above the Broome wharf, the jetty and carpark are at risk of coastal processes in the current to 2040 period. The current risk of storm erosion indicated for the section of coast from the CVS is considered very unlikely, given the protected location of the site in Roebuck Bay and the armouring of the shoreline (natural and man-made). The 2040 coastal

processes allowance line is just seaward of Port Drive, but landward of structures including the Wharf Restaurant and Customs (Port of Pearls House).

Figure 4.8: Entrance Point Compartment (west side) showing coastal processes erosion allowances recommended for future planning periods

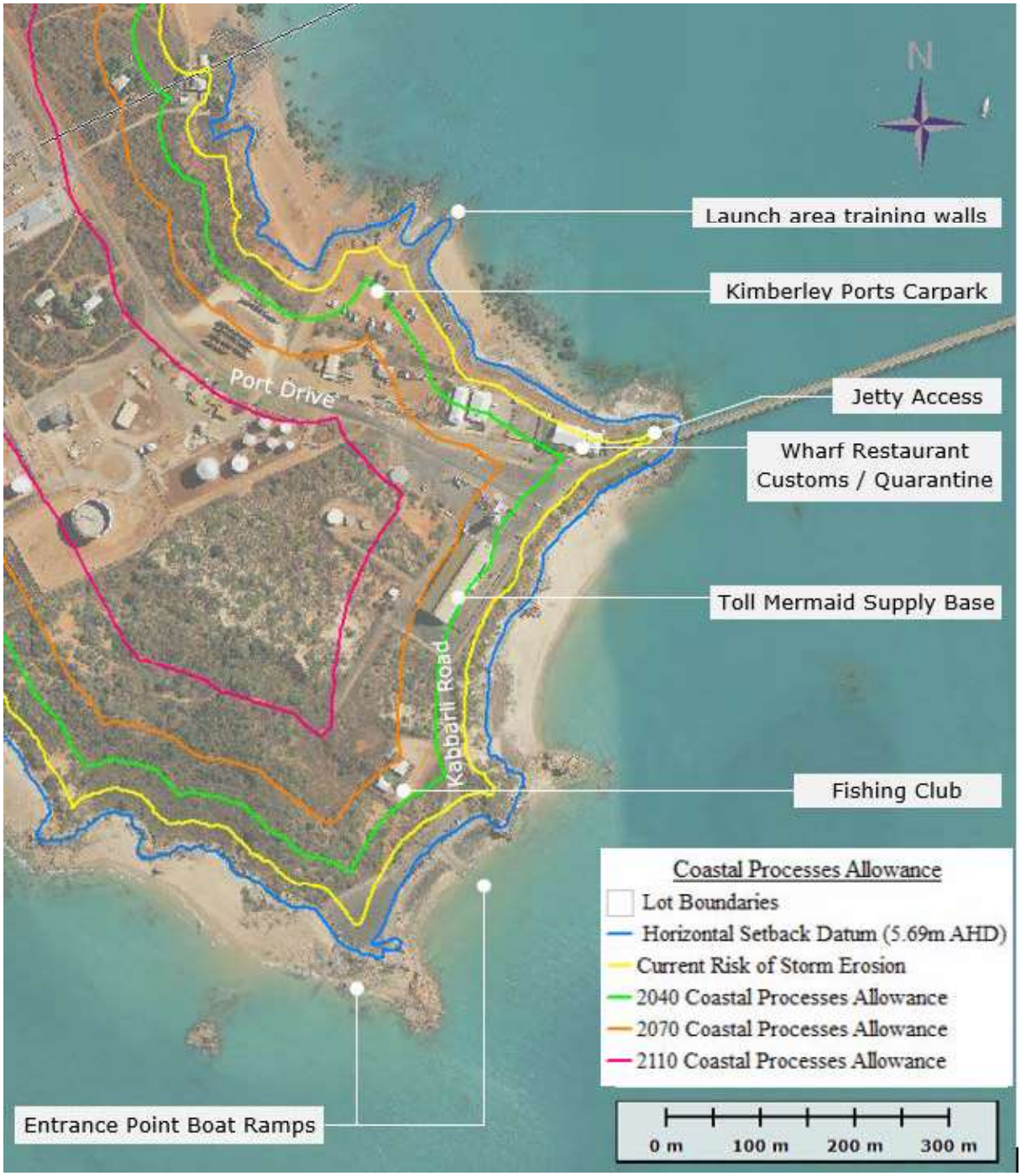


Figure 4.9: Entrance Point Compartment (east side) showing coastal processes erosion allowances recommended for future planning periods

4.2.5 Simpsons Beach

Overview

The Simpsons Beach compartment is a largely undeveloped shoreline backed by Pindan cliffs and vegetated sand dunes overlain by windblown sand. There is topographic relief at a minimum 12-14 m AHD along the compartment and the shoreline is sheltered by the Entrance Point promontory, particularly in the southernmost section where some mangrove colonisation is evident.

Key findings from CVS

The height of the cliffs protects inland areas of the coast from inundation as a result of storm surge associated with design storms in future planning periods. The shoreline is reasonably stable with annual average of 0.15 m/yr erosion based on analysis of the historical aerial data. The coastal processes allowances for the future planning periods are presented on Figure 4.10.

Coastal Issues for CHRMAP

The section of coast is largely undeveloped and existing infrastructure is located landward of the coastal processes allowance line at the 2110 planning period. The waste water treatment ponds are just landward of the 2110 coastal processes allowance line.

Figure 4.10: Simpsons Beach Compartment showing coastal processes erosion allowances recommended for future planning periods

4.2.6 Town Beach

Overview

The Town Beach compartment is significantly developed and comprises residential and commercial properties, community parks, roads and carparks located in close proximity to the shoreline. A groyne structure is located midway along the compartment at the site of the original Broome Jetty (1896). The beaches face Roebuck Bay and are largely protected from significant wave action during ambient conditions, but can be subject to erosion in cyclone events. The topography of the dunes gradually falls through this area from a height of 12m AHD at the south-western edge to approximately 6m AHD at the

north-eastern boundary. At the northernmost section of the compartment, mangrove assemblages are present along the shoreline.

It is noted the coastal foreshore area has undergone significant modification in the past 50 years. Photos of the section of Town Beach south of the old Broome Jetty area to Demco Street in the period 1965 to 1995 show the expansion of the caravan park over the foreshore dune system (Figure 4.11). This section of coast which once acted as a coastal dune buffer, has now been incorporated into the expanded caravan park site.

Key findings from CVS

The coastal dune is largely sufficient to protect the inland areas of the coast from inundation as a result of storm surge associated with design storms in future planning periods. Some flooding of areas adjacent the Catalina's development and at the Town Beach carpark and Caravan Park is noted for extreme events associated with future sea level rise scenarios. Drainage of the catchment based flooding during large events was cited in the CVS with regard to the conveyance of the runoff through the shoreline north of the old jetty to control associated erosion during large cyclonic events.

The coastal processes allowances are shown on Figure 4.12 for the shoreline south of the old jetty area and Figure 4.13 for the shoreline north. The chief contribution to the foreshore reserve allowance in the compartment is sea level rise representing 50-75 % of the total coastal processes allowance (refer Table 3.10). It is noted this is a direct horizontal application of 100 times the projected sea level change for each planning period, and the application does not take account of shoreline type or elevation.

Beaches south of the old groyne are noted as being comprised coarse sand (increasing their resilience to erosion) as opposed to the beaches north of the groyne which are composed of finer sediment and silt, with mangrove cover along most of the shoreline. The CVS assessment of changes in the historical shoreline position indicated that the southern section of the compartment from the old jetty area has been effectively stable (S2 =0 m). Advice from the Caravan Park received during public submission of the CHRMAP stated that the Park operators have been using selective fill and vegetation to control erosion along this section of the shoreline since 1990 which had proved effective for stabilisation of the coast (Figure 3.4). For the section immediately north of the old jetty area, the Pindan sand cliffs are noted as particularly at risk of erosion, with a reported rate of retreat of 0.6m to 1.5m per day during Cyclone Lindsay (1985). North of the old jetty area through to the end of the compartment, erosion rates of 0.3m annually were recommended based on the CVS analysis.

The coastal assessment for storm erosion (S1) in the northern section of the compartment takes account of mangrove cover along the shore and associated attenuation of wave impact in design storms. The seawalls constructed at the back of the beach adjacent the Mangrove Hotel section of coast have not been considered in the assessment.

Coastal Issues for CHRMAP

South of the old groyne (refer Figure 4.12), the Roebuck Bay Caravan Park is at risk from coastal processes in the current to 2040 period, with future planning periods showing increasing risk to coastal processes through 2070 and 2110. Residential properties on Demco Drive are indicated as being at risk between 2040 and 2070, with a low point behind the dune (dune swale) in this section of coast responsible

Figure 4.11: Town Beach caravan park and Demco Drive development 1965 to 2012

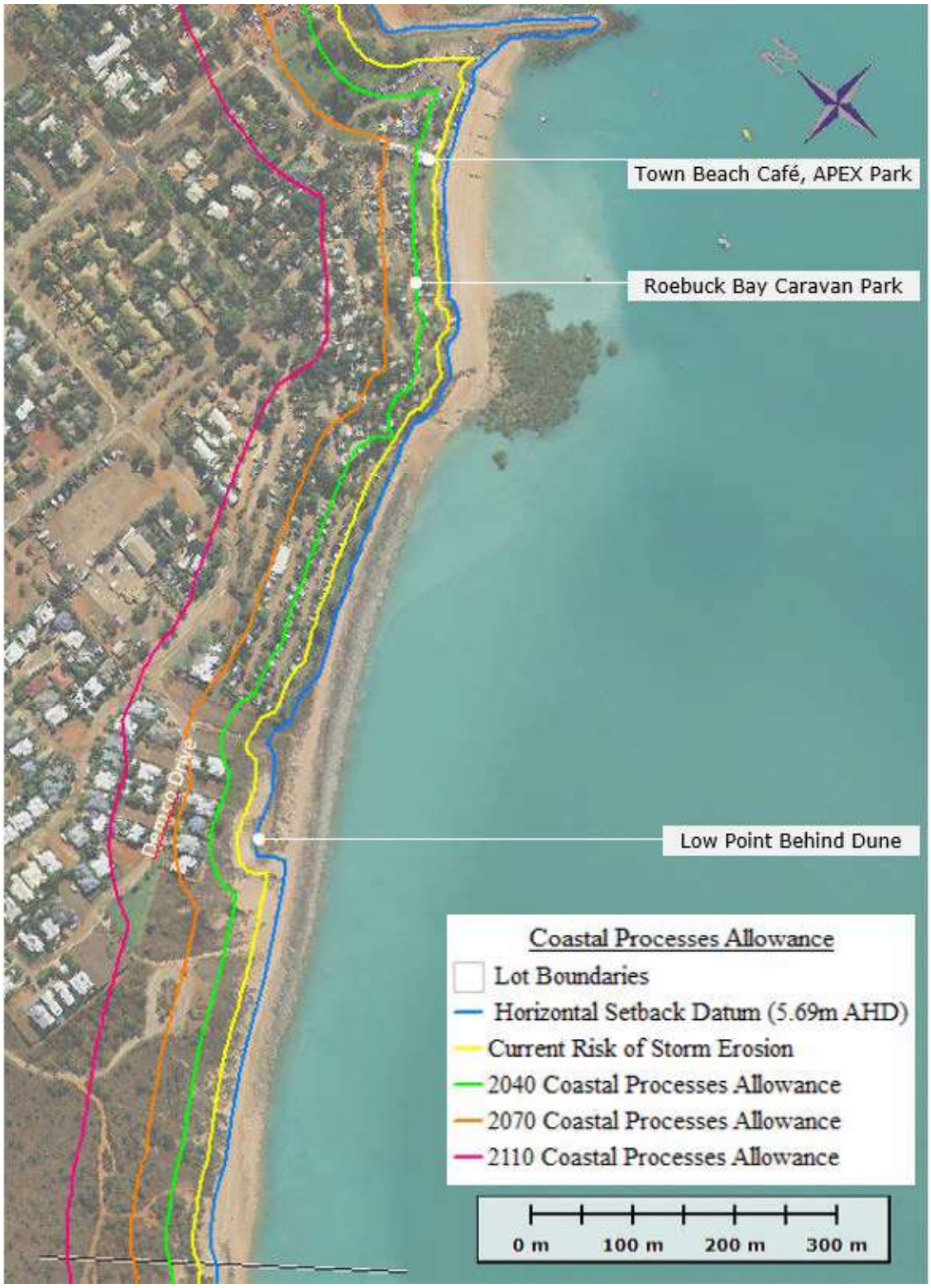


Figure 4.12: Town Beach Compartment showing coastal processes erosion allowances recommended for future planning periods south of the old jetty area

Figure 4.13: Town Beach Compartment showing coastal processes erosion allowances recommended for future planning periods north of the old jetty area

for the placement of the HSD. Apex Park, Town Beach café and the carpark are highlighted as being at risk of coastal erosion by 2040, and the 2070 coastal processes line is landward of these features.

North of the old jetty area (Figure 4.13), the site of Catalina's is indicated to be at risk presently from coastal processes, and by 2040 the site is almost entirely seaward of the coastal erosion allowance. The foreshore reserve area between Catalina's and Matso's Brewery is sufficient to maintain the forecast coastal processes until 2040, thereafter the 2070 line is located landward of Hamersley Street. Matso's Brewery, the Mangrove Hotel and the Moonlight Bay Suites locations are identified at risk of coastal processes by 2040 and going forward, are all largely seaward of the 2070 erosion allowance.

It is noted the seawall and protection structures present in this section of coast fronting Catalina's and the Caravan Park (Section 3.6) have not been considered in the coastal processes assessment under SPP2.6. Whilst these structures would offer some protection from coastal hazard in extreme events, their construction and ongoing maintenance is not managed by the Shire. The importance of the structures for managing coastal hazard risk in this section of coast is evident, however the commitment to ensure they remain in place throughout the future 100 years planning period (2110) and the responsibility of ongoing maintenance and any future rebuilding of the structures at the end of their design life will require further definition as part of the CHRMAP process.

4.2.7 Broome Town Centre

Overview

The Broome Town Centre compartment encompasses the main business area of the town. The area serves commercial, residential and tourist purposes and its Chinatown area holds historical significance for the town. The compartment is situated on the entrance to Dampier Creek surrounded by mangroves and tidal flats, and the topography is generally low lying.

The peninsula on which the Broome CBD and Chinatown is situated has been significantly modified in its short history. The development of the peninsula has included significant land reclamation in the past 50 years around Chinatown for commercial expansion, airport runway and roads as shown on Figure 4.14.

Historically the Chinatown area has been subjected to inundation from the ocean, with periodic flooding of the heritage buildings such as Sun Pictures noted in its rich history. From the 1959 aerial photo it is evident how ocean flooding could reach the location through Dampier Creek. In more recent times and likely as a result of the significant land reclamation, inundation from the ocean during extreme cyclone events has not been prevalent. The largest cyclone in recent history, tropical cyclone Rosita in 2000 had a storm tide which peaked at 4.37m AHD (9.69mCD) which was below the highest astronomical tide level (5.24m AHD).

The LiDAR for Chinatown area is presented on Figure 4.15, and shows the height of the land in the central section of the peninsula is lower than the outer edges. The outer peninsula foreshore area level is maintained by retaining walls and built up land levels that can keep the general astronomical tides from flooding the central Chinatown section. Based on an assessment of the detailed LiDAR, the outer sections of the peninsula are capable of withstanding an ocean level up to approximately 5.6m AHD which is 0.4m above the highest astronomical tide (HAT). With the projected sea level rise scenarios, from about 2070 onwards the tide at the HAT level would breach the peninsula.

Figure 4.14: Broome Town Centre comparison 1959 and 2012 Aerial

The LiDAR on Figure 4.15, shows the land levels between 4 m AHD and 7 m AHD. The low lying central section of the peninsula at the junction of Carnarvon and Short Street is a concentration point for catchment runoff in rainfall, and most at risk should the storm tide level breach the peninsula.

The catchment basin on the southwest side of Broome Road can be seen below the road level and the culverts connecting through to Dampier Creek are indicated. The 7m AHD contour is shown as a magenta line and all land area beyond this is at a higher elevation. This 7 m AHD contour corresponds with the design ocean inundation level for the 2110, 500-yr ARI event.

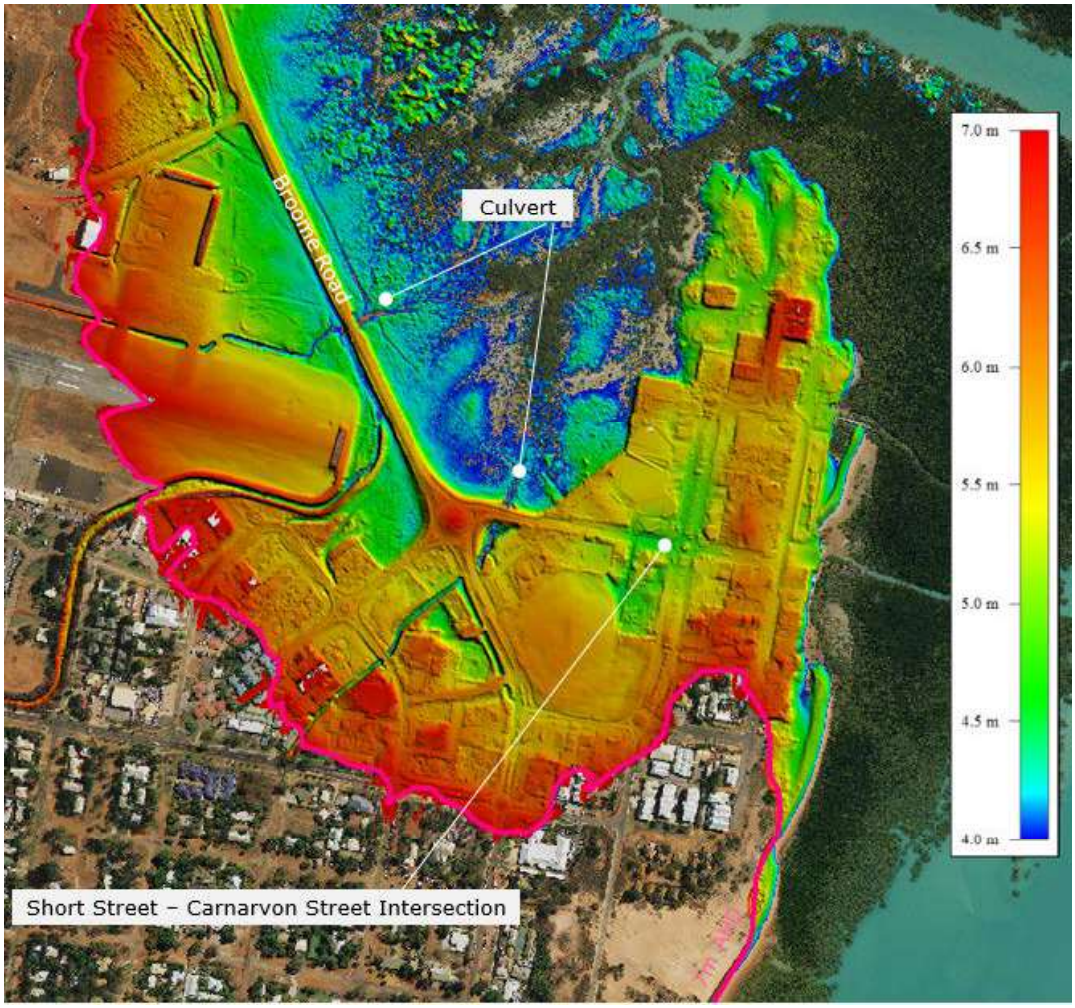


Figure 4.15: Broome Town Centre LiDAR data plotting land areas in the range 4.0m to 7.0 m

Drainage issues in the section of the town around Carnarvon Street and Short Street occur for rainfall events of ARI10yr or greater. It is noted flooding of this location is the subject of a District Stormwater Management Plan that has been undertaken for the Shire (Cardno 2016). The options to mitigate catchment flooding in this section of town are not part of the CHRMAP.

Inundation Mechanisms

Inundation of streets and property in Chinatown and the surrounding land areas of the coastal compartment can occur through three mechanisms:

1. Tropical cyclone induced storm surge which results in the outer edges of the peninsula being breached by the ocean and water flooding the central section. Lower lying sections of Chinatown at the intersection of Carnarvon Street and Short Street are most at risk when ocean levels higher than HAT occur and breach the outer edges of the peninsula, as water will flow down into this low point. The Napier Terrace – Broome Road intersection is also low lying and susceptible to flooding in large tides.
2. Stormwater runoff from rainfall poses a significant risk of flooding to the properties in the coastal compartment particularly in the lower lying sections of Chinatown (intersection of Carnarvon Street and Short Street) as water flows down into the centre of the peninsula from the surrounding streets. Stormwater upgrades are under consideration in these locations.
3. A combination of rainfall runoff *and* storm tide where significant rainfall occurs jointly with a cyclone impacting the coast that results in a significant storm tide level in Dampier Creek. Depending on the storm tide level the peninsula may be breached (as per case 1) and the rainfall runoff may be prevented from draining through Dampier Creek as a result of the elevated ocean level caused by storm tide. With the usual drainage path effectively blocked by the ocean, the rainfall runoff will backup and flood the surrounding streets and properties. The likelihood of this occurring is particularly low.

For the CHRMAP the key inundation impact that has been considered is inundation mechanism 1 - storm tide only. This is consistent with SPP2.6, where the coastal inundation hazard for future planning is based on the areas inundated in the 500yr ARI storm surge event, occurring in the year 2110 which incorporates 0.9m sea level rise.

The mapping of coastal inundation hazard provided from the CVS is a combined return period map which shows rainfall and storm tide on the same map, where the mapping data represents the maximum inundation from either ocean *or* catchment flows (Cardno 2015). Whilst the coupling of rainfall and ocean level is a sound approach to working with the joint occurrence, the mapping output to select the result at each grid point of the worst / highest flooding outcome creates an outcome for flood mapping which is more severe than the SPP2.6 requirements. For the SPP2.6 case of the 2110 planning period 500yr ARI case, the mapping shows inundation derived from two cases - a 500yr ARI storm tide (potentially with 50year rainfall concurrently) and a 500yr ARI rainfall case (potentially with 50year storm tide concurrently). The inundation from 500yr rainfall is extreme for low lying areas such as Chinatown and results in larger inundation regions in the mapping than can be warranted in the CHRMAP assessment.

Mapping cases for storm tide only models (ie no concurrent rainfall) or the base model results of coupled ocean – rainfall were not made available to the CHRMAP study. As it was impossible to separate the relative contribution from the storm tide and rainfall from the mapping sets provided from the CVS, Baird modelled a number of inundation cases based on a ‘bathtub’ method which uses the LiDAR ground surface levels and floods the land areas based on the offshore storm tide ocean level for scenarios on Table 3.4, incorporating wave setup allowances specified in Table 3.5. This approach was used to define the coastal inundation likelihood lines for the Broome Central compartment (Section 6.9). It is noted the inundation assessment does not account for freeboard - habitable floor heights may be above the lot ground level on which the LiDAR is based.

Key findings from CVS

The coastal processes allowances for the compartment are shown on Figure 4.16. The calculated allowances for storm erosion (S1) and historical rate of shoreline movement (S2) are negligible through the

compartment shoreline. The allowance for sea level rise dominates the allowance total for each planning period.

Of greater concern, the topographic relief offered in many other coastal compartments is not available along the Dampier Creek shoreline, and the threat from coastal inundation as a result of storm surge is significant. The south-eastern shoreline of the coastal compartment is elevated above both current and future storm surge levels, however inland of this dune the land drops quickly into the low lying area most notable at the intersection of Short Street and Carnarvon Street and Chinatown. Low lying sections of Chinatown are at risk of predominantly catchment based flooding in the present day under 10 to 50-yr ARI cyclone events. As sea level rise is factored into future scenarios, the Chinatown area and surrounds becomes subject to significant inundation as ocean inundation becomes more severe.

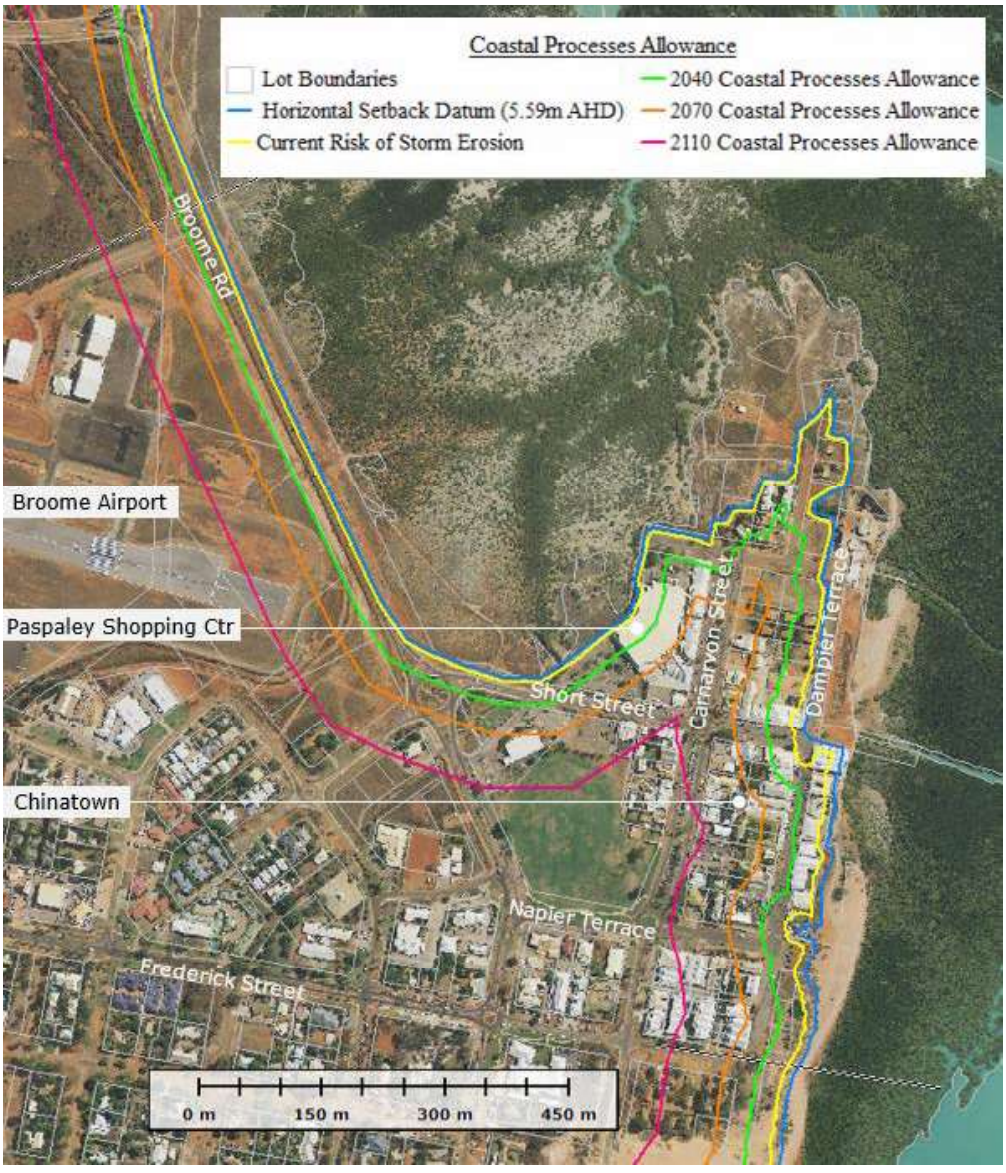


Figure 4.16: Broome Town Centre Compartment showing coastal processes erosion allowances recommended for future planning periods

Coastal inundation dominates the coastal hazard risk for the Broome Town Centre compartment, with the inundation extents associated with the 2110 planning period 500 yr-ARI event shown on Figure 4.17. Under this scenario, the entire commercial district and Chinatown area is inundated (depths > 1 m) and the inundation extent extends through to Frederick Street east to the Airport runway.

The inundation presented on Figure 4.17 includes the effects of concurrent catchment based flooding. The inundation in the southwest corner is the result of rainfall which is draining toward Dampier Creek through the road network and the creek on the southern airport boundary. Broome Road is significantly inundated (depths > 1m) and the western side of Broome Rd is severely inundated, as a result of catchment flows and the culvert connecting to Dampier Creek.

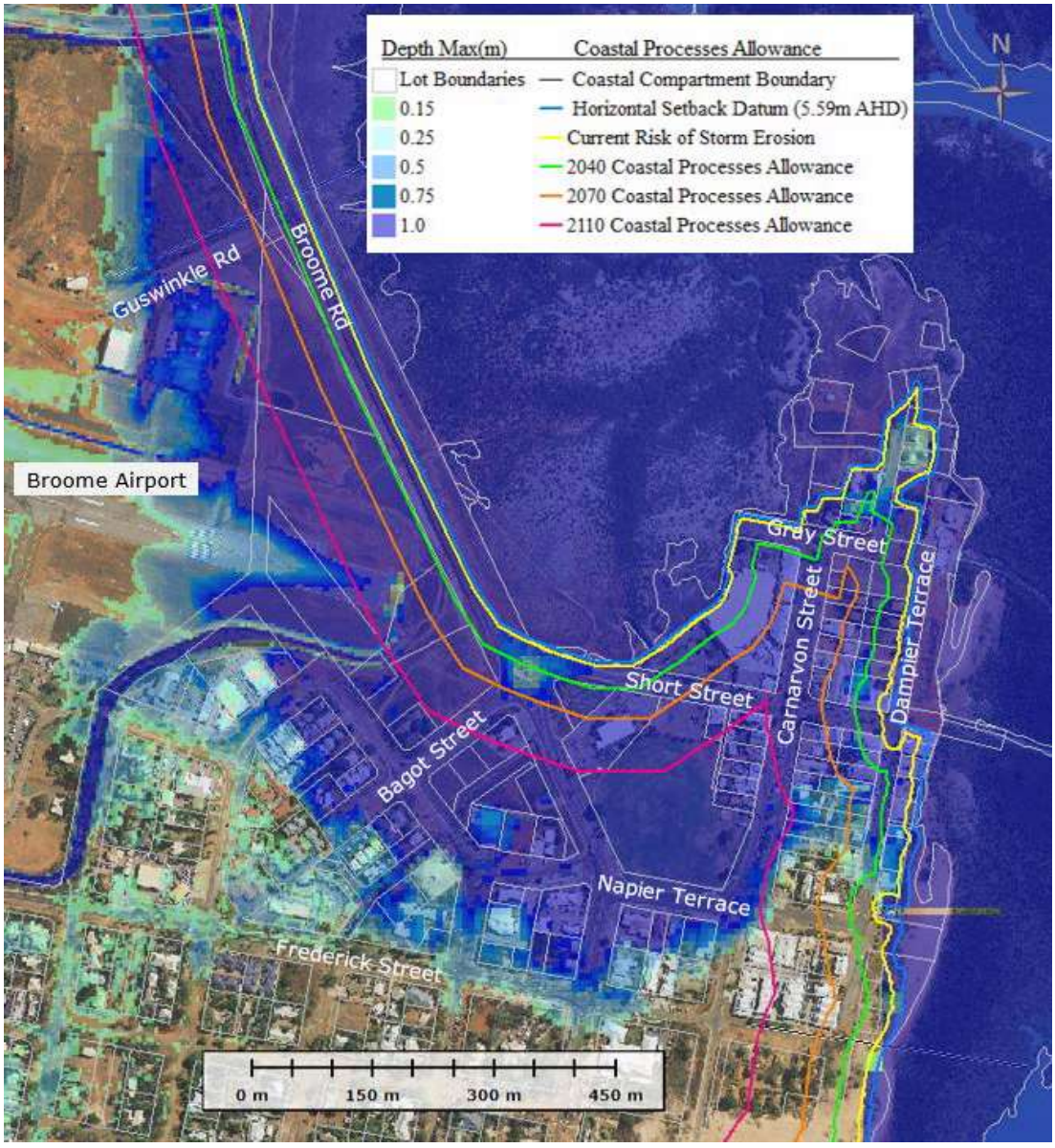


Figure 4.17: Broome Town Centre Compartment showing 2110 inundation extent for the 500-yr ARI event storm surge with concurrent catchment based flooding

4.2.8 Dampier Creek Inner

Overview

The Dampier Creek Inner compartment incorporates the tidal flat and mangrove lined shoreline section of the Dampier Creek Estuary north of the Broome International Airport.

Key findings from CVS

The dominant process for coastal hazard risk in Dampier Creek is coastal inundation. The shoreline is low lying tidal flat colonised by mangrove which provides some attenuation of water level in extreme storm surge events. The CVS investigated the mangrove system in Dampier Creek and concluded there is a plentiful available foreshore area within the Dampier Creek basin for the mangrove system to adapt and colonise as sea levels increase in future planning periods, assuming that mangrove colonisation maintains pace with accelerating sea level rise.

The CVS did not specifically assess the inner section of the Dampier Creek coastline for coastal processes allowance, instead these were determined by Baird for the future planning periods through an approach endorsed by the DoT (Baird 2016a).

Coastal Issues for CHRMAP

The coastal inundation extents for the 500-yr ARI design storm surge level in the 2110 planning time frame is shown on Figure 4.18 (lower section) and Figure 4.19 (upper section). The coastal processes allowances for the present and three future planning periods are overlaid on the plots.

The inundation in west of Broome Road is largely the result of catchment based flooding which is unable to exit through Dampier creek through drainage channels due to the elevated storm tide level. The lower section of the compartment shown on Figure 4.18 indicates that the inundation is generally concentrated within the roadways in the section between Gubinge Rd and Sandpiper Avenue. On the northern boundary of Gubinge Rd there is concentrated inundation, with impacts to lots bordering this region. Gubinge Rd is maintained above the peak flood depth, whilst Broome Road is subject to significant inundation due to its close proximity to Dampier Creek coupled with catchment effects.

Inundation extents for the upper section of the compartment indicate properties between Broome Rd and Wattle Drive affected by inundation depths of 0.25 to 0.5 m. The Broome Highway is subject to inundation depths between 0.25 and 0.5 m for the 2110 design event at the 500-yr ARI level.

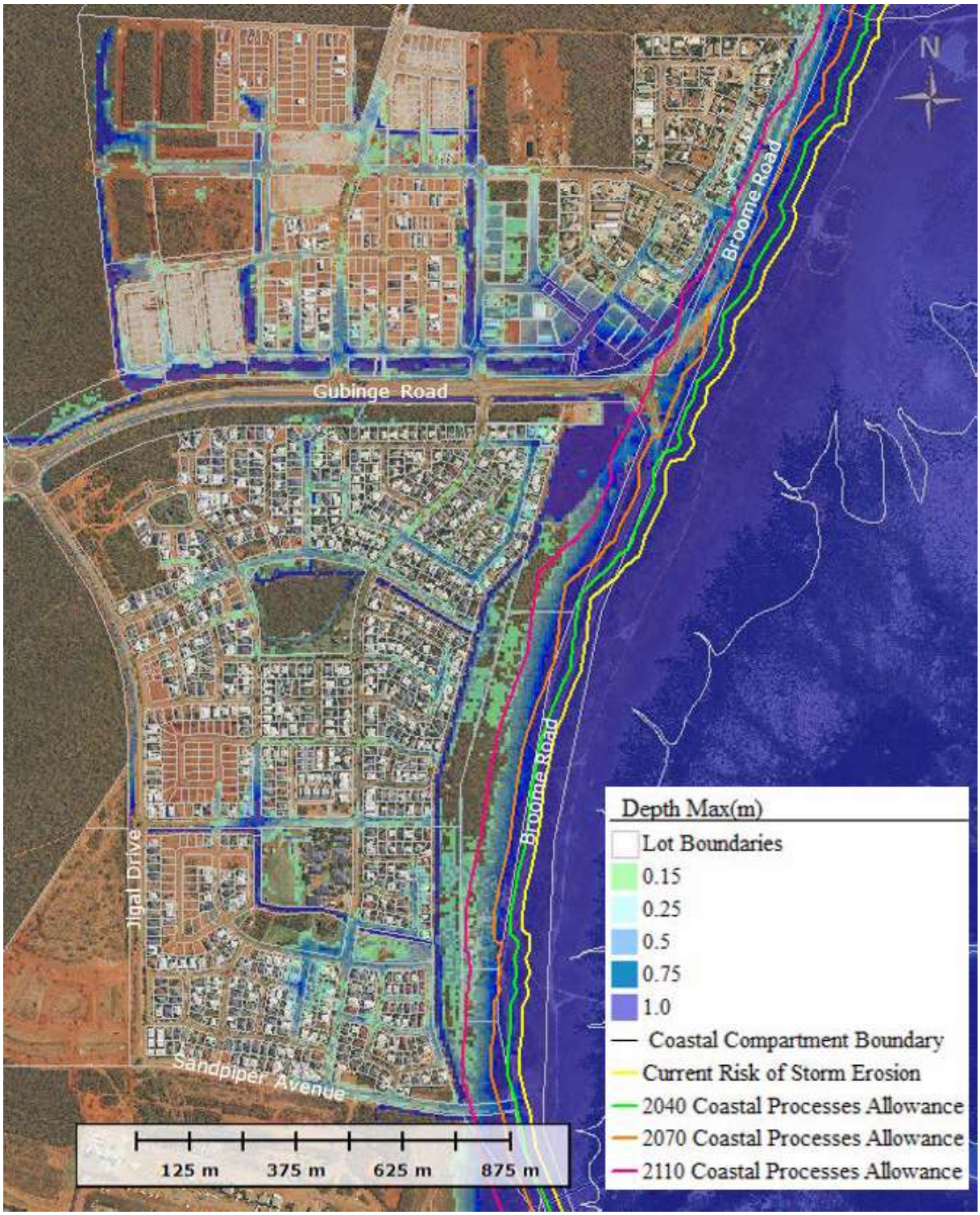


Figure 4.18: Dampier Creek Inner Compartment (lower) showing coastal processes erosion allowances recommended for future planning periods, and inundation extents for the 2110 500-yr ARI event

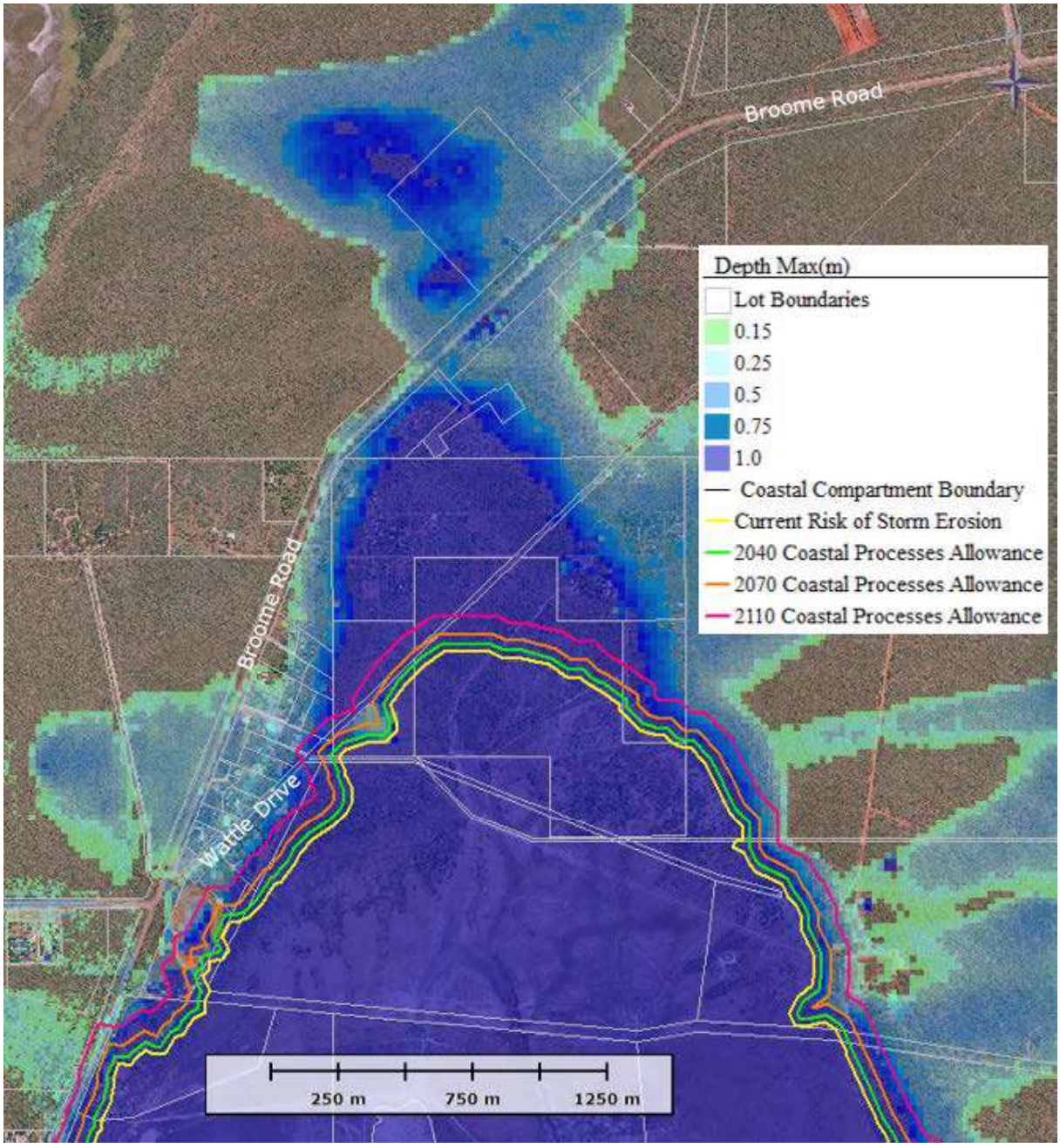


Figure 4.19: Dampier Creek Inner Compartment (upper) showing coastal processes erosion allowances recommended for future planning periods, and inundation extents for the 2110 500-yr ARI event.

4.2.9 Dampier Creek East

Overview

The Dampier Creek East compartment is a sparsely inhabited section of the study area, which comprises the eastern shoreline of the inside of Dampier Creek and continues through the estuary opening to the section of coastline on fronting Roebuck Bay on its eastern side.

Key findings from CVS

The Roebuck Bay shoreline was found to be very stable with little shoreline movement historically in the CVS analysis. Low lying beach barrier dunes at a crest level of 6 m AHD are present along the Roebuck Bay section with extensive mangrove cover. To the eastern end of the Roebuck Bay shoreline well vegetated Pindan cliffs overly more resistant outcrops of Broome formation sandstone.

Coastal Issues for CHRMAP

The coastal allowances and inundation extents for the 2110 design event are presented on Figure 4.20. There is limited infrastructure within this compartment that will be assessed for CHRMAP.

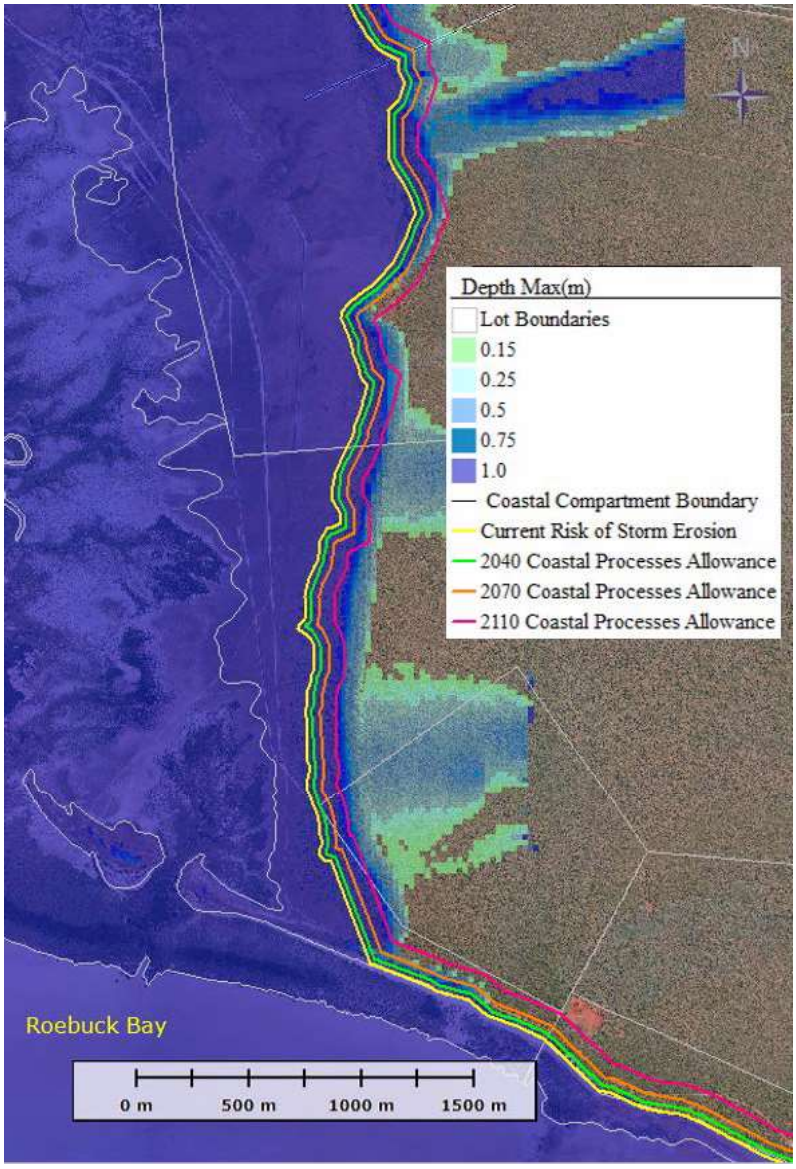


Figure 4.20: Dampier Creek East Compartment showing coastal processes erosion allowances recommended for future planning periods, and inundation extents for the 2110 500-yr ARI event

4.3 Summary of Coastal Issues

In summary, coastal processes erosion allowances are the key consideration for CHRMAP for the coastal compartments from Cable Beach around to Town Beach (compartments 1 to 6 inclusive). For the shoreline compartments along the section of the shoreline fronting Dampier Creek (compartments 7 to 9), storm surge inundation and erosion hazard will both be required to be addressed in the CHRMAP.

Catchment based flooding as a result of rainfall, impacts a number of locations across the Broome townsite study area. It is noted that catchment flooding is only considered in the CHRMAP for locations where the catchment flooding interacts with elevated ocean levels as a result of storm surge. This limits consideration to the areas of the shoreline adjacent Dampier Creek (coastal compartments 7 to 9).

The CHRMAP will not develop mitigation strategies to address catchment based flooding of Chinatown. It is noted:

- Chinatown is sited on the lowest lying topography of the Broome CBD peninsula, and as a result the local catchment based rainfall in surrounding streets is directed into this area in large rainfall events.
- inundation as a result of catchment rainfall will occur for events rated at the 10-yr ARI (without any influence from the ocean level).
- The drainage network in Chinatown in two key areas is the subject of a separate stormwater study (DSMS,Cardno 2016) commissioned by the Shire. The Short Street-Carnarvon Street intersection and Napier Street–Hammersley Street intersection have been examined with options presented to attenuate the flooding in large rainfall events.

To clearly understand the storm tide only effect on inundation in Chinatown, Baird have undertaken 'bathtub modelling' of key return period storm tide water levels using the detailed LiDAR data set (discussed further in Section 6.9). This has concluded the edge of the Chinatown peninsula can 'hold back' the storm tide level up to a height of approximately 5.7m AHD, which is equivalent to the present day 100yr ARI. With sea level rise projected for the 2040 planning period this flooding immunity reduces to the 50yr ARI storm tide.

The SPP2.6 design scenario for a 500yr ARI storm tide in the 2110 planning period has been shown to inundate areas below 7m AHD through the Broome Town Centre coastal compartment.

From the detailed review of the coastal compartments, an overall summary of the key processes within the compartment, the assets at risk and the potential timeframe identified from the CVS is presented on Table 4.2.

Table 4.2: Summary of Coastal Issues by Coastal Compartment

Coastal Compartment	Key Process	Asset	Timeframe
1. Cable Beach	Erosion	Zanders Café	Current - 2040
		Beach Access Rd	Current – 2040
		Surf Club	Current - 2040
		North Carpark	Current – 2040
		South Carpark	2070 - 2110
		Cable Beach Rd	2040 – 2070

		Gantheaume Point Rd	2040 - 2070
2. Gantheaume Cliffs	Erosion	Gantheaume Point Rd	2040 - 2070
		Kavite Road	2040 - 2070
		Broome Turf Club	2070 - 2110
3. Reddell Beach	Erosion	Kavite Road	2040 - 2070
		Residential	Current - 2040
4. Entrance Point	Erosion	Kavite Road	2040 – 2070
		Industrial Land West side	2070 – 2110
		Public Boat Ramps	Current – 2040
		Fishing Club	2040 - 2070
		Kabbarli Rd	Current – 2040
		Boat Launch NE side	Current – 2040
		Jetty Access Point	Current – 2040
		Wharf Restaurant	Current – 2040
		Customs / Quarantine	Current – 2040
		Port Drive	2070 – 2110
5. Simpsons Beach	Erosion	Water Treatment Ponds	2110 onwards
6. Town Beach	Erosion	Catalina's	Current – 2040
		Caravan Park	Current – 2040
		Apex Park	Current – 2040
		Town Beach Café	2040 – 2070
		Carpark	Current – 2040
		Residential	2040 – 2070
		Demco Drive	2070 – 2110
		Mangrove Hotel	2040 - 2070
		Matso's	2040 – 2070
		Hammersley Street	2040 – 2070
		Carnarvon Street	2070 - 2110
7. Broome Town Centre	Inundation	Chinatown / CBD	Inundation of majority of Chinatown under 2110 500-yr ARI storm surge event
		Airport Runway East	
		Broome Rd	
8. Dampier Creek Inner	Inundation	Broome Road	Inundation of properties east of Broome Rd in 2110 500-yr ARI storm surge event. Secondary catchment based flooding of properties in North Broome in 2110 event
		Wattle Drive Properties	
		One Mile	
		Morrell Park	
9. Dampier Creek East	Inundation	None	None

5 Risk Analysis and Evaluation

5.1 Risk Analysis

In this section the coastal hazard from erosion and inundation identified for Broome is considered in terms of likelihood and consequence and combined to provide a risk matrix to determine the level of risk for assets in each of the coastal compartments.

It is noted that the risk analysis for the CHRMAP concentrates on the most immediate planning period 2040, with consideration of the outcomes as far as the 2070 planning period. Through this approach the CHRMAP seeks to define what is critical for the Shire consider currently and into the immediate future (approximately the next 25 years). The projected erosion and inundation for scenarios out to the 2110 planning period are recognised in adaptation planning of development controls and infrastructure over the longer term (2110) and captured in the likelihood scales developed to assess the risk.

5.1.1 Likelihood

In risk management terms, 'likelihood' is the chance of something happening, and is similar to probability. AS5334-2013 describes this as follows:

'In risk management terminology the word likelihood is used to refer to the chance of something happening, whether defined, measured or determined objectively or subjectively, qualitatively or quantitatively, and described using general terms or mathematically (such as a probability or a frequency over a given time period).'

The likelihood scale that has been developed for the Broome town site CHRMAP follows the guidance presented in AS5334-2013 and WAPC2014. The definitions for the likelihood scale are shown on Table 5.1 with each category associated in terms of Annual Exceedence Probability (AEP) adapted from AS5334-2013 in ranges tailored for the Broome CHRMAP.

Table 5.1: Likelihood Scale Definitions (WAPC 2014, AS5334-2013)

Rating	Annual Exceedance Probability
Almost Certain	Has a greater than 85% chance of occurring in the identified time period if the risk is not mitigated
Likely	Has a 50-85% chance of occurring in the identified time period if the risk is not mitigated
Possible	Has a 25-50% chance of occurring in the identified time period if the risk is not mitigated
Unlikely	Has a 10-25% chance of occurring in the identified time period if the risk is not mitigated
Rare	May occur in exceptional circumstances, ie less than 10% chance of occurring in the identified time period if the risk is not mitigated

The CHRMAP guidelines (WAPC 2014) provide recommendations for development of a likelihood scale using the likelihood terms in Table 5.1. This requires the erosion and inundation scenarios to be considered across future planning periods on a sliding scale. In effect this recognises that a level of erosion risk that is considered 'possible' today becomes more likely in future time periods. For the Broome CHRMAP the erosion and inundation likelihood scales have been determined within the framework of SPP2.6 and through discussions with Department of Planning (DoP).

5.1.2 Coastal Erosion Likelihood Scale

The Coastal erosion likelihood scale is shown in Table 5.2 with the sliding scale approach for likelihood between successive planning periods clearly observed. For example the 'Likely' erosion definition in 2040 becomes the definition for the 'Almost Certain' category in 2070 and the 'Possible' erosion level in 2040 is considered as 'Likely' in 2070.

Table 5.2: Broome CHRMAP Likelihood Scale for Coastal Erosion (2040 to 2110 planning period)

Rating	2040	2070	2110
Almost Certain	-	2015 Erosion	2040 Erosion
Likely	2015 Erosion	2040 Erosion	2070 Erosion
Possible	2040 Erosion	2070 Erosion	2110 Erosion
Unlikely	2070 Erosion	2110 Erosion	-
Rare	2110 Erosion	-	-

The likelihood category definitions are based on the premise:

- The 'Almost Certain' category is defined as the erosion for two planning periods earlier (in 2040 this has not been possible to determine)
- The 'Likely' category is defined as the erosion for the prior planning period
- The 'Possible' category is defined as the erosion for the given planning period
- The 'Unlikely' category is defined as the erosion for the future planning period
- The 'Rare' category is defined as the erosion projected for two planning periods in the future

5.1.3 Coastal Inundation Likelihood Scale

For coastal inundation the likelihood scale definition is presented on Table 5.3. The 'Possible' category within each respective planning period is the SPP2.6 recommendations for coastal inundation hazard defined as the 500yr ARI inundation extent. Working through the likelihood scale:

- The 'Almost Certain' category is defined as the 500yr ARI inundation for two planning periods earlier (in 2040 this has been approximated to the 2015 100yr ARI)
- The 'Likely' category is defined as the 500yr ARI inundation for the prior planning period
- The 'Possible' category is defined as the 500yr ARI inundation for the given planning period
- The 'Unlikely' category is defined as the 500yr ARI inundation for the future planning period

The adopted inundation likelihood categories on Table 5.3 are based on a sliding scale consistent with WAPC policy and similar to that shown in Table 5.2. It is noted that the water level calculated in the CVS

for each of the planning scenarios and return periods incorporates sea level rise across time (0.15m for 2040, 0.4m for 2070 and 0.9m for 2110). Additionally, the modelling of the storm events allows for increased cyclone intensity in future planning periods.

Table 5.3: Likelihood Scale - Inundation Hazard Definition. Scenarios for 2040 to 2110

Rating	2040	WL (AHD)	2070	WL (AHD)	2110	WL (AHD)
Almost Certain	*2015 Inundation*[1]	5.39m	2015 Inundation	5.48m	2040 Inundation	5.70m
Likely	2015 Inundation	5.48m	2040 Inundation	5.70m	2070 Inundation	6.05m
Possible	2040 Inundation	5.70m	2070 Inundation	6.05m	2110 Inundation	6.63m
Unlikely	2070 Inundation	6.05m	2110 Inundation	6.63m		

1. Inundation based on 100yr ARI Event

Mapping is presented in **Appendix B** for each of the coastal compartments showing coastal hazard in terms of likelihood as defined on Table 5.2 and Table 5.3.

5.1.4 Consequence

Consequence is used to describe the impact to assets when coastal hazard is realised. For the Broome coastal areas, the scale of impact is rated in a five stage severity scale from Insignificant to Catastrophic as shown on Table 5.4, with respective Economic, Environmental and Social impacts noted for each category.

Table 5.4: Consequence Scale

Rank	Rating	Economic	Environmental	Social
1	Catastrophic	Permanent loss or damage > $3 million	Permanent loss of flora and fauna – will not recover	Long-term or permanent loss of function
2	Major	Permanent loss or damage $1 - $3 million	Long term loss of flora and fauna, limited chance of recovery	>75% of community affected
3	Moderate	Permanent loss or damage $200k -$1mil	Medium term loss of flora and fauna. Recovery likely	Medium-term disruption to function
4	Minor	Permanent loss or damage $20k - $200k	Short term loss of flora and fauna. Strong Recovery	<50% of community affected
5	Insignificant	Permanent loss or damage < $ 20k	Negligible to no loss of flora and fauna	Minor Long Term or major Short Term loss of function

In the community engagement workshops, stakeholders and community worked with the consequence scale on Table 5.4 to rate the impact of erosion and inundation on assets identified within each of the coastal compartments. The workshop process and outcomes are reported in **Appendix A.**

It is noted that post-workshop analysis was undertaken to determine the final consequence ratings for each of the identified assets reported in the section to follow, directed by the CHRMAP guidelines and stakeholder feedback.

5.2 Risk Evaluation

The evaluation phase considers the risk analysis for the identified assets and works through prioritising risk management and adaptation.

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

5.2.1 Risk Scale

A risk priority level scale was developed for the Broome CHRMAP and is the product of the likelihood and consequence as shown on Table 5.5. For the level of risk defined in Table 5.5, the corresponding tolerance scale is shown on Table 5.6 describing the tolerance and the associated action required to be undertaken (from WAPC 2014).

Table 5.5: Likelihood / Consequences matrix to assess level of risk

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

Table 5.6: Tolerance Scale - Erosion

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

5.3 Risk Evaluation by Coastal Compartment

Assets identified within each of the coastal compartments during the community engagement (**Appendix A**) have been assessed against the coastal hazard likelihood mapping (**Appendix B**).

The risk priority has been determined for the 2040, 2070 and 2110 planning periods for assets listed within each coastal compartment with the risk evaluation examining effects of coastal erosion and inundation separately;

5.3.1 Erosion Risk by Coastal Compartment

Coastal erosion risk is evaluated for all nine coastal compartments on Table 5.7 to Table 5.15.

Table 5.7: Coastal Compartment 1 - Cable Beach Coastal Erosion Risk

Asset	Conseq Erosion	Likelihood 2040	Risk Level 2040	Likelihood 2070	Risk Level 2070	Likelihood 2110	Risk Level 2110
Northern Section							
Turtle nesting sites	**Minor**	*Likely*	**M**	*Almost Certain*	**M**	*Almost Certain*	**M**
Lurujarri Trail	**Mod.**	*Rare*	**L**	*Unlikely*	**M**	*Possible*	**H**
Shorebirds	**Insig.**	*Likely*	**L**	*Almost Certain*	**L**	*Almost Certain*	**L**
Sand dunes	**Major**	*Unlikely*	**M**	*Possible*	**H**	*Likely*	**E**
Vine Thickets	**Major**	Not Impacted					
Central Section – Tourist Sector							
Cable Beach Shoreline	**Major**	*Almost Certain*	**E**	*Almost Certain*	**E**	*Almost Certain*	**E**
Cable Beach Amphitheatre	**Mod.**	*Likely*	**H**	*Almost Certain*	**H**	*Almost Certain*	**H**
Cable Beach Club Resort	**Major**	*Unlikely*	**M**	*Possible*	**H**	*Likely*	**E**
Residential Property	**Major**	*Possible*	**H**	*Likely*	**E**	*Almost Certain*	**E**
Surf Life Saving Club	**Major**	*Likely*	**E**	*Almost Certain*	**E**	*Almost Certain*	**E**
Vehicle Beach Access Road	**Minor**	*Likely*	**M**	*Almost Certain*	**M**	*Almost Certain*	**M**
Beach Access Stairs	**Minor**	*Likely*	**M**	*Almost Certain*	**M**	*Almost Certain*	**M**

Carparks	**Mod.**	*Possible*	**H**	*Likely*	**H**	*Almost Certain*	**H**
Landscaping, paths, fences	**Insig.**	*Likely*	**L**	*Almost Certain*	**L**	*Almost Certain*	**L**
Zanders Cafe	**Major**	*Likely*	**E**	*Almost Certain*	**E**	*Almost Certain*	**E**
Shire Infrastructure (Toilets, Playground, Tanks, Seating)	**Minor**	*Likely*	**M**	*Almost Certain*	**M**	*Almost Certain*	**M**
Lurujarri Trail	**Mod.**	*Possible*	**H**	*Likely*	**H**	*Almost Certain*	**H**
Southern Section							
Shorebirds	**Insig.**	*Likely*	**L**	*Almost Certain*	**L**	*Almost Certain*	**L**
Minyirr Park Building	**Mod.**	Not Impacted					
Lurujarri Trail	**Mod.**	*Likely*	**H**	*Almost Certain*	**H**	*Almost Certain*	**E**
Sand dunes	**Major**	*Unlikely*	**M**	*Possible*	**H**	*Likely*	**E**
Vine Thickets	**Major**	*Possible*	**H**	*Likely*	**E**	*Almost Certain*	**E**

Table 5.8: Coastal Compartment 2 – Gantheaume Rocks Coastal Erosion Risk

Asset	Conseq Erosion	Likelihood 2040	Risk Level 2040	Likelihood 2070	Risk Level 2070	Likelihood 2110	Risk Level 2110
Gantheaume Point Tourism Infrastructure	**Minor**	*Rare*	**L**	*Unlikely*	**L**	*Possible*	**M**
Dinosaur Footprints[1]	**Not Rated**						
Shorebirds	**Insig.**	*Likely*	**L**	*Almost Certain*	**L**	*Almost Certain*	**L**
Broome Turf Club	**Mod.**	*Rare*	**L**	*Unlikely*	**M**	*Possible*	**H**
Gantheaume Pt Rd	**Mod.**	*Unlikely*	**M**	*Possible*	**H**	*Likely*	**H**
Lurujarri Trail	**Mod.**	*Possible*	**H**	*Likely*	**H**	*Almost Certain*	**H**

1. Dinosaur footprints are not expected to be impacted by shoreline erosion as they are located below the mean sea level

Table 5.9: Coastal Compartment 3 – Reddell Beach Coastal Erosion Risk

Asset	Conseq Erosion	Likelihood 2040	Risk Level 2040	Likelihood 2070	Risk Level 2070	Likelihood 2110	Risk Level 2110
Reddell Beach Foreshore	**Mod.**	*Almost Certain*	**H**	*Almost Certain*	**H**	*Almost Certain*	**H**
Residential Properties	**Major**	*Likely*	**E**	*Almost Certain*	**E**	*Almost Certain*	**E**
Lurujarri Trail	**Mod.**	*Possible*	**H**	*Likely*	**H**	*Almost Certain*	**H**
Kavite Rd (unsealed)	**Mod.**	*Unlikely*	**M**	*Possible*	**H**	*Likely*	**H**
Minyir Park	**Mod.**	*Likely*	**H**	*Almost Certain*	**H**	*Almost Certain*	**H**

Table 5.10: Coastal Compartment 4 – Entrance Point Coastal Erosion Risk

Asset	Conseq Erosion	Likelihood 2040	Risk Level 2040	Likelihood 2070	Risk Level 2070	Likelihood 2110	Risk Level 2110
Port Buildings	Major	*Possible*	H	*Likely*	E	*Almost Certain*	E
Fishing club	Mod.	*Unlikely*	M	*Possible*	H	*Almost Certain*	H
Hovercraft Facility	Mod.	*Likely*	H	*Almost Certain*	H	*Almost Certain*	H
Boat Ramps, Carpark	Major	*Likely*	E	*Almost Certain*	E	*Almost Certain*	E
Vine Thickets	Major	*Likely*	E	*Possible*	E	*Almost Certain*	E
Kavite Road (unsealed)	Mod.	*Unlikely*	M	*Possible*	H	*Likely*	H
Dinosaur Trackways[1]	**Not Rated**						

1. Dinosaur footprints are not expected to be impacted by shoreline erosion as they are located below the mean sea level

Table 5.11: Coastal Compartment 5 – Simpsons Beach Coastal Erosion Risk

Asset	Conseq Erosion	Likelihood 2040	Risk Level 2040	Likelihood 2070	Risk Level 2070	Likelihood 2110	Risk Level 2110
Waste Water Treatment Plant	Catast.	**Not Impacted**					
Golf Course	Minor	**Not Impacted**					
Residential Properties	Major	*Rare*	M	*Unlikely*	M	*Possible*	H
Beach and Foreshore	Mod.	*Almost Certain*	H	*Almost Certain*	H	*Almost Certain*	H
Vine Thickets	Major	*Likely*	E	*Almost Certain*	E	*Almost Certain*	E
Shorebirds	Insig.	*Likely*	L	*Almost Certain*	L	*Almost Certain*	L
Roebuck Bay[1] – quality, seagrass meadows, mudflats	**Not Rated**						

1. Not rated as the link between coastal erosion and impacts to the Roebuck Bay marine areas is unknown

Table 5.12: Coastal Compartment 6 – Town Beach Coastal Erosion Risk

Asset	Conseq Erosion	Likelihood 2040	Risk Level 2040	Likelihood 2070	Risk Level 2070	Likelihood 2110	Risk Level 2110
Town Beach Foreshore	Mod.	*Almost Certain*	H	*Almost Certain*	H	*Almost Certain*	H
Town Beach Reserve	Major	*Likely*	E	*Almost Certain*	E	*Almost Certain*	E
Town Beach Caravan Park	Major	*Likely*	E	*Almost Certain*	E	*Almost Certain*	E
Town Beach Car Park	Mod.	*Likely*	H	*Almost Certain*	H	*Almost Certain*	H
Shire Assets (Café, Waterpark, toilets / BBQ facilities)	Major	*Unlikely*	M	*Possible*	H	*Likely*	H
Major Roads - Hammersley Road, Carnarvon Street	Mod.	*Possible*	H	*Likely*	H	*Almost Certain*	H
Major Roads - Demco Drive, Scott Street	Mod.	*Rare*	L	*Unlikely*	M	*Possible*	H
Bedford Memorial Park	Mod.	*Unlikely*	M	*Possible*	H	*Likely*	H
Properties Conti Foreshore	Major	*Unlikely*	M	*Possible*	H	*Likely*	H
Residential - Demco Drive	Major	*Possible*	H	*Likely*	E	*Almost Certain*	E
Residential – Catalina's	Major	*Likely*	E	*Almost Certain*	E	*Almost Certain*	E
Pioneer Cemetery	Major	*Likely*	E	*Almost Certain*	E	*Almost Certain*	E
Museum	Mod.	*Unlikely*	M	*Possible*	H	*Likely*	H
Boat ramp	Mod.	*Almost Certain*	H	*Almost Certain*	H	*Almost Certain*	H
Matso's Brewery	Mod.	*Unlikely*	M	*Possible*	H	*Likely*	H
Tourist Accom. (Mangrove Hotel, Moonlight Bay Suites)	Major	*Possible*	H	*Almost Certain*	E	*Almost Certain*	E
Mangroves (northern Section) [1]	Catast.	Not Rated					

1. Not rated as the link between coastal erosion and impacts to the mangrove areas is unknown

Table 5.13: Coastal Compartment 7 – Broome Town Centre Coastal Erosion Risk

Asset	Conseq Erosion	Likelihood 2040	Risk Level 2040	Likelihood 2070	Risk Level 2070	Likelihood 2110	Risk Level 2110
Chinatown Heritage Buildings Carnarvon St (eg Sun Pictures)	**Catast.**	*Rare*	**M**	*Unlikely*	**H**	*Possible*	**E**
Residential (north Gray Street)	**Major**	*Likely*	**E**	*Almost Certain*	**E**	*Almost Certain*	**E**
Commercial (Dampier Tce, eastern side)	**Major**	*Possible*	**H**	*Likely*	**E**	*Almost Certain*	**E**
Commercial (Dampier Tce, western side)	**Major**	*Possible*	**H**	*Likely*	**E**	*Almost Certain*	**E**
Paspaley Shopping Centre	**Major**	*Possible*	**H**	*Likely*	**E**	*Almost Certain*	**E**
Airport Runway, Helipads	**Catast.**	*Rare*	**M**	*Unlikely*	**H**	*Possible*	**E**
Kennedy Hill	**Major**	*Unlikely*	**M**	*Possible*	**H**	*Likely*	**E**
Pearling Heritage, Buildings	**Mod.**	*Likely*	**H**	*Almost Certain*	**H**	*Almost Certain*	**H**
Streeters jetty	**Mod.**	*Likely*	**H**	*Almost Certain*	**H**	*Almost Certain*	**H**
Roads (Dampier Terrace, Chapple St, Gray Street)	**Mod.**	*Likely*	**H**	*Almost Certain*	**H**	*Almost Certain*	**H**
Roads (Broome Road /Short St)	**Major**	*Possible*	**H**	*Likely*	**E**	*Almost Certain*	**E**
Landscaping / Open Space	**Min.**	*Unlikely*	**L**	*Possible*	**M**	*Likely*	**M**
Mangroves[1]	**Catast.**	**Not Rated**					

1. Not rated as the link between coastal erosion and impacts to the mangrove areas is unknown

Table 5.14: Coastal Compartment 8 – Dampier Creek Inner Coastal Erosion Risk

Asset	Conseq Erosion	Likelihood 2040	Risk Level 2040	Likelihood 2070	Risk Level 2070	Likelihood 2110	Risk Level 2110
Dampier Creek Environment[1]	**Major**	**Not Rated**					
One Mile	**Major**	*Unlikely*	**M**	*Possible*	**H**	*Likely*	**E**
Morrell Park	**Major**	*Likely*	**E**	*Almost Certain*	**E**	*Almost Certain*	**E**
Speedway	**Major**	*Unlikely*	**M**	*Possible*	**H**	*Likely*	**E**
Pony Club	**Mod.**	*Unlikely*	**M**	*Possible*	**H**	*Likely*	**H**
Broome Road	**Major**	*Possible*	**H**	*Likely*	**E**	*Almost Certain*	**E**
Wattle Drive Properties	**Major**	*Rare*	**M**	*Unlikely*	**M**	*Possible*	**H**
Broome Common Yards	**Major**	**Not Impacted**					
Roebuck Estate	**Major**	**Not Impacted**					

1. Not rated as the link between coastal erosion and environment degradation is unknown

Table 5.15: Coastal Compartment 9 – Dampier Creek East Coastal Erosion Risk

Asset	Conseq Erosion	Likelihood 2040	Risk Level 2040	Likelihood 2070	Risk Level 2070	Likelihood 2110	Risk Level 2110
Dampier Creek Fish Habitat[1]	**Mod.**	**Not Rated**					
Seagrass Areas[1]	**Mod.**	**Not Rated**					
Shorebirds	**Insig.**	*Almost Certain*	**L**	*Almost Certain*	**L**	*Almost Certain*	**L**
Roebuck Bay Ramsar Site	**Outside Compartment – Not Assessed**						
Unsealed Roads	**Minor**	*Unlikely*	**L**	*Possible*	**M**	*Likely*	**M**

1. Not rated as the link between coastal erosion and impact to natural system is unknown

5.3.2 Inundation Risk by Coastal Compartment

Coastal compartments identified as being at risk of storm surge inundation are those from Town Beach to Dampier Creek (coastal compartments 6 to 9). The high barrier dunes and cliffs present in coastal compartments 1 to 5 are at a level sufficient to provide natural protection against storm surge inundation.

It is noted the inundation likelihood is based on the LiDAR data and does not account for freeboard - habitable floor heights may be above the lot ground level on which the LiDAR is based. The depth is shown based on a 'bathtub' approach whereby the defined offshore ocean water level is directly transferred into the coastal area.

Table 5.16: Coastal Compartment 6 – Town Beach Coastal Inundation Risk

Asset	Conseq Inund.	Likelihood 2040	Risk Level 2040	Likelihood 2070	Risk Level 2070	Likelihood 2110	Risk Level 2110
Town Beach Foreshore	**Minor**	*Rare*	**L**	*Unlikely*	**L**	*Possible*	**M**
Town Beach Caravan Park	**Minor**	*Rare*	**L**	*Unlikely*	**L**	*Possible*	**M**
Town Beach Car Park	**Minor**	*Unlikely*	**L**	*Possible*	**M**	*Likely*	**M**
Shire Assets (Café, Waterpark, toilets / BBQ facilities)	**Mod.**	*Rare*	**L**	*Unlikely*	**M**	*Possible*	**H**
Residential – Catalina's	**Mod.**	*Unlikely*	**M**	*Possible*	**H**	*Likely*	**H**
Boat ramp	**Minor**	*Almost Certain*	**M**	*Almost Certain*	**M**	*Almost Certain*	**M**
Mangroves	**Minor**	*Almost Certain*	**M**	*Almost Certain*	**M**	*Almost Certain*	**M**

Table 5.17: Coastal Compartment 7 – Broome Town Centre Coastal Inundation Risk

Asset	Conseq Inund.	Likelihood 2040	Risk Level 2040	Likelihood 2070	Risk Level 2070	Likelihood 2110	Risk Level 2110
Chinatown Heritage Buildings Carnarvon St (eg Sun Pictures)	Mod.	*Likely*	H	*Almost Certain*	H	*Almost Certain*	H
Residential (north Gray Street)	Mod.	*Possible*	H	*Likely*	H	*Almost Certain*	H
Commercial (Dampier Tce, eastern side)	Mod.	*Likely*	H	*Almost Certain*	H	*Almost Certain*	H
Commercial (Dampier Tce, western side)	Mod.	*Likely*	H	*Almost Certain*	H	*Almost Certain*	H
Paspaley Shopping Centre	Mod.	*Likely*	H	*Almost Certain*	H	*Almost Certain*	H
Airport Runway, Helipads	Mod.	*Possible*	H	*Likely*	H	*Almost Certain*	H
Kennedy Hill	Mod.	**Not Impacted**					
Pearling Heritage Buildings	Mod.	*Almost Certain*	H	*Almost Certain*	H	*Almost Certain*	H
Streeters jetty	Insignificant	*Almost Certain*	L	*Almost Certain*	L	*Almost Certain*	L
Roads (Dampier Terrace, Chapple St, Gray Street)	Mod.	*Almost Certain*	H	*Almost Certain*	H	*Almost Certain*	H
Roads (Broome Road /Short St)	Mod.	*Likely*	H	*Almost Certain*	H	*Almost Certain*	H
Landscaping / Open Space	Minor	*Likely*	M	*Almost Certain*	M	*Almost Certain*	M
Mangroves	Minor	*Almost Certain*	M	*Almost Certain*	M	*Almost Certain*	M

Table 5.18: Coastal Compartment 8 – Dampier Creek Inner Coastal Inundation Risk

Asset	Conseq Inund.	Likelihood 2040	Risk Level 2040	Likelihood 2070	Risk Level 2070	Likelihood 2110	Risk Level 2110
Dampier Creek Environment[1]	Mod.	Not Rated					
One Mile	Mod.	Rare	L	Unlikely	M	Possible	H
Morrell Park	Mod.	Almost Certain	H	Almost Certain	H	Almost Certain	H
Speedway	Minor	Possible	M	Likely	M	Almost Certain	M
Pony Club	Minor	Possible	M	Likely	M	Almost Certain	M
Broome Road	Mod.	Possible	H	Likely	H	Almost Certain	H
Wattle Drive Properties	Mod.	Unlikely	M	Possible	H	Likely	H
Broome Common Yards	Mod.	Not Impacted					
Roebuck Estate[2]	Major	Not Impacted					

1. Not rated as the link between inundation and environment degradation is unknown
2. Flooding inundation only considers storm tide. Catchment based flooding is not considered in the assessment

Table 5.19: Coastal Compartment 9 – Dampier Creek East Coastal Inundation Risk

Asset	Conseq Inund.	Likelihood 2040	Risk Level 2040	Likelihood 2070	Risk Level 2070	Likelihood 2110	Risk Level 2110
Dampier Creek Fish Habitat[1]	Minor	Not Rated					
Seagrass Areas[1]	Minor	Not Rated					
Shorebirds	Minor	*Almost Certain*	M	*Almost Certain*	M	*Almost Certain*	M
Roebuck Bay Ramsar Site	Outside Compartment – Not Assessed						
Unsealed Roads	Minor	*Almost Certain*	M	*Almost Certain*	M	*Almost Certain*	M

1. Not rated as the link between coastal inundation and impact to natural system is unknown

6 Adaptation Options

6.1 Risk Management and Adaptation

This section outlines how the identified coastal hazard risk can be managed in each coastal compartment. The assets identified as being most at risk in Section 5.3 are considered in detail to determine the best course of action to reduce the coastal risk down to a tolerable level. Whilst the identified coastal hazard risk to 2110 is a key consideration for long term coastal planning, the 2040 and 2070 planning periods are the focus for adaptation strategies in this section, recognising the considerable uncertainty associated with making predictions for climate change impacts on complex climatic and coastal systems.

Adaptation strategies are developed from natural approaches, structural solutions and planning options. Within each of the coastal compartments an overall adaptation strategy is recommended based on the WAPC adaptation hierarchy:

- Avoid;
- Managed Retreat;
- Accommodate; or
- Protect.

For Broome currently, nature itself plays a key role in coastal resilience. Extensive mangrove cover through Roebuck Bay and Dampier Creek acts to reduce storm surge and wave action at the shore in extreme events. The barrier dunes in the open coast areas are sufficiently high to prevent inundation of inland areas in storm tide and provide a buffer in large wave events. Coastal dunes and mangrove areas are to be valued for their critical role in coastal protection, and will need to be carefully monitored and maintained in future.

The local community and tourist population place a high value on the natural environment of Broome and the structural (man-made) adaptation options to address future coastal hazard risk should think outside of traditional standard forms of hard engineering to develop structures that can work with nature. Examples of this are becoming more common in modern coastal engineering where structures not only provide resilience to a shoreline but can also act as ‘living shorelines’ that enhance shoreline ecosystems.

Effective planning control plays a decisive role in controlling future use of the coast identified as being at risk of coastal hazard, and providing guidance for existing infrastructure located within identified coastal hazard to ensure practical outcomes.

6.1.1 Risk Management and the Adaptation Hierarchy

The risk management and adaptation hierarchy (WAPC2014) provides a platform for considering risk management through a tiered approach that aims to build coastal resilience and maintain flexibility for future decision makers in coastal areas. The hierarchy is presented on Figure 6.1.

Figure 6.1: Risk Management and Adaptation Hierarchy (WAPC 2014)

There are four broad categories of potential adaptation options (WAPC 2013):

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

Some general examples of risk management and adaptation options from the four stages of the adaptation hierarchy are shown in Table 6.1 from the CHRMAP guidelines (WAPC 2014).

Table 6.1: Examples of Risk Management and Adaptation Options under the Adaptation Hierarchy

Adaptation Option	Option Examples
Avoid	Locating assets in areas that will not be vulnerable to coastal hazards.
Planned / Managed Retreat	Leaving assets unprotected. Demolition / removal/ relocation of assets from inside hazard area. Prevention of further development / prohibit expansion of existing use rights.
Accommodate	Notification on title (can also be relevant to (planned/managed retreat and protect options). Emergency evacuation plans Design assets to withstand impacts.
Protect	Beach Nourishment or replenishment Groynes Seawalls

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

The coastal hazard identified within each of the coastal compartments of Broome has been considered within the risk management and adaptation hierarchy through a process that has involved the application of WAPC and SPP2.6 requirements, and which has been guided from discussions with stakeholders and the community in the community engagement workshops.

It is important to note the CHRMAP is an ongoing process that will be reviewed approximately every five years, over which time any updates to the understanding of coastal hazard risk for Broome or changes to planning policies in WA would need to be considered. Where new information or methods become available that significantly modify the understanding of the coastal hazards, then adaptation within coastal compartments would need to be reviewed again through the CHRMAP hierarchy, as part of the ongoing monitoring and review process.

6.2 Adaptation Strategies by Coastal Compartment

Within each of the coastal compartments, coastal adaptation strategies have been identified from the adaptation hierarchy. Adaptation responses can vary within coastal compartments, and in many instances a range of complementary adaptation responses that mitigate the coastal risk are recommended.

In key compartments, Cable Beach, Town Beach and Broome Town Centre, the risk management and adaptation options have been evaluated in the most detail.

6.3 Coastal Compartment 1

6.3.1 Risk Management and Adaptation – Cable Beach North

6.3.1.1 Risk Summary

Cable Beach north is undeveloped shoreline with extensive coastal foreshore reserve area that can accommodate coastal erosion hazard for future planning periods. The coastal erosion likelihood is shown on Figure B1.1 for 2040, Figure B1.2 for 2070 and Figure B1.3 for 2110. The key assets identified in this section of coast on Table 5.7 are environmental and cultural and include the Lurujarri Trail, monsoon vine thickets, turtle nesting sites, sand dunes and shorebird habitat.

Key risk priorities in the 2040 planning period are as follows:

- A small section of the Lurujarri trail is at risk of erosion in the 2070 to 2110 periods, with risk level rated as medium in 2070 and high by 2110; and
- The coastal dunes are at risk of erosion with risk level rated as medium in 2040, high in 2070 and extreme in 2110.

6.3.1.2 Risk Mitigation Recommendation

This shoreline along the northern section of Cable Beach was noted as *accreting* based on analysis of historical shoreline position in the CVS (Cardno 2015). For this reason, it is considered that the erosion risk to the dunes and the Lurujarri trail can be mitigated through future monitoring of the shoreline, to provide confirmation of the rate at which erosion is occurring in future timeframes.

6.3.1.3 Recommended Risk Management and Adaptation Strategy

The risk management and adaptation approach for this section of coast is **Avoid**. Any future planning approaches will need to be sited landward of the identified 2110 planning period coastal erosion hazard. There may be a requirement for an additional allowance in the foreshore area for use at 2110 should the forecast coastal physical processes be realised, and this would need to be determined in future at the time of development.

6.3.2 Risk Management and Adaptation – Cable Beach Central

6.3.2.1 Risk Summary

For Cable Beach Central the coastal erosion likelihood is shown on Figure B1.4 for 2040, Figure B1.5 for 2070 and Figure B1.6 for 2110. There are a number of high to extreme level risks have been identified in Table 5.7 for assets within the foreshore area:

- the level of risk identified for the Cable Beach shoreline is extreme for all planning periods, as it is almost certain to be impacted by coastal erosion in the coming decades;
- the foreshore reserve area provides significant public amenity open space and built assets (amphitheatre, beach access roads, carparks etc) which rate in the medium to high risk category in the 2040 planning period;
- the Surf Club is an important community organisation that also provides a valuable role in beach safety, whose present location in the likely zone of coastal erosion in the 2040 planning period places it in the extreme risk category. It is planned to rebuild the surf club in coming years and the identified coastal hazard for erosion will need to be duly considered in this process. It is noted Surf clubs are an

exception to general planning considerations in SPP2.6, and can occupy areas of the foreshore identified as being at risk of coastal hazard provided coastal hazard planning is recognised in the process;

- Zanders Café is situated within the likely erosion hazard zone and is rated in the extreme risk category for 2040;
- Residential property is rated as being at high risk in the 2040 planning period increasing to extreme in the 2070 and 2110 planning periods; and
- A section of the Lurujarri trail is at risk of erosion in the 2070 to 2110 periods, with risk level rated as high for 2040, 2070 planning periods.

Discussions at the community and stakeholder workshops undertaken for the CHRMAP highlighted the critical importance of this section of the coast. The value of Cable Beach and associated tourism infrastructure to Broome's economy and community were recognised in CHRMAP, concluding that a **Protect** option should be adopted for the main tourist hub of Cable Beach. This is detailed in the sections to follow. The suite of options in the adaptation strategy for the Cable Beach Central compartment is summarised in Section 6.3.2.6 with preferred options summarised in Section 7.

6.3.2.2 Risk Mitigation - Structural Options

Shire Structures in the foreshore

Access to the coast (stairs, ramps, pathways) are exposed to an identified erosion and inundation risk hazard and these types of structures will always be at risk of erosion and inundation in an extreme cyclonic event. Following Tropical Cyclone Rosita in 2000, coastal erosion of the dune at Cable Beach led to the beach access stairs and beach access ramp being undermined as shown on Figure 6.2. As part of recommended future monitoring campaigns, the structural integrity of structures currently located in the coastal erosion zone should be verified on a periodic basis, with recommendations regarding further repair or maintenance for their continued safe use consistent with a 'managed retreat' approach.

Figure 6.2: Cable Beach post TC Rosita 2000 showing (left) undermined beach access ramp and (right) beach access stairs (photo source: Shire of Broome, JCU 2000)

Structures in the foreshore area that do not require coastal connection (eg toilets andBBQs etc) should be sited relative to their expected design life and consider the projected coastal erosion hazard across that time. As an example, for an asset with a design life of 20 years constructed before the year 2020, this

could be placed at the position of the projected 2040 coastal erosion hazard line under a 'managed retreat' approach. As the structure approached the end of design life (eg 2040), consideration would be given to the observed extent of erosion and whether the asset would need to be relocated further landward consistent with the future planning period.

Coastal Protection of Foreshore

Mitigation of the coastal erosion threat to the assets at the upper foreshore (Surf Club, Zanders, Shire structures including carparks and amphitheatre) could be achieved through a coastal protection structure, built to armour the shoreline against elevated water levels and wave attack in future extreme cyclones and as a result of sea level rise. Structural options could take the form of seawalls, revetments, groynes or offshore reefs all of which would offer some form of protection to the coast and ensure that the present location of the upper foreshore at the top of the dune is maintained.

The idea of constructing an engineered solution such as a revetment or seawall in the foreshore area of this section of Cable Beach was raised in the community and stakeholder workshops with the following noted:

- Through the community workshops, the most suitable option for an engineering solution determined was a buried seawall. Other options eliminated from the discussion were groynes (disruptive to sand transport, not in keeping with natural setting) and an offshore artificial reef (reliability in Broome's extreme tide range).
- Allowing the coast to erode naturally (ie do nothing) and implement a retreat from the shoreline areas over time as erosion impacted the shoreline was also supported by a few participants in the community workshops.
- Some concerns were raised by community with structures on the shoreline and the potential to interfere with the natural system, and the possibility that an engineered structure might potentially lead to further problems including erosion of the beach area in front of it, which would completely undermine its potential benefit.
- There was reluctance to impact the natural setting with any form of structure that would detract aesthetically people's beach experience. Tourists and locals value their beach experience for the pristine environment which would not be significantly impacted through the addition of visible engineered solutions to armour the shoreline.

From the stakeholder and community workshops, a buried seawall was identified as the preferred option for a coastal structure. In terms of how a buried seawall could provide mitigation of coastal erosion risk, a relevant example comes from Queensland's Gold Coast where the erosion threat from large cyclonic storms is managed through the use of hard structures such as buried seawalls at the back of the beach:

- seawalls are constructed from rock to provide erosion protection, and overlain with sand with the dune system re-established and planted out so as to offer a natural look at the back of the beach;
- In extreme events wave attack may remove the overlain sand, but the foreshore position is maintained at the line of the structure. The sand is then replaced over the structure through sand dumping, as part of the re-establishment and nourishment of the beach post storm.

A buried seawall option has been considered for Cable Beach to manage the erosion risk at concept level with the following features:

- A buried seawall would be positioned at the location of the current dune, effectively armouring the shore against further erosion as shown on Figure 6.3. The seawall shown on Figure 6.3 would be approximately 500m length tied in to the headland feature at the north of the beach and back into the dune south of the Surf Club. The height of the dune is shown in three transects on Figure 6.3, a key design consideration and cost implication if the design is to extend all the way to the top of the dune.
- The construction material used in seawalls can vary considerably from rubble mound (ie rock), concrete blocks, geotextile sand bags, gabion structures and marine matting system. An indicative cross section for a seawall is shown in Figure 6.4 and Figure 6.5 based on a standard rubble mound design. The current shoreline profile across the dune system ranges from 1V:2H to 1H:3V at the base to upper dune and this would be followed in the construction of the seawall. The rock would be overlain by sand upon completion and then vegetated dune cover placed over the sand.
- In terms of cost of construction, the 500m length could cost in the region of $6 million based on assumed construction costs (estimated based on similar project requirements). A current buried seawall project on the Gold Coast constructing 900m of buried seawall from rock for erosion protection is projected to cost the City $6.7 million (GCCC 2016).
- It is noted that should a buried seawall be constructed, the covered structure may be partially or fully exposed in a large storm event. Sand nourishment would be required following large storm events to restore the dune cover and erosion in the beach area immediately in front of the structure. This occurred to the dune following Cyclone Rosita and is discussed further in the next section (6.3.2.3).
- Of key importance, the geotechnical properties underlying the current dune would need to be understood, as this may identify the presence of hard material beneath the dune in some sections of the beach that may remove the need for a coastal protection structure. This geotechnical understanding is discussed further in Section 6.3.2.4.

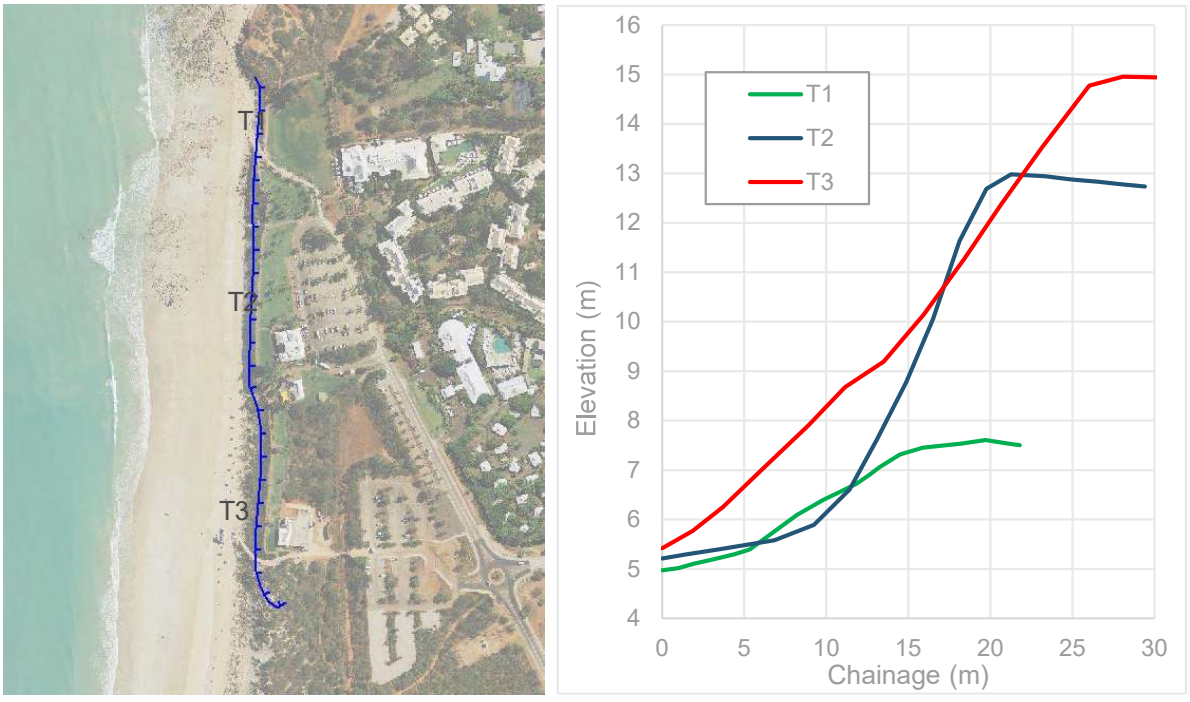
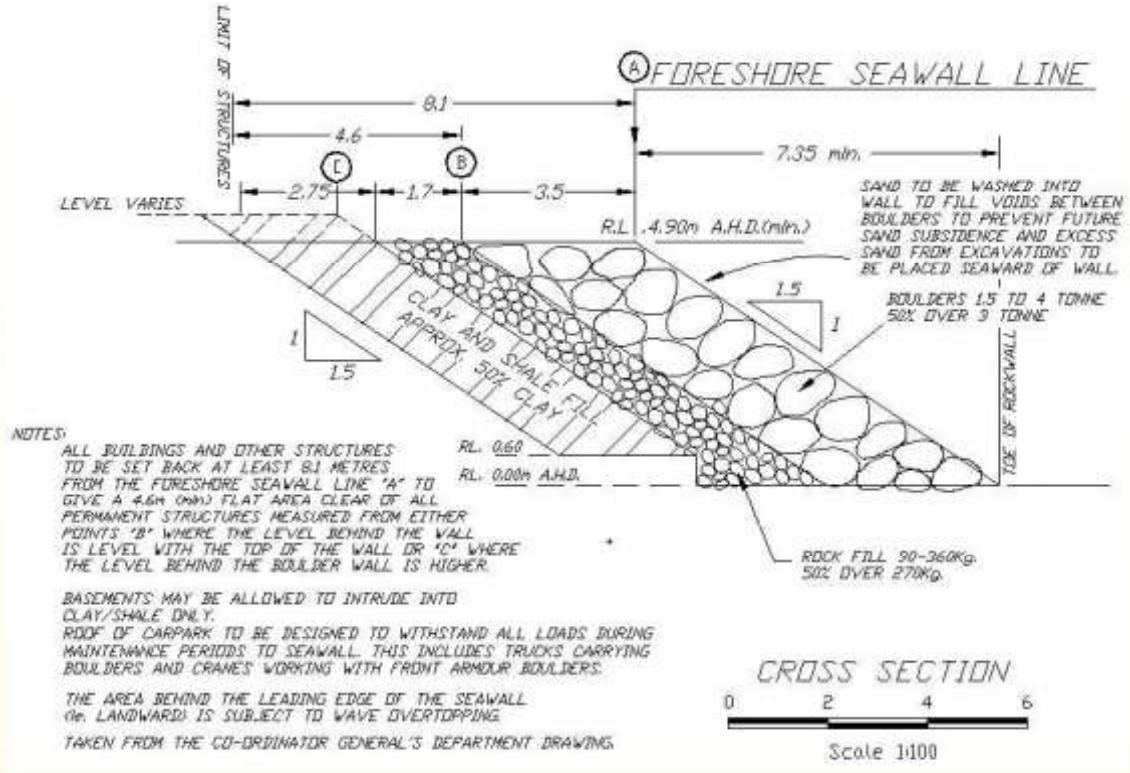


Figure 6.3: Cable Beach central section, potential location of buried seawall engineering option.



Type 1 foreshore rock standard drawing plan (Source: GCCC)

Figure 6.4: Buried seawall indicative cross section (GCCC)

Figure 6.5: Buried Seawall under construction (GCCC 2016)

6.3.2.3 Risk Mitigation - Soft Options

Beach Nourishment

Sand nourishment is a viable option for restoring beach amenity following a large cyclone event, and offers a 'quick fix' solution that restores the beach profile when the time period of the natural recovery is considered too long which is likely to be the case in this section of the beach which is high value to community and tourists. Under a buried seawall option, sand nourishment may be required to restore the beach profile post-storm.

Following Tropical Cyclone Rosita in 2000, a coastal engineering assessment of the beach (DOT 2000) estimated 30,000m^3 of sand would be required to restore the beach area in front of Zanders over a 200m x 200m section which had been stripped back to rock. Severe erosion to the dune in front of Zanders café back to the pindan layer would require another 30,000m^3 of sand to reinstate the dune (Figure 6.6). Whilst it was noted the restoration of the beach 'could be left to nature', the Shire was particularly concerned about the impact of the erosion on the tourist industry, particularly the perception outside of Broome that the beach has been lost' and additionally that the pindan sand might contaminate the white sand on the beach (DOT 2000). Based on drawings from Shire, the toe of the dune in front of Zanders shown on Figure 6.6 had been eroded back approximately 20m.

Figure 6.6: Post Cyclone Rosita – dune in front of Zanders café stripped back to Pindan Layer (Photo Shire of Broome)

Sand nourishment was undertaken by Shire in July 2000 for the dune in front of Zanders and the beach area in front between the two main access stairs either side of this section of the coast, a distance of approximately 160m. Based on Shire records a contractor was engaged to use scrapers and bulldozers to

move approximately 15,000m^3 of sand from the southern end of the beach below the high water mark into the eroded area to re-establish the profile of the beach and dune. This occurred over approximately 4 weeks at a cost of $90,000. Approvals to remove sand from the lower beach and renourish the upper area were not required at the time, with works enacted under the Local Government Act deemed as an Emergency provision as part of the cyclone recovery for the town.

In the event of a future similar large erosion impact of the foreshore area, this nourishment approach would mitigate the extreme risk identified for the beach area, as well as guard against a further storm impact noting that more than one extreme storm may impact the beach area in a cyclone season.

The nourishment of the beach through this approach to provide additional protection buffer to the fore dune is not viewed as a viable option outside of a post cyclone Emergency provision. Discussions with Shire on this matter indicate there could be potential issues around extracting sand from the beach system and modification of the coastal dune from Government agencies and local stakeholders.

Dune Revegetation

Increasing the natural resilience of the coastal dune through planting and dune rehabilitation is an effective strategy already underway at the location, with the intention of providing good vegetation cover across the dune face. The vegetation stabilises the sand on the dune from wind-blown transport, and also offers greater resilience to the dune face under wave attack in extreme events.

6.3.2.4 Monitoring and Further Information

Of key importance for the coastal adaptation strategy of this coastal compartment will be gaining a more thorough understanding of the coastal dunes and underlying composition. The shoreline stability assessment which was undertaken in the CVS and on which the CHRMAP likelihood lines are based, assumes that the dunes are composed entirely of sand. There has been no geotechnical study undertaken to establish the properties of the rock beneath the dune and its resilience to coastal erosion is unknown. Photos taken from the beach post Cyclone Rosita in 2000, clearly show the presence of rock at the base of several of the dunes in areas where the overlying sand was eroded (Figure 6.7).

A geotechnical assessment could determine the extent of the rock which is beneath the dune, and provide a clearer understanding of the resilience of the shoreline to future threats from extreme cyclonic waves and sea level rise. If the rock was shown to be offering significant resistant to erosion, the erosion hazard could be reconsidered, and coastal hazard risk mitigated for the foreshore area without the need for a seawall along the entire extent. Alternatively, based on the geotechnical information there may be the opportunity to construct the coastal protection structure (eg buried seawall) incorporated into the rock structure.

A monitoring campaign to better understand the future erosion rate and response of the shoreline under general conditions, sea level rise and extreme cyclonic events will be recommended to support the CHRMAP. This should involve photo monitoring and shoreline surveys to build an understanding of the dune and beach system.

Following significant extreme erosion events post-storm monitoring of the shoreline and dunes in this section would be highly recommended. Ground surface 3D survey of the beach could be undertaken using Unmanned Aerial Vehicle (UAV) which offers a cost-effective method for describing the surface elevation of the beach area.

Figure 6.7: Cable Beach eroded base of dune post Tropical Cyclone Rosita 2000 (JCU 2000).

6.3.2.5 Risk Mitigation - Planning Options

The proposed buried seawall would afford protection for a significant portion of land located within the Cable Beach Central Section. Specific planning mechanisms would not necessarily be required to be introduced for land afforded protection by the seawall, however the Shire may wish to consider introducing a development contribution area within its Scheme to provide a mechanism to collect funds from landowners that benefit from the seawall to contribute to the maintenance and upkeep of the seawall.

There are a number of private properties that are located north of the proposed buried seawall that would remain prone to coastal erosion processes. Specifically, portion of Lots 100, 983 and Lot 985 Millington Road, Cable Beach would remain exposed to coastal erosion within the 2110-year planning horizon. It is noted that a number of existing residential dwellings and tourist accommodation infrastructure are currently located on the seaward side of the 2110 coastal erosion line.

It is also noted that the lot boundaries for most of these lots extend beyond the landward side of the 2110 coastal erosion line, giving rise to the opportunity to plan and manage retreat by relocating development to the portion of lots not at risk of coastal erosion over time.

For these properties, a range of adaptation measures are proposed to firstly; (a) avoid new development within vacant land located within land at risk of erosion during the 2110 planning timeframe, and; (b) plan and manage retreat for existing development on land at risk of erosion during the 2110 planning timeframe.

Additionally, Part 7 of Schedule One of SPP2.6 identifies circumstances where 'variations' may be applied by permitting certain uses on land prone to coastal processes within the nominated timeframe. As Cable Beach is a popular tourist destination that caters for a wide range of community, recreation and tourist activities, it is a location that may be appropriate to permit such variations from time to time, at the discretion of the relevant authorities. Such uses may include, but not necessarily be limited to:

- Public recreation facilities with an expected useful lifespan of less than 30 years. This may include minor car parks, public ablutions, barbecue / picnic / shade structures, playground and other such infrastructure;
- Facilities for public events;
- Surf lifesaving club; and
- A coastal node which is a distinct and discrete built area that may be located within a coastal foreshore reserve. Excluding permanent residential development, it may vary in size from a grouping of recreational facilities to an area of commercial or tourism facilities or accommodation.

The planning adaptation measures for the Cable Beach Central Precinct would specifically need to consider and address the following issues.

- Require planning approval for normally exempt development for land prone to coastal erosion within the 2110 planning timeframe;
- Provide clear guidance to decision makers and developers that no new development of a substantial nature will be permitted on land prone to coastal erosion within the 2110 planning timeframe and which is not afforded protection via a proposed sea wall;
- Provide guidance to decision makers and developers to locate development on portion/s of the lot on the landward side of the 2110 coastal erosion line;
- Provide guidance to decision making authorities relating to circumstances where time limited approvals may be issued for temporary development and land use and/or development of a low financial value that is not likely to be impacted by the modelled coastal erosion during the life of the approval, or is categorised as low risk;
- Require the provision of a Section 70A notification on the title of lots identified as being prone to erosion as a condition of any planning approval to alert prospective purchasers to the risk of coastal process impacts on the lot;
- Consider introducing developer contribution requirements in relation to land that is benefited / protected by any proposed seawall to collect funds for the maintenance and upkeep of the seawall;
- Generally not support further fragmentation and subdivision of land that would result in the creation of new lot/s that would be substantially compromised with respect to development potential, access and other considerations as a result of coastal erosion processes within the 2110 planning timeframe; and
- Allow flexibility to permit certain public infrastructure on land prone to coastal processes, where deemed necessary and appropriate by relevant authorities.

6.3.2.6 Recommended Risk Management and Adaptation Strategy

The risk management and adaptation approach for this section of coast is

- **Protect** the main tourist hub through a coastal protection structure, subject to a detailed erodibility study to determine the underlying geotechnical properties of the foreshore (under the dune);
- **Avoid** further development within the identified coastal erosion hazard for properties not sited behind the proposed seawall
- **Managed Retreat** for minor structures and coastal properties within the erosion hazard area and not sited behind the proposed seawall.

The adaptation will be supported by a coastal monitoring program tracking the rate of future erosion of the shoreline.

6.3.3 Economic Evaluation of Adaptation Options

Cable Beach provides important amenity values to the local residents of Broome as well as being the pre-eminent tourism destination of Broome and the Kimberley Region more broadly. The recent study into the feasibility of Broome as a commercial hub (AVC 2015) notes that:

"Despite being a 'niche market in a niche market', Broome (and the wider Kimberley Region) is an icon tourism location in Western Australia and is nationally and internationally recognised", and that "Broome's main attraction is the scenic Cable Beach and much of the town's tourism product revolves around Cable Beach".

Discussions at the community and stakeholder workshops undertaken for the CHRMAP support this assessment, with Shire and community stakeholders emphasising the importance of Cable Beach and associated tourism infrastructure to Broome's economy and community.

Given the importance of Cable Beach and the risks to its shoreline, foreshore and recreational and community assets from coastal erosion (outlined in section 6.3), a detailed assessment of options for protecting the beach's values is warranted. Before a robust assessment of options can be undertaken however, it is important that further detailed analysis necessary to support such an assessment is undertaken. Further analysis should include:

- In-depth coastal geotechnical studies to establish with greater certainty the risks posed to Cable Beach shoreline, foreshore and built assets from coastal erosion;
- Analysis of the use and non-use values of Cable Beach to the local community and broader community; and
- More detailed concept level engineering specification of structural and other potential adaptation options to ascertain the extent to which they can mitigate the risks to Cable Beach foreshore and assets while protecting the key values of the beach.

In the absence of this analysis a cost-benefit analysis (CBA) of Cable Beach adaptation options has not been undertaken for the CHRMAP. Instead, a qualitative discussion of the potential benefits and costs of Cable Beach adaptation options is provided below.

6.3.3.1 Indicative benefits and costs of Cable Beach adaptation options

As detailed in section 4.2.1 and Table 5.7 coastal erosion at Cable Beach poses a number of high and extreme risks in the 2040 planning period including to:

- The beach shoreline and associated recreational, amenity and cultural values;
- Sand dunes in the southern and northern sections and associated ecological values;
- The Lurujarri Trail and associated cultural and recreational values; and
- A range of built assets in the main tourist area in the central section of the coastal compartment.

The first three listed risks are linked in that together they provide the recreational and amenity values that are critical to attracting visitors and locals to Cable Beach, as well as providing cultural and other non-use values.

An estimate of the economic value of tourism to Broome is provided on Table 6.2. Economic value, measured as the 'producer surplus' associated with tourism expenditure in Broome is estimated at approximately $8 million per annum.

Table 6.2: Annual economic value of tourism to Broome ($ million 2016)

Visitor type	Annual number of visitors	Average length of stay (days)	Expenditure / day ($)	Total expenditure ($m)	Producer surplus ($m)
Domestic intrastate	73,800	4.1	122	37.0	3.1
Domestic interstate	77,400	4.1	122	38.8	3.3
International	28,800	11.8	55	18.7	1.6
TOTAL	**180,000**	**5.3**		**94.5**	**8.0**

Producer surplus is a measure of the difference between the amount a producer of a good or service (e.g. tourism service provider) receives and the minimum amount the producer is willing to accept for the good. The surplus amount, is the economic benefit received by the producer for selling the service (Anning, D. 2012, Raybould, M. et al., 2011). If, as available evidence suggests, Cable Beach is Broome's primary attraction, then a very substantial proportion of this value can be attributed to the beach. Conversely, if the beach were adversely impacted (either by erosion or a poorly designed adaptation option) then a substantial proportion of this economic value would be at risk.

Furthermore, other studies into the economic value of beaches suggest the economic value of beaches to local communities (both 'use' and 'non-use' values) are likely to be as great or greater than the economic value linked to tourism, even when a beach is a popular tourism attraction. Any future adaptation options for Cable Beach will therefore need to have the protection of these values as a primary focus.

In addition to recreational and tourism values threatened by coastal erosion, a number of built assets in the foreshore reserve area of Cable Beach are at risk. These include the Surf Life Saving Club, Zanders Café, carparks and various Shire infrastructure assets. Table 6.3 provides an estimate of the value of assets at risk to coastal erosion in 2015 and 2040. Although the value of built assets at risk is quite significant ($4.4

million and $5.9 million respectively in 2015 and 2040), it is important to note that although the probability that coastal processes will impact on these assets over the period of the analysis is very low, the loss of the assets, should they be impacted, will be a one-off loss, with the expected value of losses in any one year therefore being in the order of tens or hundreds of thousands of dollars. This suggests that protecting the values of the shoreline should probably be the principal focus of a Cable Beach adaptation strategy.

Table 6.3: Assets at Cable Beach vulnerable to coastal processes

Property type	Replacement Cost ($)	Unit	Area impacted by SPP2.6 Erosion allowance (m2)		Value of assets at risk ($)	
			2015	2040	2015	2040
Carparks	83.3	m2	40	1850	$ 3,332	$ 154,105
Landscaping	10	m2	4556	9083	$ 45,560	$ 90,830
Pathways	35	m2	1200	2100	$ 42,000	$ 73,500
Road	83.3	m2	0	0	$ -	$ -
Fencing	100	m	373	373	$ 37,300	$ 37,300
Shire Structures / Assets					$ 4,457,710	$ 5,484,488
SHIRE ASSETS TOTAL					$ 4,587,917	$ 5,842,263
Private Held Land Area	700	m2	800	5800	$ 560,000	$ 4,060,000
Resort	1000	m2	0	0	$ -	$ -
TOTAL					$ 5,147,917	$ 9,902,263

Section 6.3.2 provides an overview of a range of options to addressing the risks of erosion to Cable beach, including structural options such as a buried seawall, 'soft' options such as beach nourishment, and planning controls to limit the extent or type of development in high hazard areas. Table 6.7 provides an overview of the indicative construction costs for three structural option alternatives – a buried rock wall, a buried revetment and a buried seawall. In addition to construction costs, annual maintenance costs could be up to $100,000 for each option.

Table 6.4: Cable Beach Alternative Structural Options Indicative Construction Costs ($2016)

	Option		
	Buried rock wall	Buried revetment	Buried seawall
Cost ($/metre)	10,300	13,100	12,150
Length (metres)	500	500	500
Indicative cost ($)	5,150,000	6,550,000	6,075,000
Contingency ($)	515,000	655,000	607,500
ESTIMATED COST[1] ($)	5,665,000	7,205,000	6,682,500

1. Costs estimated based on similar projects undertaken.

The cost of soft and planning options are likely to be substantially less than the structural options. It should be noted however, that the structural, soft and planning options have the potential to be complementary (e.g. a structural option could be combined with beach nourishment and planning controls). A detailed assessment of a range of adaptation options needs to carefully consider how these options could complement each other. Importantly a key consideration when assessing the options, either separately or in combination, is the extent to which they will protect (or detract from) the use and non-use values of Cable Beach, especially its shoreline.

Before a robust assessment of the structural adaptation options can be undertaken, it is important that there be supporting geotechnical studies to improve understanding of the presence of rock under the main dune system (to inform coastal erosion risk and design of potential coastal protection structures). Additional information on use and non-use values of Cable Beach to the local community and broader community and discussions at the stakeholder level could also be undertaken to further inform the economic assessment.

6.3.4 Risk Management and Adaptation – Cable Beach South

6.3.4.1 Risk Summary

Cable Beach south is undeveloped shoreline with extensive coastal foreshore reserve area that can accommodate coastal erosion hazard for future planning periods. The coastal erosion likelihood is shown on Figure B1.7 for 2040, Figure B1.8 for 2070, and Figure B1.9 for 2110. The key assets identified in this section of coast on Table 5.7 are environmental and cultural and include the Lurujarri Trail, monsoon vine thicket extents, sand dunes and shorebird habitat.

Key risk priorities were identified as follows:

- The southern section of the Lurujarri trail (near Gantheaume Point) is at risk of erosion in the 2040 period, with risk level rated as high;
- the coastal dunes are at risk of erosion with risk level rated as Medium in 2040 and high by 2070;
- the monsoon vine thickets are rated at the high risk level in 2040, and extreme in 2070;
- at the southern extent, coastal erosion threatens the road and the race track infrastructure (further discussed in Section 6.4)

6.3.4.2 Risk Mitigation Recommendation

Monitoring and management of the coast is recommended to mitigate the identified risk of erosion:

- Within this section of coast, monitoring of the shoreline to better understand the rate of erosion occurring over future timeframes will be recommended.
- It is noted that the coastal erosion risk is concentrated at the southern section of the beach, where 47m erosion in a design storm (S1) was adopted in the CVS. The erosion allowance (S1 value) of 47m, is the worst of the modelled erosion result from transects investigated in the CVS in this stretch of beach (corresponding to the northernmost transect near the Surf Club). The CVS transects evaluated close to Gantheaume Point end of the beach (CAB02, CAB03) indicated a much lower erosion value of 9.9m and 14.5m respectively. This outcome would be entirely expected for the more protected locations at the southern end of the beach. Based on this, the erosion risk could be expected to be less severe than the hazard lines indicate, a premise that could be confirmed through coastal monitoring over the next 5 to 10 years.
- Management of the shoreline should also include efforts to increase the natural resilience of the shoreline in sections of the southern dune system under erosion threat from 4WD access and informal tracks.

6.3.4.3 Recommended Risk Management and Adaptation Strategy

The risk management and adaptation approach for this section of coast is **Avoid**. Any future planning approaches will need to be sited landward of the identified 2110 planning period coastal erosion hazard (apart from exempt coastal structures identified in SPP2.6 Section 7). The requirement for additional allowance in the foreshore area for an area for recreational/environmental use at 2110 should the forecast coastal physical processes be realised would be determined at the time of development (SPP2.6).

6.3.5 Summary Risk Management and Adaptation Strategy Coastal Compartment 1

The adaptation measures proposed for the Cable Beach Compartment are summarised in Table 6.5. It is noted that this is an option summary for consideration, however it may not be viable to implement all options in the future. The adaptation strategy and preferred options are summarised in Section 7.

The CHRMAP adaptation approaches would be supported by a structured monitoring program, designed to further understanding of the coastal processes affecting the coastal areas and monitor the ongoing rate of erosion. This is further detailed in Section 8.

Table 6.5: Cable Beach Coastal Compartment Adaptation Measures Summary

Type	Risk Circumstance	Adaptation Approach	Mechanism/s
Structural	Erosion risk to beach access paths, stairs and ramps	Planned / Managed Retreat	• Consider coastal hazard in design but accept that assets are vulnerable and accept loss following major event. • Regular inspection to determine structural integrity. Implement repairs to maintain public safety and allow to retreat over time with recession of shoreline
Structural	Erosion risk to Shire assets / structures	Protect	• Construction of buried seawall along the foreshore area.

	and community use of the foreshore area in the section of beach from Surf Club north to the Resort (500m)		• Prior to any preliminary engineering design need to complete a geotechnical study to confirm erodibility of underlying strata. • Following geotechnical report findings, a preliminary engineering concept may be pursued supported by discussions with stakeholders and community and more detailed economic assessment of option.
Soft Options	Risk of severe beach erosion in cyclone events in the section of beach from Surf Club north to the Resort (500m)	Protect	• Sand nourishment through use of bulldozers and scrapers to restore beach profile • investigate permitting issues for nourishment of eroded beach area following significant erosion event • Determine if emergency works as undertaken following Cyclone Rosita would be permitted under current State policy and local support for this approach from stakeholders
Soft Options	Risk of dune erosion and long term stability of coastal dunes	Protect	• Support dune stabilisation and revegetation program to increase resilience • Control access to dune system (paths / 4WD tracks) • Regular monitoring campaign to track coastal erosion rates. Target key areas of interest (eg sections of coast fronting vine thickets, Lurujarri trail, roads)
Planning	Vacant developable land located on land prone to coastal erosion within the 2110 planning timeframe *Note: does not apply to sections landward of the coastline that would be protected by coastal protection option such as a buried seawall*	Avoid	• Introduce planning controls via a Special Control Area and/or Local Planning Policy that prevents any development of vacant land or new development within land prone to coastal erosion within the planning timeframe. • Provide guidance for decision makers and developers to locate development on portion/s of the lot on the landward side of the 2110 coastal erosion line. • Require Section 70A notifications to be placed on the certificate of title for all new development
Planning	Existing assets located on land prone to coastal erosion within the 2110 planning timeframe	Planned / Managed Retreat	• Introduce planning controls via a Special Control Area and/or Local Planning Policy that seek to prevent further major redevelopment of prone land. • For minor structures that are easily relocatable permit minor expansion / upgrade works via granting time limited approvals for a period that do not exceed the planning timeframe for the erosion event. • Require Section 70A notifications to be placed on the certificate of title for all new planning approvals.
Planning	Land proposed to be protected by a seawall in Central compartment	Protect	• Consider introducing developer contribution requirements for development protected by the seawall to contribute to the maintenance and upkeep of the seawall.

Planning	Land uses exempted by Part 7 of Schedule One of State Planning Policy 2.6. eg Surf Club	Accommodate	• Consider on an as needs basis. Applications for such uses should be accommodated by necessary justification, including, but not limited to: ◦ Community demand for such a facility; ◦ Emergency evacuation plan (where appropriate); ◦ Lifespan of structure / use; ◦ Design measures to withstand coastal events (where appropriate); ◦ Other matters as deemed appropriate by the determining authority.

6.4 Coastal Compartment 2

6.4.1 Risk Management and Adaptation – Gantheaume Point

6.4.1.1 Risk Summary

Gantheaume Point's rock shoreline reduces the coastal erosion hazard for future planning periods considerably compared to the sandy coast of the Cable Beach compartment. The coastal erosion likelihood is shown on Figure B2.1 for 2040, Figure B2.2 for 2070 and Figure B.2.3 for 2110. The key assets identified in this section of coast on Table 5.8 include the Broome Turf Club and associated infrastructure, Gantheaume Point road, Lurujarri Trail, dinosaur footprints, tourist area (parking) and shorebird habitat.

Key risk priorities are as follows:

- The Lurujarri trail is rated at high risk in 2040;
- The Turf Club and its supporting infrastructure with risk level medium in 2070
- Gantheaume Point Road is rated medium risk in 2040 moving to high risk in 2070.

6.4.1.2 Risk Mitigation – Structural Options

Shire Structures (Carparks, Roads, pathways)

A managed retreat option should be adopted for coastal structures, pathways and roads. Monitoring and review of coastal erosion along this section of the coast will be recommended to review future coastal erosion rate with particular reference to the encroachment on Gantheaume Point Road and Kavite Road.

6.4.1.3 Risk Mitigation – Planning Options

The planning adaptation measures for the Gantheaume Cliffs Precinct would specifically need to consider and address the following issues.

- Avoid any new infrastructure to be constructed on the seaward side of the 2110 coastal physical setback line.
- Locate any new infrastructure or buildings on the landward side of the 2110 coastal physical setback line (with appropriate allowance for factor of safety).

The requirement for additional allowance in the foreshore area for an area for recreational/environmental use at 2110 should the forecast coastal physical processes be realised would be determined at the time of development.

6.4.1.4 Monitoring and further information

Monitoring of the coast is recommended to manage the identified risk, and monitoring of the shoreline to better understand coastal resilience and rate of erosion over future timeframes will be required.

6.4.2 Summary Risk Management and Adaptation Strategy Coastal Compartment 2

The risk management and adaptation approach for this section of coast is **Accommodate / Managed Retreat** supported by coastal monitoring of the rate of future erosion of the rock shoreline.

The adaptation measures proposed for the Gantheaume Cliffs Coastal Compartment are summarised in Table 6.6.

Table 6.6: Gantheaume Cliffs Coastal Compartment Adaptation Measures Summary

Type	Risk Circumstance	Adaptation Approach	Mechanism/s
Structural	Erosion risk to access paths minor infrastructure	Planned / Managed Retreat	• Regular inspection to determine structural integrity. Implement repairs to maintain public safety and allow to retreat over time with recession of shoreline
Planning	Existing assets located on land prone to coastal erosion within the 2110 planning timeframe	Accommodate, Planned / Managed Retreat	• Introduce planning controls via a Special Control Area and/or Local Planning Policy that seek to prevent further major redevelopment of prone land. • For minor structures that are easily relocatable permit minor expansion / upgrade works via granting time limited approvals for a period that do not exceed the planning timeframe for the erosion event. • Require Section 70A notifications to be placed on the certificate of title for all new planning approvals.
Planning	Road infrastructure located on land prone to coastal erosion within the 2110 planning timeframe.	Planned / Managed Retreat	• Monitor the encroachment of coastal erosion in relation to this infrastructure and review recommendations on a regular basis.
Planning	Land uses exempted by Part 7 of Schedule One of State Planning Policy 2.6.	Accommodate	• Consider on an as needs basis. Applications for such uses should be accommodated by necessary justification, including, but not limited to: ◦ Community demand for such a facility; ◦ Emergency evacuation plan (where appropriate); ◦ Lifespan of structure / use; ◦ Design measures to withstand coastal events (where appropriate); ◦ Other matters as deemed appropriate by the determining authority.

6.5 Coastal Compartment 3

6.5.1 Risk Management and Adaptation – Reddell Beach

6.5.1.1 Risk Summary

For Reddell Beach, the coastal erosion likelihood is shown on Figure B3.1 for 2040, Figure B3.2 for 2070 and Figure B3.3 for 2110. The key assets identified in this section of coast are two residential lots (with built assets), Lurujarri trail, Minyir Park, carparks for beach access and Kavite Road (unsealed). It is noted that a concept for a Broome Marina / Safe Boat Harbour has been proposed for this coastal compartment (ABC Kimberley 2016), however the status of the project and its preferred location are unknown at time of writing. Any such marina development would be required to undertake CHRMAP specific to the requirements of the development, to mitigate coastal hazard in future planning periods as detailed in this document.

The pindan cliff shoreline of this coastal compartment was highlighted as being particularly vulnerable to erosion in the CVS, with recent rates of erosion of 0.9m/year in the 2000 to 2012 period above the long-term average of 0.2m/yr (1965 to present). In the post disaster report for Tropical Cyclone Rosita (JCU 2000) it was noted 'the pounding seas broke away large sections of the rocky cliffs and exposed outcrops along the coastline'. The pindan cliff shoreline has very limited adaptive capacity to future erosion - it will not recover in the same way a dune system may recover after a large erosion event, and once it erodes the shoreline is effectively lost. There is significant uncertainty as to how quickly the pindan cliff will erode under future erosion hazard posed from short term (ie cyclones) and longer term (sea level rise) events and this will be a key requirement to examine in future monitoring of the coastline.

Key risk priorities in the 2040 planning period are as follows:

- The two residential lots are rated at extreme risk, with structures less than 30m from the cliff edge;
- The Lurujarri trail rated as high risk in the 2040 period and subsequent 2070 and 2110 periods;
- Reddell Beach foreshore is rated high risk in 2040 and beyond;
- Minyir Park is rated as high for 2040 and future planning periods; and
- The southern section of Kavite Road is rated medium risk in 2040.

6.5.1.2 Risk Mitigation – Structural Options

Shire Structures (Carparks, Roads, pathways)

A managed retreat option should be adopted for carparks, pathways and roads. Monitoring and review of coastal erosion along this section of the coast will be recommended to determine the ongoing rate of erosion, with particular reference to the encroachment on beach carpark areas and Kavite Road.

6.5.1.3 Risk Mitigation – Planning Options

Coastal erosion has been modelled to impact on existing infrastructure and an area zoned for future development within the 2110 planning timeframe, as follows:

- Kavite Road;
- Rural Residential zoned properties; and
- Vacant 'Development' zoned land located to the east of Kavite Road.

There will be a general presumption against further development on land on the seaward side of the 2110 coastal physical setback line, except for minor temporary development to be considered on a case by case basis.

Any new development on zoned land, including the Rural Residential and Development zones, shall be required to be located on the landward side of the 2110 coastal physical setback line. Any required additional allowance for an area for recreational/environmental use at 2110 should the forecast coastal physical processes be realised will be determined at the time of development.

The planning adaptation measures for the Reddell Beach Coastal Compartment would specifically need to consider and address the following issues:

- Require planning approval for normally exempt development for land prone to coastal erosion within the 2110 planning timeframe;
- Provide clear guidance to decision makers and developers that no new development of a substantial nature will be permitted on land prone to coastal erosion within the 2110 planning timeframe;
- Provide guidance to decision makers and developers to locate development on portion/s of the lot on the landward side of the 2110 coastal erosion line;
- Provide guidance to decision making authorities relating to circumstances where time limited approvals may be issued for temporary development and land use and/or development of a low financial value that is not likely to be impacted by the modeled coastal erosion during the life of the approval, or is categorised as low risk;
- Require the provision of a Section 70A notification on the title of lots identified as being prone to storm surge as a condition of any planning approval to alert prospective purchasers to the risk of coastal process impacts on the lot;
- Generally not support further fragmentation and subdivision of land that would result in the creation of new lot/s that would be substantially compromised with respect to development potential, access and other considerations as a result of coastal erosion processes within the 2110 planning timeframe.

6.5.1.4 Monitoring and further information

Monitoring of the coast is recommended to manage the identified risk, and monitoring of the shoreline to better understand coastal resilience of the pindan cliff and rate of erosion over future timeframes will be required.

6.5.2 Summary Risk Management and Adaptation Strategy Coastal Compartment 3

The risk management and adaptation approach for this section of coast is **Avoid** further development within the identified coastal erosion hazard, **Managed Retreat** for current structures and properties within the erosion hazard area. The managed retreat option will be supported by coastal monitoring of the rate of future erosion of the pindan shoreline.

The adaptation measures proposed for the Reddell Beach Coastal Compartment are summarised in Table 6.7.

Table 6.7: Reddell Beach Coastal Compartment Adaptation Measures Summary

Type	Risk Circumstance	Adaptation Approach	Mechanism/s
Structural	Erosion risk to beach access paths, carparks, Kavite Road	Planned / Managed Retreat	• Regular inspection to determine structural integrity. Implement repairs to maintain public safety and allow to retreat over time with recession of shoreline
Planning	Existing assets located on land prone to coastal erosion within the 2110 planning timeframe	Accommodate, Planned / Managed Retreat	• Introduce planning controls via a Special Control Area and/or Local Planning Policy that seek to prevent further major redevelopment of prone land. • For minor structures that are easily relocatable permit minor expansion / upgrade works via granting time limited approvals for a period that do not exceed the planning timeframe for the erosion event. • Require Section 70A notifications to be placed on the certificate of title for all new planning approvals.
Planning	Vacant developable land located on land prone to coastal erosion within the 2110 planning timeframe	Avoid	• Introduce planning controls via a Special Control Area and/or Local Planning Policy that prevents any development of vacant land or new development within land prone to coastal erosion within the planning timeframe. • Provides guidance for decision makers and developers to locate development on portion/s of the lot on the landward side of the 2110 coastal erosion line. • Require Section 70A notifications to be placed on the certificate of title for all new development

6.6 Coastal Compartment 4

6.6.1 Risk Management and Adaptation – Entrance Point

6.6.1.1 Risk Summary

The Entrance Point coastal compartment landside is comprised of reserve land vested in the Kimberley Ports Authority (KPA). Significant port infrastructure under the control of the KPA is identified as being at risk of coastal erosion in future planning periods, along with two boat ramps and the attached carpark which is controlled by Department of Transport (refer Figures B4.1, B4.2 and B4.3). The CHRMAP process does not apply to this compartment in the same way as the other coastal compartments, as the land tenure is not under the Shire's control.

Port infrastructure is undertaken under the Public Works Act, and whilst this requires due regard be given to Shire's planning scheme in the area (eg CHRMAP provisions) there is no statutory enforcement to follow the Shire's CHRMAP recommendations. In certain circumstances the port leases out land areas to private interests (eg the Broome Fishing Club) and development approval for these areas will come through the Shire and be bound by the Shire's development approval process (CHRMAP). These specific areas in the coastal compartment are considered in CHRMAP, with planning recommendations provided in this section.

Due the special circumstances of this coastal compartment, the impact of coastal erosion hazard on identified assets, economic assessment of impact to assets, and risk mitigation using structural approaches has not been assessed.

6.6.1.2 Risk Mitigation Options – Planning Options

While port infrastructure is exempt from requiring the prior planning approval of the Shire, any new development associated with leases to private entities may be subject to the requirements of this CHRMAP.

In this respect, any new development associated with a private entity interest, shall typically be located on the landward side of the 2110 coastal physical setback line, except for special circumstances, such as land uses exempted by Part 7 of Schedule One of State Planning Policy 2.6 which includes

- public recreation facilities with finite lifespan (less than 30 years) (i.e. car parks, ablutions, boat ramps)
- coastally dependent and easily relocatable development (fences, shade structures)
- Department of Defence infrastructure
- Industrial and commercial development that is demonstrably dependent on foreshore location (marina, aquaculture, port facilities)
- Coastal nodes (provide a range of facilities to benefit the broader public) defined as a distinct and discrete built area that may be located within a coastal foreshore reserve. Excluding permanent residential development, it may vary in size from a grouping of recreational facilities to an area of commercial or tourism facilities or accommodation.
- Surf Lifesaving Clubs

These special circumstances will be assessed on a case by case basis.

The planning adaptation measures for the Entrance Point Coastal Compartment would specifically need to consider and address the following issues.

- Require planning approval for normally exempt development for land prone to coastal erosion within the 2110 planning timeframe;
- Provide clear guidance to decision makers and developers that infrastructure and development not associated with the port will not be permitted on land prone to coastal erosion within the 2110 planning timeframe;
- Provide guidance to decision makers and developers to locate private development on portion/s of the lot on the landward side of the 2110 coastal erosion line;
- Provide guidance to decision making authorities relating to circumstances where time limited approvals may be issued for temporary development or development of a low financial value that is not likely to be impacted by the modelled coastal erosion during the life of the approval;
- Allow flexibility to consider permitting certain public infrastructure on land prone to coastal processes, where deemed necessary and appropriate.

6.6.1.3 Monitoring and further information

Monitoring of the coast is recommended to manage the identified risk to the Monson Vine thickets on coastal fringe northwest of Entrance Point. Monitoring of the shoreline will track the rate of erosion in future timeframes, to understand more clearly the future risk for these assets.

Monitoring of coastal erosion for the eastern side of Entrance Point to confirm the erosion rate of the shoreline at the boat ramps, carpark and port areas should also be undertaken in any future monitoring program.

Geotechnical assessment of the foreshore at Entrance Point to confirm the presence of rock below the beach and dune would improve the understanding of the long term erodibility potential of the shoreline.

6.6.2 Summary Risk Management and Adaptation Strategy Coastal Compartment 4

The risk management and adaptation approach for this section of coast is **Avoid** new development within the identified coastal erosion hazard, **Managed Retreat** for current structures and properties within the erosion hazard area. The managed retreat option will be supported by a coastal monitoring program tracking the rate of future erosion of the shoreline.

It is strongly recommended that the KPA consider undertaking a detailed geotechnical assessment of the foreshore at Entrance Point similar to what is proposed at Cable Beach, to confirm the presence of rock in the foreshore area and coastal dune. This would improve understanding of the potential resilience of the shoreline to erosion in future planning periods, create greater certainty around the risk to existing port infrastructure and assist Shire officers in assessing applications for 'exempt' infrastructure on a case by case basis.

The adaptation measures proposed for the Entrance Point Coastal Compartment are summarised in Table 6.8

Table 6.8: Entrance Point Coastal Compartment Adaptation Measures Summary

Type	Risk Circumstance	Adaptation Approach	Mechanism/s
Structural	Erosion risk to beach access paths, carparks, Kavite Road	Planned / Managed Retreat	• Regular inspection to determine structural integrity. Implement repairs to maintain public safety and allow to retreat over time with recession of shoreline
Planning	Existing assets located on land prone to coastal erosion within the 2110 planning timeframe	Accommodate, Planned / Managed Retreat	• Introduce planning controls via a Special Control Area and/or Local Planning Policy that seek to prevent further major redevelopment of prone land. • Permit minor expansion and upgrade works via granting time limited approvals for a period that do not exceed the planning timeframe for the erosion event. • Require Section 70A notifications to be placed on the certificate of title for all new planning approvals.
Planning	Vacant developable land located on land prone to coastal erosion within the 2110 planning timeframe	Avoid	• Introduce planning controls via a Special Control Area and/or Local Planning Policy that prevents any development of vacant land or new development within land prone to coastal erosion within the planning timeframe. • Provides guidance for decision makers and developers to locate development on portion/s of the

			lot on the landward side of the 2110 coastal erosion line. • Require Section 70A notifications to be placed on the certificate of title for all new development
Planning	Land uses exempted by Part 7 of Schedule One of State Planning Policy 2.6.	Accommodate	• Consider on an as needs basis. Applications for such uses should be accommodated by necessary justification, including, but not limited to: ◦ Community demand for such a facility; ◦ Emergency evacuation plan (where appropriate); ◦ Lifespan of structure / use; ◦ Design measures to withstand coastal events (where appropriate); • Other matters as deemed appropriate by the determining authority.

6.7 Coastal Compartment 5

6.7.1 Risk Management and Adaptation – Simpsons Beach

6.7.1.1 Risk Summary

Simpsons Beach is undeveloped shoreline with coastal foreshore reserve area that can generally accommodate coastal erosion hazard for future planning periods.

The coastal erosion likelihood is shown on Figure B5.1 for 2040, Figure B5.2 for 2070 and Figure B.5.3 for 2110. The key economic assets identified in this coastal compartment are listed on Table 5.11 and include residential properties, waste water treatment plant and the golf course. The environmental assets include Roebuck Bay and areas of monsoon vine thicket.

Key risk priorities are all as a result of erosion as follows:

- The threat to beach and foreshore area is rated as high in 2040, 2070 and 2110;
- Residential land (partial areas of lots) is identified at medium risk in 2040 and 2070, increasing to high in 2110;
- the monsoon vine thickets are rated at the extreme risk level in 2040, 2070 and 2110; and
- It is noted the critical infrastructure of the waste water treatment plant is located landward of the 2110 coastal erosion extent so is not impacted in the planning period to 2110.

6.7.1.2 Risk Mitigation – Structural Options

Shire Structures (Carparks, Roads, pathways)

There are no identified Shire structures within the coastal compartment. The car park at north Simpsons Beach built through the Yawuru Park Council (YPC) is considered in the Town Beach compartment. Future infrastructure planning of the carpark should be considered under a managed retreat option.

6.7.1.3 Risk Mitigation – Planning Options

Land on the seaward side of the 2110 coastal physical setback line is primarily reserved for coastal purposes and for the most part does not contain infrastructure or physical improvements.

The coastal adaptation approach for this coastal compartment is therefore one of avoidance, ensuring that no new development or infrastructure is established on land prone to coastal erosion within the planning timeframe.

The planning adaptation measures for the Simpsons Beach Coastal Compartment would specifically need to consider and address the following issues.

- Require planning approval for normally exempt development for land prone to coastal erosion within the 2110 planning timeframe;
- Provide guidance to decision makers and developers that development will not be supported on the seaward side of the 2110 coastal erosion line; and
- Provide guidance to decision makers and developers to locate development on land located on the landward side of the 2110 coastal erosion line.

6.7.1.4 Monitoring and Further Information

A monitoring program will be recommended to better inform future risk management issues for the coast. The risk level for the monsoon vine thicket, identified as being at extreme risk in the coastal compartment, will be managed through a targeted monitoring program, tracking coastal erosion along the shoreline. In YPC areas, Yawuru Rangers could be tasked with this monitoring.

6.7.1.5 Recommended Risk Management and Adaptation Strategy

The risk management and adaptation approach for this section of coast is **Avoid** further development within the identified coastal erosion hazard. The avoid option will be supported by a coastal monitoring program tracking the rate of future erosion of the shoreline.

The adaptation measures proposed for the Simpsons Beach Coastal Compartment are summarised in Table 6.9.

Table 6.9: Simpsons Beach Coastal Compartment Adaptation Measures Summary

Type	Risk Circumstance	Adaptation Approach	Mechanism/s
Structural	Erosion risk to minor coastal infrastructure	Planned / Managed Retreat	• Regular inspection to determine structural integrity. Implement repairs to maintain public safety and allow to retreat over time with recession of shoreline
Planning	Reserved land located on the seaward side of the 2110 coastal physical setback line	Avoid	• Introduce planning controls which require planning approval for normally exempt development such as a single house; • Provide clear guidance that land use and development will not be supported on the seaward side of reserved land located within the 2110 coastal physical setback line.

6.8 Coastal Compartment 6

6.8.1 Risk Management and Adaptation – Town Beach

6.8.1.1 Risk Summary

For Town Beach the coastal erosion likelihood is shown on Figure B.6.1 to Figure B.6.6 for the 2040, 2070 and 2110 planning periods. There is significant residential, commercial and public use of the foreshore with high to extreme level risks noted for coastal erosion hazard in Table 5.12 as follows:

- the level of risk identified for the Town Beach foreshore reserve and for the Pioneer Cemetery is extreme in the 2040, 2070 and 2110 period;
- the section of the Roebuck Bay caravan park fronting the coast is at extreme risk in 2040, 2070 and 2110;
- Residential properties at Catalina's are rated as extreme risk of erosion in 2040, 2070 and 2110;
- Tourist accommodation on Carnarvon Street (Mangrove Hotel, Moonlight Bay suites) is rated in the high risk category in 2040, increasing to extreme in 2070 and 2110;
- Residential and commercial properties on the Conti foreshore and Demco Street are at high risk in 2040. For Demco Street properties the rating increases to extreme in 2070 and 2110;
- Town Beach Carparks and major access roads Hammersley Street and Carnarvon Street are at high risk in 2040, 2070 and 2110; and
- Shire assets in the Town Beach reserve (waterpark, Town Beach café) are at medium risk in the 2040 period, increasing to high in the 2070 and 2110 period.

The coastal inundation likelihood for Town Beach is shown on Figure B.6.7 to B.6.12 for the 2040, 2070 and 2110 planning periods. The coastal inundation risk is rated for the Town Beach assets in Table 5.16 with key risks noted as follows:

- inundation of the Town Beach reserve foreshore and car park at the planning period 2070 and 2110 is medium risk (Figure B.6.8);
- The caravan park risk level is low until 2110 at which time it is medium risk;
- Shire assets including the café, waterpark and toilets are low risk in 2040, medium risk in 2070 and high risk in 2110; and
- Catalina's residential is rated as medium risk of inundation in 2040 increasing to high in 2070 and 2110.

Discussions at the community and stakeholder workshops undertaken for the CHRMAP highlighted the importance of Town Beach to the community. Whilst the beach is not feted by the same level of tourist attention as Cable Beach, it attracts significant tourist numbers particularly during viewing of the 'staircase to the moon' phenomenon. The large local residential population adjoining its shoreline, coupled with the mix of short term accommodation options in the area including the Roebuck Bay caravan park place a high value on the beach and its foreshore areas.

Importantly for the CHRMAP, the need for coastal protection along the eroding pindan cliff north of old jetty area has been acknowledged by the Shire and construction of a coastal revetment is planned for 2018-19. The **Protect** option in this location is supported by the CHRMAP and discussed further in the sections to follow. The complete suite of adaptation options for the coastal compartment is summarised in Table 6.11.

6.8.1.2 Risk Mitigation - Structural Options

Town Beach Revetment

In November 2016 Council endorsed an updated Long Term Financial Plan (LTFP) which provides for a revetment to be constructed at Town Beach in 2018-2019 along the eroding pindan cliff shoreline north of the old jetty area (Figure 6.8).

Figure 6.8: Town Beach eroding pindan cliff with example of undercut cliff base

The revetment will mitigate the extreme level erosion risk identified for the east side of the Town Beach foreshore reserve, Pioneer Cemetery and the Museum as well as offering mitigation to high risk residential properties landward on Robinson Street. The historical erosion rate for the pindan cliff has accelerated in recent years (Cardno 2015, MRA 2012) and the undercutting of the cliff poses a danger to the community in its current state.

The revetment provides coastal erosion protection for approximately 170m of the vulnerable shoreline area of the Town Beach foreshore reserve, whilst also functioning as a viewing area for 'Staircase to the Moon' (Figure 6.9, Figure 6.14 and Figure 6.15). There are heritage and environmental approvals that would need to be sought in relation to the revetment, with a significant mangrove colony in the foreshore area that would need to be considered for impacts associated with its construction.

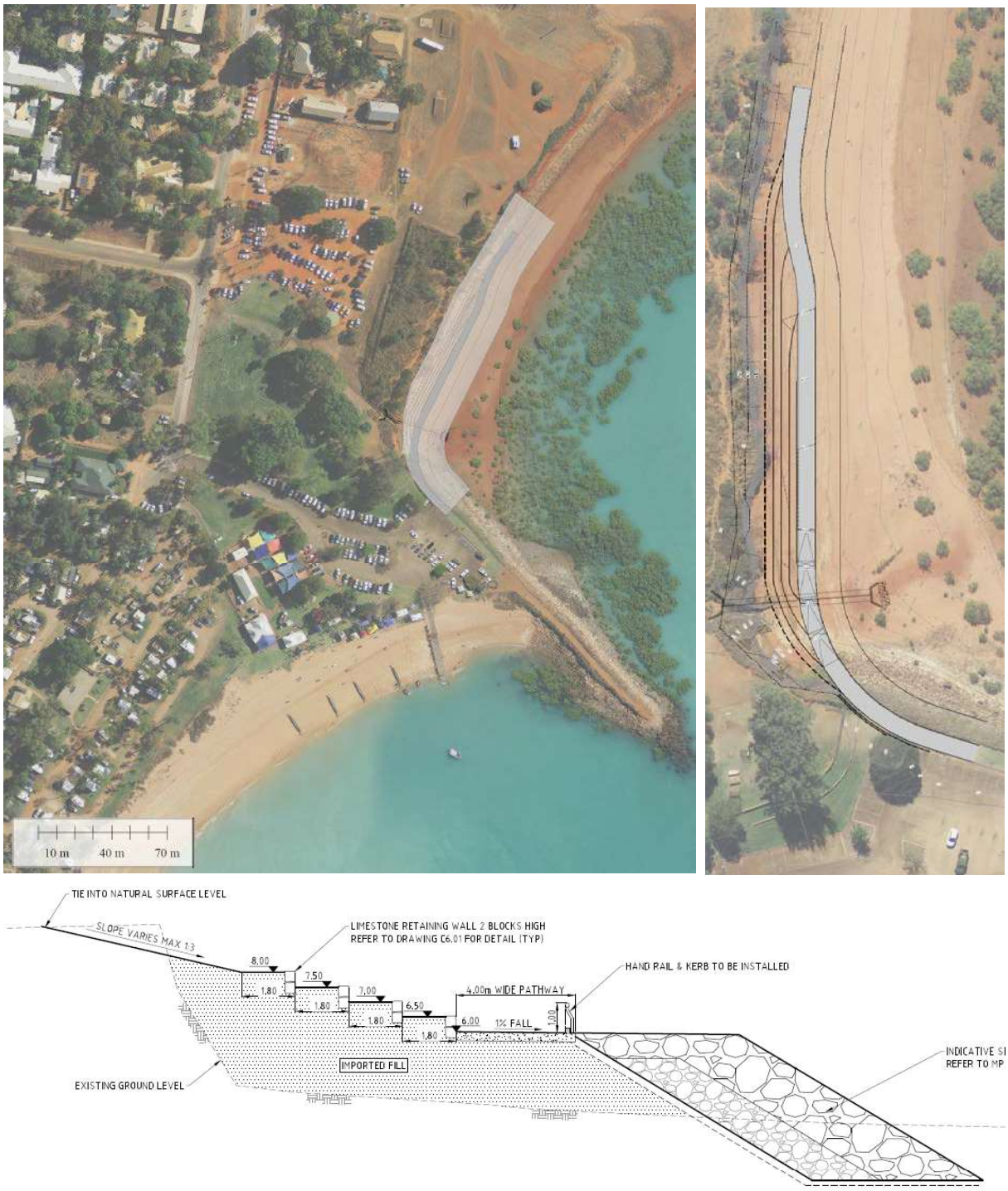


Figure 6.9: Town Beach Seawall Design (MPRA 2012).

Town Beach south of old jetty area

The section of the coast south of the old jetty area on which the Town Beach café currently stands is potentially at risk of erosion mainly through sea level rise impact. The shoreline is noted as currently stable based on historical record, and monitoring of the coastal erosion to track the horizontal response of the shoreline to vertical sea level rise is considered sufficient to mitigate the erosion risk in the immediate term (to 2040). Future adaptation responses in 2070 and beyond will likely need to consider whether to protect this section of the foreshore.

Further south in the section of coast fronting the caravan park the low dune cliff is protected by informal coastal protection in the form of rocks dumped at the top of the beach. There is uncertainty as to the future stability of the dune fronting the caravan park and this should be the focus of a geotechnical investigation in future years, to determine its resilience to coastal erosion. In the short term, monitoring of the shoreline for long term erosion is important particularly after significant storms.

Shire Structures in the foreshore

Access to the coast (stairs, ramps, pathways) would need to be planned with due consideration to the projected erosion and inundation hazard. Coastal assets in the foreshore area should be sited relative to their expected design life and the anticipated coastal erosion hazard across that time in the foreshore reserve.

As an example, foreshore structures with a design life of 20 years constructed before the year 2020, could be placed at the position of the 2040 coastal erosion hazard line. As the structure approached the end of design life (eg 2040), with a managed retreat approach, consideration would be given to the projected level of erosion in the future planning period and whether the asset would need to be relocated further landward should the projected erosion rates be observed.

As part of future monitoring campaigns, the structural integrity of structures currently located in the coastal erosion zone should be verified on a periodic basis, with recommendations regarding further repair or maintenance for their continued safe use consistent with a managed retreat approach.

Planned walkways and associated infrastructure for the *Jetty to Jetty walk trail* should consider design criteria that meet the SPP2.6 recommendations along the coastal compartment, and be designed to withstand the projected inundation and erosion level associated with their design life as noted on Table 3.4, Table 3.8, Table 3.9 and Table 3.10.

Stormwater

The concern that the condition of Roebuck Bay remain as a pristine marine environment was raised as a concern in community engagement, with reference made to the wetlands south of Broome being a declared RAMSAR site. Stormwater runoff is directed through the street network to drain directly into Roebuck Bay currently and there are no controls in place to treat the water runoff from the Old Broome area through water sensitive urban design (WSUD). In large storm events, significant erosion of the foreshore has been noted at stormwater outlets (Cardno 2015).

The Shire should consider opportunities to incorporate storm water treatment in planned future development of the shoreline. Any planned stormwater upgrades should consider an appropriate tail water condition as a result of storm tide and sea level rise in future planning periods (Table 3.4) which may impact the ability for stormwater to drain freely.

6.8.1.3 Risk Mitigation - Soft Options

Dune Rehabilitation

A low point behind the dune in the southern section of the coastal compartment means that the coastal erosion hazard line impacts a number of properties along Demco Drive. The site is shown on Figure 6.11 indicating the low point behind the dune. Potential inundation of this section of dune in a 100yr ARI storm surge based on a 'bathtub' approach to mapping is shown for the current day (ie no sea level rise). Under SPP2.6 the shoreline (HSD) is set at the landward edge of the flooded area shown on Figure 6.11.

Figure 6.10: Low Point in dune affecting coastal erosion hazard for properties on Demco Drive

Figure 6.11: Low Point in dune adjacent Demco Drive showing potential inundation in the ARI100yr water level ('bathtub' mapping approach based on LiDAR).

Whilst properties on Demco Drive are elevated well above the inundation risk, there is considered to be a risk of erosion in future planning periods with the inundated rear dune section enhancing the vulnerability of the fore-dune under elevated water levels and large wave attack in an extreme event (SPP2.6). The erosion likelihood for the residential property of Demco Drive is rated as high risk in 2040 and extreme by 2070 and 2110.

To reduce the coastal erosion risk for these properties investigations to restore the dune (ie fill the low section with sand) should be examined. Sourcing suitable sand for this option (ie with similar properties to that currently in the dune system) and obtaining permission from Yawuru to undertake this modification of the shoreline would be required. As a rough estimate from the available LiDAR data, the material required to fill the dune to the 100yr ARI level would be 14,000m^3.

Mangroves

For the northern section of the Town Beach coastal compartment the health of the mangroves is key to maintaining the natural coastal defence of the coastal foreshore area. The value of the mangroves as natural defence for this section of coast cannot be overstated as the mangroves play a vital role in attenuating storm surge and reducing the wave heights at the shoreline in extreme cyclonic events. Monitoring mangrove extent and understanding changes to the system as a result of sea level rise and other climate change variables (eg warmer ocean temperatures) will be essential in ensuring the coastal resilience of the northern sections of the compartment. Along these shorelines significant tourist infrastructure and accommodation rely on the mangrove systems to protect their shoreline during extreme cyclonic events (Figure 6.12 and Figure 6.13).

Figure 6.12: Mangroves in the northern section of the Town Beach coastal compartment (Photo from http://www.moonlightbaysuites.com.au/photos.html)

Figure 6.13: Mangroves protecting the northern section of the Town Beach coastal compartment (Photo from http://www.moonlightbaysuites.com.au/photos.html)

Foreshore planting

During the community engagement sessions, anecdotal reports that coconut trees in the foreshore of Town Beach had played an important role in stabilising the shoreline during a cyclone event were provided, noting the root systems acted to consolidate the shore and inhibit shoreline erosion. Whilst it is noted that there are potential safety issues for coconut trees due to falling coconuts, due consideration should be given to appropriate planting in the Town Beach foreshore to species suited to providing resilience to the shoreline in extreme conditions.

6.8.1.4 Mitigation Options – Planning

The 2110 coastal physical setback line impacts a number of private lots within the Town Beach compartment. While a revetment is proposed to protect the section of Town Beach north of the old jetty area (Figure 6.9), the remainder of the coastline within the Town Beach coastal compartment will remain exposed to coastal erosion processes.

Vacant residential and mixed use lots within this compartment are classified as 'infill' development as defined by SPP2.6 and therefore it is proposed to accommodate new development of vacant lots rather than avoid the development of these lots. This may need to be reviewed over time as the risk and likelihood of coastal erosion increases in relation to these properties.

It is also noted that there are a number of zoned vacant freehold lots that may not be classed as 'infill' development in accordance with SPP 2.6, specifically a number of lots located north of Town Beach are 'standalone' lots not located within a cluster or node of other lots. These lots are not proposed to be protected by a revetment and therefore another adaptation approach is required to be adopted. In these particular instances, it is recommended that applicants for development be required to undertake their own CHRMAP to identify risks and suitable adaptation responses to support their development. In these instances, private seawalls will generally be supported to protect existing freehold lots, subject to the applicant providing the necessary documentation and management arrangements to the satisfaction of the Shire.

The coastal compartment plays an important role for the community and tourists and accommodates popular destinations such as the Mangrove Hotel, Matso's Brewery, Catalina's, Town Beach and café'. Due to the popularity of Town Beach as a destination, from time to time it may be suitable to consider specific community and temporary infrastructure that is required to be located within the modelled coastal physical setback to cater for specific community uses.

The planning adaptation measures for the Town Beach Precinct would specifically need to consider and address the following issues:

Coastal Erosion

- Infill Development
  - Require planning approval for normally exempt development for land prone to coastal erosion within the 2110 planning timeframe;
  - Permit infill development on vacant zoned land with a view to reviewing this policy if and when the threat of coastal erosion substantially increases in likelihood;
  - Applications to construct private seawalls will need to address Section 5.7 of SPP2.6.
  - Require the developer to agree to indemnify the Shire through a deed of covenant and other necessary legal mechanisms;
  - Provide guidance to decision makers and developers to locate development on portion/s of the lot on the landward side of the 2110 coastal erosion line where practical;
  - Require the provision of a Section 70A notification on the title of lots identified as being prone to erosion as a condition of any planning approval to alert prospective purchasers to the risk of coastal process impacts on the lot;
  - Generally not support further fragmentation and subdivision of land that would result in the creation of new lot/s that would be substantially compromised with respect to development potential, access and other considerations as a result of coastal erosion processes within the 2110 planning timeframe.
- Non-Infill Development
  - Require planning approval for normally exempt development for land prone to coastal erosion within the 2110 planning timeframe;
  - Require developers to undertake their own CHRMAP response to define appropriate adaptation options on a site by site basis;
  - Where the development is deemed acceptable, the following conditions should be imposed:
    - Require the developer to agree to indemnify the Shire through a deed of covenant and other necessary legal mechanisms;

    - Require the provision of a Section 70A notification on the title of lots identified as being prone to storm surge as a condition of any planning approval to alert prospective purchasers to the risk of coastal process impacts on the lot;
  - Applications to construct private seawalls will need to address Section 5.7 of SPP2.6.
  - Generally, not support further fragmentation and subdivision of land that would result in the creation of new lot/s that would be substantially compromised with respect to development potential, access and other considerations as a result of coastal erosion processes within the 2110 planning timeframe.
- Foreshore Development
  - Allow flexibility to consider permitting certain public infrastructure on land prone to coastal processes, where deemed necessary and appropriate.

Storm Surge

Storm surge inundation risk is a consideration for the section of foreshore at the caravan park (Figure B.6.9) and for the Catalina's section of coast (Figure B.6.12). For land affected by the storm surge flooding within the planning timeframe (2110), it is recommended the Shire prepare a local planning policy to apply requirements with respect to the design of buildings to withstand storm surge events (discussed further in Section 6.10).

Specific objectives of the local planning policy should include the following:

- Establish approval procedures for land prone to the 500 year ARI storm surge event;
- Provide guidance for applicants and decision makers in relation to assessment procedures and development standards for development proposals in relation to land prone to the 500 year ARI storm surge event;
- To manage risk for land identified as being prone to storm surge; and
- To ensure new development is designed to withstand storm surge flooding in accordance with the adopted local planning policy.

6.8.2 Economic Evaluation of Revetment Option

The site of the Town Beach revetment is a popular recreational site for Broome local residents and visitors to Broome with a well-known and well-utilised caravan park and significant infrastructure within the beach precinct including a café, history museum, water park, residential and commercial properties, community parks, roads and carparks. Potential opportunities for enhancement and development of the precinct (including commercial, tourist and residential) are planned.

In November 2016 Council endorsed an updated Long Term Financial Plan (LTFP) which provides for the Town Beach Revetment to be constructed in 2018-19 at a cost of $4,182,506. This cost estimate is based on the detailed design prepared by MP Rogers and Associates in 2012 with escalation applied to 2016 using the Local Government Cost Index. The LTFP shows that $3 million of the cost will be met by a loan with the rest achieved through a combination of municipal funds, transfers from reserves and grants.

The Shire has developed its vision for Town Beach outlining strategies and planning initiatives through the Old Broome Development Strategy (Section 2.9.7). Shire Officers have been working on the basics for a Town Beach Master Plan to show how the public realm in the area can be enhanced. The Town Beach

Master Plan will be based on the Concept Plan in the Old Broome Development Strategy with some modifications. These components include

- the revetment;
- the extension of Hamersley Street to connect to Hopton Street via a roundabout;
- the construction of a new café on the landward site of Hamersley Street;
- the creation of a new jetty with fishing platform at the end of the groyne;
- some additional street parking; and
- a boat trailer parking area to the south of Catalina's.

The vision is that the area from the Catalina's boat parking to the current car park will be turfed and function as public parkland. The Shire engaged a landscape architect early in 2017 to produce a coordinated design for the parkland, but it will include shade, footpaths, lighting, facilities such as BBQs, potentially static exercise equipment, dedicated space for events (power/water/sewer connections) and toilets.

In 2014 the Shire of Broome commissioned Hames Sharley to develop and prepare a business case for the *Jetty to Jetty walk trail* and the Town Beach Revetment to provide a robust economic assessment of the benefits the projects would deliver (Hames Sharley 2014a, 2014b). From the Business case for the revetment (Hames Sharley 2014b), an artists impression of the concept is shown on Figure 6.14 and Figure 6.15. Key economic learnings from the reports include:

- The Town Beach development (which would include components listed in the current Town Beach Masterplan outlined above) was forecast to deliver an internal rate of return (IRR) of 11% (Hames Sharley 2014a).
- In its recommendations for developing the start (Chinatown) and end (Town Beach) sections of the *Jetty to Jetty trail* Hames Sharley 2014a stated 'this option would achieve the "best bang for the buck" in that all expenditure would occur in the two main economic precincts, providing a heightened economic demand, causing property value uplifts and a strong likelihood of extended visitor stays as well as greater expenditure by both visitors and Broome's permanent population.'
- Hames Sharley 2014b stated 'Linking the timing of completion of the revetment in with the construction activities occurring for other initiatives such as the Jetty to Jetty Roebuck Bay Coastal Walk will ensure the community, visitors and businesses all benefit from an enhanced coastline. The changes will assist in maintaining and expanding Broome's reputation as a unique environment with a rich history and ecology and provides for a sustainable economic and environmental future'.

Figure 6.14: Artists impression of the Town Beach Revetment (Hames Sharley 2014b)

Figure 6.15: Artists impression of the Town Beach Revetment and walkway linked to the Jetty to Jetty walk (Hames Sharley 2014b).

6.8.2.1 Indicative benefits and costs of Town Beach adaptation options

Unlike Cable Beach, Town Beach is not a major tourist attraction in its own right. This means that the economic values that should be considered when formulating adaptation strategies at Town Beach will largely derive from either:

- Use of the beach and beach precinct by locals; and / or
- The value of built assets that are vulnerable to coastal processes.

The revetment seawall, costing approximately $4 million proposed to stabilise the pindan cliff north of the old jetty area would also be used to protect the cemetery and the Town Beach reserve from erosion, cater for an increased capacity during tourist season viewing of the 'staircase to the moon', and through improved amenity activate the area for general use.

Additionally, the eroding pindan cliff at the shoreline currently presents safety concerns, with the area used regularly by tourists and locals as a viewing area for the 'staircase to the moon'. The safety aspect of the erosion provides a compelling case in support of the revetment option. Both from an economic and a social perspective any measures aimed at preventing injuries or fatalities, such as a revetment, could justify considerable expense.

An overview of assets in the Town Beach coastal compartment at risk from coastal processes in future planning periods (2015, 2040 and 2070) is provided on Table 6.10.

The data presented on Table 6.10 is a high-level assessment with the following noted:

- The value of built assets at risk is relatively small at present and in 2040 and only increases substantially by 2070. Assets at risk include the water park and café. Any adaptation option aimed at protecting these assets, which is likely to entail structural measures entailing significant initial capital cost, can probably be delayed for a considerable amount of time.
- The same situation probably also applies to the caravan park and to vulnerable private land, although a relatively low cost planning control aimed at avoiding future impacts may be a worthwhile interim measure which should be assessed further.

Table 6.10: Assets in the Town Beach Coastal Compartment Vulnerable to Coastal Processes

Property type	Area impacted by SPP2.6 Erosion allowance (m2)			Value of assets at risk		
	2015	2040	2070	2015	2040	2070
Carparks	1140	4264	8678	$ 94,962	$ 355,191	$ 722,877
Landscaping	2680	10865	19768	$ 26,800	$ 108,650	$ 197,680
Pathways	0	220	818	-	$ 7,700	$ 28,613
Road	0	2587	10020	-	$ 215,497	$ 834,666
Road Reserve	0	650	8686	-	$ 13,000	$173,720
Shire Structures / Assets				$1,260,163	$ 2,401,954	$ 6,630,792
SHIRE ASSETS TOTAL				$ 1,381,925	$ 3,101,992	$ 8,588,348
Private Held Land Area	3520	15076	36560	$ 2,464,000	$10,553,200	$25,592,000
TOTAL				$ 3,845,925	$13,655,192	$34,180,348

6.8.3 Summary Risk Management and Adaptation Strategy Coastal Compartment 6

The risk management and adaptation approach for this section of coast involves the following suite of strategies:

- **Protect** for the section of coast north of the old jetty area where the construction of a revetment structure will prevent further erosion of the pindan cliff; and
- **Accommodate** for sections of coast not protected by the revetment and identified as at risk of coastal erosion or storm surge in the 2110 planning timeframe.

A coastal monitoring program to support the CHRMAP and track the rate of future erosion of the shoreline as well as mangrove extent and health is recommended.

The nature of the Town Beach foreshore area being a highly valued and popular section of the coast warrants that a dedicated foreshore management plan (FMP) be developed. This would provide key guidance and recommendations for future use including beach access, erosion control, revegetation plans and stormwater management and could be supported by the economic studies undertaken to date and an assessment of social and environmental value of the beach to users.

An appropriate emergency plan should be developed for the caravan park to ensure the risk is mitigated for people and property.

The adaptation measures proposed for the Town Beach Coastal Compartment are summarised in Table 6.11.

Table 6.11: Town Beach Coastal Compartment Adaptation Measures Summary

Type	Risk Circumstance	Adaptation Approach	Mechanism/s
Structural	Erosion risk to beach access paths, stairs and ramps	Planned / Managed Retreat	• Consider coastal hazard in design but accept that assets are vulnerable and accept loss following major event. • Regular inspection to determine structural integrity. Implement repairs to maintain public safety and allow to retreat over time with recession of shoreline
Structural	Erosion risk to Shire assets, Pioneer Cemetery and the foreshore area in Town Beach Reserve	Protect	• Support further engineering studies to establish protection structure for the eroding pindan cliff. Investigate environmental and stakeholder approvals
Structural	Erosion of the dune in front of Demco Drive	Protect	• Investigate cost for remediation of this area through re-establishing the dune • investigate cost and permitting issues for restoration of the dune and local support for this approach from stakeholders (eg Yawuru)
Planning	Development located on land prone to coastal erosion within the 2110 planning timeframe	Accommodate	• Introduce planning controls which require planning approval for normally exempt development such as a single house; • Require Section 70A notifications to be placed on the certificate of title for all new planning approvals; • Consider the use of private sea walls on a case by case basis; • Review this strategy as and when the risk of coastal erosion increases over time.

Planning	Development located on land prone to storm surge within the 2110 planning timeframe	Accommodate	• Preparation of a local planning policy for Town Beach to apply requirements with respect to the design of buildings to withstand storm surge events for land prone to storm surge within a 2110 planning timeframe. Specific objectives of the local planning policy should include the following: ◦ Establish approval procedures for land prone to the 500 year ARI storm surge event; ◦ Provide guidance for applicants and decision makers in relation to assessment procedures and development standards for development proposals in relation to land prone to the 500 year ARI storm surge event; ◦ To manage risk for land identified as being prone to storm surge; and ◦ To ensure new development is designed to withstand storm surge flooding in accordance with the adopted local planning policy.
Planning	Land proposed to be protected by a revetment / seawall	Protect	• Consider introducing specialised area rates and/or developer contribution area for land proposed to be protected by the revetment to contribute to the maintenance and upkeep of the revetment. • Document this strategy within the Local Planning Strategy and ensure costings allocated within the Corporate Business Plan.
Planning	Land uses exempted by Part 7 of Schedule One of State Planning Policy 2.6. eg Community uses	Accommodate	• Consider on an as needs basis. Applications for such uses should be accommodated by necessary justification, including, but not limited to: ◦ Community demand for such a facility; ◦ Emergency evacuation plan (where appropriate); ◦ Lifespan of structure / use; ◦ Design measures to withstand coastal events (where appropriate); ◦ Other matters as deemed appropriate by the determining authority.

6.9 Coastal Compartment 7 - Broome Town Centre

6.9.1 Risk Management and Adaptation Options

6.9.1.1 Risk Summary

The Broome Town Centre coastal compartment includes the Chinatown area and the airport. Chinatown is sited on a peninsula at the entrance to Dampier Creek, and significant modification of the natural land area has been undertaken to develop the commercial precinct. Comparison of the area from aerial photos taken in 1959 and 2012 in Figure 4.14 indicate the extent of land area reclaim. The Chinatown area within the area bound by Gray Street, Dampier Terrace, Napier Terrace and Hammersley Street is surrounded by mangrove coastal foreshore on three sides and is largely used for commercial and tourist purposes. Residential dwellings are present in the section of the peninsula north of Gray Street.

The Chinatown peninsula is high enough at the edges to currently provide flood immunity from the general tides, with a low lying central section at the intersection of Short Street and Carnarvon Street susceptible to flooding in large rainfall events. Significant areas of Chinatown and other sections of the coastal compartment are at risk of storm surge inundation as a result of extreme tropical cyclones. The low lying nature of the Chinatown area make it particularly susceptible to storm surge inundation as a result of sea level rise (Figure 4.17).

The coastal erosion likelihood for Broome Town Centre is shown on Figure B.7.1 to Figure B.7.3 for the 2040, 2070 and 2110 planning periods. Assets for the coastal compartment are listed in Table 5.13 with almost all assets rated at high risk from coastal erosion in the 2040 planning period, increasing to a majority rated at extreme by 2110. The assets rated at highest risk of erosion include:

- Residential areas north of Gray Street as extreme in 2040 and all subsequent periods;
- Commercial buildings in Dampier Terrace high risk in 2040 and extreme from planning periods 2070 onwards;
- Paspaley Shopping Centre high risk in 2040 and extreme from planning periods 2070 onwards;
- Roads within the Chinatown area Dampier Terrace, Chapple Street, Gray Street, Short Street high risk in 2040 and subsequent planning periods;
- Broome road rated as high in 2040 and extreme in subsequent planning periods; and
- The south-east section of the Airport Runway medium risk in 2040, high risk in 2070 and extreme in 2110.

It is noted that the CVS assessment of coastal erosion allowance for future planning periods in the Chinatown area was based on SPP2.6 guidelines for sandy shorelines (Section 3.4.6) which is consistent with a precautionary approach. It is noted that significant mangrove cover exists at the edges of the peninsula which reduces wave energy at the shore, attenuates storm surge in extreme events and provides stability to the shoreline. This is not considered in the SPP2.6 assessments for erosion potential in future planning periods. Currently with the mangrove cover around the peninsula the erosion risk is greatly reduced, however in the future (next 100 years planning period) there is no absolute certainty that the mangrove cover will remain in place in its current extent, justifying the assessment of the shoreline as sandy under SPP2.6. The impact of sea level rise on erosion rates at the shoreline is unknown, and whilst the adaptive capacity of mangroves is rated as high, there is a possibility that sea level rise and other climate change effects to the natural system (warmer ocean temperature etc) could impact the mangroves at Dampier Creek.

In the SPP2.6 assessments, the structures in the shoreline currently surrounding the Chinatown peninsula (retaining walls, roads) are not recognised as offering coastal erosion protection to the shoreline.

The coastal inundation likelihood is shown on Figure B.7.4, Figure B.7.5 and B.7.6 for the 2040, 2070 and 2110 planning periods respectively. High level inundation risk to assets from storm tide in the 2040 planning period and all future planning periods are noted in Table 5.17 as follows:

- Chinatown Heritage Buildings in Carnarvon Street;
- Residential areas north of Gray Street;
- Commercial buildings in Dampier Terrace;
- Paspaley Shopping Centre;
- Roads within the Chinatown area Dampier Terrace, Chapple Street, Gray Street, Short Street;
- Broome road; and
- South-eastern section of the Airport Runway

It is noted that the inundation assessment presented in Fig Figure B.7.4, Figure B.7.5 and B.7.6 only considers the storm tide risk, separating the effect of catchment based rainfall flooding from the analysis. This mapping has been produced from the LiDAR data set and is a 'bathtub' flooding approach but is considered a reasonable representation of the flooding impacts.

The mitigation of the identified coastal inundation risk and erosion risk for the Chinatown peninsula was the focus of CHRMAP in workshops held with community and stakeholders. The evaluation process is detailed in the sections to follow, which culminated in a coastal adaptation recommendation of **Protect** for the Chinatown peninsula.

To protect Chinatown a coastal protection structure that can mitigate coastal flooding from storm tide as well as provide erosion protection is required around the Chinatown peninsula. The format of this structural solution and the critical considerations for the *timing* of its construction has been investigated for CHRMAP and is discussed further in sections to follow.

6.9.1.2 Chinatown Flooding Immunity Currently

Based on assessment of the LiDAR, the current land level around the Chinatown peninsula is able to hold back the storm tide ocean level until it reaches a level of approximately 5.6m AHD, after which flooding of the lower lying areas will commence (refer Figure 4.15). In its current form the maximum storm tide event that could be held back by the peninsula is as follows:

- 2015: 100yr ARI
- 2040: 50yr ARI
- 2070: 5yr ARI

The impact of sea level rise drives the reduction in return period (ARI) value for the equivalent flooding case moving forward to 2070. Of critical importance under projected sea level rise

- **Beyond 2070 the Chinatown area of the peninsula would flood under the general tide regime with increasing frequency**

Essentially Chinatown would need to have a coastal protection structure in place by 2070 to provide protection against flooding during the general tides. Mapping on Figure 6.16 shows the current Chinatown

peninsula based on the detailed LiDAR and applying an ocean water level equivalent to 5.6m AHD. At this level, which is approximately 0.4m above the current highest astronomical tide (HAT), the peninsula can provide flood immunity to the lower lying central section of Chinatown. Beyond this level the Peninsula is overtopped and lower lying areas will flood (refer Figure 4.17).

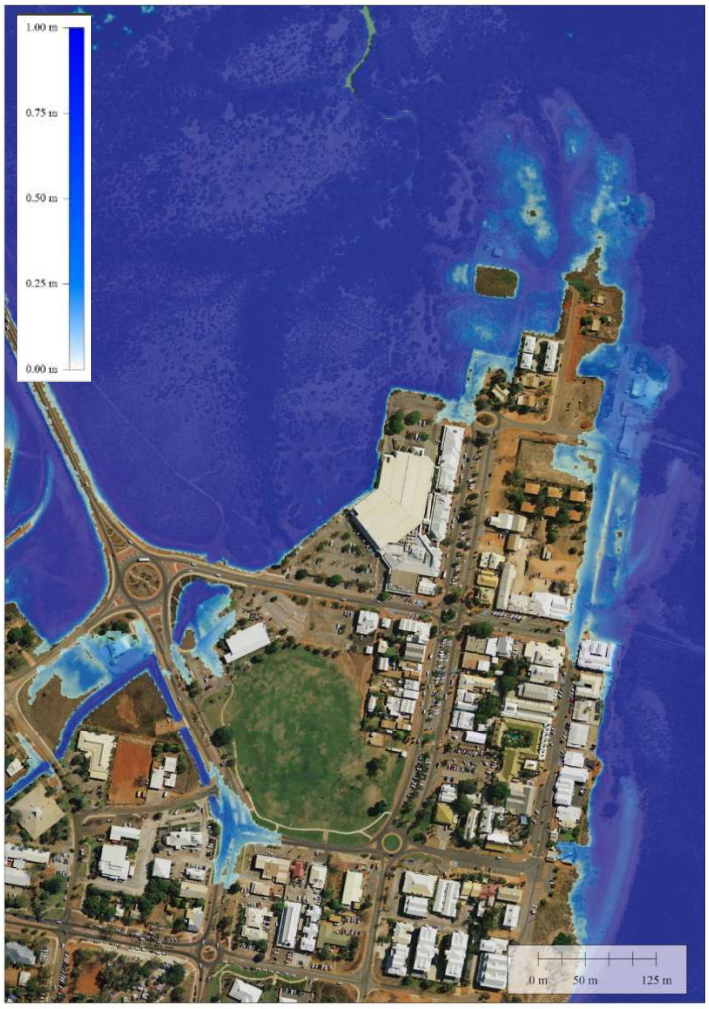


Figure 6.16: Chinatown shown with 'bathtub' modelling of ocean level at 5.6mAHD based on LiDAR

6.9.1.3 Risk Mitigation – Structural Options

To mitigate the risk of storm surge inundation and erosion for Chinatown properties in future planning periods, a structural solution in the foreshore would be constructed that can provide erosion protection and storm surge immunity in future planning periods. This could be achieved through a seawall, or by a levy/dike type of structure that would hold back the storm tide level in extreme events and provide erosion protection. There are a number of alternatives which deliver the same general result – protection against inundation for properties and infrastructure on the landward side. Additionally, the options would act to guard against erosion of the coast.

In the CHRMAP engagement workshops held with community, stakeholders and Shire staff a number of engineering alternatives were discussed that could be used to achieve inundation / erosion protection as listed in Table 6.12 with comment regarding their application. Examples are presented on Figure 6.17.

Table 6.12: Summary of Inundation Protection Options for Chinatown peninsula

Option	Description	Comments	Cost
Vertical Seawall	Constructed in the foreshore to provide inundation and erosion protection to areas landward.	In open beaches vertical seawalls will often lead to erosion of the beach due to wave action. For the Chinatown peninsula there is significant mangrove cover and wave action would be expected to be minimal. Old vertical seawall type structures are present in the section of coast adjacent Streeters Jetty along Dampier Terrace foreshore already, though in poor condition.	$
Stepped / Angled Seawall	Similar to vertical seawall and built with a sloping wall.	Similarly, for vertical seawalls there is possibility of erosion on the beach, however in the Dampier Creek low wave environment not considered likely. Good where constraint on horizontal space is not an issue. Ecologically better than vertical type	$
Gray Street Extension Storm Tide Barrier	An extension of Gray Street could be constructed to act as a storm tide barrier.	Current height of Broome Rd is approximately 6m AHD and new road would tie into this and extend over a region of tidal flats currently at land level approximately 4m AHD. Land on lee side of the Gray Street extension could be used for reclaim (eg commercial purposes) and as an area for stormwater mitigation. Potential impact to existing tidal flats and mangrove areas.	$$$
Raise Road act as Levy	Involves raising roads as part of general road upgrade to act as a levy.	If the existing section of Gray Street was raised (current height ~5.8m AHD) it would provide protection from flooding coming from the northern side of the peninsula. Uncertainty over the aesthetic look of a raised road at this end of the town and the disconnection of properties on the northern side.	$
Landscape Levy feature	Levies can be constructed as an impermeable mound from clay and soil.	Potential to create this as a landscaped feature in the foreshore area eg at Streeters Jetty shoreline along Dampier Terrace. Attraction that it could be raised over time fairly easily as required. Levy is not designed to withstand wave action so is suitable providing the mangrove cover remains in place. Potential space issues in the foreshore areas.	$
Temporary Seawall Structure	A temporary seawall structure that can be erected when needed around the peninsula	Temporary structures could be put in place at the start of cyclone season and then removed in dry season, or be mounted when a cyclone is approaching. Discussions in workshop with Shire engineering noted this to be potentially complicated with structural integrity / reliability questionable over time.	$$
Feature walkway	Seawall could be incorporated into the walkway	As part of the Jetty to Jetty walkway that is being investigated, look for opportunities to incorporate a seawall capability into the feature.	$$

Notes: $: Cheapest Option nominally <$10k per linear m, $$: Mid-range options nominally at $10 – 20k per linear m, $$$: High cost options nominally >$20k per linear m

An example of the options in Table 6.12 is presented on Figure 6.17.

http://marlimillerphoto.com/En.html ,http://www.interboropartners.com/projects/living-with-the-bay/, http://floridalivingshorelines.com/project/flagler-mangrove-planter/, http://www.hornsby.nsw.gov.au/__data/assets/pdf_file/0017/41291/Environmentally-Friendly-Seawalls.pdf

Figure 6.17: Adaptation examples. Sloping seawall (upper left), Vertical seawall with mangrove planter at base (upper right), feature walkways (middle), levy / dike structures (lower)

A summary of the current foreshore flood control features surrounding the peninsula are shown on Figure 6.13. These are variously composed of the following features:

- East Side: retaining walls in the Dampier Terrace foreshore area at a crest height of 5m AHD to 5.4m AHD (Figure 3.6, Figure 3.7). Dampier Terrace provides flood control at a height of approximately 5.9m AHD;
- North Side: natural foreshore bound by lots of differing level. The flood control provided by Gray Street is at a height of 5.7m AHD to 5.9m AHD; and
- West Side: land levels built up at the edge of tidal flats at the back of Paspaley shopping centre to approximately 5.6m AHD Figure 3.8). Broome Rd / Short Street is built up to a level of 5.9m AHD.

Figure 6.18: Indicative land height around the edges of the Chinatown peninsula

If the peninsula was raised to a height of 6.4m AHD, this would provide protection for the 500yr ARI storm tide level for the 2070 planning period. Based on current sea level rise projections, at 2070 it would be required to be raised a further 0.6m to achieve the 2110 SPP2.6 design requirement.

Two approaches for how this might be achieved through a hybrid seawall / levy approach for the 2070 planning period were developed from the stakeholder workshop phase.

Option One

- Western side of the peninsula raised levy at the foreshore edge
- Northern side raise the height of Gray Street and use this as a levy structure
- Eastern side upgrade the existing seawall in the Dampier Terrace foreshore with angled seawall
- Eastern side south of Streeters Jetty, upgrade the retaining wall with angled seawall

The concepts are shown for Option 1 on Figure 6.20 with the required increase in height from the current land level around the peninsula to achieve 6.4m AHD indicated

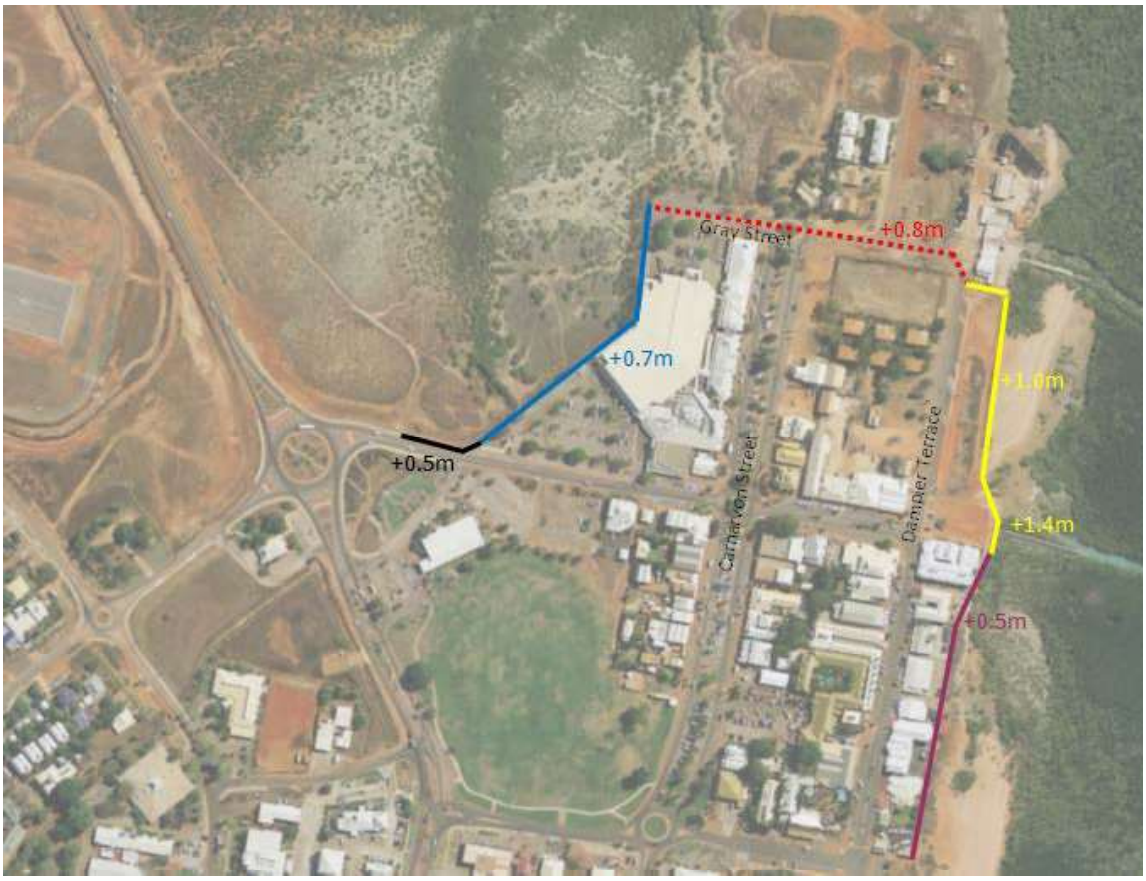


Figure 6.19: Chinatown Inundation Protection Option 1 – required height to raise current peninsula foreshore elements to meet 6.4m AHD.

Option Two

- Western side of the peninsula Construct Gray Street extension at a height that it could act as a levy
- Northern side raise the height of Gray Street and use this as a levy structure
- Eastern side replace the existing seawall in the Dampier Terrace foreshore with seawall and feature walkway as part of the Roebuck Bay Reconnection
- Eastern side south of Streeters Jetty, upgrade the retaining wall with angled seawall

Option 2 is shown in Figure 6.20 with the required increase in height from the current land level around the peninsula to achieve 6.4m AHD indicated.

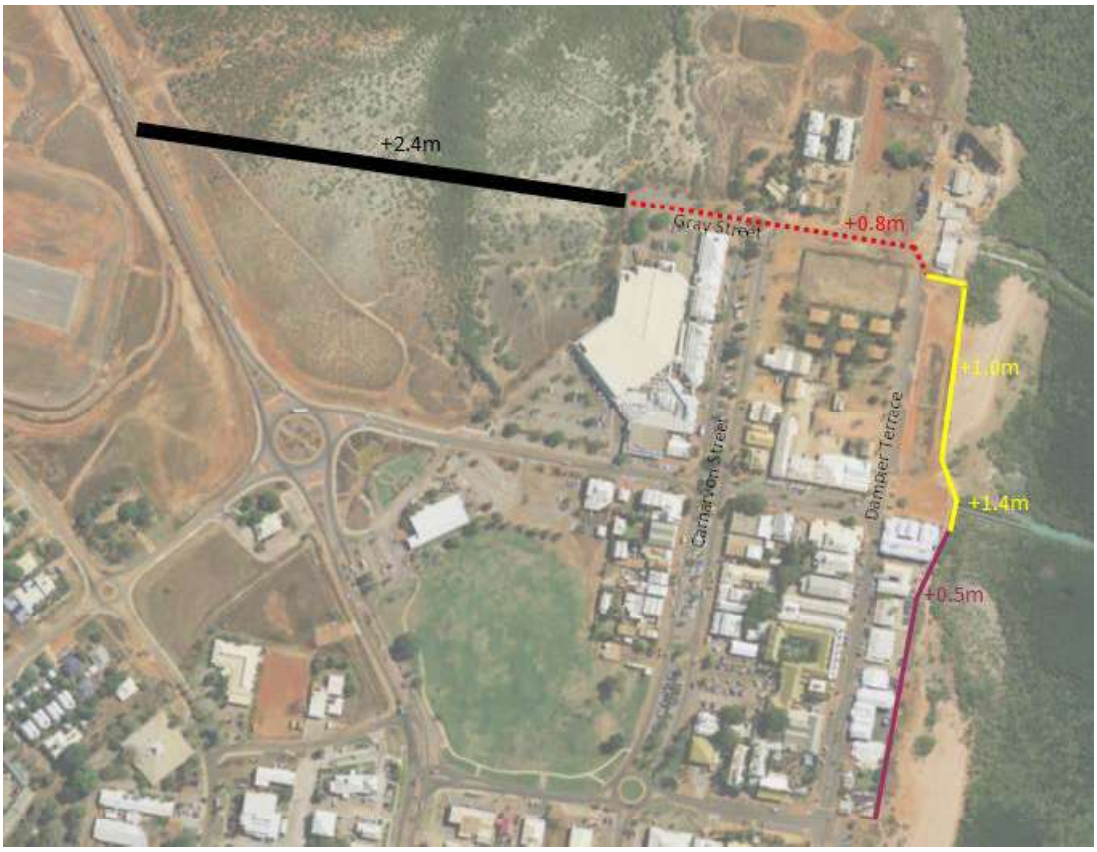


Figure 6.20: Chinatown Inundation Protection Option 2 – Indication of Gray Street extension and required height to raise current peninsula foreshore elements to meet 6.4m AHD.

The approximate cost for the adaptation options is outlined on Table 6.13. The costs are indicative only and used as a basis for economic sensitivity analysis of the options, discussed further in Section 6.10.2.

Table 6.13: Cost of Inundation Protection Options for Chinatown peninsula

Option	Component	Length	Approximate Cost	Total[1]
Option 1	West: Levy Dampier Creek	260m	$1.3 mill	$4.0 mill
	North: Raise Existing Gray Street to Levy height	250m	$1.3 mill	
	East: Seawall north of Streeters Jetty	220m	$1.1 mill	
	East: Seawall south of Streeters Jetty	240m	$1.2 mill	
Option 2	West: Gray Street Extension	380m	$10.4 mill	$16.0 mill
	North: Raise Existing Gray Street to Levy / Seawall	400m	$2.0 mill	
	East: Feature walkway/ seawall north Streeters Jetty	220m	$3.6 mill	

1.Costs are estimated based on similar projects undertaken and would need to be confirmed in feasibility / preliminary design phases

Shire Structures in the foreshore

Access to the coast (stairs, ramps, pathways) would need to be planned with due consideration to the projected erosion and inundation hazard. Coastal assets in the foreshore area should be sited relative to their expected design life and the anticipated coastal erosion hazard across that time in the foreshore reserve.

As part of future monitoring campaigns, the structural integrity of structures currently located in the coastal erosion zone would be verified on a periodic basis, with recommendations regarding further repair or maintenance for their continued safe use consistent with a managed retreat approach.

Planned walkways and associated infrastructure for the *Roebuck Bay Reconnection* should consider design criteria that meet the SPP2.6 recommendations along the coastal compartment, and be designed to withstand the projected inundation and erosion level associated with their design life (as noted on Table 3.4, Table 3.8, Table 3.9 and Table 3.10).

6.9.1.4 Risk Mitigation - Soft Options

Mangroves

For the Broome Central coastal compartment, the health of the mangroves is key to maintaining the natural coastal defence of the coastal foreshore area. The value of the mangroves as natural defence for this section of coast cannot be overstated as the mangroves play a vital role in attenuating storm surge and reducing the wave heights at the shoreline in extreme cyclonic events.

Monitoring mangrove extent and understanding changes to the system as a result of sea level rise and other climate change variables (eg warmer ocean temperatures) will be essential in ensuring the coastal resilience. Any works in the foreshore (ie coastal structures) will need to consider impact on mangroves.

6.9.1.5 Mitigation Options – Planning

Coastal Erosion

For planning purposes an approach of accommodating the risk of coastal erosion for the coastal compartment has been adopted.

It is proposed that coastal protection structures to protect the majority of land within Chinatown from coastal erosion and inundation be undertaken by 2070. The Shire may wish to consider imposing a specialised area rate and / or development contribution area in relation to land contained within the Chinatown area that is benefited by the structure to collect partial funds for the construction, maintenance and of coastal protection structures.

The coastal protection options for Chinatown should be revisited in the next review of CHRMAP (in approximately 5 years time). The revetment at Town Beach is scheduled to be undertaken within this timeframe and will be a useful reference to inform environmental and community aspects of coastal protection works as well as construction costs.

From time to time it may be suitable to consider specific community and temporary infrastructure that is required to be located within the coastal allowance setback to cater for specific community uses.

Storm Surge Inundation

For planning purposes an approach of accommodating the risk of coastal inundation for the coastal compartment has been adopted. For planning purposes mitigation of the 500yr ARI storm tide inundation is required under SPP2.6, consistent with the planning period which is generally 2110.

Ultimately, the majority of land contained within the Town Centre will be protected from storm surge inundation via the construction of a seawall in the future. Given the construction of the seawall could be some time away due to the cost implications associated with this adaptation response, it is considered necessary to adopt an *interim* adaptation response for land that could possibly be inundated by storm surge prior to the eventual construction of a seawall as follows.

- For properties located within the Chinatown section of the peninsula encompassing all properties north of Napier Terrace and Hammersley Street, accommodation of the storm surge inundation impacts associated with the 2070 500yr ARI storm surge level will need to be addressed for development approval.
- Assuming that a seawall will need to be built by 2070 at the latest to provide flood immunity against the tides and that a building or dwelling in the town centre will have an average lifespan of 50 years, the 2070 ARI 500yr inundation level is considered an appropriate planning timeframe to adopt as an interim 'accommodate' approach.
- Following the construction of a seawall, the above interim adaptation approach to accommodate buildings on flood prone land can be withdrawn or modified as necessary.

For development outside of this area the accommodation of the storm surge inundation impacts associated with the 2110 500yr ARI storm surge level will need to be addressed for development approval.

Development proposals are required to adopt the following design measures, where appropriate:

- Locating habitable floor levels 300mm above the design flood level. This may be achieved through a combination of earthworks and/or structural design solutions. Please refer to Table 6.14 below for detailed design responses;
- Ensuring that all important services, including electricity, permanent fixtures and plumbing are elevated and / or protected from the impact of flooding;
- Ensuring buildings are designed and materials are employed to withstand structural loads associated with a storm surge flood event;
- Ensuring foundations and footings are adequate to withstand potential erosive action during coastal inundation;
- Where practical, designing lower levels of buildings prone to flooding to be permeable to allow water to flow through, without damaging the structure of the building;
- Ensuring floorspace that is designed to accommodate stock inventory is located above the modelled storm surge flood level;
- Where possible, consider the use of false floors in relation to fitout of existing buildings which raise the floor level above the storm surge flood level;
- Employ the use of materials that are resistant to water damage.

Other important planning design considerations include, but are not limited to the following:

- While it may be necessary to raise commercial tenancy floor levels above the modelled storm surge event, careful consideration will need to be given to designing access to accommodate the mobility impaired;
- Commercial tenancies with raised floor levels may have a reduced relationship with the street and public interface. Other design considerations may need to be employed to achieve an active interface with the public realm, while designing for flood events. Such design solutions may include, but not be limited to, the following:
  - Incorporate street furniture and other sacrificial infrastructure at street level to promote activities such as alfresco dining and communal gathering spaces;
  - Incorporate temporary buildings such as modular sea containers at street level, which can incorporate pop-up tenancies while also being low cost and temporary solutions to street activation;
  - Verandah's of existing buildings may be used to accommodate alfresco dining and other activities to promote surveillance of the street;
- Consider floorplate and internal tenancy wall arrangements which would allow for water to flow through rather than build up in dead-end spaces;
- Consider building evacuation requirements;
- An Emergency Evacuation Plan should be prepared to evacuate occupants within the Town Centre during a storm surge event.

6.10 Proposed Planning Approach for Properties Identified at risk of Inundation

The approach to managing the storm surge risk in in Broome coastal compartments 6, 7, 8 and 9 is outlined in this section and has been developed from measures adopted in the Karratha CHRMAP. Discussion with officers of the City of Karratha have indicated that while applications for development of land prone to storm surge have been limited since the introduction of the policy, the policy and checklist developed to assist applicants are generally working well and easy to use.

Properties identified as being at risk of storm surge inundation over the 2110 planning timeframe will require planning controls under an accommodate approach recommended in CHRMAP. Managing the inundation risk is proposed to be controlled through a mechanism in a local planning policy, that specifies appropriate responses for properties within the Special Control Area (SCA) that has been delineated based on inundation hazard extents in the CVS. The SCA describes the area around the Broome town site that is affected by coastal hazard as a result of either:

- Coastal erosion for the 2110 planning period; or
- Coastal inundation for the 2110 planning period.

6.10.1 Process for Mitigating Inundation Risk in Development Approvals

For properties identified as affected by coastal inundation in the SCA there are two general categories of inundation response.

- Tier 1: Properties within the SCA and with a lot level less than 7m AHD
  - Highest category of risk. Lot levels are below the SPP2.6, 500yr ARI storm tide peak for 2110
- Tier 2: Properties within the SCA with a lot level greater than 7m AHD
  - Lower category of risk. Lot levels are above the SPP2.6, 500yr ARI storm tide peak for 2110

Tier 1

Affected properties would be informed of the storm surge inundation flood height that would occur in the 500yr ARI storm surge scenario. Depending on the depth of flooding on the property a range of adaptation measures to accommodate the risk would apply for development as outlined on Table 6.14.

Table 6.14: Planning response for property identified at risk of storm tide inundation hazard (Source: Karratha Coastal Hazard Risk Management Adaptation Plan)

Height of Storm Surge Above Natural Ground Level of Property	Design Response
0-500mm	• Raise the height of the finished floor level for all habitable rooms (dwellings) or net lettable area for commercial / retail / community buildings 500mm above the identified storm surge level[1] through either: ◦ Filling of the land; or ◦ Structural / building design response (i.e Elevated 'Queenslander' style housing); or ◦ A combination of fill/retaining and stilt construction.
500mm – 1 metre	• Raise the height of the finished floor level for all habitable rooms (dwellings) or net lettable area for commercial / retail / community buildings 500mm above the identified storm surge level[1] through either: ◦ Filling of the land [2]; or ◦ Structural / building design response (i.e Elevated 'Queenslander' style housing); or ◦ A combination of fill/retaining (to a maximum of 0.5m) and stilt construction.
1 metre – 2 metre +	• Raise the height of the finished floor level for all habitable rooms (dwellings) or net lettable area for commercial / retail / community buildings 500mm above the identified storm surge level[1] through a structural / building design response (i.e. Elevated 'Queenslander' style housing); or • A combination of fill / retaining (to a maximum of 0.5m) and stilt construction.

Notes
1. 500mm allowance recommended based on DoW 2016.
2. Filling of the site between 500mm and 1 metre above natural ground level would need to be considered on a case-by-case basis. Developers would need to demonstrate that this approach would not have a detrimental impact on the amenity of adjoining properties or the amenity of the locality generally.

Building design examples are presented on Figure 6.21 that have been prepared by the Queensland Reconstruction Authority and demonstrate design considerations for buildings in flood prone areas. Additionally, the Queensland Reconstruction Authority has significant experience with the impacts of flooding and has developed a list of preferred construction materials to be used in flood prone areas as shown in Figure 6.22.

It is noted that should coastal protection infrastructure be committed to in future planning periods that addresses the threat of storm surge, then the above design considerations could be modified or removed.

Figure 6.21: Design considerations for buildings in flood prone areas (Queensland Reconstruction Authority)

COMPONENT	SUITABLE*	MILD EFFECTS*	MARKED EFFECTS*	SEVERE EFFECTS*
Floor, Sub-Floor Structure	- slab-on-ground - suspended concrete	- timber T&G (with ends only epoxy sealed and provision of side clearance for board swelling) or plywood	- standard grade plywood	- particleboard flooring close to the ground
Walls Support Structure	- reinforced or mass concrete - large windows low to the ground	- full brick/block masonry	- brick/block veneer with venting (stud frame) cavity brick	- inaccessible openings
Wall and Ceiling Linings	- fibre cement sheet - face brick or blockwork - cement render - ceramic wall tiles - galvanised steel sheet - glass and glass blocks - stone, solid or veneer - plastic sheeting or tiles with waterproof adhesive	- common bricks - solid wood, fully sealed - exterior grade plywood fully sealed - non ferrous metals	- exterior grade particleboard hardboard - solid wood with allowance for swelling - exterior grade plywood	- particleboard fibreboard or strawboard - wallpaper - cloth wall coverings - standard plywood - gypsum plaster plasterboard
Doors	- solid panel with waterproof adhesive - flush marine ply with closed cell foam - aluminium or galvanised steel frame	- flush or single panel marine ply with waterproof adhesive - painted metal construction timber frame, full epoxy sealed before assembly	- standard timber frame	- standard flush hollow core with PVA adhesives and honeycomb paper core Note: lowest cost and generally inexpensive to replace
Window frames	- aluminium frame with stainless steel or brass rollers	- timber frame, full epoxy sealed before assembly with stainless steel or brass fittings		- timber with PVA glues - mild steel fittings
Insulation	- plastic/polystyrene boards - closed cell solid insulation	- reflective foil perforated with holes to drain water if used under timber floors		- materials which store water and delay drying open celled insulation (batts etc)
bolts, hinges, nails, fittings and connections	- brass, nylon/stainless steel, removable pin hinges	- galvanised steel, aluminium		- mild steel
floor covering	- clay/concrete tiles - epoxy or cementilious floor toppings on concrete - rubber sheets (chemically set adhesives) - vinyl sheet (chemically set adhesive)	- terrazzo - rubber tiles (chemically set adhesives) - polished floor and loose rugs - ceramic tiles	- loose fit nylon or acrylic carpet (closed cell rubber underlay)	- wall to wall carpet - wall to wall seagrass matting - cork - linoleum

Adapted from CSIRO

These materials or products are relatively unaffected by submersion and flood exposure and are the best available for the particular application.

These materials or products suffer only mild effects from flooding and are the next best choice if the most suitable materials or products are too expensive or unavailable.

These materials or products are more liable to damage under flood than the above category.

These materials or products are seriously affected by floodwaters and have to be replaced if inundated.

Figure 6.22: Preferred construction materials to be used in flood prone areas (Queensland Reconstruction Authority)

Tier 2

Properties identified as Tier 2 are at risk of secondary inundation from catchment based rainfall that is held up by storm tide level in Dampier Creek. For planning considerations, it is recommended that local drainage adopt the 2110 storm tide level (7m AHD) as a tail water condition in runoff considerations. Development must consider the management of runoff such that increased flooding to surrounding areas under the assumed tail water condition is minimised.

Planning Adaptation Considerations

The planning adaptation measures would specifically need to consider and address the following issues.

Coastal Erosion

- Include relevant strategies and actions within the Shire's Local Planning Strategy relating to the construction of a seawall to protect the Town Centre from coastal erosion processes within the 2110 planning timeframe;
- Consider introducing developer contribution requirements or specialised area rates in relation to land that is benefited / protected by the proposed seawall to collect funds for the construction, maintenance and upkeep of the seawall.
- The trigger for the requirement to construct a seawall will be at the point in time that erosion is deemed a significant threat to property and assets.

Storm Surge Inundation

Preparation of a local planning policy for the Broome Town Centre to apply requirements with respect to the design of buildings to withstand storm surge events.

Specific objectives of the local planning policy should include the following:

- Establish approval procedures for land prone to the 500 year ARI storm surge event;
- Provide guidance for applicants and decision makers in relation to assessment procedures and development standards for development proposals in relation to land prone to the 500 year ARI storm surge event;
- To manage risk for land identified as being prone to storm surge; and
- To ensure new development is designed to withstand storm surge flooding while also maximising commercial interface with the public realm.

6.10.1.1 Monitoring and Further Information

The rate of coastal erosion impacting the foreshore area will be important to understand through a monitoring program that will support the CHRMAP process. Significant coastal erosion of the Chinatown peninsula and impact to properties would be the trigger for construction of the coastal protection structure. This process will be supported by a monitoring program specifically directed at detecting significant changes to the near shore areas.

The Dampier Creek mangroves play an important role in stabilisation of shorelines and attenuation of storm surge and waves in extreme events. The mangrove health and its adaptation to pressures of climate

change such as sea level rise and increased ocean temperatures will be important to understand in the future. Significant Mangrove loss and removal would be monitored in future CHRMAP reviews.

The Dampier Creek shoreline response following large cyclone events should be monitored to identify the impacts to shoreline areas and how these compare with the assumptions in the coastal hazard assessment (S1). Similarly, the longer term response over time of the shoreline position on the eastern side of the Chinatown peninsula will be part of future monitoring.

6.10.2 Comparative Evaluation of Options

A workshop held with staff from the Shire of Broome on 21 September 2016 involved representatives from Development, Engineering, Infrastructure, Planning, Parks and Assets. This workshop involved group discussions to facilitate CBA of adaptation options.

6.10.2.1 Options

Complete list

At the workshop held with staff from the Shire of Broome on 21 September 2016 a range of potential adaptation options were identified. The long list of options, outlined in Table 6.15, include 'protect' options, such as seawalls and levees, 'adapt' options such as planning controls and 'planned retreat'. Workshop participants were asked to rate each of the options against as a series of criteria:

- effectiveness;
- flexibility;
- financial impact;
- social/ cultural impact; and
- environmental impact.

Based on this rating it was apparent that many of the structural protect options are considered to be highly effective but have the potential to be very costly and could have significant environmental or social impacts. Adapt options, on the other hand, are likely to be relatively low cost, have minimal adverse environmental and social impacts but are likely to have limited effectiveness. Planned retreat will be very effective but is likely to be prohibitively expensive, have substantial social impacts and be very inflexible. The inflexibility of the planned retreat option stems from the fact that, essentially, it is irreversible – i.e. once a decision has been made to relocate the town there is 'no going back.

Shortlist for assessment

Based on the qualitative analysis three options were selected for detailed assessment in the cost-benefit analysis (CBA) in addition to a Base Case (business-as-usual) option. These options are detailed on Table 6.15.

It is noted that the Planned retreat option discussed in the workshops involved relocating Chinatown / Town Centre from the Chinatown peninsula to the site of the existing Broome Airport at some time in the future when the airport moves from its current location. Serious consideration was given to including this option in the shortlist for more detailed cost-benefit analysis. Ultimately however, its exclusion from detailed analysis is due to a lack of information about how the option would be implemented, combined with an understanding that any decision to relocate the township is likely to be at least decades away.

Table 6.15: Detailed list of adaptation options, Shire workshop September 2016

Strategy	Option	Assessment criteria					Effectiveness rating	Other criteria rating
		Effectiveness	Flexibility	Financial impact	Social/cultural impacts	Environmental impacts		
Protect	Seawalls	5	3	1	3	2	5	9
	Drainage Upgrades for Stormwater	3	5	3	4	3	3	15
	Storm Surge Barrier (temporary / demountable)	3	3	1	4	2	3	10
	Natural Dike / Levees Landscaped	5	3	3	2	2	5	10
	Raising Ground Levels in Chinatown	3	4	2	3	4	3	13
Adapt	Raise Floor Levels (condition for new development)	3	5	5	4	5	3	19
	Raise Floor Levels Retrospectively (voluntary)	1	5	5	4	5	1	19
	Building Design (new development, flood first level)	2	5	5	4	5	2	19
	Freeze on Development in High Hazard Areas	3	4	4	1	5	3	14
	Drainage Realignment (flood storage,detention)	3	3	3	4	3	3	13
	Development Controls (targeting type of development depending on level of flood risk)	3	5	5	4	5	3	19
Planned retreat	Relocate Town Centre with Landswap	5	1	1	1	5	5	8

Note the higher the rating scores the better the option. The highest possible effectiveness rating score is '5' (dark green). The highest possible combined rating score for other criteria is '20'.

Table 6.16: Potential flooding of properties under Base Case: 'snapshot' of database of affected properties1

				Flood Depth 2015						Flood Depth 2040						Flood Depth 2070					
Property ID	Total Enclosed Area (sq m)	Rate Code Description	Gross Rent Value ($)	ARI1	ARI10	ARI50	ARI100	ARI200	ARI500	ARI1	ARI10	ARI50	ARI100	ARI200	ARI500	ARI1	ARI50	ARI50	ARI100	ARI200	ARI500
632293	2525	'GRV - COMMERCIAL'	80600	0.00	0.00	0.02	0.15	0.27	0.44	0.00	0.00	0.17	0.33	0.47	0.66	0.00	0.22	0.42	0.62	0.81	1.01
632298	2019	'NON-RATEABLE'	572000	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.14	0.32	0.00	0.00	0.09	0.28	0.48	0.68
632302	1861	'GRV - COMMERCIAL'	85280	0.00	0.00	0.00	0.00	0.57	0.74	0.00	0.00	0.00	0.63	0.77	0.96	0.00	0.00	0.72	0.92	1.11	1.31
632315	994	'GRV - COMMERCIAL'	150800	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
632316	405	'GRV - COMMERCIAL'	120640	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
632324	1012	'GRV - COMMERCIAL'	197340	0.00	0.00	0.00	0.00	0.10	0.27	0.00	0.00	0.00	0.16	0.30	0.49	0.00	0.05	0.25	0.45	0.64	0.84
632325	1012	'GRV - COMMERCIAL'	84760	0.00	0.00	0.00	0.00	0.25	0.42	0.00	0.00	0.00	0.31	0.45	0.64	0.00	0.20	0.40	0.60	0.79	0.99
632332	1011	'GRV - COMMERCIAL'	210340	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.06	0.25	0.45
632333	1011	'GRV - COMMERCIAL'	114400	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.25
632334	1012	'GRV - COMMERCIAL'	380440	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.31
632501	3398	'GRV - COMMERCIAL'	122200	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
632513	2023	'NON-RATEABLE'	0	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.06	0.25	0.00	0.00	0.01	0.21	0.40	0.60
632515	7133	'NON-RATEABLE'	0	0.00	0.25	0.35	0.48	0.60	0.77	0.08	0.30	0.50	0.66	0.80	0.99	0.33	0.55	0.75	0.95	1.14	1.34
632516	2004	'GRV - RESIDENTIAL'	24180	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.09	0.28	0.00	0.00	0.04	0.24	0.44	0.64
632522	809	'GRV - COMMERCIAL'	144040	0.00	0.00	0.00	0.00	0.53	0.70	0.00	0.00	0.00	0.59	0.73	0.92	0.00	0.48	0.68	0.88	1.07	1.27
632524	1012	'GRV - COMMERCIAL'	21008	0.00	0.00	0.00	0.00	0.55	0.72	0.00	0.00	0.00	0.61	0.75	0.94	0.00	0.50	0.70	0.90	1.09	1.29
632525	1012	'GRV - COMMERCIAL'	93600	0.00	0.00	0.00	0.00	0.63	0.80	0.00	0.00	0.00	0.69	0.83	1.02	0.00	0.58	0.78	0.98	1.17	1.37
632526	1012	'GRV - COMMERCIAL'	110344	0.00	0.00	0.00	0.00	0.86	1.03	0.00	0.00	0.00	0.92	1.06	1.25	0.00	0.81	1.01	1.21	1.40	1.60
632527	1012	'GRV - COMMERCIAL'	99320	0.00	0.00	0.00	0.00	0.74	0.91	0.00	0.00	0.00	0.80	0.94	1.13	0.00	0.69	0.89	1.09	1.28	1.48
632528	1012	'GRV - COMMERCIAL'	44000	0.00	0.00	0.00	0.00	0.57	0.74	0.00	0.00	0.00	0.63	0.77	0.96	0.00	0.52	0.72	0.92	1.11	1.31

[1] The total number of commercial and residential affected properties is 108

Recognising however, that relocation of Chinatown is likely to be to the site of the current airport, it is recommended that any future decision on airport redevelopment as part of a township master plan, consider the feasibility and potential costs and benefits of relocating Chinatown.

GIS analysis of inundation impact for properties

A GIS based assessment of the inundation impacts for properties affected by storm surge inundation in the coastal compartment was completed across a range of scenarios. Inundation impacts were assessed for six return periods (1yr,10yr,50yr,100yr,200yr,500yr) and for sea level based on present day, 2040 and 2070 planning periods.

The cadastre of the Broome Central compartment was used to determine the inundation level under each scenario for 108 properties in the compartment at risk of storm surge inundation. Inundation scenarios were assessed within each defined property boundary based on

- the average lot height determined from the LiDAR dataset
- floor height of any structures (dwellings / property) estimated based on assessing detailed LiDAR data at the intersection of the building footprint with 0.2m freeboard added for habitable floor level.

Table 6.16 shows a sample of GIS analysis results. Costs have been attributed based on rateable value of properties (Gross rent value) provided by Shire.

Base Case

The Base Case is the business-as-usual option against which the other options are assessed. Key Base Case assumptions include:

- Numerous commercial, public and residential properties/buildings in the Town Centre are vulnerable to below floor level flooding under 1 year, 10 year, 50 year, 100 year, 200 year and 500 year storm surge scenarios in future planning periods (2040, 2070, 2110);
- A smaller number of buildings are vulnerable to above floor level flooding in extreme storm surge scenarios in future planning periods (2040, 2070, 2110);
- A range of public assets are also vulnerable to inundation including roads, road reserves, carparks, and pathways;
- The number of properties and public assets potentially impacted increases over time due to sea level rise;
- A simple seawall installed in the 1990s already exists in the foreshore (Figure 3.6);
- Stormwater upgrades aimed at mitigating inundation in the centre of Chinatown (Short St-Carnarvon Street intersection) due to catchment based rainfall is assumed to be in place under the base case. This assumes the implementation of this measure will occur in the future;
- Assessment of inundation under the Base Case (and the mitigating effects of Options 1, 2 and 3) is therefore focussed solely on storm surge inundation.

6.10.2.2 Analysis of Coastal Protection Structure

Option 1 – Basic Seawall

Option 1 entails a basic seawall or levee structure around the peninsula. Key assumptions include:

- Construction of the seawall will completely mitigate inundation of properties and assets in Broome Town Centre.
- Estimated costs of the seawall are detailed in Table 6.17

Table 6.17: Chinatown Coastal Protection Structure, Concept Option 1 estimated costs ($2016)

Item	Year 1	Year 2	Year 3	Year 4	Year 5
Preliminary design	25,000				
Community consultation/exhibition (3 months)		35,000			
Detailed design			75,000		
Development approval			30,000		
Tendering			15,000		
Total planning	25,000	35,000	120,000		
Capital and labour cost ($/metre)				5,000	
Estimated length (metres)				800	
Total capital				4,000,000	
Contingency				400,000	
Maintenance					66,000
Total[1]	**25,000**	**35,000**	**120,000**	**4,400,000**	**66,000**

1.Costs are estimated based on similar projects undertaken and would need to be confirmed in feasibility / preliminary design phases

Option 2 – Gray Street Levee/ Seawall

Option 2 entails a more elaborate levee or seawall than option 1. It includes an extension of Gray Street to Broome Road across tidal flats, with the road level set above the storm tide level. This option assumes the reclaimed land on the lee side of the Gray Street extension is used for stormwater management during extreme events and catchment flooding does not present any additional flood risk to properties behind the structure. (see Figure 6.23).

Key assumptions of Option 2 include:

- Construction of the seawall will completely mitigate inundation of properties and assets in Broome Town Centre.

Other benefits of Option 2 relative to Option 1 include:

- reclamation of approximately 4.9 hectares of land which has the potential for commercial development;
- improved access to the Peninsula; and
- amenity provided by a walkway.

Due to insufficient information about the nature and extent of these benefits, they have not been valued in the analysis, however these are likely to be relatively minor. It is important to note that, in economic terms, the value of any reclaimed land will not be its full future market value. Rather, it is the difference between the market value of the reclaimed land and the market value of an alternative plot of land where a commercial development would otherwise occur. Estimated costs of Option 2 are detailed in Table 6.18.

Figure 6.23: Concept Option 2 proposing Gray Street Extension as coastal protection structure across northern side and seawall/walkway on eastern side of Chinatown.

Table 6.18: Chinatown Coastal Protection Structure, Concept Option 2 estimated costs ($2016)

Item	Year 1	Year 2	Year 3	Year 4	Year 5
Preliminary design	75,000				
Community consultation/exhibition		87,500			
Detailed design			187,500		
Development approval			30,000		
Tendering			25,000		
Total planning	75,000	87,500	242,500		
2 lane raised roadway ($/metre)				25,000	
Estimated length (metres)				400	
Capital and labour cost raised				10,000,000	
Raised roadway/seawall ($/metre)				5,000	
Estimated length (metres)				400	
Capital and labour cost raised				2,000,000	
Feature walkway ($/metre)				20,000	
Estimated length (metres)				200	
Capital and labour cost raised				4,000,000	
Total capital and labour				**16,000,000**	
Contingency	-	-	-	1,600,000	
Maintenance					264,000
Total	75,000	87,500	242,500	17,600,000	264,000

1.Costs are estimated based on similar projects undertaken and would need to be confirmed in feasibility / preliminary design phases

Option 3 - Broome Town Centre Special Control Areas

Option 3 involves introducing special development controls in the most vulnerable areas of Chinatown and other parts of Broome Town Centre. Detailed specifications of the option are provided in Table 6.19.

Key assumptions of Option 3 include:

- Raising floor levels and other measures implemented to mitigate the impact of inundation but only for those properties affected by the development controls and only after re-development of those properties takes place. Planning options are detailed in Section 6.9.1.5
- Redevelopment is expected to impact approximately one additional property each year based on current Shire demand in Chinatown. Over a 50-year analysis period therefore, less than half of all properties in Broome Town Centre that are currently at risk from inundation (108) will benefit from the implementation of Option 3.

Estimated costs of Option 3 are provided in Table 6.20.

Table 6.19: Chinatown Coastal Protection Structure, Concept Option 3 specifications

Option 3: Broome Town Centre Special Control Areas	Potential Planning Mechanisms
This option would entail introducing special development controls in the most vulnerable areas of Chinatown and other parts of Broome Town Centre. The development controls would apply to all new developments or redevelopments. Controls could include: • Designated 'acceptable' land uses. • A requirement to refer planning applications within land prone to coastal processes to relevant agencies i.e. Department of Planning, Department of Transport, other. • Prevention of major expansion / redevelopment of development on most vulnerable land. • A requirement for floor levels to be at least 300-600 mm above the 100 year inundation level. • Building design specifications including: - designated construction materials; - a requirement for the building design at ground levels prone to storm surge to be permeable to allow storm surge to flow through and able to withstand a flood event; - a requirement that ground floors are not used as habitable areas; and - specifications relating to the siting and design of major services and fittings (e.g. electrical wiring). • Requirement to place Section 70A notifications on titles of all new lots created or new development which occurs within the designated area. • Developers required to implement site specific emergency management plan (EMPs). • Potential developer contribution requirements to collect funds to contribute to the cost of implementing engineering solutions to protect the precinct from coastal processes. Although redevelopment potential within the precinct is probably limited and therefore developer contributions would not yield substantive funds to contribute to costs.	Mechanism Alternative 1 - Introduce a Special Control Area 1. This option would establish a Special Control Area over land subject to coastal processes within the timeframe. 2. This option could impose restrictions on land use. 3. The Special Control Area provisions would likely need to refer to risk mapping maintained by the Shire, and updated from time to time, which defines the extent that property is subject to and impacted by coastal processes. The extent to which property is affected as per the mapping would inform which development provisions would be applicable to development of the site. Mechanism Alternative 2 - Introduce a Local Planning Policy 1. This option would establish specific development provisions in areas identified as being prone to storm surge. 2. Mapping, would need to be appended to the policy which defined the extent of the policy area. 3. The mapping may need to be updated from time to time.

Table 6.20: Chinatown Coastal Protection Structure, Concept Option 3 estimated costs ($2016)

Item	Year 1	Year 2	Year 3
Planning phase			
Development and introduction of SCA/LPP	25,000		
Community consultation/exhibition (3 months)		35,000	
Implementation (e.g. Section 70A notification)			5,000
Development phase			
Number of redevelopments per year	1		
Average value of redevelopment ($)	250,000		
Assumed length of delay (years)	0.25		
Cost of delay	4,373		4,373
Additional cost of redevelopment	30,000		30,000
Site specific emergency management plans	2,000		2,000
Total[1]	**25,000**	**35,000**	**41,373**

1.Costs are estimated based on similar projects undertaken and would need to be confirmed in feasibility / preliminary design phases

6.10.2.3 Cost-benefit analysis approach

General approach

For the Broome Town Centre assessment, a cost-benefit analysis (CBA) framework was used to assess the economic viability of Options 1 to 3, relative to the Base Case. CBA is the most comprehensive of the economic appraisal techniques and is the preferred method of analysis for most State and Commonwealth agencies responsible for economic management. The CBA identifies the economic benefits and costs of the options on all industries and sectors including Council, other agencies and businesses and community. Where possible market and non-market economic benefits and costs are assessed.

A standard discount rate of 7% real is used for the analysis. The period of the analysis is 50 years from the assumed commencement date of each option (generally 2017).

Inundation damage costs

Inundation damage costs for a range of flood events (1 year, 10 year, 50 year, 100 year, 200 year and 500 year ARI events) were estimated using the rapid appraisal method for Floodplain Management (Flood RAM). Flood RAM is a methodology for the rapid and consistent evaluation of flood management measures in a benefit cost analysis framework. Flood RAM enables estimates of inundation damages to be made Broome Town Centre without the need for excessive property data.

Commercial building and content damage

Actual damage cost estimates for commercial buildings depend on the depth of overfloor inundation and are shown in Table 6.21. Clean up costs are accounted for in addition to building and content damage and are estimated as 40% of building and content damage.

Table 6.21: Commercial building and content damage (medium value contents) ($2016)

Depth of overfloor inundation (m)	Potential Damage ($/sqm)	Actual Damage ($/sqm)
1.80	504.6	227.1
1.50	471.8	212.3
1.20	377.9	170.1
1.00	314.5	141.5
0.90	299.3	134.7
0.60	252.3	113.5
0.50	235.9	106.2
0.30	179.6	80.8
0.20	158.4	71.3
0.10	118.5	53.3
0.05	84.5	38.0
0.00	46.9	21.1
-0.30	0.0	0.0

Residential building and content damage

Building damage cost for residential buildings is a function of over-floor inundation and building type (see Table 6.22). Building damage cost are higher for single-storey dwellings. Information on the building type was not available for residential properties. However, an online search of properties suggests that a large proportion of residential dwellings in Broome Town Centre are single storey buildings. In our Base Case assumptions, we have therefore assumed that all buildings are single-storey buildings.

Table 6.22: Residential building damages ($2016)

Building type	Damages ($)
Single-Storey Residential Building	y = 17,273 + 6,391 x
Two-Storey Residential Building	y = 12,092 + 4,388 x

Note: y = estimated damage; x = overfloor depth (m) (positive values only)

Source: Marsden Jacob Associates, based on DSE 2009

Similar to building damages, value of content lost depends on overfloor inundation levels. This is shown in Table 6.23 by building type.

Table 6.23: Residential content damages ($2016)

Building type	Depth of over-floor inundation (m)	Damages ($)
Single-Storey Residential Building	x ≤0	y = 0
	0 < x < 2	y = 28,871 + 28,871 x
	x ≥ 2	y = 86,612
Two-Storey Residential Building	x ≤0	y = 0
	0 < x < 2	y = 20,186 + 20,186 x
	x ≥ 2	Y = 60,675

Note: y = estimated damage; x = over-floor depth (m) (positive values only)

Source: Marsden Jacob Associates

Clean-up costs[2] and external damages[3] are accounted for in addition to building and content damages. Estimates recommended in the Flood RAM report have been adjusted for inflation. Clean-up costs are assumed to be $4,694 per flood affected property for internal clean-up and $1,174 per flood affected property for external clean-up. External damages are assumed to be $5,868 per flood affected property.

Damage to roads and pathways

Damages to roads, pathways and other public infrastructure are estimated using replacement cost data based on values provided by Broome Shire Council. This data is presented in Table 6.24

Average annual damage cost

The economic impact of inundation is measured using average annual damage (AAD) estimates. AADs for each year are calculated by summing the inundation damage to each commercial and residential property for each flood ARI multiplied by the probability of that event in any one year (e.g. an ARI of 100 has a probability of 1% or 0.01).

2 Clean-up cost are those costs incurred to clean a building and its contents after a flood
3 External damage includes damage to fences, pools and landscaping

Table 6.24: Replacement cost estimates ($2016)

Property type	Replacement Cost	Unit	Area impacted by inundation (m^2)			Cost		
			2015_10yr	2015_50yr	2015_100yr	2015_10yr	2015_50yr	2015_100yr
Carparks	83.3	m^2	0	230	1150	$ -	$ 19,159	$ 95,795
Landscaping	10	m^2	280	680	1200	$ 2,800	$ 6,800	$ 12,000
Pathways	35	m^2	0	40	80	$ -	$ 1,400	$ 2,800
Road	83.3	m^2	645	2480	7253	$ 53,729	$ 206,584	$ 604,175
RoadReserve	20	m^2	130	670	2010	$ 2,600	$ 13,400	$ 40,200
Shire Structures / Assets	1					$ -	$ 278,320	$ 278,320
SHIRE ASSETS TOTAL[1]						**$ 59,129**	**$ 525,663**	**$ 1,033,290**

Property type	Replacement Cost	Unit	Area impacted by inundation (m^2)			Cost		
			2040_10yr	2040_50yr	2040_100yr	2040_10yr	2040_50yr	2040_100yr
Carparks	83.3	m^2	230	1150	8350	$ 19,159	$ 95,795	$ 695,555
Landscaping	10	m^2	680	1200	14000	$ 6,800	$ 12,000	$ 140,000
Pathways	35	m^2	40	80	5650	$ 1,400	$ 2,800	$ 197,750
Road	83.3	m^2	2480	7253	38280	$ 206,584	$ 604,175	$ 3,188,724
RoadReserve	20	m^2	670	2010	5000	$ 13,400	$ 40,200	$ 100,000
Shire Structures / Assets	1					$ 278,320	$ 278,320	$ 369,320
SHIRE ASSETS TOTAL[1]						**$ 525,663**	**$ 1,033,290**	**$ 4,691,349**

Property type	Replacement Cost	Unit	Area impacted by inundation (m^2)			Cost		
			2070_10yr	2070_50yr	2070_100yr	2070_10yr	2070_50yr	2070_100yr
Carparks	83.3	m^2	1150	8750	8750	$ 95,795	$ 728,875	$ 728,875
Landscaping	10	m^2	1200	22820	34520	$ 12,000	$ 228,200	$ 345,200
Pathways	35	m^2	80	6300	6850	$ 2,800	$ 220,500	$ 239,750
Road	83.3	m^2	7253	43080	49080	$ 604,175	$ 3,588,564	$ 4,088,364
RoadReserve	20	m^2	2010	5170	5670	$ 40,200	$ 103,400	$ 113,400
Shire Structures / Assets	1					$ 369,320	$ 369,320	$ 369,320
SHIRE ASSETS TOTAL[1]						**$ 1,124,290**	**$ 5,238,859**	**$ 5,884,909**

6.10.2.4 Cost-benefit analysis results

Table 6.25 provides results of the CBA for Options 1, 2 and 3 using two key metrics:

- Net Present Value (NPV), which is the Present Value (PV) of benefits delivered by the option less the PV of costs incurred; and
- Benefit Cost Ratio (BCR), which is the ratio of the PV of benefits to PV of costs.

NPV measures the expected benefit (or cost) to society of implementing the policy expressed in monetary terms. An option with the highest NPV is expected to deliver the highest scale of benefits to society, whereas the option with the highest BCR provides the highest benefit per unit of cost, providing some measure of the risk of the various alternatives.

Table 6.25: Results of the Cost Benefit Analysis, Options 1 to 3

	NPV	BCR
Option 1	-$ 2,317,153	0.45
Option 2	-$ 14,648,112	0.11
Option 3 - low	-$ 402,034	0.27
Option 3 - high	$ 118,499	1.21

Option 1

Option 1 has an estimated NPV of - $2.3 million and a BCR of 0.45. The construction of even a basic coastal protection structure is not expected therefore to deliver a net benefit to the Shire of Broome in the immediate future based on the cost and benefit assumptions adopted for the assessment. This result reflects the fact the benefits of a coastal protection structure, measured as the avoided impacts of inundation on commercial and residential properties are relatively limited in the first few years after construction, which in turn reflects the fact that the numbers of properties impacted by inundation and the depths of inundation are relatively low in the early years of analysis but increase substantially in later years of the analysis due to projected sea level rise (see Table 6.26 and Table 6.27).

Option 2

Option 2 has an estimated NPV of - $14.6 million and a BCR of 0.11. This poor result is unsurprising given that the benefits of the Grey Street extension coastal protection concept are the same as Option 1 but the costs are much greater. The comparison of outcomes for Option 1 and Option 2 provide a basis for understanding the cost implications of a coastal protection option, and given that costs of both options are estimates allows further understanding of the sensitivity of the overall price on the decision outcome.

Option 3

High and low values are presented for Option 3. This is because the benefits of Option 3 (measured as a reduction in inundation costs) are dependent on which properties undergo redevelopment in the future – properties in the Town Centre that are very vulnerable to inundation or properties that are less vulnerable. For the analysis a random number generator was used to randomly select properties for redevelopment each year. If very vulnerable properties are redeveloped according to the Option 3 planning requirements in the early years of the analysis then the benefits are likely to be significant – reflected in a positive NPV and a BCR of 1.2 or greater. If less vulnerable properties are redeveloped according to the Option 3 planning requirements in the early years of the analysis then the benefits will be less significant – reflected in a negative NPV and a BCR of less than 0.3. A BCR of 0.9 to 1.0 was a typical result of the analysis for Option 3 suggesting that implementation of the option could well deliver a net benefit to the community even if implemented in the near future.

Table 6.26: Expected annual benefits and costs of Options 1 to 3 (first 10 years of analysis)

Benefits	NPB	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Option 1	$ 1,880,864	$ -	$ -	$ -	$ -	$ 86,858	$ 91,961	$ 96,779	$ 101,534	$ 106,201	$ 110,882	$ 115,709
Option 2	$ 1,880,864	$ -	$ -	$ -	$ -	$ 86,858	$ 91,961	$ 96,779	$ 101,534	$ 106,201	$ 110,882	$ 115,709
Option 3	$ 149,390	$ -	$ -	$ 936	$ 977	$ 1,016	$ 1,585	$ 1,851	$ 1,922	$ 1,960	$ 1,994	$ 2,696

Costs	NPC	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Option 1	$ 4,198,017	$ 25,000	$ 35,000	$ 120,000	$ 4,400,000	$ 66,000	$ 66,000	$ 66,000	$ 66,000	$ 66,000	$ 66,000	$ 66,000
Option 2	$ 16,528,976	$ 75,000	$ 87,500	$ 242,500	$ 17,600,000	$ 264,000	$ 264,000	$ 264,000	$ 264,000	$ 264,000	$ 264,000	$ 264,000
Option 3	$ 551,424	$ 25,000	$ 35,000	$ 41,373	$ 41,373	$ 41,373	$ 41,373	$ 41,373	$ 41,373	$ 41,373	$ 41,373	$ 41,373

Table 6.27: Expected annual benefits and costs of Options 1 to 3 (final ten years of analysis)

Benefits	NPB	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067
Option 1	$ 1,880,864	$ 463,575	$ 471,203	$ 481,643	$ 493,008	$ 502,245	$ 511,447	$ 521,778	$ 531,782	$ 542,171	$ 550,284	$ 560,711
Option 2	$ 1,880,864	$ 463,575	$ 471,203	$ 481,643	$ 493,008	$ 502,245	$ 511,447	$ 521,778	$ 531,782	$ 542,171	$ 550,284	$ 560,711
Option 3	$ 149,390	$ 41,566	$ 52,709	$ 54,022	$ 102,186	$ 103,289	$ 105,782	$ 212,929	$ 216,472	$ 238,629	$ 240,720	$ 244,798

Costs	NPC	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067
Option 1	$ 4,198,017	$ 66,000	$ 66,000	$ 66,000	$ 66,000	$ 66,000	$ 66,000	$ 66,000	$ 66,000	$ 66,000	$ 66,000	$ 66,000
Option 2	$ 16,528,976	$ 264,000	$ 264,000	$ 264,000	$ 264,000	$ 264,000	$ 264,000	$ 264,000	$ 264,000	$ 264,000	$ 264,000	$ 264,000
Option 3	$ 551,424	$ 41,373	$ 41,373	$ 41,373	$ 41,373	$ 41,373	$ 41,373	$ 41,373	$ 41,373	$ 41,373	$ 41,373	$ 41,373

Threshold analysis

A threshold analysis was undertaken to determine how long construction of a coastal protection structure would need to be delayed to deliver a positive NPV to the community.

- For Option 1: from the year 2037 could likely deliver a net benefit to the community under assumed construction cost and with rate of sea level rise in future years equal to that predicted under SPP2.6.
- For Option 2: to the year 2070 unlikely to deliver net benefit to the community under assumed construction cost and with rate of sea level rise in future years equal to that predicted under SPP2.6

The threshold analysis supports the adoption of planning controls in the short term to address coastal inundation risk and defers the construction of a coastal protection structure for approximately 20 years (2037). It is noted the assumptions for rate of sea level rise and cost of the structure influence the timing of this outcome. A less expensive structure could be warranted for construction earlier in the planning period, with a more expensive structure (ie Option 2) later in the planning period.

The impacts from coastal erosion have not been factored into the decision timeline. The coastal erosion potential for the shoreline area of the coastal compartment is driven by sea level rise (S3) allowance and there is considerable uncertainty over how erosion will be realised in the coastal foreshore areas in the Dampier Creek location which is an estuarine, mangrove lined tidal creek environment. Notwithstanding this, a future coastal protection structure that offers coastal erosion protection for properties at risk identified in the coastal compartment will be required. Under projected sea level rise scenarios in SPP2.6 a 2037 timeframe is considered realistic.

6.10.3 Summary Risk Management and Adaptation Strategy Coastal Compartment 7

The risk management and adaptation approach for this section of coast is as follows:

- **Protect** strategy for Chinatown, through the construction of coastal protection structures around the Chinatown peninsula that will mitigate the risk of erosion and inundation.
- **Accommodate** current structures and properties within the identified coastal inundation hazard

It is important to consider the following:

- The recommended planning guidelines for properties identified within the SCA should be reviewed and implemented into local planning policy;
- To support mitigation of inundation risk as a result of catchment based flooding (rainfall) the upgrades to the stormwater system in Chinatown (Cardno 2016b) should be supported;
- A coastal monitoring program to support the CHRMAP and track the rate of future erosion of the shoreline as well as mangrove extent and health is recommended;
- An appropriate emergency plan should be developed for the Broome Chinatown area to ensure the storm surge inundation risk for people and property is mitigated in extreme cyclone events;

The planning adaptation measures proposed for the Broome Central Compartment are summarised in Table 6.28.

Table 6.28: Broome Central Coastal Compartment Adaptation Measures Summary

Type	Risk Circumstance	Adaptation Approach	Mechanism/s
Structural	Erosion risk to beach access paths, stairs and ramps	Planned / Managed Retreat	• Consider coastal hazard in design but accept that assets are vulnerable and accept loss following major event. • Regular inspection to determine structural integrity. Implement repairs to maintain public safety and allow to retreat over time with recession of shoreline
Structural	Erosion and inundation risk to Chinatown	Protect	• Support further feasibility engineering investigation of coastal protection structures for Chinatown
Planning Erosion	Development located on land prone to coastal erosion within the 2110 planning timeframe	Accommodate	• Introduce planning controls which require planning approval for normally exempt development such as a single house • Require Section 70A notifications to be placed on the certificate of title for all new planning approvals • Consider the use of private sea walls on a case by case basis • Review this strategy as and when the risk of coastal erosion increases over time.
Planning Erosion	Land proposed to be protected by a coastal protection	Protect	• Consider introducing specialised area rate and/or developer contribution area for land proposed to be protected by the seawall to contribute to the maintenance and upkeep of the seawall.

	structure (seawall or similar)		• Document this strategy within the Local Planning Strategy and include within the SCP and LFTP. • The trigger for the requirement to construct a seawall will be at the point in time that erosion is deemed a significant threat to property and assets.
Planning Inundation	Development located on land prone to storm surge	Accommodate	• Preparation of a local planning policy to apply requirements with respect to the design of buildings to withstand storm surge events. Specific objectives of the local planning policy should include the following: ◦ Establish approval procedures for land prone to the 500 year ARI storm surge event; ◦ Provide guidance for applicants and decision makers in relation to assessment procedures and development standards for development proposals in relation to land prone to the 500 year ARI storm surge event; ◦ To manage risk for land identified as being prone to storm surge; and ◦ To ensure new development is designed to withstand storm surge flooding. • For land within the Chinatown Peninsula that is planned to be protected by a structure in the future the design inundation level will be the 2070 500yr ARI. For all other areas the 2110 500yr ARI inundation level will apply.
Planning Erosion	Land uses exempted by Part 7 of Schedule One of State Planning Policy 2.6. eg Surf Club	Accommodate	• Consider on an as needs basis. Applications for such uses should be accommodated by necessary justification, including, but not limited to: ◦ Community demand for such a facility; ◦ Emergency evacuation plan (where appropriate); ◦ Lifespan of structure / use; ◦ Design measures to withstand coastal events (where appropriate); ◦ Other matters as deemed appropriate by the determining authority.

6.11 Coastal Compartment 8 – Dampier Creek Inner

6.11.1.1 Risk Summary

The Dampier Creek Inner coastal compartment is situated along tidal flat shoreline areas connected through estuarine mangrove to Dampier Creek. Tides enter Dampier Creek through Roebuck Bay and travel as much as 3km across the extensive tidal flats to reach the shoreline areas. The very low lying nature of the coastal compartment make it particularly susceptible to storm surge inundation in future periods under projected sea level rise scenarios.

The coastal erosion hazard for future planning periods is shown on Figure B8.1 and B.8.4 for 2040, Figure B8.2 and B.8.5 for 2070 and Figure B8.3 and B.8.6 for 2110. The key assets identified as being at high to extreme risk of coastal erosion on Table 5.14 include:

- Broome Road is at high risk of erosion along the section south of Gubinge Road in 2040, increasing to extreme in the 2070 and 2110 periods;
- Morrell Park land area is rated extreme in 2040, 2070 and 2110;
- One Mile is rated at medium erosion risk in 2040, increasing to high in 2070 and extreme in 2110; and
- Wattle Drive Properties are rated at medium risk in 2040 and 2070 increasing to high in 2110.

The coastal inundation hazard for future planning periods is shown on Figure B8.7 to B.8.12 for 2040, 2070 and 2110 with corresponding inundation risk summarised on Table 5.18. The key assets identified as being at risk of coastal inundation are:

- Broome Road is rated at high risk for the section south of Gubinge Road in 2040, 2070 and 2110;
- Morrell Park land area is significantly inundated and rated high in 2040, 2070 and 2110; and
- Wattle Drive Properties are rated medium risk in 2040 and increase to high risk in 2070 and 2110.

6.11.1.2 Risk Mitigation – Structural Options

Shire Structures in the foreshore

No Shire structures were identified in the coastal compartment. It is noted that there is an itinerant camping facility on the eastern side of Broome Road which is currently being considered by the Shire. Minor structures that are planned in the identified coastal inundation and erosion zone would need to be planned with due consideration to the projected erosion and inundation hazard in future planning periods. Coastal assets in the foreshore area should be sited relative to their expected design life and the anticipated coastal erosion hazard across that time in the foreshore reserve.

Broome Road

Broome Road is a key infrastructure component that will require consideration in the time frame to 2040. The resilience of the foreshore area and embankment on which Broome Road is sited is unknown. Erosion of the foreshore area south of Gubinge Road should be periodically assessed as part of future monitoring programs to identify the ongoing erosion rate.

6.11.1.3 Risk Mitigation – Planning Options

Storm Surge

A number of private lots have been modelled as being prone to storm surge inundation within the planning timeframe. It is recommended that a local planning policy be prepared which establishes the following design requirements for future development within this coastal compartment:

- Locating habitable floor levels 500mm above the modelled flood level (DoW 2016). This may be achieved through a combination of earthworks and/or structural design solutions;
- Ensuring that all important services, including electricity, permanent fixtures and plumbing are elevated and / or protected from the impact of flooding;

- Ensuring buildings are designed and materials are employed to withstand structural loads associated with a storm surge flood event;
- Ensuring foundations and footings are adequate to withstand potential erosive action during coastal inundation;
- Where practical, designing lower levels of buildings prone to flooding to be permeable to allow water to flow through, without damaging the structure of the building;
- Ensuring floorspace that is designed to accommodate stock inventory is located above the modelled storm surge flood level;
- Where possible, consider the use of false floors in relation to fitout of existing buildings which raise the floor level above the storm surge flood level;
- Employ the use of materials that are resistant to water damage.

The planning adaptation measures for the Dampier Creek Inner Coastal Compartment would specifically need to consider and address the following issues.

- Preparation of a local planning policy to apply requirements with respect to the design of buildings to withstand storm surge events. Specific objectives of the local planning policy should include the following:
- Establish approval procedures for land prone to the 500 year ARI storm surge event;
- Provide guidance for applicants and decision makers in relation to assessment procedures and development standards for development proposals in relation to land prone to the 500 year ARI storm surge event;
- To manage risk for land identified as being prone to storm surge; and
- To ensure new development is designed to withstand storm surge flooding.

Coastal Erosion

The 2110 coastal physical setback line impacts the entire extent of Broome Road within this coastal compartment. This is a key consideration given that Broome Road is the primary road connecting the townsite with the wider region to the north.

In the northern section of this coastal compartment, the coastal physical setback line impacts on a number of 'Rural Residential' zoned lots on Wattle Drive. An approach to avoid development on the portion of these lots located within the seaward side of the line should be developed. This would be achieved through allowing development to be sited on the portion of the land unaffected by coastal processes (where possible).

The setback line is generally located to the east of the lots zoned 'Light and Service Industry' in the central section of the coastal compartment. Therefore, development of these lots is not directly impacted by coastal erosion within the planning timeframe.

Extending further south, the setback line impacts on vacant land zoned 'Development' and therefore an adaptation approach of avoid will need to be employed for the portion of 'Development' zoned land located on the seaward side of the coastal physical setback line.

The planning adaptation measures for the Dampier Creek Inner Coastal Compartment would specifically need to consider and address the following issues.

- Require planning approval for normally exempt development for land prone to coastal erosion within the 2110 planning timeframe;
- Provide clear guidance to decision makers and developers that no new development of a substantial nature will be permitted on land prone to coastal erosion within the 2110 planning timeframe;
- Provide guidance to decision makers and developers to locate development on portion/s of the lot on the landward side of the 2110 coastal erosion line;
- Provide guidance to decision making authorities relating to circumstances where time limited approvals may be issued for temporary development and land use and/or development of a low financial value that is not likely to be impacted by the modeled coastal erosion during the life of the approval, or is categorised as low risk;
- Require the provision of a Section 70A notification on the title of lots identified as being prone to storm surge as a condition of any planning approval to alert prospective purchasers to the risk of coastal process impacts on the lot;
- Generally not support further fragmentation and subdivision of land that would result in the creation of new lot/s that would be substantially compromised with respect to development potential, access and other considerations as a result of coastal erosion processes within the 2110 planning timeframe.

6.11.2 Summary Risk Management and Adaptation Strategy Coastal Compartment 8

The risk management and adaptation approach for this section of coast is **Avoid** further development within the identified coastal erosion hazard, **Managed Retreat** for current structures and properties within the erosion hazard area.

A coastal monitoring program to support the CHRMAP and track the rate of future erosion of the shoreline and sea level rise impacts, mangrove extent and health is recommended.

An appropriate emergency response plan should be developed for sections of Broome Road susceptible to inundation in significant storm surge events.

The adaptation measures proposed for the Dampier Creek Inner Coastal Compartment are summarised in Table 6.11.

Table 6.29: Dampier Creek Inner Coastal Compartment Adaptation Measures Summary

Type	Risk Circumstance	Adaptation Approach	Mechanism/s
Structural	Erosion risk to paths minor infrastructure in the coastal areas	Planned / Managed Retreat	• Consider coastal hazard in design but accept that assets are vulnerable and accept loss following major event. • Regular inspection to determine structural integrity. Implement repairs to maintain public safety and allow to retreat over time with recession of shoreline
Planning Erosion Controls	Vacant developable land located on land prone to coastal erosion within the 2110 planning timeframe	Avoid	• Introduce planning controls within require planning approval for normally exempt development; • Introduce planning controls via a Special Control Area and/or Local Planning Policy that prevents any development of vacant land or new development within land prone to coastal erosion within the planning timeframe. • Provide guidance for decision makers and developers to locate development on portion/s of the lot on the landward side of the 2110 coastal erosion line. • Require Section 70A notifications to be placed on the certificate of title for all new planning approvals. • Not support applications for subdivision which would result in the creation of lots that are compromised with respect to coastal erosion, access and other issues within the planning timeframe.
Planning Storm surge	Land prone to storm surge flooding	Accommodate	• Prepare a Local Planning Policy to establish development standards to ensure new development can withstand storm surge events. • Introduce a Special Control Area to trigger the requirement for normally exempt development to require planning approval. • Section 70A notification on title to alert prospective purchasers to the risk of storm surge events. • Prepare an Emergency Evacuation Plan to employ measures to manage the safety of the community within the Town Centre during storm surge events..

6.12 Coastal Compartment 9

6.12.1 Risk Management and Adaptation – Dampier Creek East

6.12.1.1 Risk Summary

Dampier Creek East compartment is undeveloped shoreline extending from the mangrove lined sandy foreshore of Roebuck Bay into the tidal flat environment on the eastern side of Dampier Creek. The coastal hazard in terms of coastal erosion and coastal inundation likelihood is shown on Figure B9.1 to B.9.6 for 2040, 2070 and 2110 planning periods.

The key assets identified in this section of coast through the community workshops are environmental and include the Dampier Creek fish habitat, shorebirds seagrass and the Roebuck Bay Ramsar status. A number of unsealed roads are also in the foreshore area that provide access to the coast. The risk level evaluation for the assets is shown on Table 5.15 for erosion and on Table 5.19 for inundation.

The environmental assets in the compartment are difficult to rate in terms of erosion and inundation consequence, as the link between shoreline changes and the natural system ie seagrass meadows, fish habitat, bird life is not definitive. Environmental groups and local studies that seek to further understand the environmental response of the Dampier Creek flora and fauna to climate change will be a key to understanding the risks to the environmental assets in the compartment in future.

6.12.1.2 Risk Mitigation – Structural Options

Shire Structures (Carparks, Roads, pathways)

No significant Shire structures were identified in the foreshore areas of the coastal compartment. Future infrastructure planning should be considered under a managed retreat option.

6.12.1.3 Risk Mitigation – Planning Options

Storm Surge

The modelled storm surge inundation through this coastal compartment impacts vacant land reserved for coastal purposes and unallocated crown land. No specific adaptation measures are proposed apart from avoiding any land use and development on land prone to storm surge inundation within the 2110 planning timeframe.

Coastal Erosion allowance

The 2110 coastal erosion allowance extends within uninhabited coastal reserve land in this compartment, however also impacts a portion of unallocated crown land that is zoned for ‘Settlement’ purposes.

As this land is uninhabited, an adaptation approach of avoiding any development on the seaward side of the coastal erosion setback line should be taken. Planning considerations for the erosion hazard must be provided that will:

- Require planning approval for normally exempt development for land prone to coastal erosion within the 2110 planning timeframe;
- Provide clear guidance to decision makers and developers that no new development of a substantial nature will be permitted on land prone to coastal erosion within the 2110 planning timeframe;
- Provide guidance to decision makers and developers to locate development on portion/s of the lot on the landward side of the 2110 coastal physical setback line.

6.12.1.4 Risk Mitigation Recommendation

Shire Assets

There are a number of unsealed roads in the coastal compartment. A managed retreat approach to these should be enacted in future planning periods. The low risk can be managed through future monitoring of the shoreline erosion and inundation in large storm surge events to identify any significant changes to the identified hazard reported in the CVS.

6.12.1.5 Monitoring and Further Information

The Dampier Creek mangroves play an important role in stabilisation of shorelines and attenuation of storm surge and waves in extreme events. The mangrove health and its adaptation to pressures of climate change such as sea level rise and increased ocean temperatures will be important to understand in the future.

The Dampier Creek shoreline response following large cyclone events should be monitored to identify the impacts to shoreline areas and how these compare with the assumptions in the coastal hazard assessment (S1). Within the enclosed estuarine environment of Dampier Creek the response of the shoreline to these extreme events is unknown. Similarly, the longer term response over time of the shoreline position should be monitored.

6.12.1.6 Recommended Risk Management and Adaptation Strategy

The risk management and adaptation approach for this section of coast is **Avoid**. Any future planning approaches will need to be sited landward of the identified 2110 planning period coastal erosion hazard. Development should also be avoided within the extents of the coastal hazard inundation for the 2110 planning period 500yr ARI event. Any approved development within the hazard extent will be required to **accommodate** the inundation hazard through building design.

The avoid option will be supported by a coastal monitoring program tracking the rate of future erosion of the shoreline, mangrove extent and rate of increase in sea levels. Changes in the environmental condition of Dampier Creek and Roebuck Bay should be monitored.

The adaptation measures proposed for the Dampier Creek East Coastal Compartment are summarised in Table 6.30

Table 6.30: Dampier Creek East Coastal Compartment Adaptation Measures Summary

Type	Risk Circumstance	Adaptation Approach	Mechanism/s
Structural	Erosion risk to Shire coastal infrastructure	Planned / Managed Retreat	• Regular inspection to determine structural integrity. Implement repairs to maintain public safety and allow to retreat over time with recession of shoreline
Planning Erosion	Vacant developable land located on land prone to coastal erosion within the 2110 planning timeframe	Avoid	• Introduce planning controls within require planning approval for normally exempt development; • Introduce planning controls via a Special Control Area and/or Local Planning Policy that prevents any development of vacant land or new development within land prone to coastal erosion within the planning timeframe. • Provide guidance for decision makers and developers to locate development on portion/s of the lot on the landward side of the 2110 coastal erosion line. • Do not support applications for subdivision which would result in the creation of lots that are compromised with respect to coastal erosion, access and other issues within the planning timeframe.
Planning Storm Surge	Land identified as being prone to storm surge inundation during the planning timeframe	Avoid	• There is a general presumption against supporting land use and development on land identified as being prone to storm surge within this coastal compartment.

7 Implementation Plan

7.1.1 Proposed Actions

The recommendations and adaptation approaches are summarised by coastal compartment on Table 7.1.

Table 7.1: CHRMAP Adaptation Strategy by Coastal Compartment

Coastal Compartment	Adaptation Strategy Recommendations
Cable Beach	For areas north and south of central tourist area Planning Approach • **Avoid**. Any future planning approaches will need to be sited landward of the identified 2110 planning period coastal erosion hazard For central section (Surf Club, Zanders café, Amphitheatre etc) Recommendations • Further studies on a coastal protection option for up to 500m of the main foreshore area is recommended and supported through the CHRMAP with a view to adopting a **Protect** strategy for this section of coast. Will require a detailed erodibility study to determine the underlying geotechnical properties of the foreshore beneath the dune. Following the erodibility assessment, requirement for concept engineering, consultation with community / stakeholders and further economic analysis of option/s. Planning Approach • **Avoid** further development of vacant land within the identified coastal erosion hazard areas north and south of the central tourist hub; • **Planned / Managed Retreat** Existing assets located on land prone to coastal erosion within the 2110 planning timeframe for land not proposed to be protected by a seawall; and • **Accommodate** Land uses exempted by Part 7 of SPP2.6 Schedule 1 eg Community use of foreshore. For areas behind a coastal protection structure (type of coastal protection, alignment and timing to be confirmed in future studies) • **Protect** Existing assets through a coastal protection structure. Shire Structures • **Managed Retreat** for current structures and properties within the erosion hazard area.
Gantheaume Cliffs	Planning Approach • **Avoid** further development within the identified 2110 coastal erosion hazard on vacant land; and • **Accommodate, Managed Retreat** for existing assets located on land prone to coastal erosion within the 2110 planning timeframe (eg Broome Turf Club). Shire Structures in foreshore areas • **Managed Retreat** for coastal structures and roads.

Reddell Beach	Planning Approach • **Avoid** further development within the identified 2110 coastal erosion hazard on vacant land; and • **Accommodate, Managed Retreat** for existing assets located on land prone to coastal erosion within the 2110 planning timeframe. Shire Structures in foreshore areas • **Managed Retreat** for coastal structures and roads.
Entrance Point	Recommendations • Recommended the Kimberley Port Authority undertake a detailed erodibility study to determine the underlying geotechnical properties of the foreshore area. Planning Approach • **Avoid** further development within the identified 2110 coastal erosion hazard on vacant land; and • **Accommodate, Managed Retreat** for existing assets located on land prone to coastal erosion within the 2110 planning timeframe. Shire Structures in foreshore areas • **Managed Retreat** for coastal structures and roads.
Simpsons Beach	Planning Approach • **Avoid** further development within the identified 2110 coastal erosion hazard on vacant land; and • **Accommodate, Managed Retreat** for existing assets located on land prone to coastal erosion within the 2110 planning timeframe. Shire Structures in foreshore areas **Managed Retreat** for coastal structures.
Town Beach	Recommendations • Further studies on construction of the Town Beach revetment (engineering, environmental and local stakeholder issues); • Develop an appropriate Emergency Response Plan for the Roebuck Bay caravan park; • Undertake a foreshore management plan; and • Investigate remediation of the dune in front of the properties in Demco Drive. Planning Approach • **Accommodate** developable land located on land prone to coastal erosion within the 2110 planning timeframe; and • **Accommodate** Land uses exempted by Part 7 of SPP2.6 Schedule 1 eg Community use of foreshore. For areas landward of the planned revetment / seawall north of the old jetty area • **Protect** Existing assets through a coastal protection structure. Shire Structures in foreshore areas • **Managed Retreat** for minor structures within the erosion hazard area;

	• **Accommodate** for minor structures in the defined storm surge inundation area; and • **Protect** Shire assets covered by the revetment / seawall at the eroding Pindan Cliff north of the old jetty area (Pioneer Cemetery, foreshore area in Town Beach Reserve).
Broome Central	Recommendations • A coastal protection structure to **Protect** Chinatown peninsula providing storm surge immunity and coastal erosion protection is supported through CHRMAP. Further studies required to determine type, alignment and timing. At latest the structure is assumed to be constructed for the 2070 planning period; Planning Approach • **Accommodate** developable land located on land prone to coastal erosion within the 2110 planning timeframe; • **Accommodate** land prone to storm surge flooding through Special Control Area and specific requirements for planning approval of properties within the defined storm surge inundation area; and • **Accommodate** Land uses exempted by Part 7 of SPP2.6 Schedule 1 eg Community use of foreshore. For areas within the Chinatown peninsula • **Protect** Existing assets. Shire Structures in foreshore areas • **Managed Retreat** for minor structures within the erosion hazard area; and • **Accommodate** for minor structures in the defined storm surge inundation area.
Dampier Creek Inner	Planning Approach • **Avoid** further development within the identified 2110 coastal erosion hazard on vacant land; and • **Accommodate** land prone to storm surge flooding, through a Special Control Area and specific requirements for planning approval of properties within the defined storm surge inundation area. Shire Structures in foreshore areas • **Managed Retreat** for minor structures and properties within the erosion hazard area; and • **Accommodate** for minor structures in the defined storm surge inundation area.
Dampier Creek East	Planning Approach • **Avoid** further development within the identified 2110 coastal erosion hazard on vacant land; and • **Avoid** land prone to storm surge flooding. Shire Structures in foreshore areas • **Managed Retreat** for minor structures and properties within the erosion hazard area; and • **Accommodate** for minor structures in the defined storm surge inundation area

7.1.2 Resource Requirements, Roles and Responsibilities

Implementation of the CHRMAP will be the responsibility of the Shire of Broome, with support from Yawuru and the Department of Parks and Wildlife in regards to monitoring activities within the Yawuru Conservation Estate. The CHRMAP is to be supported by a monitoring program that should commence in 2018, with a focus on building the understanding of the coastal areas to inform future revisions of the document.

The monitoring program is to be co-ordinated by the Shire, and will require support from specialist contractor input for survey and coastal assessment requirements. Opportunities to involve key stakeholder organisations and the local community should be encouraged.

The CHRMAP process is supported by the Department of Transport and the Department of Planning and these agencies can provide technical advice to Shire on current policy.

7.1.3 Reporting and Monitoring

A targeted monitoring program is detailed in the next section which is designed for the next five years. The reporting program should be delivered with an annual report provided to Shire. At the end of the five-year monitoring period, the interim CHRMAP review would be undertaken, informed by the outcomes from the five years of monitoring.

A decision on the structure of the future monitoring program (target locations, frequency) would be determined as part of the CHRMAP review at the five-year mark.

7.1.4 Performance Measures

It is recommended the CHRMAP be reviewed five years following its implementation (in 2022). At this date the Shire would appoint a working group to review the CHRMAP and would examine the effectiveness of the adaptation options.

The effectiveness of the CHRMAP recommendations over the five-year period would seek to examine their success against community values determined for the assets and coastal areas (Section 2.11) and how the CHRMAP might be updated / improved.

8 Monitoring and Review

8.1 Building Understanding

To develop understanding of the coastal areas and target key areas identified as being of key importance to the long term natural defence of the foreshore areas, an ongoing structured monitoring program is planned to support the CHRMAP. This would look to build on the data developed in the CVS and regularly assess the changes to the dunes, mangroves and pindan shorelines to track the rate of future shoreline erosion. This approach will seek to adaptive capacity of these systems through increasing the understanding of their response to future coastal pressures including climate change and rising sea levels.

The types of monitoring required in the monitoring program are briefly discussed in this section. The monitoring requirements by coastal compartment are outlined in Table 8.1. An example monitoring program is shown on Table 8.2 for consideration by Shire. Sources of available funding support for coastal monitoring are outlined in Section 8.2.

8.1.1 Photo monitoring of the shoreline

A photo monitoring campaign would be designed to target a number of the key locations along the coast to build the understanding of the natural system, and changes seasonally (wet / dry) and cyclically (over numbers of years).

Currently these types of surveys are in operation across many WA locations (including Town of Cottesloe and Busselton) with monitoring at regular intervals to develop a repository of information for the future. The Department of Transport provides a guide on how to photo monitor beaches.
http://www.transport.wa.gov.au/mediaFiles/marine/MAC_IS_HowToPhotoMonitorBeaches.pdf

There is opportunity for the community to be involved in this process, taking photos at designated locations and uploading them to a central database. This approach is currently in practice through northern Agricultural Council (NACC) who are monitoring 90 beaches between Guilderton and Geraldton
http://www.nacc.com.au/project/beach-photo-monitoring/

8.1.2 Geotechnical Assessment

An erodibility assessment involving geotechnical assessment of the shoreline and dunes is recommended for Cable Beach dunes in the vicinity of the Surf Club, Zanders café and Amphitheatre. Town Beach would also be a location where this assessment would further the understanding of rock below the sediment layer in the foreshore areas, to support coastal adaptation strategies. The use of geophysical survey methods would be recommended for these locations, which relies on seismic methods and ground penetrating radar (GPR) to identify presence, depth and hardness of rock layers with minimal to no impact on the surface environment.

8.1.3 Post Cyclone Surveys

Immediately following significant cyclone events a site visit by a Shire engineer or coastal engineer should be planned to specifically report on coastal impacts at key locations.

8.1.4 Beach Transect Survey

Beach profile transect surveys should be undertaken at a number of locations that can be repeated in subsequent survey periods to understand the changes to the shoreline profile over a number of years. This will require a surveyor and be tied into the local datum.

The use of unmanned aerial vehicle (UAV) to provide targeted survey of the dune in front of the Cable Beach tourist hub could be investigated following significant extreme storm erosion as was observed following TC Rosita in 2000. UAV provides a competitive alternative to LiDAR to describe land surface for small areas. UAV based survey of the shoreline along the Cable Beach dunes following a significant erosion event could be compared against the 2013 LiDAR dataset to provide a detailed analysis of changes to this section of the coast.

8.1.5 Monitoring of the Mangrove Areas

The mangrove areas of northern Town Beach and at the entrance to Dampier Creek (around Chinatown) should be assessed for changes to their coverage in future years. It is recommended this can be done through analysis of aerial photos on a five yearly basis.

Following a large cyclone impact any significant changes to the mangroves should be reported and captured in the CHRMAP. Mangroves provide a key function in reducing storm surge and wave height at the shoreline during extreme events and any significant changes should be recorded to develop understanding in future CHRMAP revisions.

8.1.6 Monitoring of the Pindan Shorelines

The erodibility of these shorelines has been highlighted at a number of locations along the coast at Reddell Beach, Entrance Point and Town Beach. These will require annual assessment to establish the current erosion rates. Analysis of aerial photography to be used as base assessment supported by inspection as part of annual surveys.

Following large cyclone events it will be required to identify any sudden changes noted for these shorelines.

8.1.7 Emergency Response Planning

Emergency response plans for cyclones are recommended to be developed for the town site, with particular focus on Chinatown area, Broome Road access and the Town Beach foreshore area (including caravan park). It is anticipated the Shire can develop these with relevant emergency services agencies in the town.

Within each coastal compartment, a range of monitoring and stabilisation recommendations were identified as part of the CVS and further refined through the CHRMAP process. The recommendations are summarised on Table 8.1.

Table 8.1: Summary of Coastal Monitoring Requirements by Coastal Compartment

Coastal Compartment	Recommendations for Future Monitoring and Assessment
1. Cable Beach	For Central Coastal Compartment (adjacent Zanders Café) improve the understanding of the natural system through beach profile survey and photo monitoring. Erodibility assessment which includes geotechnical assessment of the dune system and which can support a buried seawall option Monitor vegetation on the dune around the Zanders Café section of the coast and through the very southern extent.
2. Gantheaume Cliffs	Monitor stability of the cliffs following severe cyclone events
3. Reddell Beach	Monitored erosion of pindan shoreline against observed rates in CVS. Beach survey and photo monitoring encouraged to build understanding of the coast, and track rates of change following severe cyclone events.
4. Entrance Point	Site specific measurement of acute Pindan cliff erosion as a result of cyclonic events or elevated water levels.
5. Simpsons Beach	Manage access to the beach through a foreshore management plan
6. Town Beach	Monitor condition of the groyne structure remaining from the old Broome jetty and maintain as required Monitoring of mangrove extents and sea level rise Measurement of wave attenuation by mangroves Erodibility assessment which includes geotechnical investigation in southern section to confirm the presence and extent of rock
7. Broome Town Centre	Feasibility study for coastal protection structure through Gray Street extension and / or Roebuck Bay Monitoring of mangrove extents and sea level rise Measurement of wave and water level attenuation by mangroves
8. Dampier Creek Inner	Monitoring of mangrove extents and sea level rise Measurement of wave and water level attenuation by mangroves
9. Dampier Creek East	Monitoring of mangrove extents and sea level rise Measurement of wave and water level attenuation by mangroves

An indicative monitoring program with cost estimates for delivery is presented on Table 8.2.

Table 8.2: Indicative Monitoring Program, Timing and Estimate of Probable Cost

Year	Tasks	Cost Estimate
1	Annual Monitoring Program to include: • Photo monitoring program – Coastal Compartments 1 to 6 • Shoreline Transect Survey • Site specific investigations at critical risk locations • Shoreline movement assessment from aerial photogrammetry • Mangrove Coverage Assessment from Aerials Compartments 6 to 9 Report of Findings. First year is baseline report	$12,000
2	Annual Monitoring Program to include: • Photo monitoring program – Coastal Compartments 1 to 6 • Shoreline Transect Survey • Site specific investigations at critical risk locations • Report of Annual Findings Geotechnical Assessment and Erodibility Study, Cable Beach Dune	$8,000 $80,000
3	Annual Monitoring Program to include: • Photo monitoring program – Coastal Compartments 1 to 6 • Shoreline Transect Survey • Site specific investigations at critical risk locations • Shoreline movement assessment from aerial photogrammetry • Report of Annual Findings Geotechnical Assessment and Erodibility Study, Town Beach (in front of Roebuck Bay Caravan Park)	$10,000 $60,000
4	Annual Monitoring Program as per year 2 Feasibility assessment of Sand Nourishment for Demco Drive Dune	$8,000 $25,000
5	Annual Monitoring Program as per year 1	$12,000

Post Cyclone inspection (as required)

Cost Estimate $5000

Immediately Following Significant cyclone event a site visit by a Shire engineer or coastal engineer should be planned to specifically report on coastal impacts including as a minimum:

- shoreline erosion in any coastal compartment, particularly Cable Beach compartment 1;
- assessment at Gantheaume Cliffs to investigate significant changes post cyclone;
- impacts and erosion of the pindan shoreline in coastal compartment 3 (Reddel Beach) and 6 (Town Beach adjacent the caravan park);
- impacts to shorelines and structures (boat ramps) at Entrance point (compartment 5);
- impacts to Chinatown peninsula; and
- Any significant loss of mangroves in compartments 6 and 7 (Town Beach and Broome Central).

8.2 Sources of funding

8.2.1 Department of Transport Coastal Adaptation and Protection Grants.

Coastal Adaptation and Protection (CAP) grants are available to public bodies responsible for coastal management in Western Australia, including:

- Local governments;
- State government agencies;
- Aboriginal land councils; and
- Other corporate bodies directly involved with coastal management.

Coastal Adaptation and Protection (CAP) grants are available for coastal projects such as:

- Coastal monitoring;
- Investigations;
- Asset management;
- Coastal adaptation; and
- Maintenance works.

There is a project application minimum of $10,000 ex GST and project application maximum of $300,000 ex GST. Up to $1 million grant funding is available annually.

Up to 50 per cent of the total project cost is available for all project types; the remainder of the project cost is to be funded by the applicant. The DoT grants page provides details of recently awarded grants. (http://www.transport.wa.gov.au/capgrants)

As an example, for Beach Survey and Photo Monitoring programs similar to those recommended as part of the CHRMAP monitoring in Table 8.2 the following CAP grants were awarded for 2015/16:

- City of Busselton ($20,000);
- Town of Cottesloe ($15,000);
- City of Joondalup ($21,252); and
- Shire of Augusta Margaret River ($44,000)

It is proposed that 50% of the costs presented in Table 8.2 could be met through CAP grant funding, with the Shire providing the other 50% of funding.

8.2.2 Coastwest

Coastwest is a State Government initiative aimed at providing opportunities for Western Australians to learn about, conserve and protect our coast. The Department of Planning administers the Coastwest program on behalf of the West Australian Planning Commission.
https://www.planning.wa.gov.au/coastwest.asp

The objectives of Coastwest grants are to:

- contribute to the implementation of local and regional coastal plans and strategies especially those devised in accordance with SPP2.6
- assist in the identification, protection and maintenance of environmental values, aesthetic qualities, biodiversity and water quality in the coastal zone
- foster sustainable recreational and tourist use of the coast by assisting in the maintenance of the recreational amenity and provision of public access to the coast
- build capacity in Western Australian communities in order to increase their involvement in coastal zone management activities, through joint coastal research activities, education and training.

Up to $325,000 is available with applications invited for grants of between $5,000 and $ 50,000.

8.2.3 Other Potential Sources of Funding

Additional potential funding sources include Natural Resource Management groups, Royalties for Regions and Building Better Regions fund (Commonwealth).

9 Conclusions and Recommendations

The Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) for the Broome townsite has been developed to provide guidance for the Shire on managing and adapting to coastal hazard risk in future planning periods. The CHRMAP is delivered through a risk based management approach to treating coastal hazard and has been completed under the requirements of State Coastal Planning Policy 2.6 (SPP2.6) and the Western Australian Planning Commission (WAPC2014).

The CHRMAP has been supported by an extensive community and stakeholder engagement process, which has sought input from the Broome community to shape its outcomes. CHRMAP has examined the coastal areas and the assets that are affected by storm surge inundation and coastal erosion over planning periods for the present, 2040, 2070 and 2110, developing strategies to mitigate the identified risk based on the adaptation hierarchy of Avoid- Managed or Planned Retreat-Accommodate-Protect (WAPC 2014).

One of the key objectives of the CHRMAP was to outline the forecast coastal hazard risk for the Broome community and define the assets they value in coastal areas and how these might be impacted. This was delivered through a series of information forums and workshops, where community input was sought to develop understanding of the coastal assets (natural, economic, social) and inform the development of suitable adaptation strategies to respond to coastal hazard risk. The project team of coastal engineers, planners, economists and community engagement specialists worked with the Shire of Broome and key stakeholder groups and the community to examine adaptation strategies that could most effectively mitigate the identified coastal hazard risk.

In key compartments, Cable Beach, Town Beach and Broome Town Centre, the risk management and adaptation options have been evaluated in the most detail and economic evaluation of adaptation options including cost benefit analysis of alternatives (CBA) is reported. The key findings for these coastal compartments is summarised here:

- The value of Cable Beach and associated tourism infrastructure to Broome's economy and community supports the need for a **Protect** option to be adopted for the main tourist hub of Cable Beach. Further studies on a coastal protection option for up to 500m of the main foreshore area is recommended by the CHRMAP. This will require a detailed erodibility study to determine the underlying geotechnical properties of the foreshore beneath the dune.
- For Town Beach, the large local residential population adjoining its shoreline, coupled with the mix of short term accommodation options in the area including the Roebuck Bay caravan park place a high value on the beach and its foreshore areas, which attracts significant tourist numbers particularly during viewing of the 'staircase to the moon' phenomenon. The need for coastal protection along the eroding pindan cliff north of the old jetty area has been acknowledged by the Shire and construction of a coastal revetment is planned for 2018-19. The **Protect** option in this location is fully supported by the CHRMAP
- The mitigation of the identified coastal inundation risk and erosion risk for the Chinatown peninsula was the focus of the CHRMAP in workshops held with community and stakeholders, a process which ultimately led to a coastal adaptation recommendation of **Protect** for the Chinatown peninsula. To protect Chinatown a coastal protection structure that can mitigate coastal flooding from storm tide as well as provide erosion protection is required around the Chinatown peninsula. The format of this structural solution and the critical considerations for the *timing* of its construction has been reported in the CHRMAP, with concept designs and costings assessed through CBA. The outcomes of the CBA

presented in this report indicate that the coastal protection structure could deliver a net benefit within 20 years (2037) depending on the assumed construction costs.

There is considerable uncertainty regarding both the timing and the extent of the impact that climate change may bring for the shorelines of Broome in future planning periods. Developing an understanding of the key natural coastal defences around the town including dune systems, mangroves and pindan shorelines will be important for future planning and adaptation. For this reason, the CHRMAP is supported by a monitoring program which will build knowledge of the coastal areas and examine the rate of change that is occurring.

The CHRMAP considers coastal hazard risk over the planning period to 2110, but is focussed on the immediate term to 2040, providing recommendations for Shire to guide its infrastructure and planning requirements. It is recommended the CHRMAP be reviewed every five years to review its effectiveness, and applicability in response to changes that may occur in local understanding of the coast as well as policy change that may occur at the State level with regard coastal risk management.

The key recommendations for adaptation are outlined by coastal compartment in Section 7 of this report in Table 7.1.

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