Denham Townsite CHRMAP

Final Report

Shire of Shark Bay

31 March 2020

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31 March 2020

Paul Anderson
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Via email ceo@sharkbay.wa.gov.au

Dear Paul

Final Report

We are pleased to present the Denham Townsite Coastal Hazard Risk Management and Adaptation Plan Final Report. If you have any queries, please do not hesitate to contact me on (08) 6555 0105.

Yours sincerely

Joanna Garcia-Webb
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WATER TECHNOLOGY PTY LTD

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EXECUTIVE SUMMARY

It is internationally recognised that increasing sea levels will intensify coastal hazards such as coastal inundation (temporary coastal flooding), storm erosion and long-term shoreline recession (IPCC 2014). Consequently, State governments across Australia have introduced obligations that require local governments to consider and plan for the effects of these hazards on current and future development. In Western Australia (WA), the governing policy is the Western Australian Planning Commission's State Coastal Planning Policy 2.6 (WAPC, 2013, herein referred to as "SPP2.6"). SPP2.6 recommends management authorities develop a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) for the next 100 years. Specific guidelines have been developed to assist in this process (WAPC, 2019).

One of the key objectives of SPP2.6 is to establish coastal foreshore reserves which include allowances for the protection, conservation and enhancement of coastal values across the state. Risk assessment processes are then utilised to identify risks that are intolerable to the community and other stakeholders, such as the Shire of Shark Bay, indigenous and cultural interests, and private enterprise. Adaptation measures are then developed according to the preferential adaptation hierarchy outlined in SPP2.6.

The overall CHRMAP purpose is as follows:

- To identify vulnerable assets (public and private) and the risk posed to them by coastal hazards.
- To preserve community values for present and future generations.
- To develop a plan that will allow the Shire to respond to identified risks through adaptation planning activities.
- To recommend monitoring plans to ensure the risk management and adaptation plan activities are working into the future as expected.
- For the Shire of Shark Bay to manage their coastline at Denham. It is not intended to be used by others to replace their own CHRMAP requirements (e.g. specific new coastal developments)

For the purposes of the assessment, the study area was divided into 5 distinct coastal compartments based on natural and built features; these are displayed in Figure 2-2. This study considers a 100-year planning timeframe (to 2118). Interim epochs also considered are the present day, 2030 and 2050.

In the process of developing a holistic adaptation plan, suitable options were to be identified and assessed. A core principle of SPP2.6 is the adaptation planning hierarchy which specifies that coastal management options should be preferred in the following order (most to least):

- **Avoid** development in all previously undeveloped coastal areas seaward of the 2118 hazard line;
- **Planned or Managed Retreat,** i.e. maintaining a foreshore reserve through public acquisition of private property; or,
- **Accommodate** at-risk developments over the short term while new development is appropriately designed and located; or
- **Protect,** i.e. preventing the shoreline from receding beyond private property boundaries by stabilising the current shoreline position using various protection measures (e.g. rock groynes, offshore breakwaters).

Other important considerations when assessing adaption options are as follows:

- Adaptation options should minimise coastal process interference and legacy issues
  - The adaptation hierarchy is presented in Figure 2-5.
- Coastal development must be sustainable in the long term, and must balance the community, economic, environmental and cultural needs

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- Local Governments are responsible for managing risks to **public assets** and any assets they manage. They should also:
  - Develop local policies and regulations consistent with state legislation and policy
  - Facilitate building resilience and adaptive capacity within the local community
  - Work in partnership with community to identity and manage risks / impacts
- Management strategies that preserve the natural coastline and move development away from the active coastal zone in an orderly manner are considered ideal.
- Of relevance to the CHRMAP process is the **user pays principle**, whereby those who benefit most from protection must provide the greatest financial contribution.
- Adaptation options should maintain future flexibility, in order to build resilient coastal communities.
- A key adaptation option is the use of planning instruments, including managed retreat

Success criteria were developed for this study to represent the community and stakeholders' overarching goals and define the Town's tolerance to identified coastal hazards. The adopted success criteria based on community consultation and surveys are as follows:

- Protection of the environmental assets of the study area / planning to retain environmental integrity
- Protection of the recreational value of the coastline
- Protection of the cultural values of the coastline & town centre
- Maintenance of a level of public recreational assets
- Development controls not to inhibit the landscape

Coastal processes allowances were calculated as per the guidelines in SPP2.6 for inundation and erosion over the full 100-year planning timeframe. Key policy objectives of SPP2.6 are to include an allowance for predicted sea level rise and a provision for a coastal foreshore reserve. The coastal foreshore reserve is essentially a publicly owned 'space' between the ocean and coastal development. The erosion and inundation allowance are not predictors of future shoreline position or sea level respectively, they are indicators of the area of potential vulnerability over the planning timeframe.

The final inundation allowance (and recommended finished floor level) was calculated to be **4.2 m AHD**. This value includes tidal, surge and wave set-up components. Given the paucity of local field data the final finished floor level was considered to be very conservative and as such, wave run-up was not included. The final erosion allowance is the sum of storm erosion, persistent erosion trends, and an estimate of the erosion due to sea level rise. The final inundation and erosion allowances for coastal processes are available to view online overlaying the study area. An explanation as to how to interpret the maps is provided when first visiting this link.

To further understand the Town's exposure to coastal hazards and its adaptive capacity at present, assets in the coastal zone were identified. Each asset was colour coded based on its classification (commercial, public, tourism related and residential) and these are also viewable in the online database.

Now that the study area's coastal environmental context was well established and the community's goals were defined, adaptation options were identified and assessed. Each option was first assessed using a multi-criteria (MCA) framework by scoring six different categories; (expected) effectiveness, environmental impact, social impact, aesthetic impact, future adaptability, and cost. Adaptation options that passed the MCA were then assessed through a cost-benefit analysis (CBA) to determine if there was a strong economic argument to pursue the option. Through these analyses, final adaptation options to be included in the CHRMAP were identified.

The identified options were developed into an implementation plan; the short-term plan is summarised in the table overleaf, with the full table and long-term plan presented in Section 8. In addition to the implementation plan, specific trigger-based adaptation criteria were recommended as follows:

- **Proximity trigger**: Where the most landward part of the Horizontal Shoreline Datum (HSD) is within 40 metres of the most seaward point of a development / structure / foreshore reserve area.
  - Due to the high value placed on the foreshore coastal reserve, the recreational area would itself be considered the asset in this case
- **Access trigger**: Where a public road is considered no longer available or able to provide legal access to the property
  - This may occur for Knight Terrace, particularly to the east of Denham Hamelin Road. The Shire may choose to investigate access options from the landward side of these properties.
- **Utilities trigger**: When water, sewage or electricity to the lot is no longer available as they have been removed/decommissioned by the relevant authority due to coastal hazards.
- **Damage trigger**: Any property within the hazard zone and Special Control Area (SCA) that is damaged by a coastal hazard from an extreme weather event shall require Shire approval before being repaired. The review process should involve:
  - Re-fit of minor or moderately damaged assets to better accommodate coastal hazards in the future
    - OR
  - Removal and redevelopment outside the hazard zone for assets that suffer major damage

Finally, potential long-term adaptation strategies were discussed and recommendations for a monitoring plan for filling present knowledge gaps were also included in Section 8.

CHRMAP SHORT-TERM IMPLEMENTATION PLAN BY STUDY AREA (COASTLINE) SECTION

CHRMAP Section	Short term implementation plan (to 2030)
All areas	▪ Implementation of the Special Control Area (SCA) with the conditions presented in Section 7 which will have the following adaptation strategies: – **Avoid** any permanent development not classified as infill seaward of the 2118 hazard line. The SCA could be used to ensure this. – **Managed retreat** when houses damaged or otherwise triggered by coastal hazards must be relocated or rebuilt out of the hazard zone. – **Accommodate** through Section 70A of the *Transfer of Land Act 1893* on appropriate land titles and finished floor level requirements for developments within the hazard zone. ▪ **Accommodate** assets at high or extreme risk of inundation through minor modifications to limit damage from high water level events.
Section 1	▪ **Protect** through periodic renourishment could be considered over the short term. Strategies for all areas take preference to protection options. **Best practice coastal management recommendations:** ▪ Dune stability improvements through revegetation, modification of stormwater drains, and sand fencing. ▪ Possibility of utilising dredged material to supplement dune reinstatement strategies above (Noting dredging happens rarely) ▪ Beach monitoring to document changes in the coastline and increase understanding of the coastal system (see Monitoring Plan in Section 8.5).
Section 2	▪ **Protect** through formal design of the ad-hoc rock armour revetment between the beach and the coastal path. **Best practice coastal management recommendations:** ▪ Asset stability in the lee of the ad-hoc revetment could be improved through reshaping of the wall and adjacent revegetation ▪ Beach monitoring to document changes in the coastline and increase understanding of the coastal system (see Monitoring Plan in Section 8.5).
Section 3	▪ **Accommodate;** planning controls could be relaxed while the marina is still functioning. However, inundation controls must always be enforced. **Best practice coastal management recommendations:** ▪ Section north of marina between revetment and limestone retaining wall could be revegetated. Although the Shire did note that some areas are very difficult to revegetate due to the local climate and this option may not be cost effective in that case.
Section 4	▪ As per all sections. Limited assets in the hazard zone, should be relatively easy to retreat. **Best practice coastal management recommendations:** ▪ Consolidation and bedrock in this area may limit erosion more than predicted. Further investigation would be required if any development was proposed within the hazard zone. ▪ Stability of tourism assets could be improved through revegetation and sand fencing techniques. ▪ Beach monitoring to document changes in the coastline and increase understanding of the coastal system (see Monitoring Plan in Section 8.5).
Section 5	▪ As per all sections. Limited assets in the hazard zone, should be relatively easy to retreat. Single public asset (car park) in this area should use managed retreat based on a trigger. **Best practice coastal management recommendations:** ▪ Environmental impacts of recreational vehicle use in this area could be mitigated through tighter management. ▪ Beach monitoring to document changes in the coastline and increase understanding of the coastal system (see Monitoring Plan in Section 8.5).

CONTENTS

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APPENDICES

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

It is internationally recognised that increasing sea levels will intensify coastal hazards such as coastal inundation (temporary coastal flooding), storm erosion and long-term shoreline recession (IPCC, 2014). Consequently, State governments across Australia have introduced obligations that require local governments to consider and plan for the effects of these hazards on current and future development. In Western Australia (WA), the governing policy is the Western Australian Planning Commission's State Planning Policy 2.6: State Coastal Planning Policy (WAPC, 2013, herein referred to as "SPP2.6"). SPP2.6 recommends management authorities develop a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) for the next 100 years. Specific guidelines have been developed to assist in this process (WAPC, 2019).

One of the key objectives of SPP2.6 is to establish coastal foreshore reserves which include allowances for the protection, conservation and enhancement of coastal values across the state. Risk assessment processes are then utilised to identify risks that are intolerable to the community, and other stakeholders such as the Shire of Shark Bay, indigenous and cultural interests, and private enterprise. Adaptation measures are then developed according to the preferential adaptation hierarchy outlined in SPP2.6 (described in Section 2.5).

The aim of the present study is to investigate and plan for coastal hazards which are likely to affect the Denham townsite from the present day to the year 2118. Denham is located within the local government area of the Shire of Shark Bay, approximately 800km north of Perth (refer Figure 1-1 for locality). Denham and its surrounds are used extensively for tourism, commercial and recreational purposes. Tourism is the primary industry in the Shire, with fishing and aquaculture also playing a major role.

Given the above, visitors to and residents of Denham and its surrounds place a high value on the coastline. Processes affecting the coastal zone are multiple and complex: storm surge; tidal movement; shoreline stability; stormwater drainage; and the interactions between surface and groundwater all contribute in differing degrees. Furthermore, the potential impacts of climate change, specifically increasing sea levels and storm intensities, will place increased pressure on the coastal zone, and threaten public infrastructure and assets, private property, foreshore reserves, coastal attractions and public open spaces. The CHRMAP aims to create a strategy to effectively manage these potentially vulnerable areas over the next hundred years.

This document presents the draft Final CHRMAP report. This summarises the approach taken and presents the overall adaptation plan. This document will go out for peer review and public comment prior to finalisation. The study identified coastal assets within the town that may be vulnerable to coastal hazards over the next 100 years utilising the methodology outlined in SPP2.6.

The Shire's adaptation responsibility is limited to preserving public interests by minimising risks to public assets where possible. As per the WA Coastal Zone Strategy 2017, it is not the Shire's responsibility to address risks to private assets.

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FIGURE 1-1 EXTENT OF CHRMAP

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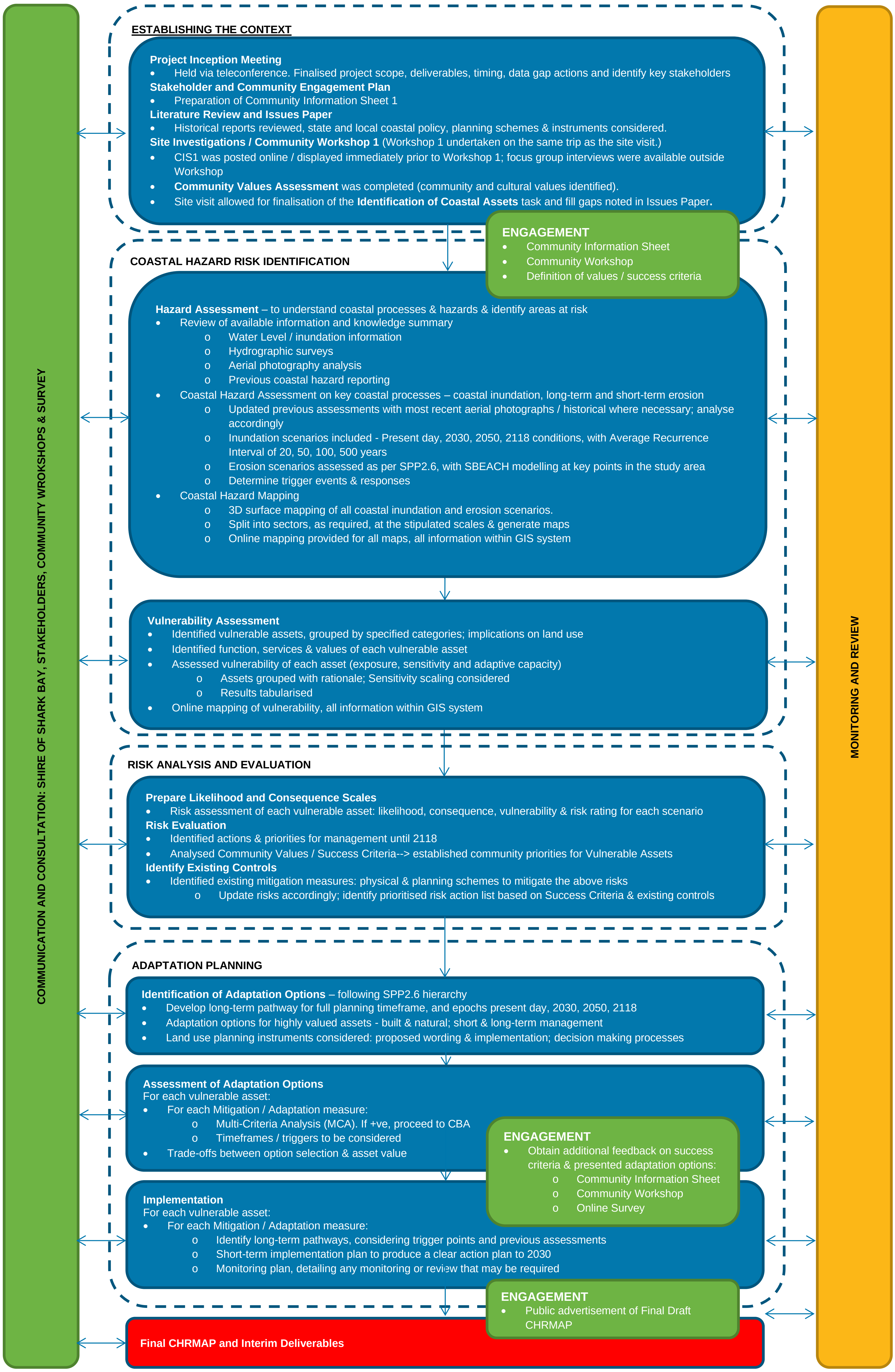

FIGURE 1-2 CHRMAP METHODOLOGY FLOW CHART (ADAPTED FROM WAPC CHRMAP GUIDELINES)

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2 ESTABLISH THE CONTEXT

2.1 CHRMAP Purpose & Objectives

As discussed in Section 1, the CHRMAP is a legislative recommendation from the state government.

The Denham CHRMAP aims to investigate and provide the blueprint for adapting and addressing coastal hazards which are likely to affect the Denham townsite over various planning timeframes. The CHRMAP will provide strategic guidance for coordinated, integrated and sustainable decision making by the Shire of Shark Bay in terms of future land use planning and management within the project area. The project will generate information on climate change and its impacts in the coastal zone within the Denham Townsite. This will enable the Shire to optimise its use of the coastal foreshore reserve in present day, and plan for how this may change in the future.

The overall CHRMAP purpose is as follows:

- To identify vulnerable assets (public and private) and the risk posed to them by coastal hazards.
- To preserve community values for present and future generations.
- To develop a plan that will allow the Shire to respond to identified risks through adaptation planning activities.
- To recommend monitoring plans to ensure the risk management and adaptation plan activities are working into the future as expected.
- For the Shire of Shark Bay to manage their coastline at Denham. It is not intended to be used by others to replace their own CHRMAP requirements (e.g. specific new coastal developments)

2.2 Planning Timeframes

This study considers a 100-year planning timeframe (to 2118). Interim epochs also considered are the present day, 2030 and 2050. The predicted erosion and inundation extents for these epochs were defined in the *Coastal Hazard & Vulnerability Assessment Chapter Report* (Appendix C). These extents are utilised to develop corresponding adaptation options. However, planning and adaptation actions should be undertaken and reviewed more frequently than these epochs.

2.3 Site Description

The Denham townsite is located approximately 800 km north of Perth in the Shire of Shark Bay on Western Australia's Gascoyne Coast. The town's unique location (refer Figure 2-1) on the western flank of the Peron Peninsula, in the lee of Dirk Hartog Island, provides it with some protection from open ocean conditions. With the exception of the dredged channel, the nearshore bathymetry adjacent to the town remains within -3m AHD up to a distance 2km offshore, with significant portions of this area becoming exposed under regular tidal action.

The townsite itself is centred around the foreshore area and accompanying main street (Knight Terrace), which comprises new and old developments primarily under 5 m AHD. The low-lying foreshore area is part of a storm ridge and tidal flat system and is reported to be the original settlement location (Eliot et al. 2012). This area has experienced some seaward advancement due to reclamation works, the presence of built structures and periodic renourishment from dredged materials. The foreshore is bounded on the landward side by a scarp up to 25 m AHD, upon which much of the town's later development has occurred.

A detailed description of the oceanographic conditions, geomorphological setting and the existing shoreline along the study area is provided in Section 3 of Appendix C, as well as the sediment transport and coastal processes. For the purposes of the assessment, the coastline was divided into 5 distinct compartments based on natural and built features; these are displayed in Figure 2-2. This separation into coastal precincts does not imply that the coastal processes within each section are in any way compartmentalised. They are by no means isolated or discrete sections of shoreline, since the processes affecting each have considerable influence on the others. However, this partitioning lends itself to a more concise explanation of natural processes affecting the shoreline.

In summary, the dominant sediment transport processes influencing the shoreline around Denham are:

- Net northwards longshore transport
- Cross-shore transport during cyclones / storms
- Seawall adjacent to the boat harbour limits cross-shore erosion
- Wind driven transport is a contributor to beach stability
- Low-lying dunes along Knight Terrace from Denham Hamelin Road to the east may be susceptible to erosion

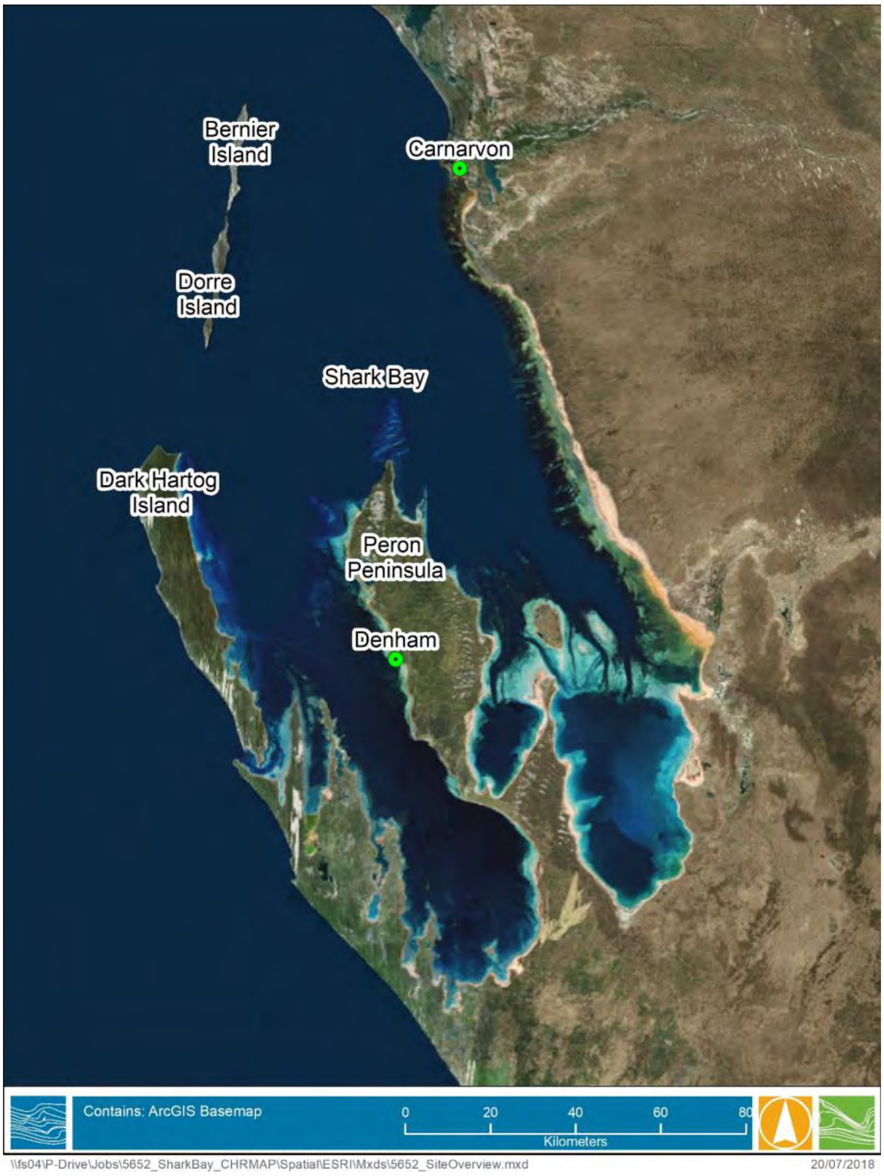

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FIGURE 2-1 LOCATION OF THE STUDY SITE WITH WITHIN SHARK BAY

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FIGURE 2-2 STUDY AREA SECTIONS

2.4 Existing Planning Controls

Planning in Western Australia is guided and regulated by the State Planning Framework. This framework includes overarching strategic planning strategies, and specific planning policies and supportive guidelines. Figure 2-3 explains this framework, which includes planning at the state, regional, and local levels and indicates how strategic planning documents can be implemented through statutory planning controls (e.g. local planning schemes) and local planning policies. This Framework sits within the *Planning and Development Act 2005*.

The *Establish the Context Chapter Report* (Appendix B) reviewed the planning documents within this Framework which are relevant to coastal hazard planning in the project area. The review aimed to:

- Assess the adequacy of the existing planning documents for addressing coastal hazards.
- Identify gaps that need to be addressed through the CHRMAP process.
- Identify any potential planning issues that may constrain the CHRMAP process.
- Ensure that the Shire's adaptation plan aligns with state, regional and local planning frameworks.

Figure 2-4 presents the identified and reviewed planning documents in order of their application within the state and local planning framework. Table 2-1 describes specifically how adaptation planning in the study area aligns with this planning framework. Figure 2-5 (on page 19) presents the planning and adaptation hierarchy referred to in Table 2-1.

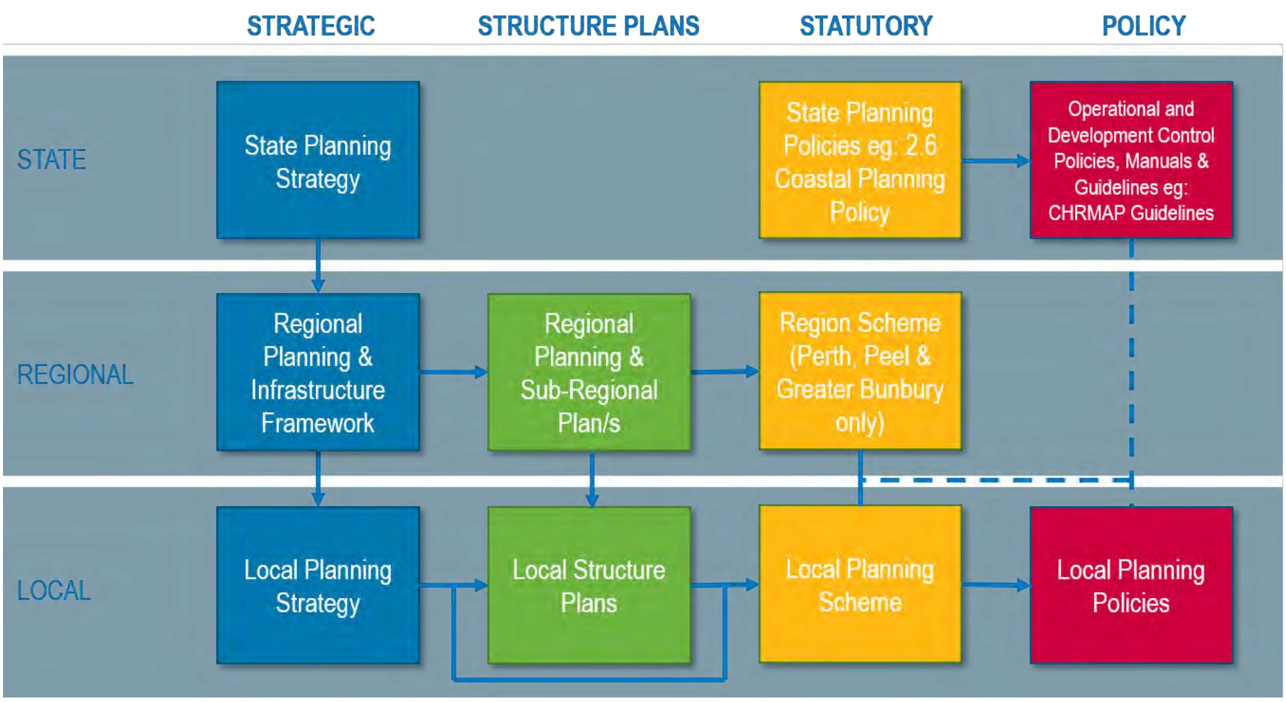

FIGURE 2-3 STATE PLANNING FRAMEWORK FOR WESTERN AUSTRALIA

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State Planning Strategy

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WA Coastal Zone Strategy

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State Planning Policy 2.6: State Coastal Planning Policy (SPP2.6)

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Gascoyne Planning and Infrastructure Framework (PIF)

↓

Gascoyne Coast Sub-Regional Strategy

↓

Shire of Shark Bay Local Planning Scheme Nº 4

↓

Shire of Shark Bay Local Planning Strategy

FIGURE 2-4 SITE-SPECIFIC PLANNING INSTRUMENTS

TABLE 2-1 EXISTING PLANNING CONTROLS – KEY MESSAGES (EXTRACTED FROM FULL TABLE: TABLE 2-1 IN APPENDIX E)

Documentation	Items of Relevance
WA Coastal Zone Strategy	Planning framework to ensure that coastal development is sustainable in the long term, and meets community, economic, environmental and cultural needs. The stated goals of the strategy are to: 1. Conserve the State's natural coastal values and assets through sustainable use 2. Ensure safe public access to the coast and involve the community in coastal planning and management activities 3. Provide for the sustainable use of natural coastal resources 4. Ensure the location of facilities and infrastructure in the coastal zone is sustainable and suitable 5. Build community confidence in coastal planning and management **All levels of government, as well as individuals, businesses, and the community, each have important and complementary roles in adapting to coastal hazards**. Particular principles of relevance: ▪ Private parties are responsible for managing risks to their private assets. ▪ **Governments (i.e.: the Shire) are responsible for managing risks to public assets and any assets they manage**. They should also: – Develop local policies and regulations consistent with state adaptation approaches – Facilitate building resilience and adaptive capacity within the local community – Work in partnership with community to identify and manage risks / impacts Adaptation options should minimise coastal process interference and legacy issues; the adaptation hierarchy is presented in Figure 2-5. **Management strategies that preserve the natural coastline and move development away from the active coastal zone are considered ideal**. Of particular relevance to the CHRMAP process is the **user pays principle**, whereby those who benefit most from protection must provide the greatest financial contribution.
SPP2.6	WA's guideline for making decisions within the coastal zone; stipulates the requirement for a CHRMAP. The ultimate aims for the policy are: ▪ To ensure all future development considers coastal hazards, climate change, and landform stability. ▪ To ensure appropriate areas are identified for a range of coastal activities. ▪ To provide public coastal foreshore reserves. ▪ To conserve coastal values (landscape, biodiversity, ecosystems, indigenous and cultural) **Potential adaptation options to be identified under the coastal hazard risk management and adaptation planning hierarchy, as presented in Figure 2-5**.

2.5 Risk Management & Adaptation Hierarchy

As discussed in Table 2-1, SPP2.6 provides a hierarchy of adaptation pathways to guide decision making in coastal areas. This should be used by planning authorities and development proponents when considering adaptation options to minimise coastal hazard risks at the local level. The hierarchy, presented in Figure 2-5, indicates a clear preference against the adoption of 'protect' as a long-term adaptation pathway. This preference is re-emphasised in SPP2.6, the policy guidelines, and the WA Coastal Zone Strategy. This hierarchy is discussed further in Chapter 2.3 of Appendix E (*Identification of Adaptation Options Chapter Report*).

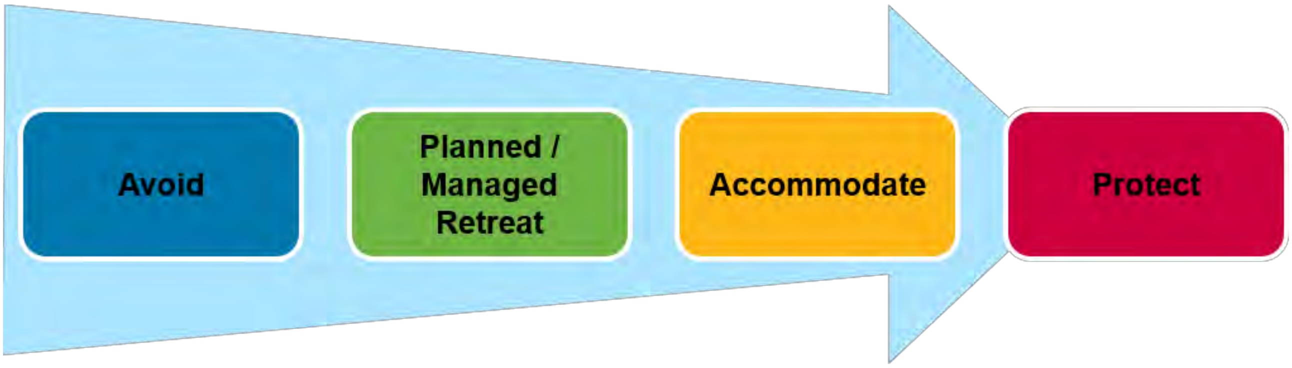

FIGURE 2-5 COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING HIERARCHY (ADAPTED FROM WAPC, 2013)

Maintaining public access to the coast in developed areas is one of the main objectives of SPP2.6 and identified as a key value of the Denham community. As discussed, the current State legislative framework means that where the shoreline recedes beyond private property boundaries, issues of public access and trespass are likely to arise. Public authorities must utilise the adaptation planning hierarchy to preserve public coastal access for the long term:

- **Avoid** development in all previously undeveloped coastal areas seaward of the 2118 hazard line;
- **Planned or Managed Retreat,** i.e. maintaining a foreshore reserve through public acquisition of private property; or,
- **Accommodate** at-risk developments over the short term while new development is appropriately designed and located; or
- **Protect,** i.e. preventing the shoreline from receding beyond private property boundaries by stabilising the current shoreline position using various protection measures (e.g. rock groynes, offshore breakwaters).

Public authorities may also choose to consider the appropriateness of interim 'Accommodate' or Protection measures when there is an imminent threat to life, coastal values or assets (WA Coastal Zone Strategy, 2017). The cost of these works to preserve public interests by temporarily delaying shoreline recession or minimising the effect of regular inundation events on existing development and infrastructure should be less than the value of the asset(s) at risk. In general, the economic, environmental and social benefits of pursuing planned retreat over the long term is considered highly advantageous to 'Accommodation' and Protection options.

2.6 Summary for Decision Makers

Table 2-2 presents a summary of the relevant information provided in this chapter and the chapter reports provided in Appendix B and Appendix E. It is important to note that there is no law requiring public authorities to provide protection of private property from natural hazards, including erosion and inundation, nor compensation when land is lost due to coastal hazards (WA Coastal Zone Strategy, 2017). Private parties must manage their own risks through options that do not detriment other local landholders. The CHRMAP process aims to identify coastal hazard risks so as to plan to maximise beneficial use of the coast.

TABLE 2-2 ADAPTATION CONSIDERATION SUMMARY

- Adaptation options should minimise coastal process interference and legacy issues
  - The adaptation hierarchy is presented in Figure 2-5.
- Coastal development must be sustainable in the long term, and must balance the community, economic, environmental and cultural needs
- Local Governments are responsible for managing risks to **public assets** and any assets they manage. They should also:
  - Develop local policies and regulations consistent with state legislation and policy
  - Facilitate building resilience and adaptive capacity within the local community
  - Work in partnership with community to identify and manage risks / impacts
- Management strategies that preserve the natural coastline and move development away from the active coastal zone in an orderly manner are considered ideal.
- Of relevance to the CHRMAP process is the user pays principle, whereby those who benefit most from protection must provide the greatest financial contribution
- Adaptation options should maintain future flexibility, in order to build resilient coastal communities.
- A key adaptation option is the use of planning instruments, including managed retreat.

3 COMMUNITY ENGAGEMENT

3.1 Engagement Process

The *Stakeholder and Community Engagement Plan* (Appendix A) aimed to engage all relevant stakeholders to provide them with ownership of the CHRMAP and acceptance of its outcomes. The objectives of the strategy were as follows:

- Consult with stakeholders and the community on climate change and its impacts in the coastal zone within the Denham Townsite:
  - What does this mean for the community?
  - How can we adapt?
- Generate the success criteria for the risk assessment component of the CHRMAP. Success criteria represent stakeholders' tolerance and acceptability of the impact to assets from the identified coastal hazards.
- Aid in the selection of site-specific adaptation measures. Stakeholders on the ground are likely to have a knowledge of the site developed over years of interaction. This provides invaluable information that can be applied to generate innovative adaptation measures.

The success criteria were developed as part of the community values assessment workshop, described in the *Establish the Context Chapter Report* (Appendix B). The finalised success criteria are presented in Table 3-1. These criteria were used to guide the identification of adaptation options. To assist with a review of the adaptation options identification and assessment process, the engagement strategy (Appendix A) utilised a second community workshop and an online survey. Community views on the initial outcomes of the adaptation planning as well as comments on the implementation plan direction were collated.

The final component of community and stakeholder engagement for this CHRMAP was the release and advertisement of this final report in its draft version. The Shire uploaded the Draft Final CHRMAP to the Shire's website on December 9th, 2019. Submissions from the public were welcomed from then until the 5th February inclusive. Submissions received during this time are summarised and responded to in Appendix G.

3.2 Success Criteria

The success criteria for the study identified in the *Risk Assessment Chapter Report* (Appendix D) are presented in Table 3-1. These criteria demonstrate that the stakeholder and community values in the study area reflect the requirements of the state, regional and local planning controls. The success criteria highlight the need for continuing public access to beaches, beach amenity, and the provision of a coastal foreshore reserve. They also identify protecting the natural environment. The importance of tourism to Denham's local economy is strongly tied to the sustainability of environmental tourist attractions. The public amenity and culture of the foreshore area is thus directly linked back to the economic values of the town.

TABLE 3-1 ADOPTED SUCCESS CRITERIA

- **Protection of the environmental assets of the study area / planning to retain environmental integrity**
- **Protection of the recreational value of the coastline**
- **Protection of the cultural values of the coastline & town centre**
- **Maintenance of a level of public recreational assets**
- **Development controls not to inhibit the landscape**

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4 COASTAL HAZARD IDENTIFICATION

4.1 Hazard Assessment Approach

4.1.1 Coastal Foreshore Reserve

SPP2.6 provides guidance on the planning principles and guidelines required for coastal development in Western Australia. A key policy objective of SPP2.6 is the provision of a coastal foreshore reserve. The coastal foreshore reserve is essentially a public ‘space’ between the ocean and coastal development. It accommodates a range of functions and values such as geomorphological integrity, biodiversity, heritage, public ownership and access.

Schedule One of SPP2.6 provides guidance for calculating the extent of the coastal foreshore reserve in terms of the physical processes alone. This reserve allows for coastal processes including present day erosion, historical shoreline movement, sea-level rise and storm surge inundation. However, as per the above, the coastal foreshore reserve should be determined on a case by case basis and include allowance for additional functions provided by the coastal foreshore associated with environmental, social and indigenous values. The primary aim of establishing coastal foreshore reserves is to ensure the values, functions and uses prescribed for coastal foreshore reserves will be available at the end of the 100-year planning timeframe.

The component of the coastal foreshore reserve to allow for coastal processes should be sufficient to mitigate the risks of coastal hazards by allowing for landform stability, natural variability and climate change. The coastal foreshore reserve is a critical input into the coastal hazard risk management and adaptation planning framework outlined in SPP2.6. The assessment considers allowances for coastal erosion and storm surge inundation in parallel. It should be emphasised that this reserve is a designated area that may be vulnerable to coastal processes over the next 100 years, not a prediction of the future shoreline.

4.1.2 Sea Level Rise

The sea-level rise scenarios applied in this study are presented in Table 4-1. This is a combination of DoT (2010) and the Fifth Assessment Report on climate change by the Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2014). The 2118 value matches that of DoT (2010) and is therefore consistent with SPP2.6.

TABLE 4-1 PROPOSED SEA LEVEL RISE SCENARIOS

	2030	2050	2118
Sea Level Rise (m)	0.15	0.3	0.9

4.1.3 Inundation Allowance

The allowance for current risk of inundation, according to SPP2.6, is calculated as the maximum extent of storm inundation, defined as the peak steady water level plus wave run-up. Consideration must be given to the likelihood of breaching any manmade structure or natural barriers, for example a dune system.

The allowance for the current risk of inundation is required to be based on a tropical cyclone storm event with a 500-year Average Recurrence Interval (ARI). This cyclone should track to maximise its inundation potential.

4.1.4 Allowance for Coastal Erosion

The allowance for erosion on sandy coasts is calculated as the sum of the S1, S2 and S3 Erosion components, plus 0.2 m per year allowance for uncertainty:

- (S1 Erosion) Allowance for the current risk of storm erosion

- (S2 Erosion) Allowance for historic shoreline movement trends
- (S3 Erosion) Allowance for erosion caused by future sea level rise

The coastal processes allowance is applied from a horizontal shoreline datum (HSD), defined as the active limit of the shoreline under storm activity. The Denham townsite is located in an area prone to tropical cyclones. SPP2.6 stipulates that a cyclone event corresponding to the 100-year ARI event should be selected to assess the erosion due to an extreme storm event, tracking to maximise its erosion and inundation potential.

4.2 Coastal Inundation Assessment

Details of the modelling undertaken for this assessment can be found in Chapter 4 of Appendix C, the *Coastal Hazard and Vulnerability Assessment Chapter Report*. The design water levels are presented in Table 4-2. The final inundation allowance, as specified by SPP2.6, is **4.2 m AHD** as shown in bold in the table. This value includes tidal, surge, and wave set-up components. Run-up was not included in the finished floor level calculations for this study. The finished floor level recommended by the Shire (4.2 m AHD) is considered to be very conservative for the present day to 2050. It is a strong recommendation of this study that a data collection program be implemented to allow for reduced uncertainties in future coastal hazard assessments. Mapping of the predicted inundation is located in Appendix C of Appendix C. These maps can also be viewed online (full link is provided in Section 7.1 of Appendix C).

TABLE 4-2 DESIGN WATER LEVELS FOR THE TOWN OF DENHAM (M AHD); NUMBERS IN BOLD ARE THE ALLOWANCE FOR INUNDATION

ARI (years)	Present Day	2030	2050	2118
20	1.9	2.05	2.2	2.8
50	2.4	2.55	2.7	3.3
100	2.7	2.85	3	3.6
500	**3.3**	3.45	3.6	**4.2**

It is a requirement of SPP2.6 to include an allowance for inundation due to tsunami when planning for development in the coastal zone. A literature review of existing studies was undertaken to provide this allowance for the study site. A run-up similar to or slightly less than the 500-year ARI cyclonic water level can be expected for the 500-year ARI tsunami.

4.3 Coastal Erosion Allowance

Details of the modelling undertaken for this assessment can be found in Chapter 5 of Appendix C. The allowance for coastal erosion is presented in Table 4-3 to Table 4-5 for 2030, 2050 and 2118 respectively. The Present Day coastal erosion allowance is the S1 row in Table 4-3, highlighted in light blue.

These lines are plotted by study area Section (1 to 5) in Appendix D of Appendix C. These maps can also be viewed online. It should be noted that the vertical relief is not considered in the setback due to sea level rise. For example, the high elevation of the Denham Seaside Caravan Park means the 2118 coastal processes allowance is unlikely to occur to that extent, due to the significantly higher volume of sediment required to be eroded.

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TABLE 4-3 COASTAL PROCESSES ALLOWANCE - 2030

Parameter	Section 1	Section 2	Section 3	Section 4	Section 5
S1	4.4	4.2	12.8	8.9	7.7
S2	2.0	3.2	0	2.4	13.1
S3	15.0	15.0	15.0	15.0	15.0
Uncertainty Allowance	2.4	2.4	2.4	2.4	2.4
TOTAL	**24**	**25**	**30**	**29**	**38**

TABLE 4-4 COASTAL PROCESSES ALLOWANCE - 2050

Parameter	Section 1	Section 2	Section 3	Section 4	Section 5
S1	4.4	4.2	12.8	8.9	7.7
S2	5.3	8.6	0	6.4	34.9
S3	30.0	30.0	30.0	30.0	30.0
Uncertainty Allowance	6.4	6.4	6.4	6.4	6.4
TOTAL	**46**	**49**	**49**	**52**	**79**

TABLE 4-5 COASTAL PROCESSES ALLOWANCE - 2118

Parameter	Section 1	Section 2	Section 3	Section 4	Section 5
S1	4.4	4.2	12.8	8.9	7.7
S2	16.7	27.0	0	20.0	109.1
S3	90.0	90.0	90.0	90.0	90.0
Uncertainty Allowance	20.0	20.0	20.0	20.0	20.0
TOTAL	**131**	**141**	**123**	**139**	**227**

4.4 Coastal Hazard Identification Limitations

There is no appropriate, locally measured water level or wave data with which to calibrate the models developed for this study. It is strongly recommended that a locally placed nearshore water level and wave data logger be deployed to provide a better understanding as to the accuracy of the model results. This should be installed as soon as possible, and ideally take continuous measurements for at least a period of 5 years with the aim of capturing a cyclone in the dataset. The data can be used to validate models under ambient conditions after a few months. However, to more confidently calibrate the model under cyclonic conditions, it is best that measured local cyclonic conditions are utilised.

The predicted inundation levels have a direct implication for recommended finished floor levels of future development. Raising finished floor levels to meet the design levels carries significant costs for the Shire, the community and stakeholders. If these are set higher than necessary due to modelling uncertainty, this represents costs the Shire and community could be spending elsewhere. Similarly, if these levels are set too low, this poses a significant risk to housing and infrastructure.

It is understood discussions regarding the instalment of such a device are already underway between the Shire and DoT.

This limitation, as well as others pertaining to inaccuracies in the coastal processes allowance are addressed in the recommended adaptation implementation and monitoring actions in Section 8 of this report.

5 RISK ASSESSMENT

5.1 Risk Assessment Process

The risk assessment process adopted for this CHRMAP is described in Figure 5-1. A likelihood and consequence rating are assigned for each asset, which determines the preliminary risk classification. Existing controls are then examined to generate the unmitigated risk classification. Future stages of the CHRMAP investigated possible adaptation options, as shown by the grey boxes in Figure 5-1. These adaptation options aim to bring any risks identified as intolerable back into the tolerable range.

The risk assessment employs the suggested methods of WAPC (2019) and AS 5334-2013 “Climate change adaptation for settlements and infrastructure - A risk-based approach”.

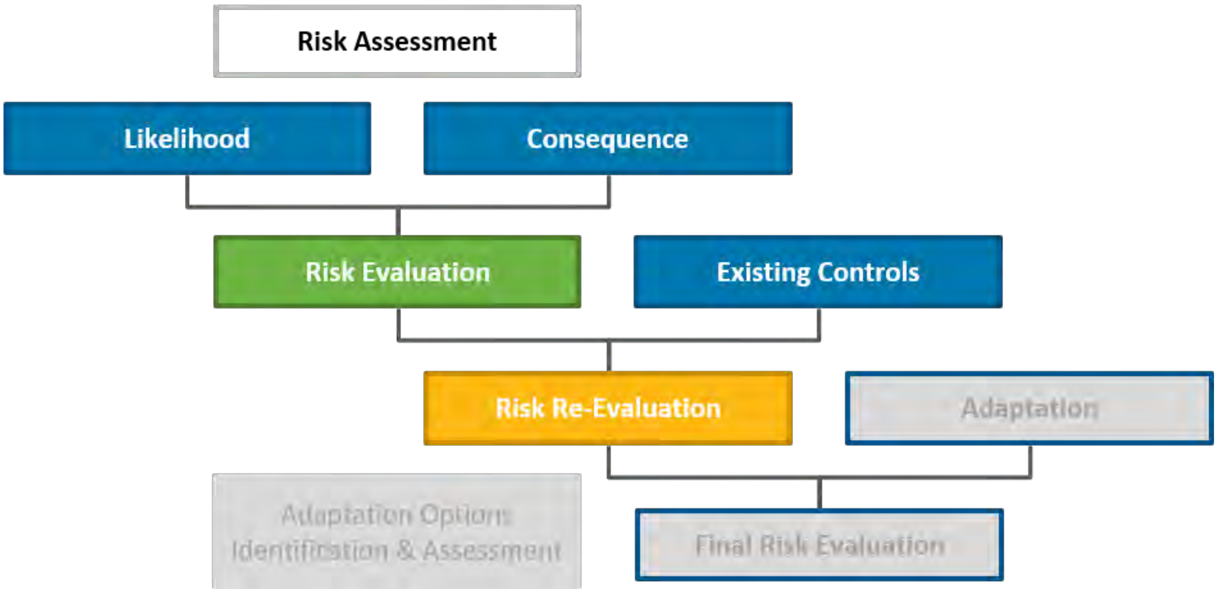

FIGURE 5-1 RISK ASSESSMENT PROCESS

The risk assessment is described in detail in the *Risk Assessment Chapter Report* (Appendix D). As per the above, the likelihood and consequence are combined to generate a risk classification. Likelihood examines the probability of an inundation or erosion event occurring, as well as its frequency (WAPC, 2019). The likelihood was applied to each hazard in the risk assessment in terms of annual exceedance probability and frequency.

Consequence examines the impact to the assets as a result of the coastal hazard. This is both the physical impact of the event to an asset, as well as that of the values attributed to it by the success criteria defined in Section 3.2. The process aims to assess the risks in terms of the stakeholder and community values first.

The risk classification corresponding to each likelihood and consequence is presented in Table 5-1. The risk classification definitions are presented in Table 5-2.

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TABLE 5-1 RISK ASSESSMENT MATRIX

Likelihood	Consequence				
	1 - Insignificant	2 - Minor	3 - Moderate	4 - Major	5 - Catastrophic
5 – Almost Certain	**Low**	**Medium**	**High**	**Extreme**	**Extreme**
4 – Likely	**Low**	**Medium**	**Medium**	**High**	**Extreme**
3 – Possible	**Low**	**Low**	**Medium**	**High**	**Extreme**
2 – Unlikely	**Low**	**Low**	**Medium**	**Medium**	**High**
1 – Rare	**Low**	**Low**	**Low**	**Medium**	**Medium**

TABLE 5-2 RISK PROFILE DEFINITION

Risk Profile	Definition
Low	Tolerable risk. A level of risk that is low and manageable without intervention outside routine asset maintenance.
Medium	A level of risk that may require intervention to mitigate, such as changes to design standards or asset maintenance.
High	A level of risk requiring significant intervention to mitigate.
Extreme	Immediate action required

5.2 Assets at Risk

As part of the *Establish the Context Chapter Report* (refer Appendix B), the assets in the coastal zone were identified. Each asset was colour coded based on its classification (commercial, public, tourism related and residential) for ease of identification in the hazard maps and online database. The online database displays the identified assets, as well as the spatial extent of the various coastal hazards. The present planning scheme zoning is also included as a layer. The online database can be found at the following link:

https://watech.maps.arcgis.com/apps/webappviewer/index.html?id=6e092b4d0f044e038a721705e907c084

Following the risk assessment evaluation, the identified assets at risk were prioritised. The prioritised assets at risk of inundation are presented in Table 5-3, and for erosion in Table 5-4. The inundation assessment investigated the 500-year ARI inundation event for the different planning timeframes: Present Day, 2030, 2050 and 2118. This event has a predicted level of 3.3m AHD in the present day, and 4.2 m AHD by 2118.

The erosion assessment calculated a coastal erosion allowance. This is a setback distance from the horizontal shoreline datum, roughly equivalent to the present location of the dune vegetation line. This setback distance ranged from 4 to 13m in the present day, and 123 to 230m by 2118.

Along Knight Terrace, the extent of the hazard area in 2118 is similar for both inundation and erosion.

TABLE 5-3 PRIORITISED ASSETS - INUNDATION RISKS

Present Day	2030	2050	2118
Utilities consist of: ▪ Electrical box, the water pumping station and the water well located at the south-eastern end of Knight Terrace ▪ Electrical substation on Durlacher St near the corner of Knight Terrace ▪ Fire hydrants located at the marina facility			
	Drains to beach, foreshore recreational infrastructure such as benches, picnic tables, BBQs, toilets, public art		
	Fuel tank at marina		
	Petrol pumps / tanks at the 2 petrol stations		
	Public buildings: Shire Offices Department of Biodiversity, Conservation & Attractions, Shark Bay Discovery Centre, Community resource centre		
	Knight Terrace, car parks, parks		
	Commercial, tourism and residential buildings		
			Vacant blocks

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TABLE 5-4 PRIORITISED ASSETS - EROSION RISKS

Present Day	2030	2050	2118
Adhoc seawall			
	Utilities: ▪ Fire hydrants located at the marina facility	Utilities: ▪ Electrical box and water pumping station located at south-eastern end of Knight Terrace ▪ Fire hydrants located at the marina facility	Utilities: ▪ Electrical box and water pumping station located at south-eastern end of Knight Terrace ▪ Fire hydrants located at the marina facility ▪ Electrical substation on Durlacher St near the corner of Knight Terrace
	Foreshore recreational infrastructure: BBQs, toilets, fish cleaning station	Foreshore recreational infrastructure: BBQs, public toilets	Foreshore recreational infrastructure: BBQs, public toilets, fish cleaning station
	Knight Terrace	Knight Terrace & Stella Rowley Drive	
	Fuel tank at marina		
		Public buildings: Shire Offices	Public buildings: Shire Offices, Department of Biodiversity, Conservation & Attractions, Shark Bay Discovery Centre, Community resource centre
		Commercial, tourism and residential buildings	
		Petrol pumps / tanks at the 2 petrol stations	
		Vacant blocks	
		Foreshore recreational infrastructure: foreshore path, limestone retaining wall, playground, parks, car parks, drain to beach, public art, public bench, pergola	
			Marine infrastructure: Engineered seawall, FRP sheet-pile groyne, jetty, boat ramp, beach access

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6 ADAPTATION OPTION IDENTIFICATION

6.1 Adaptation Options - General

As per the *Options Identification Chapter Report* (Appendix E), general adaptation options to mitigate coastal hazards are presented below. These options have been adapted from the CHRMAP Guidelines (WAPC, 2014) for this project. Note that the 'Do Nothing' approach here means applying no additional adaptation options to assets within the hazard zone, and simply repairing or condemning and removing assets after damage is incurred.

TABLE 6-1 AVAILABLE ADAPTATION OPTIONS (APPENDIX E, TABLE 3-3; ADAPTED FROM WAPC, 2019)

Option Nº	Option Name	Option Type	Asset
1.1	Locating new assets outside of vulnerable areas	Avoid	This applies to future assets in the coastal zone, as those assets already in the zone do not apply by definition
2.1	'Do Nothing'	Planned / Managed Retreat	All assets in the hazard zone
2.2	Demolition or removal / relocation of assets from inside hazard area	Planned / Managed Retreat	All assets in the hazard zone
2.3	Prevention of further development / expansion of existing use rights	Planned / Managed Retreat	All assets that are impractical to protect
3.1	Notification on title	Accommodate	All assets located within an area vulnerable to the adverse impacts of coastal erosion and inundation within the planning timeframe
3.2	Emergency evacuation plans	Accommodate	Roads (with particular regard to managing traffic flows during an event), car parks, residential property, hospitals, aged care facilities, schools, childcare facilities, surf life-saving clubs etc.
3.3	Design assets to withstand hazards	Accommodate	Roads, car parks, residential property, hospitals, aged care facilities, schools, childcare facilities, surf life-saving clubs etc
3.4	Revegetation	Accommodate / Protect	Primary and secondary dunes
4.1	Renourishment & revegetation	Protect	High use beaches and foreshore reserves where retreat is not an option.
4.2	Groynes	Protect	High use beaches and foreshore reserves where retreat is not an option. Where assets values are high, and relocation is not an option.
4.3	Seawalls	Protect	High use beaches and foreshore reserves where retreat is not an option. Where assets values are high, and relocation is not an option.

6.2 Adaptation Options - Planning

This section summarises the key planning instruments which were considered for incorporation into the Shire's local planning framework. These instruments are particularly useful for implementing Accommodate and Planned or Managed Retreat options. These options are described in more detail in the *Options Identification Chapter Report* (Section 3.3 of Appendix E); recommended options are presented in Section 8.

- **Incorporate SPP2.6 into Local Planning Scheme No. 4**
  - Amend Clause 29 (1) to include SPP2.6 as a State Planning Policy to be read as part of the Scheme. No amendments to SPP2.6 under clause 30 are suggested.
- **Amend the local planning scheme to introduce a Special Control Area (SCA)**
  - Cover all land identified as being at risk of coastal inundation. The SCA would be delimited by the inundation extent of the 500-year ARI event in the year 2118.
  - Include additional provisions (over and above or overriding provisions for development not within the SCA), such as:
    - All proposed development within the SCA requires approval. (This would include development that would not ordinarily require development approval under the scheme).
    - Approval to be issued on a temporary or time limited basis. (The applicant could later apply for a further approval, which could be granted if the risk from coastal processes was still considered acceptable).
    - Referral of applications. (Any planning application should be referred to the Department of Transport, the Western Australian Planning Commission and any other relevant authority for advice and comment on the coastal risk.)
    - Minimum finished floor levels (FFLs) and/or other development standards. (4.2 metres AHD has been identified as the appropriate minimum FFL)
- **Prepare a local policy to clarify the Shire's attitude and expectations in relation to coastal development**
  - Including the type of permanent or temporary assets the Shire is prepared to accept within the coastal reserve and/or on land subject to coastal processes.
  - Provides detail and guidance on what sort of development is acceptable and assist in making planning decisions.
  - Policy would also identify the Council's intention to require notifications on title as a condition of development approval.
- **Notifications on title for assets identified as being at risk of impact from coastal processes**
  - Indicative wording is as follows, as per SPP2.6:
    - *VULNERABLE COASTAL AREA – This lot is located in an area likely to be subject to coastal erosion and/or inundation over the next 100 years*.

The intent of these instruments aligns with guidance provided in the WA Coastal Zone Strategy, noting that private parties are responsible for managing risks to their private assets and incomes which might arise from coastal erosion and inundation hazards.

6.2.1 Summary for Decision Makers – Identified Planning Instruments

- Amend Local Planning Scheme No. 4 Clause 29 (1) to include SPP2.6 as a State Planning Policy to be read as part of the Scheme.
- Amend the local planning scheme to introduce a Special Control Area (SCA) over all land identified as being at risk of coastal inundation.
- Prepare a local policy to clarify the Shire's attitude and expectations in relation to coastal development including the type of permanent or temporary assets it is prepared to accept within the coastal reserve.
- All freehold land identified as being at risk of impact from coastal processes should have a notification placed on its certificate of title/s.

6.3 Adaptation Options – Inundation

As per the planning instruments, numerous adaptation options to mitigate the risks of inundation were identified as part of the *Options Identification Chapter Report* (Appendix E). Options were identified over the different planning epochs to address the changing risks. A summary of the identified options to mitigate inundation risks is presented below. Options presented for future epochs are in addition to or add to those discussed for the Present Day.

Economically, relocation or managed retreat options may be triggered by the physical costs of repair exceeding the relocation costs. As per the success criteria and adaptation hierarchy, consideration should be given to the continued allowance for a recreational reserve. This may mean relocating buildings ahead of their risk rating in order to continue to allow this space.

6.3.1 Present Day

- Prevention of further development / limiting existing use rights
  - Introduce 'Special Control Area - Coastal Hazard' with a requirement for new development to achieve a minimum finished floor level of 4.2m AHD for habitable areas of buildings. Depending on the nature of development proposed, approval may be time limited or require structures to be removed by a specified date or when a specified trigger is reached.
  - Introduce a local planning policy outlining the Shire's requirements for building construction, land fill, and other relevant matters within the Special Control Area.
  - Incorporate SPP2.6 into Local Planning Scheme
- Any new assets should avoid the coastal zone.
  - If they must be located within the coastal zone, they should be designed to withstand the inundation hazard. For example, new buildings to be constructed with permeable lower levels (e.g. a stilt arrangement), and services located above the flood level. This avoids the need to use fill to raise the FFL. Fill is expensive, and also alters the flood flow, which could lead to increased hazards.
- Emergency evacuation plans for the affected areas
  - It is noted that access to the town is not predicted to be blocked in the event of a hazard.
- Commence investigations to determine options for appropriate longer-term relocation of affected parts of the town.

6.3.2 2030

- Services moved to be located above the recommended FFL

- Commercial stock or important possessions stored above the flood level
- Installation of false (raised) floors
- Use of materials that are water resistant
- Floorplate / wall arrangements to allow flow of water (and therefore minimise damage)
- Building evacuation requirements

6.3.3 2050

- Utilities and foreshore recreational infrastructure may require significant repair. Relocation may be a viable option by this timeframe.
- At this time, the drains and drainage system to the beach may need to be modified to continue to function. The drains rely on gravity flow from the streets down to the ocean. Under increased sea levels and storm frequency, the ability of the drains to function will be reduced as they may be more frequently inundated from the ocean side, such that there is nowhere for the landward-side water to go.
- Public, commercial, tourism and residential buildings should consider mechanisms for minimising the impact of flood damage, as per the recommendations in 2030 above.
- There may be some flood related damage to Knight Terrace, car parks, and grassed foreshore area leading to increased maintenance requirements.
- Structure plans for relocation areas should have been completed and the Scheme Map amended as necessary.

6.3.4 2118

- Utilities, foreshore recreational infrastructure, Knight Terrace, Stella Rowley Drive and the adjacent car parking areas and drains may require significant repair or relocation.
- Under the 2118 predicted sea level rise, the drains may be completely inundated during a tidal cycle, leading to the inability to drain rainwater at high tide.
- Public, commercial, tourism and residential buildings may need significant repairs or relocation.
- Flood related damage to public open space, beach access, boat ramps and marine infrastructure may require significant repairs.

6.4 Adaptation Options - Coastal Erosion

Adaptation options with the specific aim of mitigating risks from coastal erosion were also **identified for assessment** (assessed in Section 7 of this report). The identified options over all planning epochs are presented in this section. Significantly more detail on the process of options identification is contained within the *Options Identification Chapter Report* (Appendix E).

6.4.1 Adaptation Triggers (all timeframes)

These options signify when to abandon or relocate an asset.

- **Trigger 1**: Where the most landward part of the Horizontal Shoreline Datum (HSD) is within 40 metres of the most seaward point of a development / structure / foreshore reserve area.
  - Due to the high value placed on the foreshore coastal reserve, the recreational area would itself be considered the asset in this case
- **Trigger 2**: Where a public road is no longer available or able to provide legal access to the property

  - This may occur for Knight Terrace, particularly to the east of Denham Hamelin Road. The Shire may choose to investigate access options from the landward side of these properties.
- **Trigger 3**: When water, sewage or electricity to the lot is no longer available as they have been removed/decommissioned by the relevant authority due to coastal hazards.

6.4.2 Present Day

- Formal design and construction of the adhoc seawall in Section 2 of the study area.
- Revegetation in the adhoc seawall's lee with some minor renourishment to stabilise the profile, in addition to an initial re-placement of the existing rocks into a more stable shape.
- Groynes were initially identified as an option but were not considered to be suitable at the site unless multiple groynes are in place, together with significant renourishment and bypassing works. This would require ongoing maintenance in the long term and thus constitute a 'legacy' adaptation option. Groynes can also lead to unintended consequences.
- As per the inundation adaptation options, planning mechanisms are recommended. These are as follows:
  - Introduce Special Control Area - Coastal Hazard with a requirement for new development to achieve a minimum finished floor level of 4.2m AHD for habitable areas of buildings. Depending on the nature of development proposed, approval may be time limited or require structures to be removed by a specified date or when a specified trigger is reached.
  - Require Notification on Title for all land located seaward of the 100-year hazard line for coastal erosion **within the next planning epoch**. That is, at present, this applied to all land located seaward of the 2030 line. This should be made a condition of any approval for development or subdivision/amalgamation of land. The Shire should also negotiate with landholders whose land is not subject to an application for planning approval to place such a notification on the title with their consent.
  - Introduce a local planning policy outlining the Shire's requirements for building construction, land fill, and other relevant matters within the Special Control Area.
- Commence investigations to determine options for appropriate longer-term relocation of affected parts of the town.

6.4.3 2030

- Amend the provisions (and boundaries, if necessary) of the Special Control Area to limit development in locations at risk of erosion.
- Continue to require notification on Title as a condition of planning approval and/or on a voluntary basis.
- Ensure that appropriately zoned land is available for relocation of the town as necessary. Structure planning of the land may be required.
- Utility connected foreshore infrastructure, marina fuel tank, utilities and Knight Terrace may require additional maintenance / repair by this timeframe.

6.4.4 2050

- Utilities, marina fuel tank, petrol pumps and utility connected foreshore infrastructure may require significant repairs.
- Public, commercial, tourism and residential buildings may sustain damage.
- Knight Terrace, Stella Rowley Drive and foreshore recreational infrastructure may require additional maintenance.

- Structure plans for relocation areas should have been completed and the Scheme Map amended as necessary.

6.4.5 2118

- Utilities, marina fuel tank, petrol pumps, utility connected foreshore infrastructure, public, commercial, tourism and residential buildings, Knight Terrace and a section of Stella Rowley Drive may require relocation.
- Foreshore recreational infrastructure may require significant repair or relocation.
- Beach access, boat ramps and marine infrastructure may require significant repairs.

7 ADAPTATION OPTIONS ASSESSMENT

The adaptation options assessment is a process of investigating which options provide a positive outcome against the range of success criteria; the full assessment is provided in Appendix F the *Adaptation Options Assessment Chapter Report*. Using the identified potential adaptation options for the prioritised list of assets at risk of coastal hazards, a multi-criteria analysis (MCA) and cost-benefit analysis (CBA) were undertaken. The MCA framework consisted of six different categories; (expected) effectiveness, environmental impact, social impact, aesthetic impact, future adaptability, and cost.

The result of the MCA and CBA is a succinct list of recommendations that confidently provide a strong benefit to the values of the stakeholders. Table 7-1 presents a summary of the adaptation options assessment and recommended options. Green shading indicates the option is recommended, orange is only recommended as per the noted proviso, and red is not recommended.

TABLE 7-1 SUMMARY OF ADAPTATION OPTIONS ASSESSMENT (*POINTS BELOW)

Option Nº.	Option Name	Section 1	Section 2	Section 3	Section 4	Section 5
1.1	Avoid (where possible)		NA	NA		
2.2	Relocate					
2.3	Prevent further development		*2	*1		
3.1	Notification on land titles					
3.3I	Minor re-design to help accommodate inundation (where possible)					
4.1	Renourishment	*3				
4.2/3	Hard structure protection		*4			

1. Potential to continue development behind seawall protection as long as the finished floor level requirements are met, and developers are made aware of the potential for long-term retreat when marina facilities are retired (could be implemented with a timeframe limit to the development). Note that the marina facility has a design life of 25 years (WP, 2016) and is managed by the DoT so the Shire should carefully consider allowing significant development with a design life longer than 25 years in this area based on the assumption that facility's life span will be extended.
2. Restriction of further development dependent on the final adaptation pathway chosen for this area. If protection is chosen, then a similar strategy to Point 1 could be implemented.
3. Renourishment to limit erosion may be viable for Section 1 and could be based on a monitoring and trigger-based strategy.
4. Potential to install a more formal coastal protection structure in Section 2 to allow more time for assets inland to be relocated over time.

Some general recommendations for the Shire are as follows:

- All new ***permanent*** development not classified as ***infill*** within the identified hazard zones should be avoided
- A special control area (SCA) should be created including, but not limited to the following:
  - All proposed development within the SCA requires approval. (This would include development that would not ordinarily require development approval under the scheme).

  - Referral of applications (any planning application should be referred to the Department of Transport, the Western Australian Planning Commission and any other relevant authority for advice and comment on the coastal risk).
- Placement of Section 70A of the *Transfer of Land Act 1893* notification on appropriate land titles (notifying of coastal hazard risk).
- Prevention of further development for lots within the erosion hazard zone of the next epoch (i.e.: staged prevention of development, initially for lots at risk by 2030, then later for lots at risk by 2050 if hazard triggers are reached). This criterion may be relaxed for lots inland of protection structures as long as the new development and protection structure design lives are taken into account.
- Requirement of houses damaged or otherwise triggered (see Section 6.4.1) by coastal hazards to be relocated or rebuilt out of the hazard zone.
- Minimum finished floor levels and/or other development standards (4.2 metres AHD has been identified as the appropriate minimum FFL).

- Land developers should also be made aware of the risks from inundation at present and in the future and be educated of the steps they can take to minimise damage from such events.

If Section 70A (*Transfer of Land Act 1893)* notifications were to be implemented for all residential and commercial lots within the 2118 hazards zone, a total of 51 residential and 14 commercial properties would be impacted. If a policy of managed retreat were adopted, Table 7-2 (adapted from Appendix C) shows the number of assets that would be affected. Assets vulnerable between the present day and 2030 are considered extreme risk and relocation should be considered. Assets vulnerable by 2050 are considered high risk and monitoring and consideration of long-term options should occur. Assets at risk by 2118 should also monitor the progress of erosion and sea level rise and consider their options as the risk of hazards increases. Note that most of these assets are already exposed to inundation risks.

TABLE 7-2 ASSETS EXPOSED TO EROSION UNDER MANAGED RETREAT PREDICTIONS

Asset Classification	Present day to 2030 (extreme risk)	By 2050 (high risk)	By 2118 (moderate risk)
Commercial	1	5	14
Public	64	70	74
Residential	0	18	51
Tourism Related	1	4	10

The Denham townsite is situated close to or within the active coastal zone, especially high value areas such as the hub of Knight Terrace and the marina facilities. This makes some interaction with coastal processes unavoidable. This has already been observed through the placement of various coastal protection structures over time, ranging from the new marina rock revetment to old ad-hoc erosion guards near vulnerable assets. The upgrade of marina facilities has somewhat cemented a section of the town's coastline in place for the next few decades. Both the MCA and the CBA recommended this protection be maintained for the time being.

8 IMPLEMENTATION

This section summarises the recommended adaptation approaches for all sections of the study area for the Town of Denham. The implementation plan is divided into a relatively well-defined short-term plan (to 2030) and trigger-based strategy, as well as a long-term plan that is designed to prompt local decision makers into long term thinking strategies.

8.1 Short Term Implementation Plan

The short-term implementation plan is divided into the five coastal sections defined during the project. Table 8-1 outlines the preferred adaptation approach as well as some best practice coastal management recommendations that should be implemented as an overall Foreshore Management Plan to increase the resilience of the coastline. All recommendations in the short-term plan should be considered now unless a trigger-based initiation is preferred by the Shire.

8.1.1 Trigger-based Adaptation

The following triggers are listed in cascading order. That is, proximity trigger is considered first, and damage last (if the first three are enacted, the damage trigger would have lower likelihood of occurrence). For example, the utilities would be planned to be removed by a proximity trigger. This would then require landholders to relocate as the utilities trigger would have been reached.

- **Proximity trigger**: Where the most landward part of the Horizontal Shoreline Datum (HSD) is within 40 metres of the most seaward point of a development / structure / foreshore reserve area.
  - Due to the high value placed on the foreshore coastal reserve, the recreational area would itself be considered the asset in this case
- **Access trigger**: Where a public road is considered no longer available or able to provide legal access to the property
  - This may occur for Knight Terrace, particularly to the east of Denham Hamelin Road. The Shire may choose to investigate access options from the landward side of these properties.
- **Utilities trigger**: When water, sewage or electricity to the lot is no longer available as they have been removed/decommissioned by the relevant authority due to coastal hazards.
- **Damage trigger**: Any property within the hazard zone and SCA that is damaged by a coastal hazard from an extreme weather event shall require Shire approval before being repaired. The review process should involve:
  - Re-fit of minor or moderately damaged assets to better accommodate coastal hazards in the future
    - OR
  - Removal and redevelopment outside the hazard zone for assets that suffer major damage.

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TABLE 8-1 CHRMAP SHORT-TERM IMPLEMENTATION PLAN BY STUDY AREA (COASTLINE) SECTION (APPLIES TO WHOLE SECTION UNLESS STATED OTHERWISE)

CHRMAP Section	Short term implementation plan (to 2030)
All areas	**Planning strategy**: ▪ Implementation of the Special Control Area (SCA) with the conditions presented in Section 7 which will have the following adaptation strategies: – **Avoid** any permanent development not classified as infill seaward of the 2118 hazard line. The SCA could be used to ensure this. – **Managed retreat** when houses damaged or otherwise triggered (see Section 8.1.1) by coastal hazards must be relocated or rebuilt out of the hazard zone. – **Accommodate** through placement of Section 70A of the *Transfer of Land Act 1893* notification on appropriate land titles (notifying of coastal hazard risk). – **Accommodate** through finished floor level requirements for all developments within the hazard zone. ▪ **Accommodate** assets at high or extreme risk of inundation through minor modifications to limit damage from high water level events.
Section 1	**Planning strategy:** ▪ **Protect** through periodic renourishment could be considered over the short term to allow for **Managed Retreat** and **Accommodate** options to be implemented smoothly. Note that the strategies presented for all areas take preference to protection options. **Best practice coastal management recommendations:** ▪ Dune stability improvements through revegetation and modification of stormwater drains. ▪ Investigation into the suitability of sand fencing to build the dune system. ▪ Possibility of utilising dredged material to supplement dune reinstatement strategies above (Noting dredging happens rarely and should not be relied upon as a long-term strategy). ▪ Beach monitoring to document changes in the coastline and increase understanding of the coastal system (see Monitoring Plan in Section 8.5).
Section 2	**Planning strategy:** ▪ **Protect** through formal design of the ad-hoc rock armour revetment between the beach and the coastal path. **Best practice coastal management recommendations:** ▪ Asset stability in the lee of the ad-hoc revetment could be improved through reshaping of the wall (to consider in redesign) and revegetation of the area seaward of the coastal path. ▪ Beach monitoring to document changes in the coastline and increase understanding of the coastal system (see Monitoring Plan in Section 8.5).
Section 3	**Planning strategy:** ▪ **Accommodate;** planning controls could be relaxed here until the end of the marina revetment design life. However, controls related to inundation such as finished floor levels must always be enforced. **Best practice coastal management recommendations:** ▪ Section north of marina between revetment and limestone retaining wall could be revegetated. Although the Shire did note that some areas are very difficult to revegetate due to the local climate and this option may not be cost effective in that case.
Section 4	**Planning strategy:** ▪ As per all sections. Limited assets in the hazard zone, should be relatively easy to allow for **Managed Retreat**. **Best practice coastal management recommendations:** ▪ Consolidation and bedrock in this area may limit erosion more than predicted. Further investigation would be required if any development was proposed within the hazard zone. ▪ Stability of tourism assets could be improved through revegetation and sand fencing techniques. ▪ Beach monitoring to document changes in the coastline and increase understanding of the coastal system (see Monitoring Plan in Section 8.5).
Section 5	**Planning strategy:** ▪ As per all sections. Limited assets in the hazard zone, should be relatively easy to allow for **Managed Retreat**. Single public asset (car park) in this area should use M**anaged Retreat** based on a trigger. **Best practice coastal management recommendations:** ▪ Environmental impacts of recreational vehicle use in this area could be mitigated through tighter management. ▪ Beach monitoring to document changes in the coastline and increase understanding of the coastal system (see Monitoring Plan in Section 8.5).

8.2 Long-Term Adaptation Strategies

The Shire is encouraged to select one of the presented long-term adaptation strategies for the Town of Denham that will allow for the continuous function of the town whilst accommodating the increasing burden of coastal hazards. The two primary options, also presented in Figure 8-1, for this are:

- Managed retreat:
  - Use the planning instruments and long-term plan to slowly move assets with low adaptive capacity out of the hazard zone.
- Accommodate and protect:
  - Maintain/upgrade the existing rock revetments as necessary to limit erosion to assets along Knight Terrace and limit damage from inundation events through finished floor level requirements.

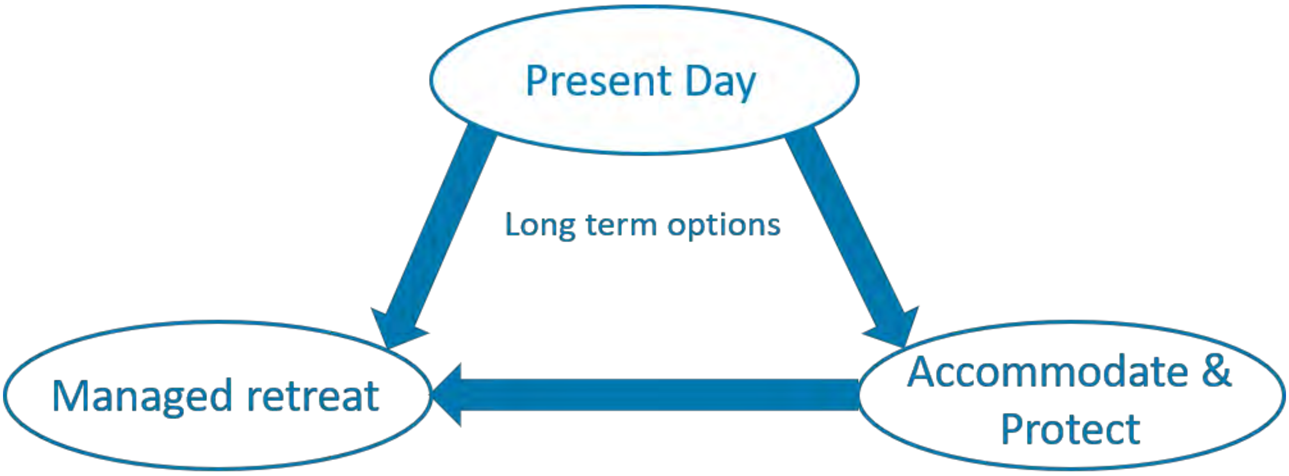

FIGURE 8-1 PRIMARY LONG-TERM ADAPTATION PATHWAYS AVAILABLE FOR THE SHIRE (MANAGED RETREAT RECOMMENDED)

The two long-term strategy options are presented by study area section in Table 8-2 and Table 8-3.

It should be noted that the economic case for expanding coastal protection structures was poor. Managed retreat options are recommended due to the lack of legacy issues and the avoidance of the 'sunk cost' fallacy in the future. As sea level rise progresses it is expected that the resources required to continue to protect assets near the coast will become too onerous. However, the area's weather characteristics are such that it does not experience a significant number of cyclones. Statistically, decision makers may have several decades before significant changes have to be made. Having a long-term strategy in place early will inform planning instruments, and a comprehensive monitoring and review plan will ensure the Town is not caught off-guard.

TABLE 8-2 PROPOSED LONG-TERM ADAPTATION PATHWAY FOR A MANAGED RETREAT STRATEGY

Denham Coastal Compartment	2030	2050	2118
Section 1	Monitoring & Planning Instruments	Managed retreat	
Section 2	Monitoring & structure maintenance; Planning Instruments	Town centre redevelopment; Planning Instruments	Managed retreat
Section 3			
Section 4	Monitoring & Planning Instruments	Monitoring & Planning Instruments Managed retreat (Denham Seaside Caravan Park)	
Section 5	Monitoring & Planning Instruments		

TABLE 8-3 PROPOSED LONG-TERM ADAPTATION PATHWAY FOR AN ACCOMMODATE AND PROTECT STRATEGY

Denham Coastal Compartment	2030	2050	2118
Section 1	Monitoring; Accommodate	Monitoring; Accommodate / Managed retreat	Managed retreat
Section 2	Monitoring; Structure maintenance	Monitoring; Protect & accommodate (seawall and FFL)	
Section 3			
Section 4	Monitoring & Planning Instruments	Monitoring & Planning Instruments Managed retreat (Denham Seaside Caravan Park)	
Section 5	Monitoring & Planning Instruments		

8.3 Challenges

Any adaptation option implemented will likely face push-back from some portion of the community. For this reason, it is important that the community, especially asset holders in the hazard zone, be educated about the risks from coastal hazards. This will increase their resilience through education and awareness. Members of the community should also be informed about their responsibilities, the local and state government responsibilities to private assets. All new developments within the hazard zone should be signed by the owner to show they understand everyone's roles and responsibilities with regard to the new development. This is important to prevent legal action and low community confidence in the Shire's planning decisions.

Furthermore, long-term adaptation strategies must not inhibit the lifestyle and culture of the town. The low-lying foreshore is home to much of the commercial and social aspects of the town at present. A haphazard shift to a new town centre or heavy development restrictions in the existing area may discourage investment in the town. Therefore, a forward-facing long-term strategy with high levels of community engagement in the development process is important for the Shire.

8.4 Funding and Responsibilities

Managing the CHRMAP implementation will be the responsibility of the Shire. The Shire should seek assistance from relevant local and state organisations as required. A monitoring plan is briefly outlined in this report to assist with decision making and future updates to the Town's CHRMAP, which should be undertaken every 5-years, and at a maximum of every ten years.

In the short-term we recommend investigating funding avenues based on the town's high tourism value, and the World Heritage listing. Maintaining the culture and recreational value of the Denham townsite is strongly linked to the continuation of both tourism and environmental protection of the region.

In the long-term, effective use of planning instruments will ideally ensure that adaptation of assets in the town happens organically with low resource burden to the Shire. Long-term adaptation strategies should ensure that Shire assets such as utilities are relocated at the end of their useful life without significant additional cost over what would normally be required.

It is recommended that a specific Coastal Adaptation Fund is created to fund coastal adaptation for the long-term. The following funding sources should be considered to contribute to this fund. These are in line with the user pays principle:

- Percentage increase in all rates – the full Shire community benefits from the coast
- Special Area Rates – for those landholders that are directly affected by coastal hazards, and will therefore directly benefit from adaptation measures
- Existing state government grants:
  - Coastal Adaptation and Protection (CAP) Grants implemented by the Department of Transport
  - Coastwest Grants implemented by DPLH
  - Coastal Management Plan Assistance Program grants administered by DPLH
  - Royalties for Regions funding administered by the Regional Development Commission
- Continuing advocacy for further funding from the state and introduction of federal government funding
  - The recently released Coastal Erosion Hot Spots report (general information provided here; released by Department of Transport) aims to assist with gaining traction with federal government.
- Mechanisms for visitors to the town, i.e. Users of the coastline, to contribute. This could be in the form of a levy applied to their accommodation, or paid parking at key tourist sites.
- Developer contributions where specific developments benefit from their coastal location

TABLE 8-4 STRATEGY RESPONSIBILITY SUMMARY: SHORT & LONG-TERM IMPLEMENTATION PLANS

Strategy	Recommended Location	Implementation Timeframe	Funding & legal responsibility
Incorporate SPP2.6 into Local Planning Scheme No. 4	All	ASAP	Shire
Special Control Area	All	ASAP	Shire
Prepare a local coastal policy	All	ASAP	Shire
Section 70A of the *Transfer of Land Act 1893* notification	All	ASAP	Shire
Finished floor level requirements	All	Implemented	Shire
Managed retreat of damaged / at-risk commercial, tourism and residential buildings	▪ Section 1; Section 4 ▪ Section 2 ▪ Section 3	▪ Section 1; Section 4 Trigger based ▪ Section 2 trigger will depend on if accommodate is selected ▪ Section 3 trigger depends on marina design life (refer Table 7-1 for options)	Landholder Shire (Coastal Adaptation Fund) if buy-back is proposed
Modification of property to accommodate minor flooding	All	2030	Landholder
Periodic renourishment	Section 1	As required; By 2025 or next dredge (whichever is sooner)	Shire
Dune stability improvements – revegetation etc	Section 1	ASAP	Shire
Beach monitoring	All	ASAP	Shire
Formal seawall design & construction	Section 2	2025 (if accommodate option selected)	Shire
Future town centre concept design	All	2030	Shire
Public asset managed retreat (see at-risk assets in Table 5-3 and Table 5-4)	All	As required; triggers as per Section 8.1.1; Indicative timings discussed in Section 6.3 and 6.4	Shire

8.5 Monitoring Plan

A comprehensive monitoring and data collection plan will increase the confidence of future coastal hazard studies and resulting design requirements. It is recommended that the Shire perform seasonal / annual photographic monitoring of the coastline to assist in identifying long-term changes. It is also recommended that the CHRMAP be updated every 5-10 years (for now) with re-analysis of new data including:

- Review of the photographic monitoring;
- Review of any new survey data;
- Shoreline vegetation movement analysis from the last report to present;
- Analysis of any severe inundation or erosion events;
- Discussion with the Shire on the status of both short and long-term adaptation strategy progress; including
  - Assessment of the present strategy's performance and review of any new strategies identified;
- Assessment of whether modelling of the study area should be updated given any recent data collection, planning change or sea level rise prediction updates.

The final management options will include the continued revision of the CHRMAP and update of the recommended options at regular intervals (i.e. every five to ten years). This is due to corresponding future updates in climate change science, coastal engineering methodology, changes to the town's success criteria, triggers reached, and so on.

8.6 Knowledge Gaps & Recommendations

At present there are several challenges to undertaking a CHRMAP for the town. Primarily this is a lack of local oceanographic data which can limit confidence in the results of analysis / modelling and, in some cases, result in unnecessary economic burden to asset holders near the coast through overly conservative design requirements.

When dealing with coastal adaptation, whilst it is important to understand the level of accuracy of the modelling as it informs the risk and vulnerability ratings, we believe the most effective approach is to use the proposed modelling to identify triggers and their corresponding coastal management action. An indicative likelihood and timeframe can be provided for guidance, but the ultimate adaptive action is driven by the triggers.

To assist in filling the knowledge gaps, the following ongoing data collection is recommended. These are listed in order of priority. Except where indicated, the benefit of the data will not be gained during the present study, but in the application of the resulting coastal management plan:

- Locally placed nearshore water level and wave data logger. This will enable calibration of wave models, especially if a storm / cyclone is captured during the deployment. Following the completion of the CHRMAP, the data can be used to get a better understanding of event probabilities, rather than just triggers.
  - Ideally, this instrument would be deployed before the commencement of the next cyclone season.
- Regular photographic beach monitoring is a useful tool in analysing beach behaviour. This can be conducted at 6-monthly intervals at the end of the summer and winter. Photos should also be taken immediately following severe storms. They should be undertaken from a set vantage point to allow accurate comparisons between images. The images can be used to supplement available data when undertaking adaptation option design. These images can also be used to support adaptation option funding applications, and in educating the community about natural fluctuations in beach shape.

  - These can be commenced immediately. Water Technology have proformas for these which allow Shire staff to undertake the inspections, once initial guidance is provided. Coastal specialists should review the data every couple of years, or if erosion is causing an issue.
  - This data can also be used to identify if a trigger has been reached.
- Beach surveys, ideally every 6-months following the summer and winter periods. If possible, immediately following cyclones. Corresponding monitoring photos should be taken at the same time.
- Regular monitoring of the marine structures / assets – e.g. seawall, jetties. These should be undertaken with consistent proformas to allow comparison between inspections
  - These can be commenced immediately. Water Technology have proformas for these which allow Shire staff to undertake the inspections, once initial guidance is provided. Coastal / marine specialists should review the data every couple of years, or if there is an issue with an asset.
- Geotechnical investigations to determine the presence of bedrock. If located relatively near the surface, bedrock can act as a natural protection structure, and negate the need for other mitigation works. However, in low lying areas the presence of bedrock may not alter the level of risk to coastal hazards. If the area is inundated the hard surface will not provide the expected protection to erosion.
- A foreshore management plan for the Town could boost the protective capacity of the natural dune system. The local Foreshore Management Plans should consider broader issues such as biodiversity and environmental impacts.

9 SUMMARY

The adaptation options presented within this report have followed the coastal hazard risk management hierarchy, as per SPP2.6. The aim of the CHRMAP is to provide a planning framework that the Shire can follow that allows sustainable development, but also allows the continued use of the land until the risk is realised.

Three primary adaptation pathways for the next 50 years are presented below. These options were discussed with stakeholders and feedback was implemented into the final recommended adaptation pathways. Stakeholders should note that while the assessment indicated that certain protection options may be viable, they do not include all the potential costs. For example, implementation of a protection strategy may encourage developers to commit to areas at risk of inundation or erosion and may increase difficulty of a successful managed retreat in the future.

The key summary of the implementation plan pathways is as follows:

1. **Managed retreat for all areas except coastline Section 3**
2. **Construction of more formal seawall in coastline Section 2; managed retreat for all other areas except Section 3.**
3. **Possibility of renourishment for protection of Section 1 (trigger-based); independent of whether Option 1 or 2 is selected, managed retreat for all other areas except Section 3**.

Whilst erosion may be locally restricted in the near future if a protection strategy is pursued, it is clear from inundation hazard mapping that as sea level rise progresses, the feasibility of development in low lying areas will decline. The Shire should select and optimise one of the long-term adaptation pathways (refer Section 8), which may potentially involve managed retreat of significant parts of the town, mainly Knight Terrace and associated lots, over the next 30-100 years. While the above options under the **Managed Retreat** and **Accommodate** groupings aim to make this process easier in the long run, such a significant shift will require a clear and collaborative vision for Denham's future. It is recommended that the Shire investigate potential town structure plans that can achieve this goal over the next decade. Staged infill to raise low lying parts of the town between new and old developments may be expensive and require coastal protection indefinitely, which may be appropriate for private landholders but could be difficult to justify for public assets given the alternatives.

10 REFERENCES

Cooper, J. A. G., and O. H. Pilkey. (2004). “Sea-level rise and shoreline retreat: Time to abandon the Bruun Rule”, *Global and Planetary Change*, 43: 157-71.

Eliot I, Gozzard JR, Eliot M, Stul T and McCormack G. (2012). *The Coast of the Shires of Shark Bay to Exmouth, Gascoyne, Western Australia: Geology, Geomorphology & Vulnerability*, prepared by Damara WA Pty Ltd and Geological Survey of Western Australia for the Department of Planning and the Department of Transport

FitzGerald, D., Fenster, M., Agrow, B., Buynevich, I. (2008). “Coastal impacts due to sea-level rise”, *Annu. Rev. Earth Planet. Sci 2008*. 36:601-47.

Gutierrez, B. T., Plant, N. G., and Thieler, E. R. (2011), “A Bayesian network to predict coastal vulnerability to sea level rise”, *J. Geophys. Res.*, 116, F02009, doi:10.1029/2010JF001891.

Hetzel, Y., Pattiaratchi, C., Lowe, R., Hofmeister, R., (2015). “Wind and tidal mixing controls on stratification and dense water outflows in a large hypersaline bay”. *J. Geophys. Res. Oceans* 120 (9), 6034–6056.

Intergovernmental Panel on Climate Change (IPCC, 2014). *Climate Change 2014: Synthesis Report, Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Geneva, Switzerland, Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)], IPCC, Geneva, Switzerland, 151 pp.

McInnes, K., White, C., Haigh, I., Hemer, M., Hoeke, R., Holbrook, N., Kiem, A., Oliver, E., Ranasinghe, R., Walsh, K., Westra, S., Cox, R. (2016). “Natural hazards in Australia: sea level and coastal extremes”, *Climatic Change*, 139:69:83.

Nahas, E.L., Pattiaratchi, C.B., Ivey, G.N., (2005). “Processes controlling the position of frontal systems in Shark Bay, Western Australia”. *Estuarine, Coastal and Shelf Science*. 65 (3), 463–474.

Ranasinghe, R., Callaghan, D. & Stive, M.J.F (2012). “Estimating coastal recession due to sea level rise: beyond the Bruun rule”. *Climatic Change* 110, 561–574 (2012). https://doi.org/10.1007/s10584-011-0107-8.

Short, A. D. (2005). *Beaches of the Western Australian Coast: Eucla to Roebuck Bay: A guide to their nature, characteristics, surf and safety*, Sydney University Press.

Woodroffe C, Cowell P, Callaghan D, Ranasinghe R, Jongejan R, Wainwright D, Barry S, Rogers K, Dougherty A. (2012). *Approaches to risk assessment on Australian coasts: a model framework for assessing risk and adaptation to climate change on Australian coasts*, National Climate Change Adaptation Research Facility, Gold Coast, 205 pp.

Western Australian Planning Commission (WAPC, 2013). *State Planning Policy No. 2.6 – State Coastal Planning Policy*, prepared under the Planning and Development Act 2005.

Western Australian Planning Commission (WAPC, 2019). *Coastal Hazard Risk Management and Adaptation Planning Guidelines*.

Western Australian Planning Commission (WAPC, 2017). WA Coastal Zone Strategy, Department of Planning, Lands and Heritage.

WorleyParsons (WP, 2016). Denham Foreshore Revitalisation Stage 1A: Design Report, Report No 301012-02233 – GE-REP-002, prepared for Department of Transport

APPENDIX A
STAKEHOLDER AND COMMUNITY ENGAGEMENT PLAN

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Denham Townsite CHRMAP

Stakeholder and Community Engagement Plan

Shire of Shark Bay

17 April 2018

Document Status

Version	Doc type	Reviewed by	Approved by	Date issued
V01	DRAFT	Christine Arrowsmith	Christine Arrowsmith	17/04/2018

Project Details

Project Name	Stakeholder and Community Engagement Plan
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Client Project Manager	Paul Anderson
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17 April 2018

Paul Anderson
Chief Executive Officer
Shire of Shark Bay
65 Knight Terrace Denham WA 6537
Via email ceo@sharkbay.wa.gov.au

Dear Paul

Stakeholder and Community Engagement Plan

We are pleased to present our Stakeholder and Community Engagement Plan. If you have any queries, please do not hesitate to contact me on (03) 8526 0830.

Yours sincerely

Joanna Garcia-Webb
Senior Coastal Engineer

joanna.garcia-webb@watertech.com.au

WATER TECHNOLOGY PTY LTD

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

It is internationally recognised that the increasing sea levels and storm intensities associated with climate change will intensify coastal hazards such as coastal inundation (temporary coastal flooding), storm erosion and long-term shoreline recession. Consequently, State governments across Australia have introduced obligations that require local governments to consider and plan for the effects of these hazards over various planning timeframes. In Western Australia (WA), the governing policy is the Western Australian Planning Commission's State Coastal Planning Policy 2.6 (WAPC, 2013, herein referred to as "SPP2.6"). SPP2.6 recommends management authorities develop a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP). Specific guidelines have been developed to assist in this process (WAPC, 2014).

One of the key objectives of SPP2.6 is to establish coastal foreshore reserves which include allowances for the protection, conservation and enhancement of coastal values across the state. Risk assessment processes are then utilised to identify risks that are intolerable to stakeholders. Adaptation measures are then developed according to the preferential adaptation hierarchy outlined in SPP2.6.

The aim of the present study is to investigate and plan for coastal hazards which are likely to affect the Denham townsite. Denham is located within the local government area of the Shire of Shark Bay, located approximately 800km north of Perth (refer Figure 1-1 for locality). Denham and its surrounds are used extensively for tourism, commercial and recreational purposes. Tourism is the primary industry in the Shire, with fishing and aquaculture also playing a major role.

Given the above, visitors to and residents of Denham and its surrounds place a high value on the coastline. Processes affecting the coastal zone are multiple and complex: storm surge; tidal movement; shoreline stability; stormwater drainage; and the interactions between surface and groundwater all contribute in differing degrees. Furthermore, the potential impacts of climate change, specifically increasing sea levels and storm intensities, will place increased pressure on the coastal zone, and threaten public infrastructure and assets, private property, foreshore reserves, coastal attractions and public open spaces.

The WA CHRMAP Guidelines (WAPC, 2014) recommend that community and stakeholder values and knowledge inform each step of the CHRMAP process. A clear Stakeholder and Community Engagement Plan is therefore required to be developed at the commencement of the project. This document presents the proposed engagement activities for the study; their relative timings with respect to the overall project are displayed in Figure 1-2.

FIGURE 1-1 EXTENT OF CHRMAP

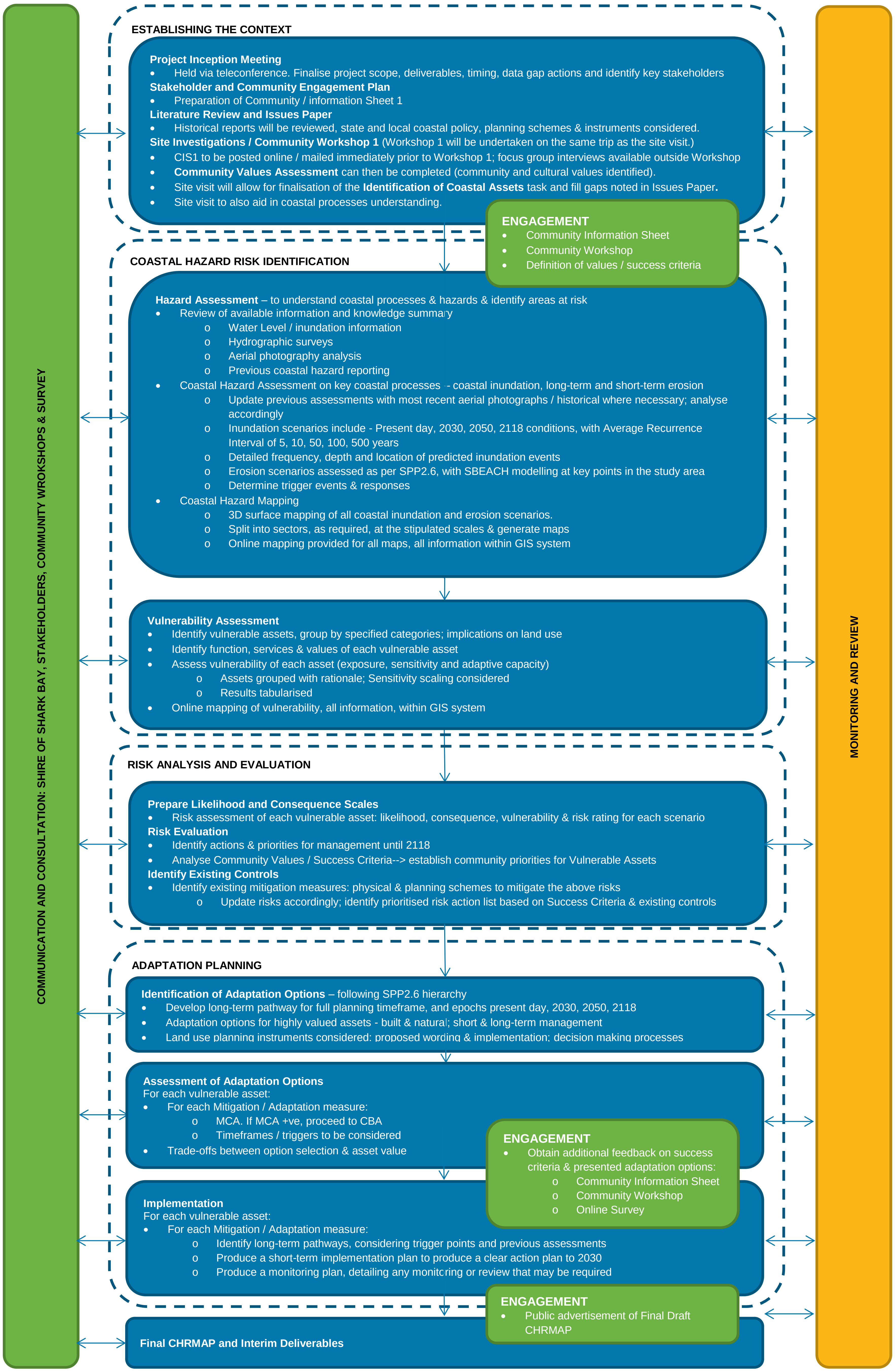

FIGURE 1-2 PROPOSED CHRMAP METHODOLOGY FLOW CHART (ADAPTED FROM WAPC CHRMAP GUIDELINES)

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2 STAKEHOLDER IDENTIFICATION

2.1 Internal Stakeholders

Internal stakeholders are those part of the decision-making team. Predominantly, these will be Shire of Shark Bay Councillors and staff, although state government will also play a role. A Steering Committee has been established to oversee preparation and completion of the CHRMAP, including review of project deliverables. The Steering Committee plays an advisory role in the project and consists of representatives from:

- Shire of Shark Bay
- Gascoyne Development Commission
- Department of Transport
- Department of Biodiversity, Conservation and Attractions
- Department of Planning, Lands and Heritage.

Members of the Steering Committee are invited to take part in all engagement activities. Practically, it may be that a subset of members is involved in each, and this is reported back to the group during the Steering Committee meetings. Outcomes and summaries of each engagement activity would be incorporated into the overall project deliverables and included in the fortnightly progress updates to the Shire's project manager.

Engagement internally within the Shire, during and after the completion of the CHRMAP, will be paramount to the ultimate success and implementation of the CHRMAP.

2.2 External Stakeholders

External stakeholders are those that are not decision-makers, but who are affected by the project. They might live near the coast, use an asset or resource located in the coastal zone, or simply have an interest in the coastal foreshore reserve. Some external stakeholders have been identified below; each engagement activity will be publicly advertised to ensure those not captured below still have an opportunity to attend.

- Department of Fisheries
- Community members
- Recreational & Community groups
  - http://www.sharkbay.wa.gov.au/community/community/community-directory.aspx
- Businesses based in Denham and surrounds
- Shark Bay Tourism Association
- World Heritage Discovery Visitor Centre
- Representatives from Yamatji Marlpa Aboriginal Corporation
- Emergency Management Agencies / Services Organisations
  - Denham Volunteer Fire Brigade
  - Shark Bay State Emergency Service
  - Volunteer Marine Rescue (Shark Bay)
- Infrastructure Providers / Utilities

- Horizon Power
- Water Corporation
- Telstra

3 CONSULTATION APPROACH

3.1 Objectives of Strategy

This strategy aims to engage all relevant stakeholders to provide them with ownership of the CHRMAP and acceptance of its outcomes. The objectives of the strategy are as follows:

- Consult with stakeholders and the community on climate change and its impacts in the coastal zone within the Denham Townsite:
  - What does this mean for the community?
  - How can we adapt?
- Generate the success criteria for the risk assessment component of the CHRMAP. Success criteria represent stakeholders' tolerance and acceptability of the impact to assets from the identified coastal hazards.
- Aid in the selection of site-specific adaptation measures. Stakeholders on the ground are likely to have a knowledge of the site developed over years of interaction. This provides invaluable information that can be applied to generate innovative adaptation measures.

3.2 Level of Consultation

As per the Shire's consultant scope of work, levels of engagement have been defined as the following:

- **Inform** stakeholders about the outcomes of the hazard assessment and the risks identified through the project.
- **Collaborate** with stakeholders to determine the level of risk tolerance, community values attributed to coastal assets and to identify potential adaptation options.
- **Involve** stakeholders in assessing the adaptation options presented.
- **Consult** with stakeholders on the draft CHRMAP.

Each phase of consultation is assigned a level of consultation, allowing the consultation activity to be scoped appropriately. At the commencement of each activity, the level of influence their contribution will have on the overall outcome should be clearly defined. Managing stakeholder expectations regarding their involvement will assist with ownership and acceptance of the CHRMAP.

3.3 Strategy Messaging

A consistent, central information source will be helpful in managing the consultation process. The Shire may like to prepare a webpage of information related to the project as a central repository for the community. This would include a brief description of the project, upcoming steps for the community to be involved in, and links to materials such as SPP2.6, the State Coastal Zone Strategy, and CoastAdapt.

All queries should be directed through a member of the Steering Committee. At this time, we have identified the Shire's project representative: **Shire of Shark Bay –Chief Executive Officer**. The range of activities planned in the strategy (refer Section 4) should minimise the CEO's requirement as a key information source.

A set of key messages of the Stakeholder and Community Engagement Plan can be used in response to queries (these can also be available on the webpage):

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- The project is initiated by the Shire of Shark Bay. The project is funded jointly through the Shire, Department of Planning, Lands and Heritage, and the Department of Transport.
- The consultants carrying out the project are Water Technology, with support from sub-consultants.
- A Steering Committee has been established to oversee preparation and completion of the CHRMAP, including review of project deliverables. The Steering Committee plays an advisory role in the project and consists of representatives from: the Shire; Gascoyne Development Commission; Department of Transport; Department of Biodiversity, Conservation and Attractions; and, the Department of Planning, Lands and Heritage.
- The CHRMAP will provide strategic guidance for coordinated, integrated and sustainable decision making by the Shire in terms of future land use planning and management within the project area. It will also be used to guide necessary changes to the Shire's Local Planning Strategy, Local Planning Scheme and other relevant strategies or planning documents.
- The project will generate information on climate change and its impacts in the coastal zone within the Denham Townsite. This will enable the Shire to optimise its use of the coastal foreshore reserve in present day, and plan for how this may change in the future.
- Unless otherwise stated, information gathered from stakeholders during the project will only be applied to the project and will remain confidential.

4 ENGAGEMENT PLAN

4.1 Implementation Plan

Water Technology propose three main phases to the engagement process as follows:

- Values Assessment
- Adaptation Assessment
- Draft CHRMAP Advertising

4.2 Values Assessment

We propose a workshop to collate the community's values. The community values workshop will be an interactive process. Aerial imagery / maps will be presented, and community members allowed the opportunity to identify areas and assets of high social, environment and cultural value.

Values may be grouped during or after the workshop, as appropriate. Our experience in values assessment suggests that the following groupings may be appropriate:

- Recreational
- Commercial
- Environmental
- Historic / heritage
- Physical infrastructure
- Aboriginal

As per Table 4-1, a Community Information Sheet will be developed to advertise the first workshop. This will also allow workshop attendees to be informed as to the purpose of the session. Additional focus groups / semi structured interviews will be held as required during the site visit to ensure that all stakeholder groups' views are captured.

The outputs from the community values assessment will be used to generate the success criteria for the risk assessment component of the CHRMAP. These will be key to the whole CHRMAP as it is these that will ultimately drive the selection of adaptation options. It is important that a comprehensive approach be applied at this stage of the project, in order to provide a CHRMAP applicable to the Shire and stakeholders.

TABLE 4-1 PROPOSED ENGAGEMENT ACTIVITIES

Engagement Activity	Engagement Level	Description
Community Information Sheet 1 (CIS1)	Inform	A summary sheet that describes the CHRMAP process, and advertises the upcoming Community Workshop 1
Community Workshop 1	Collaborate	This will be an interactive workshop where the community has the opportunity to identify areas of value. Values will be categorised to aid the identification process.
Focus groups / semi structured interviews	Collaborate	Some stakeholder groups may not respond well to workshops and surveys. The Steering Committee can identify such groups; they can then be consulted in a more focussed, one-on-one approach in order to ensure their needs are met and views heard

4.3 Adaptation Assessment

Following the generation of the coastal hazard maps, the risk assessment and the draft adaptation options, a second workshop will be held. This workshop will explore the tolerance and acceptability of risks. The success criteria defined from the outcomes of Community Workshop 1 will be reviewed, and the community can see how the criteria have been applied.

The community will have a chance to view the hazard maps, increase their understanding of the CHRMAP process, preview draft adaptation options and discuss any comments they may have in-person with coastal specialists, Shire staff and potentially, elected representatives. Table 4-2 describes the workshop and survey suggested for this assessment. Feedback received from this round of consultation will be included in the draft CHRMAP document.

As part of the advertising process for the workshop, it is recommended the Shire send a mail out to landholders that are likely to be affected by coastal hazards. The mail out would contain a letter from the Shire, an FAQ sheet and links to the online hazard maps; basically, a targeted distribution of Community Information Sheet 2. This allows absorption of the information prior to the workshop.

4.4 Draft CHRMAP Advertising

The Draft CHRMAP will first be submitted to the Steering Committee for a peer review. Comments will be responded to in table format. The completed draft CHRMAP document will then be advertised publicly for comment, as per Table 4-3. Following the feedback process, comments will be collated, addressed and included as a summary spreadsheet in the final CHRMAP.

TABLE 4-2 PROPOSED ENGAGEMENT ACTIVITIES

Engagement Activity	Engagement Level	Description
Community Information Sheet 2 (CIS2)	Inform	A summary sheet that describes the Coastal Hazards, provides a link to the online hazard mapping, and advertises the upcoming Community Workshop 2.
Community Workshop 2	Involve	This will be an informal, open session. Community may come and go during the allotted time. Posters will be displayed with information (adapted from the CISs) regarding sea level rise, hazard maps, values at risk, adaptation planning options that other communities are implementing, info brochures from CoastAdapt.
Focus groups / semi structured interviews	Involve	As per Workshop 1, there may be focus groups identified to be consulted outside the Community Workshop 2.
Survey	Involve	An online survey link will be posted to: ▪ Shire website ▪ Shire Facebook pages: ▪ Shark Bay News & Views ▪ Shark Bay Buy Sell & Swap ▪ Hard copies can be made available at Post Office, Shire Office and World Heritage Discovery Visitor Centre Survey will obtain additional feedback on success criteria, and adaptation options presented.

TABLE 4-3 PROPOSED ENGAGEMENT ACTIVITIES

Engagement Activity	Engagement Level	Description
Public Advertisement	Consult	The Draft CHRMAP will be publicly advertised for comment.

5 MONITORING & EVALUATION

Following initial engagement, each subsequent engagement activity will clearly include how previous engagement has been applied. This builds community trust, as stakeholders can see they have been listened to and views were recorded. In addition, transparency of the CHRMAP process will aid community acceptance.

Additional feedback mechanisms are as follows:

- Each workshop will issue a post-workshop evaluation survey.
- The survey itself will include a feedback component
- Feedback sought from the Steering Committee at each deliverable submission.
- A summary of the engagement process will be included in the Final CHRMAP.

6 REFERENCES

West Australian Planning Commission (WAPC, 2013). *State Planning Policy No. 2.6 – State Coastal Planning Policy*, prepared under the Planning and Development Act 2005.

Western Australian Planning Commission (WAPC, 2014). *Coastal Hazard Risk Management and Adaptation Planning Guidelines*

Western Australian Planning Commission (WAPC, 2017). *Draft Planned or Managed Retreat Guidelines*, published by WAPC, Department of Planning, Lands and Heritage

APPENDIX B
CHAPTER REPORT: ESTABLISH THE CONTEXT

Denham Townsite CHRMAP

Chapter Report: Establish the Context

Shire of Shark Bay

12 July 2018

Document Status

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Project Details

Project Name	Chapter Report: Establish the Context
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12 July 2018

Paul Anderson
Chief Executive Officer
Shire of Shark Bay
65 Knight Terrace Denham WA 6537
Via email ceo@sharkbay.wa.gov.au

Dear Paul

Chapter Report: Establish the Context

We are pleased to present the Denham Townsite Coastal Hazard Risk Management and Adaptation Plan Chapter Report: Establish the Context. If you have any queries, please do not hesitate to contact me on (03) 8526 0830.

Yours sincerely

Joanna Garcia-Webb
Senior Coastal Engineer

joanna.garcia-webb@watertech.com.au

WATER TECHNOLOGY PTY LTD

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EXECUTIVE SUMMARY

It is internationally recognised that increasing sea levels and storm intensities will intensify coastal hazards such as coastal inundation (temporary coastal flooding), storm erosion and long-term shoreline recession (IPCC 2014). Consequently, State governments across Australia have introduced obligations that require local governments to consider and plan for the effects of these hazards over various planning timeframes. In Western Australia (WA), the governing policy is the Western Australian Planning Commission's State Coastal Planning Policy 2.6 (WAPC, 2013, herein referred to as "SPP2.6"). SPP2.6 recommends management authorities develop a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP). Specific guidelines have been developed to assist in this process (WAPC, 2014).

One of the key objectives of SPP2.6 is to establish coastal foreshore reserves which include allowances for the protection, conservation and enhancement of coastal values across the state. Risk assessment processes are then utilised to identify risks that are intolerable to the community, and other stakeholders such as the Shire of Shark Bay, indigenous and cultural interests, and private enterprise. Adaptation measures are then developed according to the preferential adaptation hierarchy outlined in SPP2.6.

The Denham CHRMAP aims to investigate and provide the blueprint for adapting and addressing coastal hazards which are likely to affect the Denham townsite over various planning timeframes. The CHRMAP will provide strategic guidance for coordinated, integrated and sustainable decision making by the Shire of Shark Bay in terms of future land use planning and management within the project area. The project will generate information on climate change and its impacts in the coastal zone within the Denham Townsite. This will enable the Shire to optimise its use of the coastal foreshore reserve in present day, and plan for how this may change in the future.

The overall CHRMAP purpose is as follows:

- To identify vulnerable assets (public and private) and the risk posed to them by coastal hazards.
- To preserve community values for present and future generations.
- To develop a plan that will allow the Shire to respond to identified risks through adaptation planning activities.
- To recommend monitoring plans to ensure the risk management and adaptation plan activities are working into the future as expected.

This document outlines the key management and adaptation issues that need to be considered in the CHRMAP, as well as identifying the coastal assets and success criteria (community values). It is the 'Establishing the Context' component of the CHRMAP process, as described in the top bubble of the flow chart displayed in Figure 1-2, also replicated below. The Stakeholder and Community Engagement Plan, Community Information Sheet 1 and the Issues Paper have been prepared separately in earlier documents. A summary of these is included within this report.

Project Inception Meeting
- Held via teleconference. Finalise project scope, deliverables, timing, data gap actions and identify key stakeholders

Stakeholder and Community Engagement Plan
- Preparation of Community Information Sheet 1

Literature Review and Issues Paper
- Historical reports will be reviewed, state and local coastal policy, planning schemes & instruments considered.

Site Investigations / Community Workshop 1 (Workshop 1 will be undertaken on the same trip as the site visit.)
- CIS1 to be posted online / mailed immediately prior to Workshop 1; focus group interviews available outside Workshop
- **Community Values Assessment** can then be completed (community and cultural values identified).
- Site visit will allow for finalisation of the **Identification of Coastal Assets** task and fill gaps noted in Issues Paper**.**
- Site visit to also aid in coastal processes understanding.

The following sections summarise the key items of note identified in this report.

Coastal Hazards Summary

To identify coastal hazards, analysis and investigation is required. The full assessment of coastal hazards will be undertaken in the next phase of the project. This report presents a literature review of work undertaken to date in order to establish the context for the study, as summarised below:

- When dealing with coastal adaptation, it is important to understand the level of accuracy of the modelling, as it informs the risk and vulnerability ratings. However, we believe the most effective approach is to use the modelling to identify triggers, and their corresponding coastal management action. An indicative likelihood and timeframe can be provided for guidance, but the ultimate adaptive action is driven by the triggers.
- Modelling will be undertaken using the available data to quantify the coastal erosion and inundation hazards. Present data gaps mean assumptions will be made that limit the accuracy of the results.
- To assist in filling the knowledge gaps, the following ongoing data collection is recommended. These are listed in order of priority. Except where indicated, the benefit of the data will not be gained during the present study, but in the application of the resulting coastal management plan:
  - Locally placed nearshore water level and wave data logger. This will enable calibration of wave models, especially if a storm / cyclone is captured during the deployment. Following the completion of the CHRMAP, the data can be used to get a better understanding of event probabilities, rather than just triggers.
    - Ideally, this instrument would be deployed before the commencement of the next cyclone season. If the data is to be used in the present study, the instrument would need to be deployed within the next few months.
  - Regular photographic beach monitoring is a useful tool in analysing beach behaviour. This can be conducted at 6-monthly intervals at the end of the summer and winter. Photos should also be taken immediately following severe storms. They should be undertaken from a set vantage point to allow accurate comparisons between images. The images can be used to supplement available data when undertaking adaptation option design. These images can also be used to support adaptation option funding applications, and in educating the community about natural fluctuations in beach shape.
    - These can be commenced immediately. Water Technology have proformas for these which allow Shire staff to undertake the inspections, once initial guidance is provided. Coastal specialists should review the data every couple of years, or if erosion is causing an issue.
    - This data can also be used to identify if a trigger has been reached.
  - Beach surveys, ideally every 6-months following the summer and winter periods. If possible, immediately following cyclones. Corresponding monitoring photos should be taken at the same time.
  - Regular monitoring of the marine structures / assets – e.g. seawall, jetties. These should be undertaken with consistent proformas to allow comparison between inspections.
    - These can be commenced immediately. Water Technology have proformas for these which allow Shire staff to undertake the inspections, once initial guidance is provided. Coastal / marine specialists should review the data every couple of years, or if there is an issue with an asset.
  - Geotechnical investigations to determine the presence of bedrock. If located relatively near the surface, bedrock can act as a natural protection structure, and negate the need for other mitigation works. However, in low lying areas the presence of bedrock may not alter the level of risk to coastal

hazards. If the area is inundated the hard surface will not provide the expected protection to erosion. The benefits of such an investigation will be explored in future stages of the CHRMAP.

Planning Items / Controls Summary

When managing the coastal zone and its hazards, a number of planning instruments may be relevant. For example, there may be existing coastal hazard risk mitigation measures in the planning policies, schemes, strategies and plans for the Denham townsite and surrounds. Adaptation plans may include the recommendation of additional plans / clauses to address the coastal hazard risk. A literature review of the relevant planning documentation was carried out; this is summarised below:

- SPP2.6 aims to avoid future development within areas identified to be at risk within the planning timeframe of 100-years. For areas at risk, all potential adaptation options will be identified under the risk management categories of avoid, managed retreat, accommodate and protect to manage the unacceptable risks.
- The ultimate aims of the policy are to ensure all future development takes into account coastal hazards, climate change, and landform stability. Coastal values (landscape, biodiversity, ecosystems, indigenous and cultural) are to be conserved.
- The WA Coastal Zone Strategy is a critical planning guide for any coastal community. It outlines the State Government's aims for sustainable coastal development into the future. The State Government emphasises the preference of public interests over private and industry interests, and reinforces the presumption of landholder responsibility. The State Government also reiterates protection should be used only in the most exceptional circumstances. Ultimately, the Shire will be responsible for determining how local landholders address risk, possibly by writing an LPP under the guidance of this strategy.
- This CHRMAP may identify developed land that will be at risk to coastal hazards, that, for various reasons have not yet been formally identified. The current draft of LPS 4 does not outline how such areas are to be managed. Guidance may be required to address these risks.
  - The risks will be identified in Chapter Reports:
    - Coastal Hazard & Vulnerability Assessment
    - Risk Assessment.
- Presently there are limited development controls relating to the impacts of coastal hazards for land use and development. At present, only the risk of inundation is addressed. Finished floor levels in these areas are addressed in LPS 4 but there is no guidance for managing the impact that increased floor levels will have on the interface between buildings and the adjacent public realm. This will be a challenge especially within the Town Centre, where the highest concentration of retail premises and pedestrians requires easily negotiated thresholds. It also creates a challenge in integrating new development with existing development, especially along Knight Terrace.
  - This will be addressed in the Chapter Report: Identification of Adaptation Options
- Absence of a local planning policy to provide guidance for developers and decision makers on the form and nature of acceptable development on land exposed to coastal processes. For example, whilst increasing finished floor levels for habitable buildings may succeed in minimising damage to the affected property, the manner in which the increase is achieved can have implications for how quickly water can recede as well as impact on other development.
  - This will be addressed in:
    - Chapter Report Assessment of Adaptation Options
    - Draft CHRMAP (includes Implementation Plan).

Identification of Coastal Assets

All the assets in the coastal foreshore reserve were collected as defined by the literature review. A total of 144 assets were identified, photographed, georeferenced and classified into the categories of Commercial, Public, Residential and Tourism Related. Risks to these assets will be considered by applying the success criteria in the Risk Analysis and Evaluation phase of the project (refer Figure 1-2 for project phases).

Each asset was colour coded based on its classification for ease of identification in the mapping. The online database can be found at the following link:

https://watech.maps.arcgis.com/apps/webappviewer/index.html?id=6e092b4d0f044e038a721705e907c084

Within the database are brief descriptions of each asset, together with a photograph. All assets are georeferenced.

Community Values Assessment

Community and stakeholder involvement is a critical component of the CHRMAP process, as it defines what and how much value is placed on assets within the study area. This will inform the adaptation planning process and ensure all needs are considered. As such, the project contains a high level of community and stakeholder engagement. This provides ownership of the CHRMAP with those that it affects, and acceptance of its outcomes. The engagement is discussed further in Section 6.

The community values workshop identified the following success criteria from which to assess the coastal hazard risks:

- Protection of the environmental assets of the study area / planning to retain environmental integrity
- Protection of the recreational value of the coastline
- Protection of the cultural values of the coastline
- Maintenance of the culture of the Denham Town Centre
- Maintenance of a level of public infrastructure
- Development controls not to inhibit the landscape

The aim of this stage of the engagement process is to engage with both internal and external stakeholders. As only internal stakeholders were present at the workshop, there is the option of bringing the proposed online survey (Water Technology, 2018) forward. The development of the success criteria could be further enhanced by the addition of external stakeholder input in the form of an online survey.

Next Steps

The next phases of the study are to identify the coastal hazard risks and undertake a vulnerability assessment. That is, examine the impacts of coastal erosion and storm surge inundation on the assets and their corresponding values.

CONTENTS

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APPENDICES

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

It is internationally recognised that increasing sea levels and storm intensities will intensify coastal hazards such as coastal inundation (temporary coastal flooding), storm erosion and long-term shoreline recession (IPCC 2014). Consequently, State governments across Australia have introduced obligations that require local governments to consider and plan for the effects of these hazards over various planning timeframes. In Western Australia (WA), the governing policy is the Western Australian Planning Commission's State Coastal Planning Policy 2.6 (WAPC, 2013, herein referred to as "SPP2.6"). SPP2.6 recommends management authorities develop a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP). Specific guidelines have been developed to assist in this process (WAPC, 2014).

One of the key objectives of SPP2.6 is to establish coastal foreshore reserves which include allowances for the protection, conservation and enhancement of coastal values across the state. Risk assessment processes are then utilised to identify risks that are intolerable to the community, and other stakeholders such as the Shire of Shark Bay, indigenous and cultural interests, and private enterprise. Adaptation measures are then developed according to the preferential adaptation hierarchy outlined in SPP2.6.

The aim of the present study is to investigate and plan for coastal hazards which are likely to affect the Denham townsite. Denham is located within the local government area of the Shire of Shark Bay, approximately 800km north of Perth (refer Figure 1-1 for locality). Denham and its surrounds are used extensively for tourism, commercial and recreational purposes. Tourism is the primary industry in the Shire, with fishing and aquaculture also playing a major role.

Given the above, visitors to and residents of Denham and its surrounds place a high value on the coastline. Processes affecting the coastal zone are multiple and complex: storm surge; tidal movement; shoreline stability; stormwater drainage; and the interactions between surface and groundwater all contribute in differing degrees. Furthermore, the potential impacts of climate change, specifically increasing sea levels and storm intensities, will place increased pressure on the coastal zone, and threaten public infrastructure and assets, private property, foreshore reserves, coastal attractions and public open spaces.

This document presents the Establish the Context Chapter Report, which outlines the key management and adaptation issues that need to be considered in the CHRMAP, identifies the coastal assets and the success criteria (community values). The flow chart displayed in Figure 1-2 indicates where this component sits with reference to the greater study; the 'Establishing the Context' phase is the top bubble shaded in red.

Figure 1-1 Extent of CHRMAP

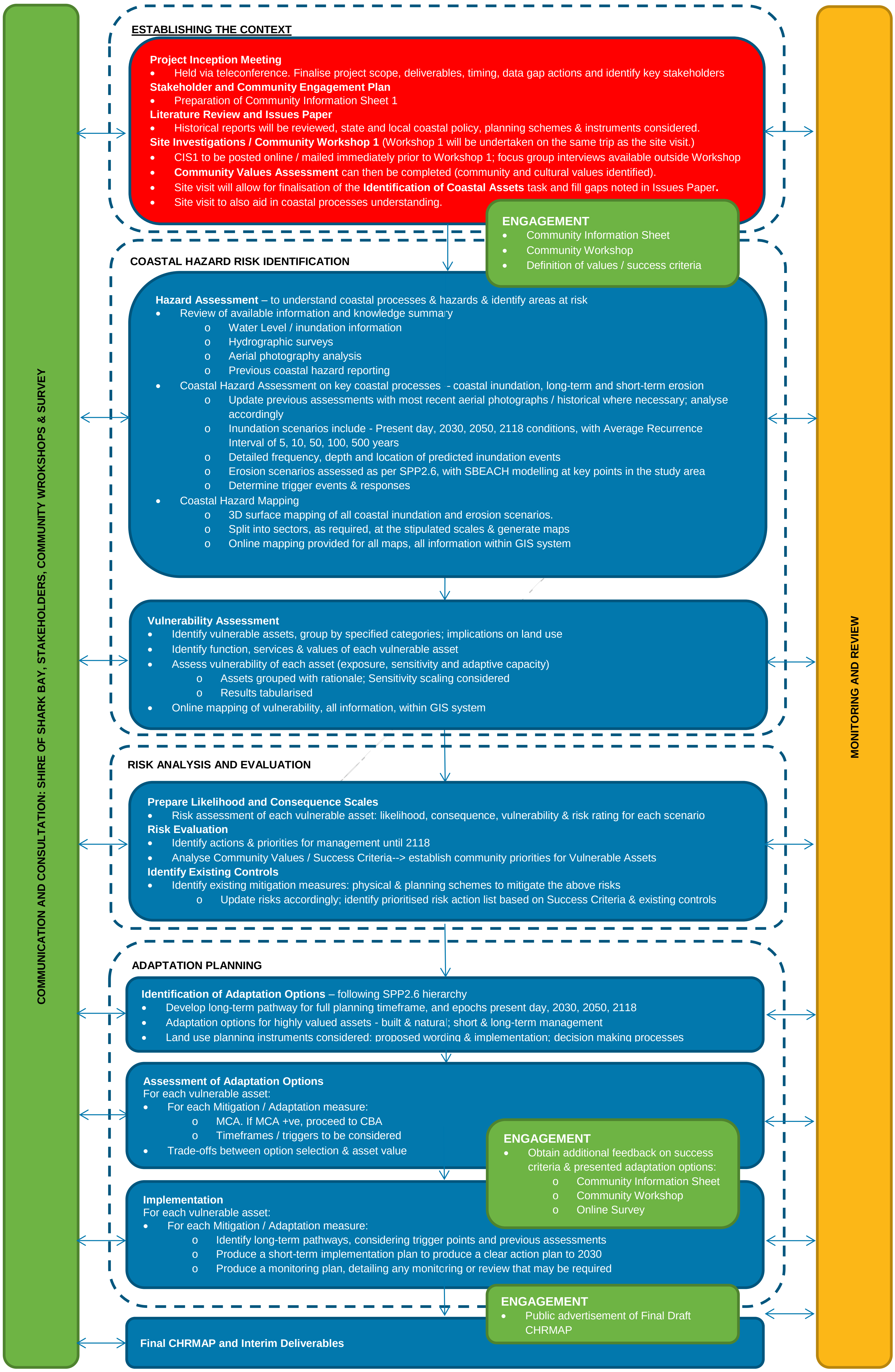

FIGURE 1-2 PROPOSED CHRMAP METHODOLOGY FLOW CHART (ADAPTED FROM WAPC CHRMAP GUIDELINES)

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2 CHRMAP PURPOSE & OBJECTIVES

As discussed in Section 1, the CHRMAP is a legislative recommendation from the state government.

The Denham CHRMAP aims to investigate and provide the blueprint for adapting and addressing coastal hazards which are likely to affect the Denham townsite over various planning timeframes. The CHRMAP will provide strategic guidance for coordinated, integrated and sustainable decision making by the Shire of Shark Bay in terms of future land use planning and management within the project area. The project will generate information on climate change and its impacts in the coastal zone within the Denham Townsite. This will enable the Shire to optimise its use of the coastal foreshore reserve in present day, and plan for how this may change in the future.

The overall CHRMAP purpose is as follows:

- To identify vulnerable assets (public and private) and the risk posed to them by coastal hazards.
- To preserve community values for present and future generations.
- To develop a plan that will allow the Shire to respond to identified risks through adaptation planning activities.
- To recommend monitoring plans to ensure the risk management and adaptation plan activities are working into the future as expected.

Analysis and investigation is required to identify the coastal hazards. The full assessment of coastal hazard will be undertaken in the next phase of the project. This report presents a literature review of work undertaken to date in order to establish the context for the study – refer Section 3.

When managing the coastal zone and its hazards, a number of planning instruments may be relevant. For example, there may be existing coastal hazard risk mitigation measures in the planning policies, schemes, strategies and plans for the Denham townsite and surrounds. A literature review of the relevant planning documentation is carried out in Section 4. Adaptation plans may include the recommendation of additional plans / clauses to address the coastal hazard risk.

All the assets in the coastal foreshore reserve, as defined by the literature review presented in Section 3, were collected and described in Section 5.

Community and stakeholder involvement is a critical component of the CHRMAP process, as it defines what and how much value is placed on assets within the study area. This will inform the adaptation planning process and ensure all needs are considered. As such, the project contains a high level of community and stakeholder engagement. This provides ownership of the CHRMAP with those that it affects, and acceptance of its outcomes. The engagement is discussed further in Section 6.

3 PREVIOUS COASTAL INVESTIGATIONS

The Shire of Shark Bay has undertaken several studies in recent years relating to coastal hazards for the Denham townsite. These studies form the basis of the coastal knowledge for the CHRMAP initiation and have been reviewed to identify critical information that will assist in the analysis of coastal hazards. The methodology of relevant studies has also been considered to provide insight into the level of confidence to be drawn from the previous conclusions. These reviews are presented in Appendix B. Gaps in the present knowledge regarding coastal hazards affecting Denham have been considered to ensure that the CHRMAP process can be wholly and satisfactorily completed. A summary of these data gaps and recommendations required to fill these gaps are provided within this section.

3.1 Available Data

There is limited measured data available for the study site. A summary of the available data is provided in Table 3-1 below. The applicability of the data to the present study is included in the final column.

A key gap is long-term water level data within Shark Bay, specifically in the proximity of Denham, as well as wave data. The lack of data makes it difficult to calibrate numerical models for the area.

Whilst the Digital Elevation Model covers the full study area, it is data converted from aerial imagery. Levels derived from this source can have errors due to the presence of vegetation and other features. It is considered good practice to ground truth this data with survey data. For example, if the Shire has surveys of road levels, this can be used to test the accuracy of the dataset.

3.2 Knowledge Gaps & Recommendations

3.2.1 Coastal Erosion

The erosion assessments undertaken to date will be expanded on in the present study in order to meet the planning policy requirements. The present paucity of measured data means triggered management responses will be important for the Shire in coming years. That is, adaptation will be driven by events and their impacts, rather than a set predicted timeframe.

TABLE 3-1 SUMMARY OF AVAILABLE DATA

Data Type	Source	Period	Location	Suitability for Study Use
Water level	DoT	1996 - 2018	Carnarvon	Can be used to generate low return period storm surge information – not directly applicable to site but an approximate representation
Water level	DoT	1979-1980; 1986; 1988-1989	Denham	Not a long-term data set, inappropriate for use in generating storm surge data
Wind Data	BoM	1988 - 2018; 3-hourly	Denham	Appropriate for use in wave / hydrodynamic hindcasts, comparison of cyclonic wind speeds for specific events
Wind Data	BoM	2000 - 2018; 30-minute	Shark Bay Airport	Appropriate for use in wave / hydrodynamic hindcasts, comparison of cyclonic wind speeds for specific events
Wind Data	BoM	1945 – 2018; 3-hourly 1993 – 2018; 30-minute	Carnarvon Airport	Appropriate for use in wave / hydrodynamic hindcasts, comparison of cyclonic wind speeds for specific events
Hydrographic Survey	DoT	1986 - 2017	Nearshore and dredged channel	Appropriate for use in generating the model bathymetry
Digital Elevation Model	Landgate	2017	Denham Townsite	Appropriate for use in generating the model bathymetry. Levels derived from aerial imagery can have errors due to the presence of vegetation and other features. Considered good practice to ground truth this data with survey data. For example, if the Shire has surveys of road levels, this can be used to test the accuracy of the dataset
Shoreline Movement Plots	DoT	1957, 1978, 1980, 1990, 1999, 2001, 2006, 2015	Denham Townsite	Appropriate for use in determining S2 of SPP2.6

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3.2.1.1 Gap-Filling Recommendations

To assist in filling the knowledge gaps, the following ongoing data collection is recommended:

- Regular photographic beach and structure monitoring is a useful tool in analysing beach behaviour. This can be conducted at 6-monthly intervals at the end of the summer and winter. Photos should also be taken immediately following severe storms. They should be undertaken from a set vantage point to allow accurate comparisons between images. The images can be used to supplement available data when undertaking adaptation option design. These images can also be used to support adaptation option funding applications, and in educating the community about natural fluctuations in beach shape.
- Beach surveys, ideally every 6-months following the summer and winter periods. If possible, immediately following cyclones. Corresponding monitoring photos should be taken at the same time.
- Regular monitoring of the marine structures / assets – e.g. seawall, jetties. These should be undertaken with consistent proformas to allow comparison between inspections.
- Geotechnical investigations to determine the presence of bedrock. If located relatively near the surface, bedrock can act as a natural protection structure, and negate the need for other mitigation works. However, in low lying areas the presence of bedrock may not alter the level of risk to coastal hazards. If the area is inundated the hard surface will not provide the expected protection to erosion. The benefits of such an investigation will be explored in future stages of the CHRMAP.

3.2.2 Coastal Inundation

Water Technology included cyclone modelling specialist Dr Bruce Harper, of Systems Engineering Australia Pty Ltd (SEA), in the project team. Bruce has over 40-years of specialist experience in cyclone modelling. He has conducted a peer review of the methodology employed in the MRA (2014) report and will subsequently undertake a review of Water Technology's application of this work. The aim is to provide an assessment regarding the accuracy of the assumptions, and correspondingly greater certainty of the error margins, and thus likelihood of occurrence of the various simulated events.

The full memorandum of the MRA report review is included in Appendix C. Key knowledge gaps identified in the review are as follows:

- While the overall study approach is supported, there is a lack of detail around the many essential steps needed to fulfil the benefits of the methodology. This does not allow a ready endorsement of the results.
- It would have been more compelling to see the comparisons of measured and modelled wind speeds and pressures for each modelled event (e.g. using winds at Carnarvon) to provide confidence in the hydrodynamic model results, noting that the BoM parameters in conjunction with a Holland (1980) model often do not match these well.
- To further demonstrate that the model has predictive skill for this region the long-term winds for (say) Carnarvon could be generated and compared with the measured winds (e.g. Harper and Mason 2016). Unfortunately, this is not done and so the reliability of the whole analysis remains unknown.
- The method ignores the potential contribution of wave setup at Denham, which although not likely to be critical given the exposure and the shallow margins, is also not likely to be insignificant at higher ARI. Given the proximity of assets to the shoreline, wave setup and runup are likely important components of any tropical cyclone storm tide impact and should be estimated as part of the CHRMAP.
- There is no validation of the Monte Carlo storm climatology against regional data. Given that storm tide is a complex function of wind-field scale, magnitude, speed of movement, frequency and track, the synthetic storms should be demonstrated to produce a similar statistical distribution to regionally-measured winds where they are available (Harper, 2001). The need for this is compounded by the adoption of the US-

based Emanuel approach combined with the lack of parameter information in the BoM dataset and the assumptions made in the WES model, which together leave a wide range of interpretation. Finally, there is a lack of disclosure of how the final 154 event extrapolation was performed and what likely range of uncertainty exists with that.

- It is difficult to conclude the reliability of the final MRA (2014) Table 5.1 “Tide plus Surge” recommendations. The various uncertainties in the methodology mean it may be ± 0.5 m at the 500 y ARI. Wave setup allowances will add to the upper limit of this uncertainty by potentially another 0.5 m at the 500 y ARI. In contrast, the estimated 20 y ARI level of 1.9 m AHD seems relatively high given that HAT is only around 0.9 m AHD.

3.2.2.1 Gap-Filling Recommendations

Whilst the review highlights some gaps in the modelling reported in MRA (2014), the project scope and budgetary constraints may have restricted the detail of the study. When dealing with coastal adaptation, it is important to understand the level of accuracy of the modelling, as it informs the risk and vulnerability ratings. However, we believe the most effective approach is to use the modelling to identify triggers, and their corresponding coastal management action. An indicative likelihood and timeframe can be provided for guidance, but the ultimate adaptive action is driven by the triggers.

As part of the present study, the cyclone tracks applied in the MRA (2014) will be utilised in the regional model of the study area to be developed in the next phase. We will use the Danish Hydraulic Institute’s (DHI) Mike21 HD/SW (Hydrodynamic / Spectral Wave) model. This allows the interaction of the water levels and currents to be included in the wave calculations. It also allows for wave setup. Wave runup will be included in the SBEACH model. This then allows for wave setup and runup to be considered in the inundation and erosion hazards.

The potential impact from a tsunami will be investigated via a literature review as part of the coastal hazard assessment. This will predominantly make use of the offshore tsunami hazard information provided by Geoscience Australia. The offshore risk of tsunami at the study site is moderate in comparison to the area to the north, for example Onslow and the Exmouth Gulf. However, the shape of Shark Bay is such that funnelling effects may exacerbate the wave amplitude and subsequent inundation. Conversely, the presence of Dirk, Dorre and Bernier Islands will limit the extreme long wave energy associated with tsunamis from penetrating into the bay.

In addition to the present study, the following ongoing data collection is recommended:

- Locally placed nearshore water level and wave data logger. This will enable calibration of wave models, especially if a storm / cyclone is captured during the deployment. It is not anticipated that this data collection can be applied during the present study, as it would involve extending the project duration by at least 6-months whilst the data is being collected. However, following completion of the CHRMAP, the data can be used to get a better understanding of event probabilities, rather than just triggers.

3.3 Summary for Decision Makers and Community

From the analysis of previous coastal investigations, the key take-home messages and data gaps requiring attention in the future are displayed in Table 3-2.

TABLE 3-2 SUMMARY FOR DECISION MAKERS AND COMMUNITY – COASTAL HAZARDS

Key Items / Issues
▪ Modelling will be undertaken using the available data. Present data gaps mean assumptions will be made that limit the accuracy of the results. ▪ When dealing with coastal adaptation, whilst it is important to understand the level of accuracy of the modelling as it informs the risk and vulnerability ratings, we believe the most effective approach is to use the proposed modelling to identify triggers and their corresponding coastal management action. An indicative likelihood and timeframe can be provided for guidance, but the ultimate adaptive action is driven by the triggers. ▪ The uncertainties in the triggers will be included in the analysis. An increase in the data available potentially means these values can be adjusted.
To assist in filling the knowledge gaps, the following ongoing data collection is recommended. These are listed in order of priority. Except where indicated, the benefit of the data will not be gained during the present study, but in the application of the resulting coastal management plan: ▪ Locally placed nearshore water level and wave data logger. This will enable calibration of wave models, especially if a storm / cyclone is captured during the deployment. Following the completion of the CHRMAP, the data can be used to get a better understanding of event probabilities, rather than just triggers. – Ideally, this instrument would be deployed before the commencement of the next cyclone season. If the data is to be used in the present study, the instrument would need to be deployed within the next few months. ▪ Regular photographic beach monitoring is a useful tool in analysing beach behaviour. This can be conducted at 6-monthly intervals at the end of the summer and winter. Photos should also be taken immediately following severe storms. They should be undertaken from a set vantage point to allow accurate comparisons between images. The images can be used to supplement available data when undertaking adaptation option design. These images can also be used to support adaptation option funding applications, and in educating the community about natural fluctuations in beach shape. – These can be commenced immediately. Water Technology have proformas for these which allow Shire staff to undertake the inspections, once initial guidance is provided. Coastal specialists should review the data every couple of years, or if erosion is causing an issue. – This data can also be used to identify if a trigger has been reached. ▪ Beach surveys, ideally every 6-months following the summer and winter periods. If possible, immediately following cyclones. Corresponding monitoring photos should be taken at the same time. ▪ Regular monitoring of the marine structures / assets – e.g. seawall, jetties. These should be undertaken with consistent proformas to allow comparison between inspections – These can be commenced immediately. Water Technology have proformas for these which allow Shire staff to undertake the inspections, once initial guidance is provided. Coastal / marine specialists should review the data every couple of years, or if there is an issue with an asset. ▪ Geotechnical investigations to determine the presence of bedrock. If located relatively near the surface, bedrock can act as a natural protection structure, and negate the need for other mitigation works. However, in low lying areas the presence of bedrock may not alter the level of risk to coastal hazards. If the area is inundated the hard surface will not provide the expected protection to erosion. The benefits of such an investigation will be explored in future stages of the CHRMAP.

4 EXISTING PLANNING CONTROLS

Planning in Western Australia is guided and regulated by the State Planning Framework, which ranges from overarching strategic planning strategies, to specific planning policies and supportive guidelines. Figure 4-1 explains the framework, which includes planning at the state, regional, and local levels and demonstrates how strategic planning is implemented through statutory planning controls (e.g. local planning schemes) and local planning policies. This Framework sits within the *Planning and Development Act 2005*. The relationships of the various policies are presented in Figure 4-2.

This chapter reviews the planning documents within this Framework which are relevant to coastal hazard planning in the project area; additional information is provided in Appendix A. This review will help to: assess the adequacy of the existing planning documents for addressing coastal hazards; identify gaps that need to be addressed through the CHRMAP process; identify any potential planning issues that may constrain the CHRMAP process; and, ensure that the Shire's adaptation plan aligns with state, regional and local planning frameworks.

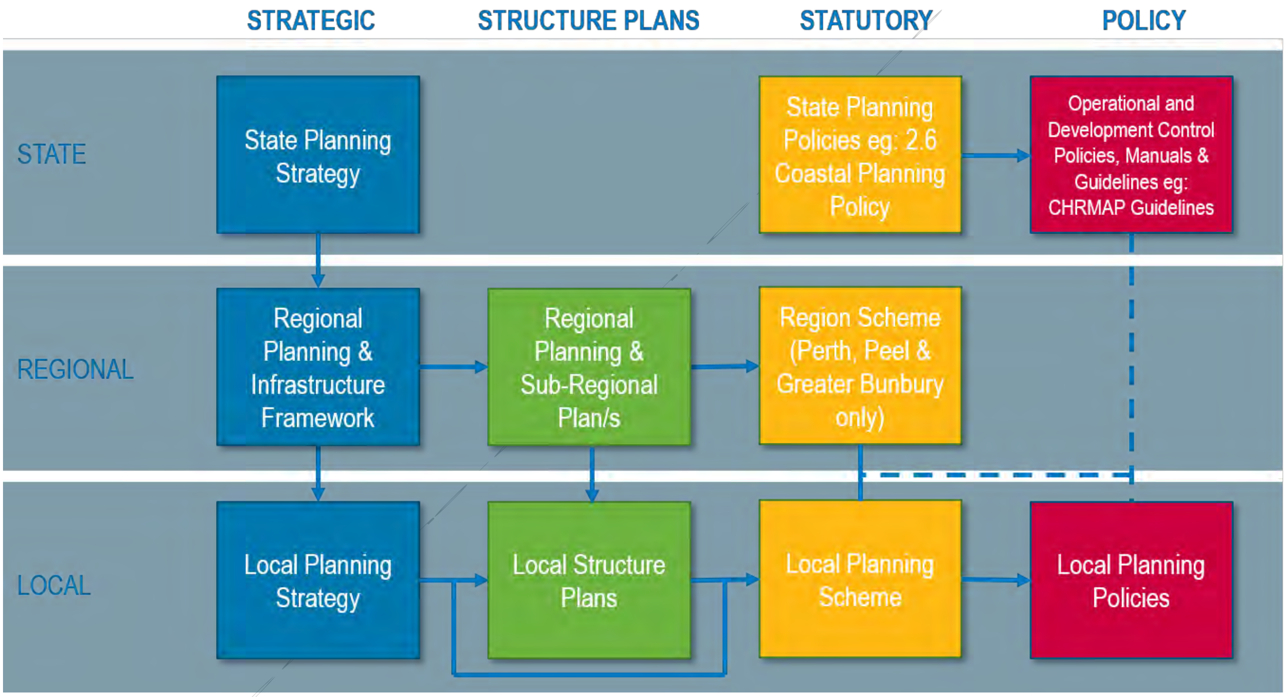

FIGURE 4-1 STATE PLANNING FRAMEWORK FOR WESTERN AUSTRALIA

4.1 State Planning Documentation

4.1.1 State Planning Strategy

The *State Planning Strategy 2050 (State Planning Strategy)* provides a strategic framework, principles, strategic goals and strategic directions for planning and development in Western Australia. The *State Planning Strategy* approach to climate change seeks to achieve development and adoption of risk management strategies for natural hazards in the context of climate change patterns and trends.

The *State Planning Strategy* identifies the Shire of Shark Bay coast as being at risk of coastal landform change. It makes some key statements that are fundamental to the approach taken to coastal hazard risk assessment and management adaptation planning. These include:

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- Retaining natural bushland and coastal areas that are accessible is essential to human health and a sense of wellbeing.
- All decisions about sustained growth and prosperity must strike the appropriate balance between environmental issues, economic conditions and community wellbeing.

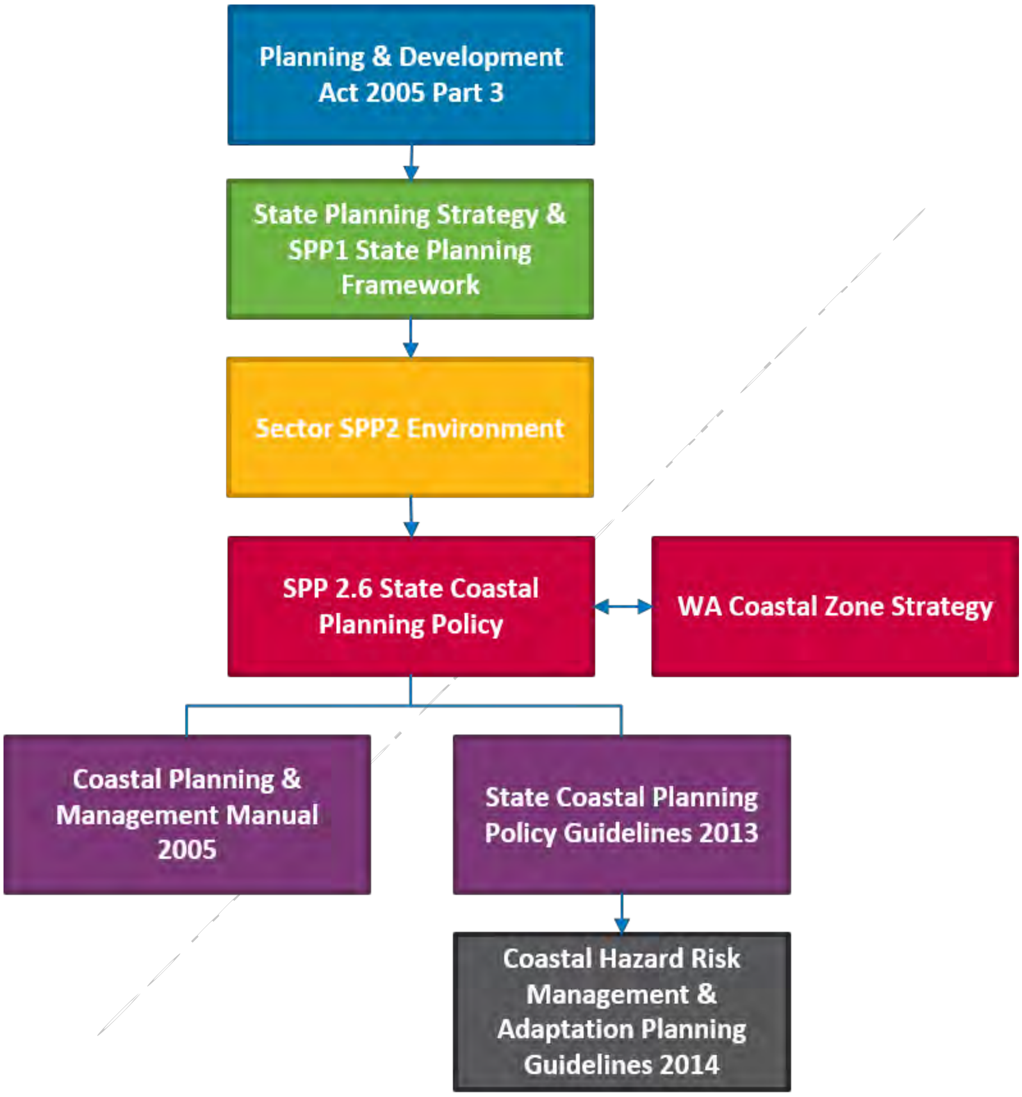

FIGURE 4-2 POLICY RELATIONSHIPS

4.1.2 WA Coastal Zone Strategy

The WA Coastal Strategy was released in 2017, in recognition of the need for a strong land-use planning framework to ensure that coastal development can be sustainable in the long term, meeting community, economic, environmental and cultural needs. It complements existing State legislation, strategies and policies, including SPP2.6. Any new Government and stakeholder strategies and policies are expected to be consistent with this strategy.

The document identifies all relevant legislation and policies related to coastal management. It outlines the key issues affecting the coast. It also defines stakeholder roles and responsibilities for coastal stewardship, making it a good overview document for a range of stakeholders. The stated goals of the strategy are to:

1. Conserve the State's natural coastal values and assets through sustainable use
2. Ensure safe public access to the coast and involve the community in coastal planning and management activities
3. Provide for the sustainable use of natural coastal resources
4. Ensure the location of facilities and infrastructure in the coastal zone is sustainable and suitable
5. Build community confidence in coastal planning and management.

This CHRMAP will be required to complement these goals in the context of Denham townsite.

The strategy clearly defines the roles and responsibilities for managing the coastal hazards of coastal erosion and inundation. It states that all levels of government, as well as individuals, businesses, and the community, each have important and complementary roles in adapting to coastal hazards. However, particular principles are outlined which have relevance to this CHRMAP:

- Private parties are responsible for managing risks to their private assets;
- Governments (i.e.: the Shire) are responsible for managing risks to public assets and any assets they manage; they should also:
  - Develop local policies and regulations consistent with state adaptation approaches;
  - Facilitate building resilience and adaptive capacity within the local community.
  - Work in partnership with community to identity and manage risks / impacts.

The strategy then outlines its guide to how management of coastal hazards should be addressed, which will be a definitive guiding principle for the adaptation component of this CHRMAP. The State's coastal planning policy adaptation preferences in order of priority are:

Avoid > Planned or Managed Retreat > Accommodate > Protect

The state has a strong preference towards adaptation options that minimise coastal process interference and away from those that may leave legacy issues. Management strategies that preserve the natural coastline and move development away from the active coastal zone are considered ideal. As a result of this hierarchy, the strategy steers planners away from protection options and provides strict rules for the consideration of protection works. Of particular relevance to the CHRMAP process is the user pays principle, whereby those who benefit most from protection must provide the greatest financial contribution. This arrangement applies to any area of the coast, and can include incidences where the coastal foreshore reserve is being protected as a buffer to private assets.

The WA Coastal Zone Strategy is a critical planning guide for any coastal community. It outlines the State Government's aims for sustainable coastal development into the future. The State Government emphasises the preference of public interests over private and industry interests, and reinforces the presumption of landholder responsibility. The State Government also reiterates earlier planning documents declaring that protection should be used only in the most exceptional circumstances. Ultimately, the Shire will be responsible for determining how local landholders address risk, potentially by writing a Local Planning Policy under the guidance of this strategy.

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4.1.3 State Planning Policy 2.6: State Coastal Planning Policy (SPP2.6)

The State Coastal Planning Policy (SPP2.6) is WA's guideline for making decisions within the coastal zone as well as determining the coastal hazards, and strategies to manage identified hazards. The policy covers many aspects of land management, so this report only addresses components useful to the CHRMAP process.

For coastal zone management, SPP2.6 aims to avoid future development within areas identified to be at risk within the planning timeframe, generally 100-years. As outlined in Sections 1 and 2, the state government recommends management authorities develop a CHRMAP for areas at risk. Adaptation is undertaken by applying the preferential hierarchy mentioned in the WA Coastal Zone Strategy. This means that all potential adaptation options will be identified under the risk management categories of **avoid, managed retreat, accommodate and protect** to manage the unacceptable risks. As outlined in the WA Coastal Zone Strategy summary, avoid and managed retreat options are considered ideal; planning for the future should reflect this.

SPP2.6 reinforces the WA Coastal Zone Strategy and goes on to provide fairly rigorous outlines for the calculations of coastal hazards, specifically inundation and erosion. Whilst different parties may utilise different methods to assess coastal hazards, all studies must fall under the guidelines of SPP2.6 and must be approved by the WA Department of Transport.

The ultimate aims for the policy are:

- To ensure all future development considers coastal hazards, climate change, and landform stability.
- To ensure appropriate areas are identified for necessary stakeholders.
- To provide public coastal foreshore reserves.
- To conserve coastal values (landscape, biodiversity, ecosystems, indigenous and cultural)

SPP2.6 aims to avoid future development within areas identified to be at risk within the planning timeframe, generally 100-years. For areas at risk, all potential adaptation options will be identified under the risk management categories of avoid, managed retreat, accommodate and protect to manage the unacceptable risks.

The ultimate aims of the policy are to ensure all future development considers coastal hazards, climate change, and landform stability. Coastal values (landscape, biodiversity, ecosystems, indigenous and cultural) are to be conserved.

4.1.4 Other Relevant State Documents

4.1.4.1 CHRMAP Guidelines

The CHRMAP Guidelines have been developed to assist in the development of a CHRMAP (WAPC, 2014). This document was applied when creating the scope of the present study.

4.1.4.2 Planned or Managed Retreat Guidelines

The Department of Planning, Lands and Heritage (DPLH), together with the Western Australian Planning Commission have recently developed the Draft Planned or Managed Retreat Guidelines (WAPC, 2017). This document provides guidance on how to implement a policy of planned or managed retreat. Retreat options are mostly applicable to areas already developed, where there is less potential for mitigation through planning controls. The strategy of retreat is based on social, environment and economic sustainability, and ties into the SPP2.6 objectives. It allows for continuing public access to beaches, beach amenity, and the provision of a coastal foreshore reserve.

Existing land uses would continue until the coastal hazard risk becomes unacceptable. This trigger is to be defined during the CHRMAP process.

This adaptation option will be considered, where appropriate, as part of the present study in the Chapter Reports Identification of Adaptation Options and Assessment of Adaptation Options.

4.2 Local Planning Documents

4.2.1 Shire of Shark Bay Local Planning Strategy

The *Shire of Shark Bay Local Planning Strategy 2013* (*Local Planning Strategy)*, is generally in alignment with the *Gascoyne PIF* strategy direction (refer Section A-2-1 of Appendix A for a description of this strategy). A local planning strategy outlines the local government's intentions and objectives for development of the district over a timeframe of around 15 years. It informs the content of the local planning scheme to provide the statutory controls and guidance to direct development towards achieving these longer-term objectives. The local planning strategy is an important guiding document for the exercise of discretion in determining planning applications within the district as it provides context and enunciates the intentions behind various planning strategies, scheme provisions and local planning policies.

The local planning strategy has several stated objectives that are directly or indirectly related to planning for coastal areas. These objectives are reproduced in Table 4-1, with remarks as to the relevance to coastal planning.

The strategy acknowledges that there are key constraints of cyclonic storm and coastal processes. It identifies the following physical constraint challenges relevant to coastal processes:

- The proximity of development to the coast and lack of coastal setbacks. Coastal risks are a planning implication and constraints can be associated with storm surge, coastal processes and setbacks.
- Flooding in the Town Centre resulting from major and intense storm events and the need to implement minimum floor levels, which causes streetscape and design challenges for interaction between existing and new development.

The Shire's objective is to prepare strategies that will minimise the risk of damage to the Denham Town Centre caused by flooding, inundation and stormwater damage. In December 2014, MP Rogers and Associates Pty Ltd prepared the *Denham Inundation Levels Storm Surge Modelling Report*, which provided information about inundation that had not been available when the local planning strategy was prepared in 2013. The findings resulted in a recommendation to increase the minimum floor level to 4.2m AHD from the 3.2m AHD currently required in the Shire's *Local Planning Scheme No. 3* (refer Section 4.2.3).

This constraint is recognised in the existing Scheme and is addressed by implementing minimum floor levels for development. The Shire implements the recommendations of the Shark Bay—Denham Foreshore Topography and Storm Surge levels map which is used to inform Finished Floor Levels (FFL) for new development.

The Local Planning Strategy suggests that increased flexibility could be examined to allow lower levels for detached non-habitable buildings such as outbuildings. This is in recognition that increased floor levels applied to new development will represent a challenge in dealing with streetscape and interfaces between existing buildings and new development of Knight Terrace, the main street. This is difficult when the visual impact of development on land adjacent to the coast is also an important consideration.

TABLE 4-1 LOCAL PLANNING STRATEGY OBJECTIVES - COASTAL AREAS

Objective	Comment
To identify key components of the long-term direction for the Shire of Shark Bay that are crucial to orderly growth and development of the Denham townsite, and to recommend strategies to pursue these.	Orderly growth and development of the townsite require a considered and strategic response to coastal processes, given the vulnerability of some areas and assets.
Ensure that there is sustainable provision of land to meet existing and future needs for housing, business, community facilities, recreation, open space, industry, tourist accommodation, foreshore facilities, and civic uses.	Sustainable provision implies the ability to use the land in the long term, without undue economic, social or environmental cost. New development should therefore be located or built to minimise or avoid impacts from coastal processes if possible.
To provide a range of quality services and amenities to meet the existing and future needs of the local community and support local tourism in a manner that enhances the existing townsite and does not adversely impact on local character and amenity.	A balance will be required between mitigating inundation from storm surges and an acceptable town centre amenity.
Support ongoing improvements and expansion of infrastructure and provide a basis for coordinated decision making on future servicing of the local government area by local, state government, and service providers.	This will require clarity about coastal processes and requirements to ensure assets are not put at unacceptable risk from inundation or erosion.
Protect the natural environment, resources and coastal areas from inappropriate development that may have any undesirable or negative impact in terms of amenity, social, environmental, or visual.	Inappropriate development would include any that could exacerbate the impact of coastal processes on assets.
Give direction to the Shire of Shark Bay, the DPLH, WAPC, the Minister, and the State Administrative Tribunal in assessment of Scheme Amendments, subdivision, applications, development, applications for review, and provide strategic planning support for this decision making.	To achieve this requires clear statutory and policy support in relation to what is acceptable for development on land vulnerable to coastal processes.

4.2.2 Denham Townsite Plan

Denham Townsite Plan: A Blueprint for Infrastructure and Investment is a strategic report adopted by the Council on July 2014, which focuses on infrastructure and strategic projects that will help the Shire to achieve its vision for the Denham townsite. It is intended as a supporting document for the local planning strategy, and a 'blueprint' for Council investment in the townsite.

4.2.3 Local Planning Scheme

The Shire's current scheme, *Local Planning Scheme No. 3* (LPS 3) will be superseded in due course by *Local Planning Scheme No. 4* (LPS 4), which is currently in draft form. The content of draft LPS 4 follows the recommendations of the *Scheme Review* prepared in November 2016. The *Scheme Review* documents various changes to LPS 3 to be reflected in LPS 4, largely to implement the *Local Planning Strategy.*

One of the stated aims of draft LPS 4 is to impose special conditions for development of land within Denham to mitigate the adverse effects of land subject to inundation and other physical constraints.

Clause 29 of the *Model Scheme Text* provides local government the option to give statutory effect to any relevant State Planning Policy (SPP) in whole or in part, in a similar way as the R-Codes are linked to a Scheme. The Shire has not elected to do this with *SPP 2.6 State Coastal Policy*. Instead, it is proposed to include provisions relating to requirements for development approval and minimum floor levels in areas identified as being vulnerable to coastal storm surge inundation.

As at April 2018 draft LPS 4 contains the following clause of relevance to land subject to inundation from coastal processes.

31.1 Land Subject to Inundation

a. *No development shall be constructed upon any land within an area considered by the local government as being vulnerable to coastal storm surge inundation unless granted specific planning approval by the local government.*

b. *The local government shall require any new development within an area as being vulnerable to coastal storm surge inundation to comply with a minimum finished floor level not less than RL 4.2 metres AHD.*

c. *Notwithstanding Clause 32.1(b), Council has discretion to consider a minimum finished floor level less than RL 4.2 metres AHD for non-habitable development that is detached from any single house or dwelling unit on the same lot in the Denham townsite and / or any minor non-habitable development that is ancillary to existing tourist development in the Scheme Area.*

d. *In considering applications for development in areas vulnerable to coastal storm surge inundation, the local government may have regard to any Local Planning Policy or any site specific coastal storm surge inundation report acceptable to the local government.*

e. *Notwithstanding Clause 32.1(b), the local government has discretion to consider and require alternative minimum finished floor levels where:*

   i. *The proponent provides a site specific coastal storm surge inundation report by a suitably qualified professional coastal engineer that is acceptable to the local government and clearly identifies appropriate alternative minimum finished floor levels and / or;*

   ii. *Approval of the development is consistent with variations allowable under the relevant State Coastal Planning Policy; and /or*

   iii. *the proposed development only involves refurbishment of or a minor extension to an existing development.*

It is noted that this clause relates only to vulnerability to coastal storm surge inundation. Other potential impacts of increases to sea level rise and storm intensities, such as storm erosion and shoreline recession, are not addressed.

Some proposed zones make reference to the requirement for preparation of foreshore management plans and to have regard to SPP 2.6.

4.3 Summary for Decision Makers and Community

From the analysis of current planning documents relevant to the Denham townsite, the potential issues requiring attention in the future are displayed in Table 4-2.

TABLE 4-2 SUMMARY FOR DECISION MAKERS AND COMMUNITY – PLANNING CONTROLS

Planning Issues	Relevant component of CHRMAP
This CHRMAP may identify developed land that will be at risk to coastal hazards, that, for various reasons has not yet been formally identified. The current draft of LPS 4 does not outline how such areas are to be managed. Guidance may be required to address these risks.	The risks will be identified in Chapter Reports: ▪ Coastal Hazard & Vulnerability Assessment ▪ Risk Assessment
Presently there are limited development controls relating to the impacts of coastal hazards for land use and development. At present, only the risk of inundation is addressed. Finished floor levels in these areas are addressed in LPS 4 but there is no guidance for managing the impact that increased floor levels will have on the interface between buildings and the adjacent public realm. This will be a challenge especially within the Town Centre, where the highest concentration of retail premises and pedestrians requires easily negotiated thresholds. It also creates a challenge in integrating new development with existing development, especially along Knight Terrace.	This will be addressed in the Chapter Report: ▪ Identification of Adaptation Options
Absence of a local planning policy to provide guidance for developers and decision makers on the form and nature of acceptable development on land exposed to coastal processes. For example, whilst increasing finished floor levels for habitable buildings may succeed in minimising damage to the affected property, the manner in which the increase is achieved can have implications for how quickly water can recede as well as impact on other development.	This will be addressed in: ▪ Chapter Report Assessment of Adaptation Options – Suggested text of the local planning policy would be developed ▪ Draft CHRMAP (includes Implementation Plan).

5 IDENTIFICATION OF COASTAL ASSETS

5.1 Collection Methodology

A site investigation of the study area was conducted from 2nd to 4th May 2018. The area to be assessed was defined as all land below the 5m AHD contour. This contour was selected based on the 500-year ARI inundation level of 4.2m AHD defined in the MRA (2014) study. The value was rounded up to 5 m AHD to allow for any variations in the next phase of work, and make sure all assets were identified.

The study team traversed this area, documenting each observed asset. Assets were identified, classified and photographed. For this study, the coastal hazard mapping, asset datasets and Shire zoning are linked in the form of an ESRI ArcGIS Online map, allowing all project partners access to the information through a web-browser. For the asset collection, recorded assets were uploaded to the online map and added to our GIS database. The photograph taken of each asset is stored in the GIS platform for ease of future interrogation.

5.2 Asset Classifications

At the time of identification, each asset was categorised into a classification. This aims to simplify the adaptation planning process in subsequent phases of the project. The study team grouped assets as follows:

- Commercial
  - This includes shops, businesses, offices etc.
- Public
  - This item mainly relates to public infrastructure, and includes the boat ramp and jetty structures
- Tourism Related
  - This mainly includes tourist accommodation such as caravan parks, hostels and private rentals
- Residential
  - Private houses, apartments and supporting structures such as sheds and garages

Whilst tourism is a commercial venture, it is a key industry for the Shark Bay area, so is relevant as a category of its own.

Included in the classification is the definition of the asset's function and service. It can also be assigned a value as part of the community values assessment (refer Section 6).

5.3 Asset Data

Each asset was colour coded based on its classification for ease of identification in the mapping. The online database can be found at the following link:

https://watech.maps.arcgis.com/apps/webappviewer/index.html?id=6e092b4d0f044e038a721705e907c084

Within the database are brief descriptions of each asset, together with a photograph. All assets are georeferenced.

A table summarising the assets by classification is presented in Table 5-1. A total of 144 assets were identified. Figure 5-1 to Figure 5-2 present the assets as mapped in the database. Larger maps are presented in Appendix

E. As discussed in Section 4, the Shire is only responsible for managing assets defined as public. However, they are responsible for zoning and assigning development constraints to ensure appropriate development.

TABLE 5-1 ASSET SUMMARY

Asset Classification	Number of Assets
Commercial	12
Public	74
Residential	48
Tourism Related	10

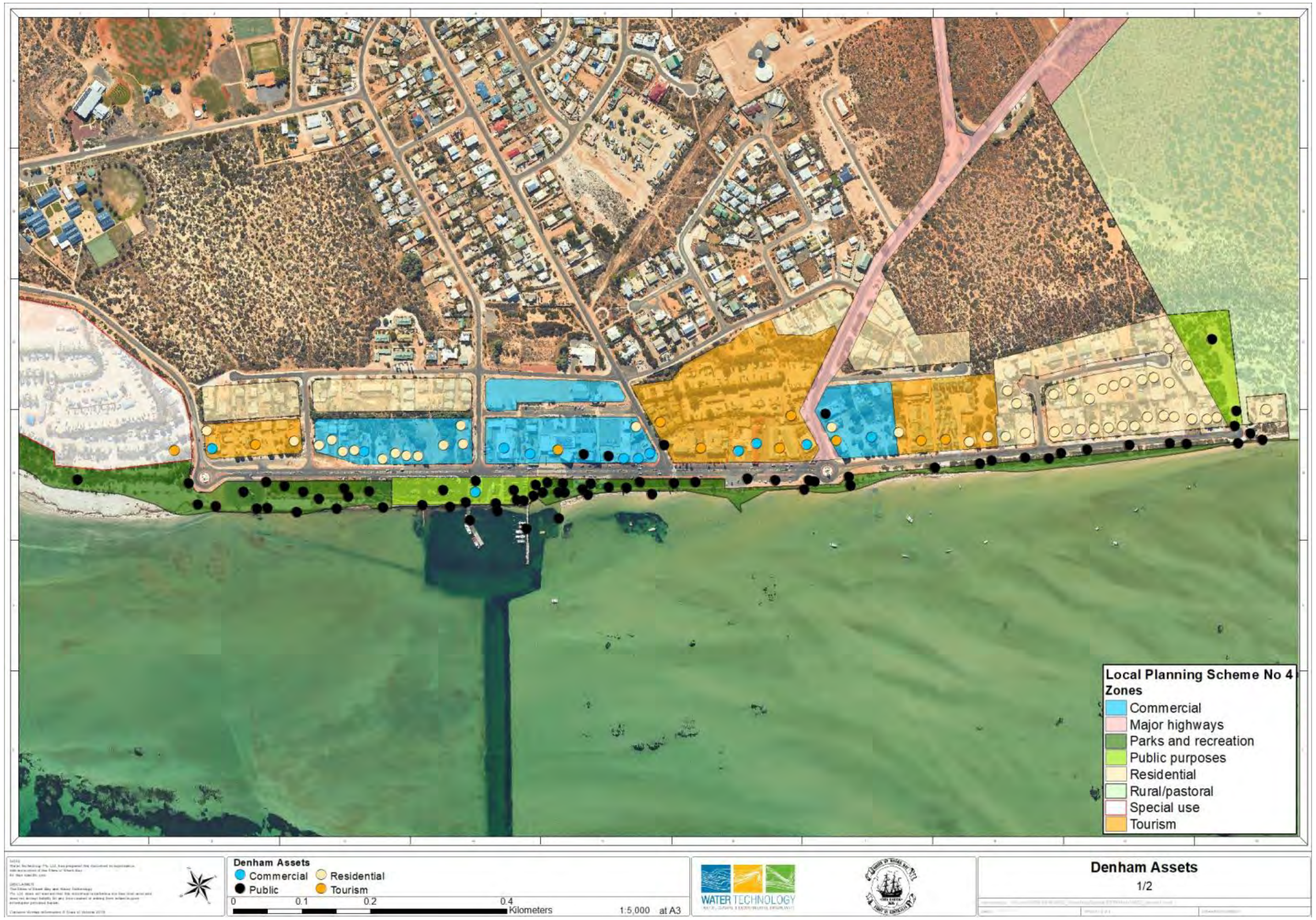

FIGURE 5-1 IDENTIFIED ASSETS IN DENHAM TOWNSITE

FIGURE 5-2 IDENTIFIED ASSETS IN STUDY AREA

6 COMMUNITY VALUES ASSESSMENT

6.1 Engagement Process

The Stakeholder and Community Engagement Plan (Water Technology, 2018) aims to engage all relevant stakeholders to provide them with ownership of the CHRMAP and acceptance of its outcomes. The objectives of the strategy are as follows:

- Consult with stakeholders and the community on climate change and its impacts in the coastal zone within the Denham Townsite:
  - What does this mean for the community?
  - How can we adapt?
- Generate the success criteria for the risk assessment component of the CHRMAP. Success criteria represent stakeholders' tolerance and acceptability of the impact to assets from the identified coastal hazards.
- Aid in the selection of site-specific adaptation measures. Stakeholders on the ground are likely to have a knowledge of the site developed over years of interaction. This provides invaluable information that can be applied to generate innovative adaptation measures.

The Community Values Assessment represents the collaborate component of the consultation: **to determine the community values attributed to coastal assets and the corresponding level of risk tolerance**.

The engagement strategy (Water Technology, 2018) identified a workshop to collate the stakeholder and community's values.

6.2 Stakeholders

As defined in Water Technology (2018), stakeholders for the project can be split into two categories:

- Internal Stakeholders:
  - Part of the decision-making team. Predominantly, these will be Shire of Shark Bay Councillors and staff, although state government will also play a role. A Steering Committee has been established to oversee preparation and completion of the CHRMAP, including review of project deliverables. This includes representatives from state government.
- External Stakeholders:
  - Not decision-makers but are affected by the project outcomes. They might live near the coast, use an asset or resource located in the coastal zone, or simply have an interest in the coastal foreshore reserve.

The aim of the Community Values Assessment was to engage both internal and external stakeholders. To this end, a Community Information Sheet was developed to advertise the workshop and its purpose (refer Appendix D).

6.3 Community Values Workshop Summary

The workshop was held at 5:30pm on Thursday 3rd May. There were 7 attendees in addition to Water Technology staff – 4 Shire of Shark Bay Councillors, and 3 Shire of Shark Bay staff. That is, only internal stakeholders were present. The workshop was an interactive process. Aerial imagery / maps were presented, and attendees allowed the opportunity to identify areas and assets of high social, environment and cultural value. The values were grouped as follows:

- Recreational (red)
- Commercial (blue)
- Environmental (green)
- Historical / heritage / cultural (yellow)
- Physical infrastructure (black)

Figure 6-1 to Figure 6-2 presents the identified values overlain the presented maps. Table 6-1 presents the 'key' to the numbered items on the maps. Larger maps are presented in Appendix E.

TABLE 6-1 VALUES 'KEY'

Value	Id	Name
Recreational	1	Recreational Activities/Values.
	2	Recreational Activities/Values.
	3	Recreational and Physical Infrastructure
	4	Rod Fishing
	5	Windsurf/Collect Cockles/Fish/SUP/Canoe/Kayak
	6	Quad Bike Tours/ Uncontrolled 4WD on Beach
	7	Beach Fishing/Walking/Scenic
	8	Recreational Activities/Values. Prefer no Seawall
Commercial	1	Kite Surf School
	2	Quad Bike Tours
Environmental	1	Environmental Risk - Petrol Station
	2	Environmental Risk - Petrol Station
	3	Marine Park
Historical / heritage / cultural	1	Historic 'groyne'
	2	Backpackers 'boat ramp'
	3	Burn Scar
Physical infrastructure	1	Physical Infrastructure
	2	Physical Infrastructure
	3	Potential recreational/infrastructure upgrade

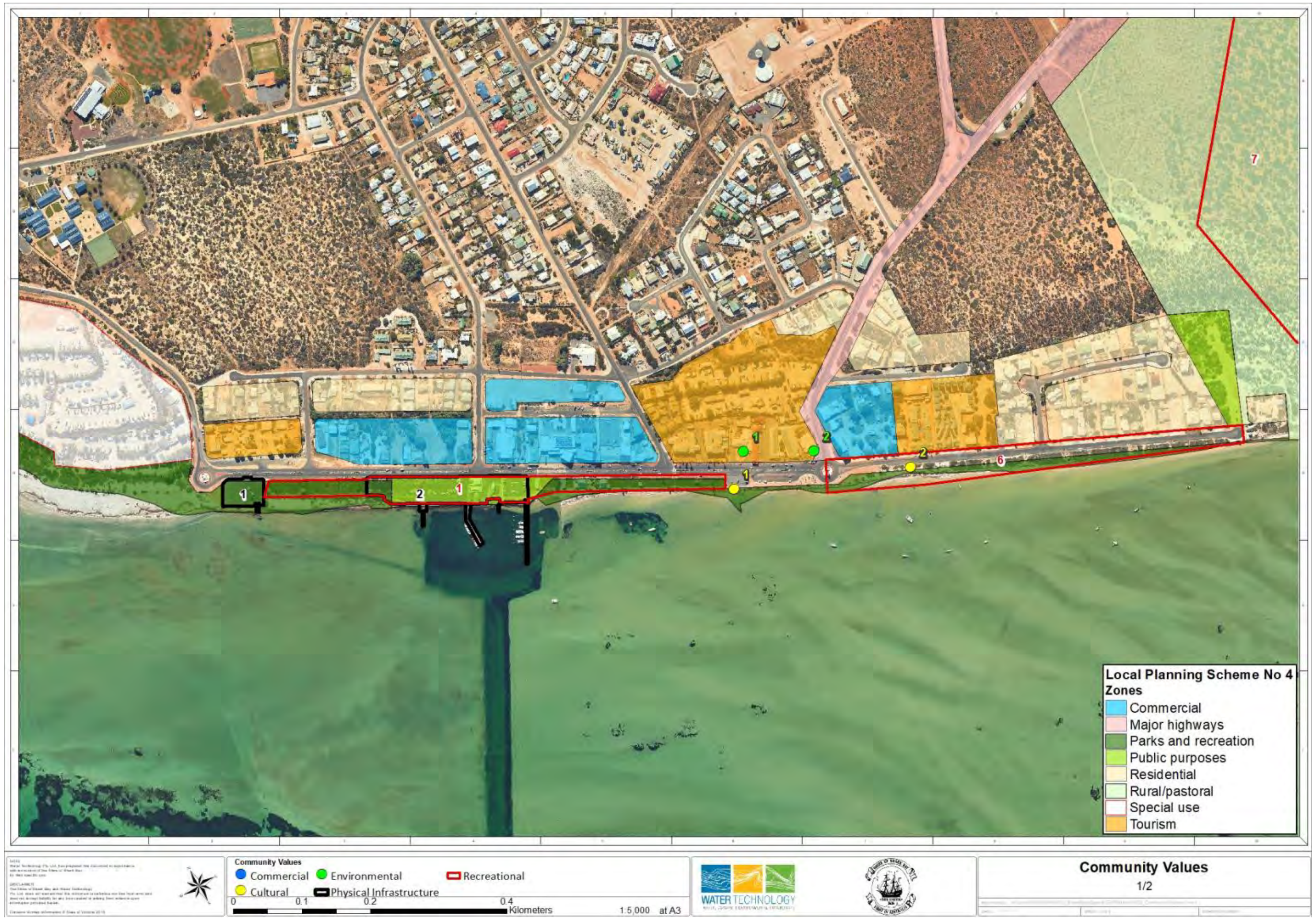

FIGURE 6-1 IDENTIFIED COMMUNITY VALUES IN DENHAM TOWNSITE

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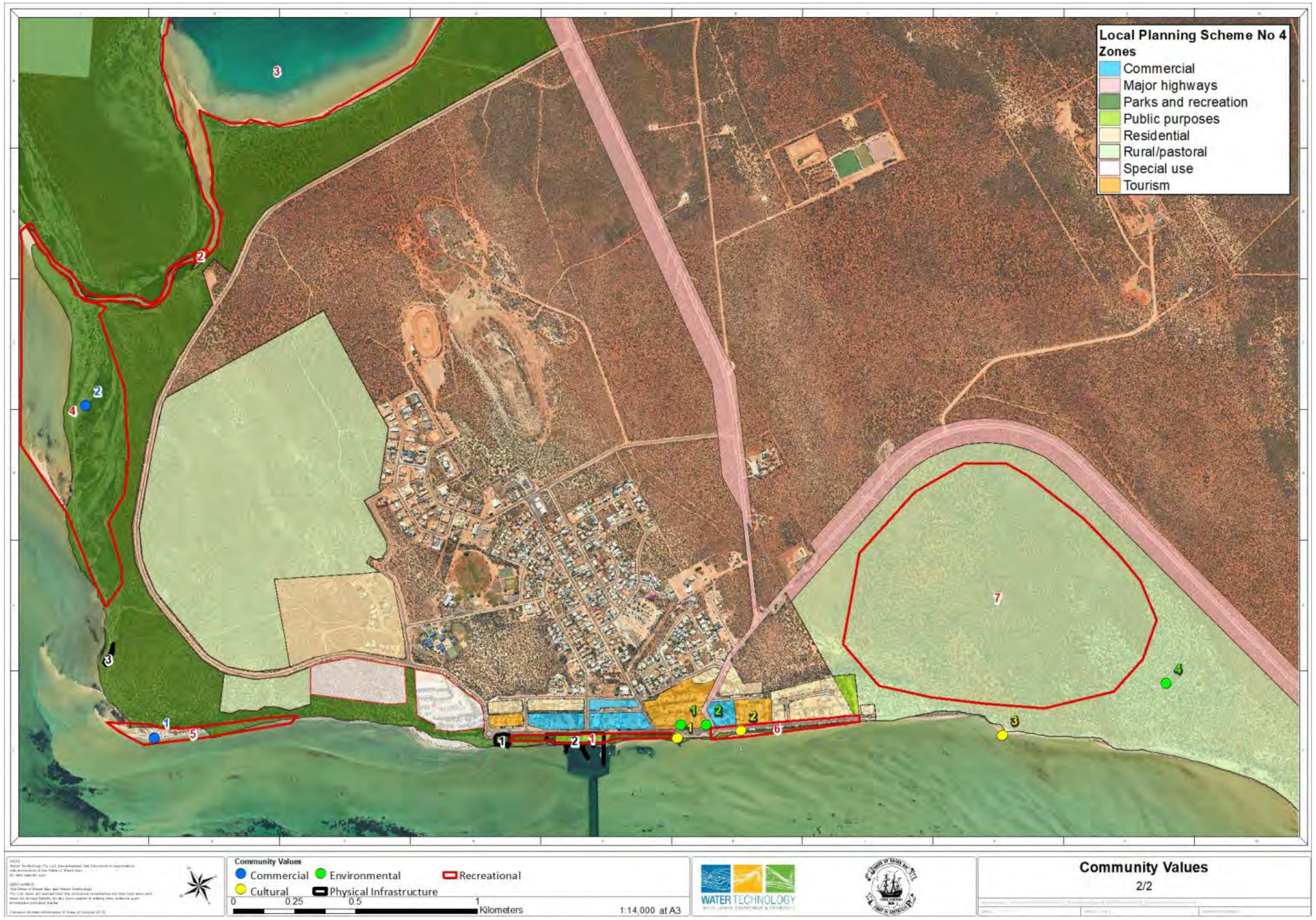

FIGURE 6-2 IDENTIFIED COMMUNITY VALUES IN STUDY AREA

6.3.1 Anecdotal Observations

During the workshop, attendees provided anecdotal observations of historical events and thoughts on the study area:

- 2015 cyclone (not identified, however most likely Olwyn from the cyclone track information) crossed the townsite during low tide. The leading edge was to the southeast and damage / impacts were minimal.
- It was thought that in general, erosion during a cyclone was minimal due to the high inundation levels. That is, wave attack would almost occur on the roads rather than the beach face itself.
  - This will be investigated during the coastal hazard assessment.
- The southern end of town appears to be more resilient to erosion, including cyclonic erosion.
- Decision-makers are unwilling to interfere with the more ‘natural’ coastline at the southern end of town, due to its high recreational value and impacts from previous works.
  - A ‘groyne’ located between Durlacher Street and Denham Road led to detrimental impacts.
- Historically, horse racing was held along the foreshore during the 1950’s.
- The beach is accreting at the backpacker ‘boat ramp’.
- The nearshore sandbanks are dynamic. Historically (i.e. 1980’s / 1990’s) seagrass was present.
  - In 2010 there was a heatwave, and it was suggested that this was the cause of a noticeable reduction in seagrass within much of the western inlet of Shark Bay. Seagrass disappearance offshore from the eastern coastline of Dirk Hartog Island was linked to erosion in the area. Seagrass disappearance offshore from Denham was noticed but not attributed directly to erosion.
- Concerned about the impacts to water quality and recreation of if the lagoon entrance were to close.
- Concerned about the uncontrolled 4WD beach driving / quad bike riding and their impact on the environment.
- Human degradation considered to be a coastal hazard.
- There is a potential upgrade scheduled for the recreational infrastructure at the recreational node off Stella Rowley Drive.
- Tidal action appears to reduce further south within the bay.
- There are identified indigenous sites to the east of town.
- Significant reclamation works over the years has made it difficult to ascertain shoreline movements.

6.3.2 Workshop Close

All attendees were provided with a feedback form at the end of the session to provide anonymous (if desired) feedback. All attendees completed the form; feedback suggested the session was of value.

6.4 Success Criteria

The values collated from the workshop have been used to generate the success criteria for the risk assessment component of the CHRMAP. These will be key to the whole CHRMAP as it is these that will ultimately drive the selection of adaptation options. It is important that a comprehensive approach be applied at this stage of the project, in order to provide a CHRMAP applicable to the Shire and stakeholders.

The success criteria are defined in Table 6-2.

TABLE 6-2 SUCCESS CRITERIA

- **Protection of the environmental assets of the study area / planning to retain environmental integrity**
- **Protection of the recreational value of the coastline**
- **Protection of the cultural values of the coastline**
- **Maintenance of the culture of the Denham Town Centre**
- **Maintenance of a level of public infrastructure**
- **Development controls not to inhibit the landscape**

6.4.1 Engagement

The aim of this stage of the engagement process is to engage with both internal and external stakeholders. As only internal stakeholders were present at the workshop, there is the option of bringing the proposed online survey (Water Technology, 2018) forward. This survey was originally aimed at advertising the project and the proposed adaptation options. However, as there will be an Adaptation Assessment Workshop, and the draft CHRMAP open for public comment, the second half of the study will be covered with suitable engagement. The development of the success criteria could be further enhanced by the addition of external stakeholder input in the form of an online survey. The Success Criteria developed from the Community Values Workshop can be supplied for comment, and the opportunity to put forward additional values provided.

The survey link can be posted to:

- Shire website
- Shire Facebook pages:
- Shark Bay News & Views
- Shark Bay Buy Sell & Swap
- Hard copies can be made available at Post Office, Shire Office and World Heritage Discovery Visitor Centre

7 CONCLUSIONS & RECOMMENDATIONS

This document outlines the key management and adaptation issues that need to be considered in the CHRMAP, as well as identifying the coastal assets and success criteria (community values). It is the 'Establishing the Context' component of the CHRMAP process, as described in the top bubble of the flow chart displayed in Figure 1-2. To establish the context of the study, state and local coastal policy, planning schemes and instruments were reviewed, as well as historical reports detailing physical phenomena affecting the coastline.

The following sections summarise the key items of note identified in this report:

7.1 Coastal Hazards Summary

- Modelling will be undertaken using the available data. Present data gaps mean assumptions will be made that limit the accuracy of the results.
- When dealing with coastal adaptation, it is important to understand the level of accuracy of the modelling, as it informs the risk and vulnerability ratings. However, we believe the most effective approach is to use the modelling to identify triggers, and their corresponding coastal management action. An indicative likelihood and timeframe can be provided for guidance, but the ultimate adaptive action is driven by the triggers
- To assist in filling the knowledge gaps, the following ongoing data collection is recommended. These are listed in order of priority. Except where indicated, the benefit of the data will not be gained during the present study, but in the application of the resulting coastal management plan:
  - Locally placed nearshore water level and wave data logger. This will enable calibration of wave models, especially if a storm / cyclone is captured during the deployment. Following the completion of the CHRMAP, the data can be used to get a better understanding of event probabilities, rather than just triggers.
    - Ideally, this instrument would be deployed before the commencement of the next cyclone season. If the data is to be used in the present study, the instrument would need to be deployed within the next few months.
  - Regular photographic beach monitoring is a useful tool in analysing beach behaviour. This can be conducted at 6-monthly intervals at the end of the summer and winter. Photos should also be taken immediately following severe storms. They should be undertaken from a set vantage point to allow accurate comparisons between images. The images can be used to supplement available data when undertaking adaptation option design. These images can also be used to support adaptation option funding applications, and in educating the community about natural fluctuations in beach shape.
    - These can be commenced immediately. Water Technology have proformas for these which allow Shire staff to undertake the inspections, once initial guidance is provided. Coastal specialists should review the data every couple of years, or if erosion is causing an issue.
    - This data can also be used to identify if a trigger has been reached.
  - Beach surveys, ideally every 6-months following the summer and winter periods. If possible, immediately following cyclones. Corresponding monitoring photos should be taken at the same time.
  - Regular monitoring of the marine structures / assets – e.g. seawall, jetties. These should be undertaken with consistent proformas to allow comparison between inspections.

    - These can be commenced immediately. Water Technology have proformas for these which allow Shire staff to undertake the inspections, once initial guidance is provided. Coastal / marine specialists should review the data every couple of years, or if there is an issue with an asset.
  - Geotechnical investigations to determine the presence of bedrock. If located relatively near the surface, bedrock can act as a natural protection structure, and negate the need for other mitigation works. However, in low lying areas the presence of bedrock may not alter the level of risk to coastal hazards. If the area is inundated the hard surface will not provide the expected protection to erosion. The benefits of such an investigation will be explored in future stages of the CHRMAP.

7.2 Planning Items / Controls Summary

- SPP2.6 aims to avoid future development within areas identified to be at risk within the planning timeframe of 100-years. For areas at risk, all potential adaptation options will be identified under the risk management categories of avoid, managed retreat, accommodate and protect to manage the unacceptable risks.
- The ultimate aims of the policy are to ensure all future development takes into account coastal hazards, climate change, and landform stability. Coastal values (landscape, biodiversity, ecosystems, indigenous and cultural) are to be conserved.
- The WA Coastal Zone Strategy is a critical planning guide for any coastal community. It outlines the State Government's aims for sustainable coastal development into the future. The State Government emphasises the preference of public interests over private and industry interests, and reinforces the presumption of landholder responsibility. The State Government also reiterates protection should be used only in the most exceptional circumstances. Ultimately, the Shire will be responsible for determining how local landholders address risk, possibly by writing an LPP under the guidance of this strategy.
- This CHRMAP may identify developed land that will be at risk to coastal hazards, that, for various reasons have not yet been formally identified. The current draft of LPS 4 does not outline how such areas are to be managed. Guidance may be required to address these risks.
  - The risks will be identified in Chapter Reports:
    - Coastal Hazard & Vulnerability Assessment
    - Risk Assessment.
- Presently there are limited development controls relating to the impacts of coastal hazards for land use and development. At present, only the risk of inundation is addressed. Finished floor levels in these areas are addressed in LPS 4 but there is no guidance for managing the impact that increased floor levels will have on the interface between buildings and the adjacent public realm. This will be a challenge especially within the Town Centre, where the highest concentration of retail premises and pedestrians requires easily negotiated thresholds. It also creates a challenge in integrating new development with existing development, especially along Knight Terrace.
  - This will be addressed in the Chapter Report: Identification of Adaptation Options
- Absence of a local planning policy to provide guidance for developers and decision makers on the form and nature of acceptable development on land exposed to coastal processes. For example, whilst increasing finished floor levels for habitable buildings may succeed in minimising damage to the affected property, the manner in which the increase is achieved can have implications for how quickly water can recede as well as impact on other development.
  - This will be addressed in:
    - Chapter Report Assessment of Adaptation Options
    - Draft CHRMAP (includes Implementation Plan).

7.3 Identification of Coastal Assets

A total of 144 assets were identified, photographed, georeferenced and classified into the categories of Commercial, Public, Residential and Tourism Related. Risks to these assets will be considered by applying the success criteria in the Risk Analysis and Evaluation phase of the project (refer Figure 1-2 for project phases).

Each asset was colour coded based on its classification for ease of identification in the mapping. The online database can be found at the following link:

https://watech.maps.arcgis.com/apps/webappviewer/index.html?id=6e092b4d0f044e038a721705e907c084

Within the database are brief descriptions of each asset, together with a photograph. All assets are georeferenced.

7.4 Community Values Assessment:

The community values workshop identified the following success criteria from which to assess the coastal hazard risks:

- Protection of the environmental assets of the study area / planning to retain environmental integrity
- Protection of the recreational value of the coastline
- Protection of the cultural values of the coastline
- Maintenance of the culture of the Denham Town Centre
- Maintenance of a level of public infrastructure
- Development controls not to inhibit the landscape

The aim of this stage of the engagement process is to engage with both internal and external stakeholders. As only internal stakeholders were present at the workshop, there is the option of bringing the proposed online survey (Water Technology, 2018) forward. The development of the success criteria could be further enhanced by the addition of external stakeholder input in the form of an online survey.

7.5 Next Steps

The next phases of the study are to identify the coastal hazard risks and undertake a vulnerability assessment. That is, examine the impacts of coastal erosion and storm surge inundation on the assets and their corresponding values.

8 REFERENCES

Bureau of Meteorology (BoM, 2014). *Tropical Cyclone Hazel*, [ONLINE] Available at: http://www.bom.gov.au/cyclone/history/hazel.shtml, [Accessed 18th April 2018]

Eliot I, Gozzard JR, Eliot M, Stul T and McCormack G. (2012). *The Coast of the Shires of Shark Bay to Exmouth, Gascoyne, Western Australia: Geology, Geomorphology & Vulnerability*, Prepared by Damara WA Pty Ltd and Geological Survey of Western Australia for the Department of Planning and the Department of Transport

Harper B.A. (ed.), (2001). *Queensland Climate Change and community vulnerability to tropical cyclones - ocean hazards assessment - stage 1*, Report prepared by Systems Engineering Australia Pty Ltd in association with James Cook University Marine Modelling Unit, Queensland Government, March, 375pp. [available from: http://www.longpaddock.qld.gov.au/about/publications/pdf/climatechange/vulnerabilitytotropicalcyclones/stage1/FullReportLowRes.pdf]

Harper B.A., Stroud S.A., McCormack M. and West S. (2008). 'A review of historical tropical cyclone intensity in north-western Australia and implications for climate change trend analysis'. *Australian Meteorological Magazine*, Vol. 57, No. 2, June, 121-141. [Available online at: http://www.bom.gov.au/amoj/docs/2008/harper.pdf]

Harper B.A. and Mason L.B. (2016) A tropical cyclone wind event data set for Australia. Proc. 18th Australasian Wind Engineering Society Workshop, 6-8 July, McClaren Vale, SA.

Intergovernmental Panel on Climate Change (IPCC, 2014). *Climate Change 2014: Synthesis Report*, Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland, Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)], IPCC, Geneva, Switzerland, 151 pp.

MRA (2014). *Denham Inundation Levels Storm Surge Modelling Report*, report to the Shire of Shark Bay

Seashore Engineering (2017). *Shire of Shark Bay - Final Draft Hotspots Snapshots*, Report Nº SE052, prepared for Department of Planning

Water Technology (2018). *Denham Townsite CHRMAP: Stakeholder and Community Engagement Plan*, Report Nº 5562-01 R01v01, prepared for Shire of Shark Bay

Western Australian Planning Commission (WAPC, 2013). *State Planning Policy No. 2.6 – State Coastal Planning Policy*, prepared under the Planning and Development Act 2005.

Western Australian Planning Commission (WAPC, 2014). *Coastal Hazard Risk Management and Adaptation Planning Guidelines*

Western Australian Planning Commission (WAPC, 2017). *Draft Planned or Managed Retreat Guidelines*, published by WAPC, Department of Planning, Lands and Heritage

Worley Parsons (WP, 2016). *Denham Foreshore Revitalisation Stage 1A: Design Report*, Report Nº 301012-02233 – GE-REP-002, prepared for Department of Transport

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APPENDIX A
SUPPORTING PLANNING CONTROLS / INFORMATION

A-1 State Planning Documentation

A-1-1 State Planning Policies

State Planning Policies (SPPs) provide the highest level of planning policy control and guidance in Western Australia and are prepared under Part 3 of the *Planning and Development Act 2005*. The *Coastal Planning Policy* (SPP 2.6) is an environmental sector policy consistent with the higher order *SPP 2 Environmental and Natural Resources Policy.* This relationship is illustrated in Figure 4-2, which also shows how the CHRMAP process fits into the hierarchy. The CHRMAP is a local level policy document (refer to Figure 4-2), though not a local planning policy unless the Shire adopts it as such via the processes of the local planning scheme.

A-1-2 State Planning Policy 3.4: Natural Hazards and Disasters

This document aims to include natural disaster planning in town planning schemes and local planning strategies so as to minimise the adverse impacts of natural disasters on communities, both in terms of the economy and environment. Natural disasters in the context of the present study include (land) flood, cyclones, storm surge, and bushfires. Bushfires can have an impact in the coastal zone in terms of dune vegetation integrity, and therefore erosion susceptibility.

The cost of recovery following a natural disaster is significant. The most effective strategy is to integrate mitigation activities into land use planning.

The contents of this planning policy are directly in line with the advice provided in SPP2.6.

A-1-3 Other Relevant State Documents

8.1.1.1 Coastal Adaptation and Protection (CAP) Grants

These are grants implemented by the Department of Transport (DoT) to assist WA local coastal managers with coastal management. These grants are available for monitoring, investigation, asset management, adaptation and maintenance in the coastal zone. In 2017, $750,000 was available across the state; in 2018 this was increased to $1.057 million. The grant process adheres to the CHRMAP principles and aims to ensure coastal managers adapt sustainably to coastal hazards for the benefit of the public. Adaptation options are to preserve and enhance coastal values, and assets to benefit the community. New coastal protection works are not permitted under the grant scheme unless they can be adequately justified in the context of the CHRMAP process.

It is important to bear the above in mind when developing adaptation options, as funding will only be available if the principles are followed. Some useful weblinks for these grants are included below:

- Main page:
  - https://www.transport.wa.gov.au/imarine/coastal-adaptation-and-protection-cap-grants.asp
- Frequently Asked Questions:
  - https://www.transport.wa.gov.au/mediaFiles/marine/MAC_P_CAP_2018_19_Grant_FAQ.pdf
- Detailed Grant Information
  - https://www.transport.wa.gov.au/mediaFiles/marine/MAC_P_CAP_2018_19_Grant_InfoApps.pdf

A-2 Regional Planning Documents

A-2-1 Gascoyne Planning and Infrastructure Framework

After the *State Planning Strategy*, the key regional strategic planning document is the *Gascoyne Planning and Infrastructure Framework 2015* (*Gascoyne PIF*). The *Gascoyne PIF* takes into consideration the recommendations of the *Shark Bay Regional Strategy 1998,* which was itself a review of the 1988 *Shark Bay Region Plan,* the primary purpose of which related to guidance for planning and management to protect and enhance the Shark Bay World Heritage values. The *Gascoyne PIF* provides an overall strategic regional context for land-use planning within the region and identifies several priority initiatives required to facilitate comprehensive regional planning and guide local planning processes.

A-2-2 Gascoyne Coast Sub-Regional Strategy

A *Gascoyne Coast Sub-Regional Strategy* is in preparation and the draft was advertised for public comment early in 2017. The draft strategy aims to guide local planning processes, including the preparation of and amendments to local planning schemes and strategies. It identifies coastal processes and hazards as an issue and recognises that these may compromise the suitability of proximate areas for development, noting that coastal foreshore reserves are generally required. Also noted is the fact that development may be subject to specific construction requirements as per the Building Code of Australia as a result of the region being prone to cyclonic activity. Coastal processes are not mentioned specifically in relation to the ongoing development and expansion of the Denham townsite; however, the importance of tourism to the local economy is strongly tied to the sustainability of environmental tourist attractions and the tourism services provided within Denham.

A-3 Local Planning Documents

A-3-1 Local Planning Policies

Local planning policies can be made to support local planning scheme provisions. Currently, the Shire has no published Local Planning Policies which address coastal hazards.

A-3-2 Structure Plans

Structure Plans can provide guidance for the future subdivision and development of land. A structure plan is not a statutory document, but decision makers for applications for development or subdivision approval within a structure plan area must have regard to its content when deciding the application. Decision makers are not bound by the structure plan, but it would require compelling alternative considerations to ignore its intent.

The Shire of Shark Bay has no approved structure plans relevant to the Denham townsite; however, the *Denham Townsite Plan* (refer to section 4.2.2) is referred to by the Shire as a structure plan.

APPENDIX B
REVIEW OF HISTORICAL COASTAL INVESTIGATIONS

B-1 Coastal Hazard Assessments

B-1-1 Historical Cyclones

Whilst numerous cyclones have affected Denham in the last 60 years, there is a lack of climatic and oceanographic data for the Town of Denham and its surrounds that captures the passage of Tropical Cyclones (TC's) within a significant distance. This means that examination of many historical TC's may be rudimentary and discussion of their impacts may be provided by circumstantial evidence and second-hand observations. Details of observed erosion or inundation effects and previous modelling relating to cyclones have been reviewed in Sections B-1-2 and B-1-3.

Eliot et al (2012) analysed tropical cyclone data for the Pilbara and Gascoyne coasts. The report states that direct impact of cyclones for the Gascoyne coastline are less frequent than further north, occurring on average once every two to three years. The report references Hubbert et al. (1991) which reported that TC Hazel developed a high storm surge due to the path of the cyclone parallel to the coast, compared with an equivalent theoretical system approaching the coast at a perpendicular angle.

MRA (2014) investigated cyclones that passed within 250 km of the Denham townsite, noting that 29 named and 4 unnamed cyclones fit such criteria between the 1960's and 2014. MRA selected three TC's (Elaine, Hazel, and Narelle) due to the availability of water level data at Denham or nearby. MRA noted that the cyclone track information for the selected storms was available from the BoM, however details of specific characteristics or impacts observed at Denham could not be found either in the MRA report or other literature.

BoM (2014) summarised the meteorological description and observed impacts of TC Hazel from March 1979. This report refers to Denham as one of the towns damaged by cyclonic activity, specifically that there were reports of inundated buildings as a result of a storm surge. The report also mentions that people were evacuated and local jetties damaged.

The BoM report states that the lowest pressure recorded by an on-the-ground monitoring station was 977.3 hPa at Kalbarri and Geraldton. However, the cyclone track information estimates that TC Hazel reached a maximum low pressure of 938 hPa just 20 km south of Denham. Track information from the BoM also indicates that the eye of the storm passed directly over the townsite.

B-1-2 Coastal Erosion

Under the guidance of the planning controls mentioned in Section 2 (WAPC, 2013), the allowance for erosion on sandy coasts is calculated as the sum of the S1, S2 and S3 Erosion components, plus 0.2 m per year allowance for uncertainty, and should be measured from the horizontal shoreline datum (HSD):

- S1 Erosion: Allowance for the present risk of storm erosion
- S2 Erosion: Allowance for the historic shoreline movement trends
- S3 Erosion: Allowance for erosion caused by future sea level rise.

As stated above, these allowances form the coastal foreshore reserve for coastal erosion required by the WAPC when applied from a horizontal shoreline datum (HSD), a fixed line that is defined on the basis of the type of coastline being assessed. The HSD defines the active limit of the shoreline under storm activity and should be determined against the physical and biological features of the coast. In most cases it should be defined as the seaward shoreline contour representing the peak steady water level under storm activity. Investigations into the historic, present, and future erosion estimates have not yet been undertaken for the study area.

Seashore Engineering (2017) investigated erosion at the Denham townsite identifying two 'erosion hotspots' at the western and eastern extents of Knight Terrace corresponding with each end of the ad-hoc revetment's transition to beachfront. The report provides a summary of erosion and associated problems, a brief register of public and private assets potentially exposed to erosion, as well as anticipated management options for the immediate future and their triggers.

The report outlines that the area of Denham foreshore at risk is mainly reclaimed land that is managed by the revetment and ongoing renourishment. The report also states that the western hotspot is more susceptible to erosion (than the east) due to the interruption of sediment transport by the dredged channel. The report agrees that no quantitative or otherwise significant hazard assessment regarding erosion has been done at this location.

As summarised in Section 3.2 and 3.2.2.1, this study aims to fill some of the identified knowledge gaps and recommend measures to fill the remaining gaps.

B-1-3 Coastal Inundation

The allowance for the current risk of inundation, according to SPP2.6, is calculated as the maximum extent of storm inundation, defined as the peak steady water level plus wave run-up. Consideration must be given to the likelihood of breaching any manmade structure, e.g. the seawall fronting the Denham town site, or natural barriers, for example a dune system.

As Denham is located in an area subject to tropical cyclones, the allowance for the present risk of inundation must consider tropical cyclonic storm events. The design event must have a 0.2% Annual Exceedance Probability (AEP), which corresponds to a 500-year Average Recurrence Interval (ARI). Planning guidelines state that this cyclone should track to maximise its inundation potential. Planning guidelines also indicate that 0.9 m of sea level rise must be added to design water levels to determine the final inundation levels for 2110.

The inundation allowance should also include an allowance for the current risk of inundation from a tsunami.

MRA (2014) provides the most comprehensive summation of historically observed water levels for the study area, as well as the only detailed investigation into the design water levels required by the planning controls outlined in Section 2. Notable water levels observed at Denham are:

- TC Hazel (1979) reached a maximum water level of 1.9 m AHD. MRA references the SoSB Cyclone Contingency Plan from 2009 however it is unclear in what way this original observation was recorded. This document has now been superseded with the 2017/18 Cyclone Season Community Information Sheet.
- TC Herbie (1988) reached a maximum water level of 2.1 m AHD. This observation was also referenced from the SoSB Cyclone Contingency Plan from 2009 and its origin is not stated.

The report states that no cyclonic event was captured during the brief water level records at Denham (refer Table 3-1 for Denham water level data record).

MRA (2014) used limited available data to set up and calibrate a Delft3D cyclone hydrodynamic model for the town of Denham. Modelling of historical cyclones was used to create a first order storm surge approximation. Following this, a Monte Carlo model was used to generate and simulate 1,000 years of synthetic cyclone tracks to determine extreme water levels for Denham. The results of this methodology are shown in Table B-1.

TABLE B-1 MRA (2014) DESIGN STORM SURGE INUNDATION LEVELS FOR DENHAM

ARI (years)	Inundation Level 2014 (m AHD)	Inundation Level 2110 (m AHD)
20	1.9	2.8
50	2.4	3.3
100	2.7	3.6
500	3.3	4.2

MRA noted that the final design water level of 4.2 m AHD was higher than the level required in the Shire's LPS 3 (3.2 m AHD), likely due to updates to the calculation of inundation levels in State Planning Policies. As noted in Section 2.2.1, the Shire's draft LPS 4 includes a recommendation to raise the minimum FFL to 4.2 m AHD.

Subsequent to the MRA (2014) study, DoT commissioned a report identifying tropical cyclone design storms for town sites along the Western Australian coastline (Seashore Engineering, 2018). The report was developed specifically for application of SPP2.6 requirements. It produced design storms for use across the state in the absence of site-specific probabilistic assessments.

Whilst this study is a comprehensive investigation into cyclone behaviour and corresponding impact on the WA coastline, it is limited in its applicability to the Denham townsite. The design storm provided for Denham is similar to that of TC Narelle, but with an altered shore-crossing track and central pressure to increase the impacts. It was derived from a synthesis of detailed assessments; individual storm events were not modelled or validated. The MRA (2014) study used TC Narelle as a model validation storm in their assessment, which included the generation of a synthetic cyclone track database from which to undertake extreme value analysis. Given the extra level of investigation in MRA (2014), it is not considered appropriate to use the storm provided in Seashore Engineering (2018) for the present study. However, the water levels predicted for Denham using the recommended design storm are presented for reference in Table B-2. The study included a level of conservatism to overcome the coarse nature of the assessment. This is likely the reason the 500-year ARI value is significantly higher than the MRA (2014) study.

TABLE B-2 SEASHORE ENGINEERING (2018) DESIGN STORM SURGE INUNDATION LEVELS FOR DENHAM

ARI (years)	Inundation Level 2018 (m AHD)
10	1.3
25	1.7
50	2.3
100	2.8
500	4.0

B-2 Coastal Adaptation Assessments

Worley Parsons (WP, 2016) undertook the design of the Denham Foreshore Revitalisation project which encompassed a review and recommended upgrade of the town's existing revetment. WP noted that the design was completed by desktop analysis without inclusion of any modelling services. WP states that, in order to satisfy the overtopping requirement standards they follow, the crest of the upgraded revetment would have to exceed 5.2 m AHD. A brief assessment of this option considered it unrealistic due to cost, aesthetics, and functionality. The final recommended revetment design has a recommended crest level of 3.4 m AHD with a width of three armour stones at the crest to minimise damage due to overtopping. This level is 1.1 m above the existing revetment crest level. It is not stated how the recommended crest level was obtained.

Seashore Engineering (2017) undertook a preliminary assessment of adaptation options due to the anticipated further erosion at the two identified erosion hotspots described in Section B-1-2. This assessment only considered the next 5-years and, in both cases, it was deemed necessary to protect, rather than avoid, retreat, or accommodate. For the western hotspot, renourishment with dredged material was recommended. For the eastern hotspot, minor embankment repairs and revegetation efforts were recommended.

APPENDIX C
STORM SURGE MODELLING REPORT REVIEW

Memorandum

Job:	Denham Townsite CHMRP	**Job No:**	J1802
Subject:	Comments on MRA Storm Tide Report	**Doc ID:**	MO001A
Date:	10/04/2018		
To:	Joanna Garcia-Webb/ Water Technology	**Status:**	Final
From:	Bruce Harper / SEA	**Mode:**	Email

1 Introduction

Estimates of storm tide risk available via MRA (2014) for the Denham Township in Western Australia (25.927S, 113.534E) are reviewed to assess their reliability and suitability for the CHMRP process (WAPC 2014).

The townsite (Figure 1) is located in the broader Shark Bay region, situated on the western side of the Peron Peninsula facing Denham Sound. It lies some 50 km south of Cp Inscription that marks the northern-most extent of Dirk Hartog Island, which likely forms a protective barrier to open ocean swell emanating from the Indian Ocean. The southern-most point of Dirk Hartog Island is separated from the mainland by a very narrow passage that likely limits both tide and wave penetration. The fetch westward from Denham to Dirk Hartog Island is approximately 40 km, comprised of relatively shallow water (< 5 to 10m) . The area has a modest tide range of order 1.5 m.

It is likely that quite significant storm surge responses (>5m) are possible at Denham for very intense storms approaching from the NW.

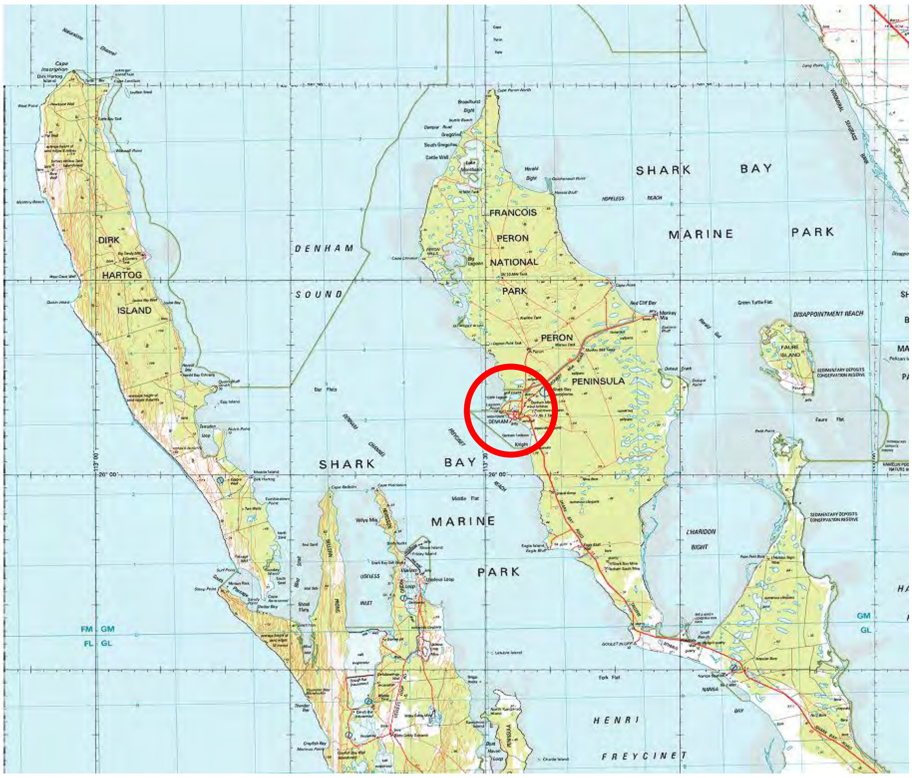


Figure 1 – The study site and surrounds (GA Topo250k image).

2 The Hazard

Storm tide is the combined effects of the astronomical **tide**, the storm **surge** magnitude and the **wave setup** magnitude (refer Figure 2). It is an absolute level, referred here to Australian Height Datum (AHD). Because the astronomical tide varies (up to the Highest Astronomical Tide, or HAT), the total storm tide also varies with the tidal range. Additionally, wave runup can intermittently reach higher vertical levels if the beachfront has not already been submerged.

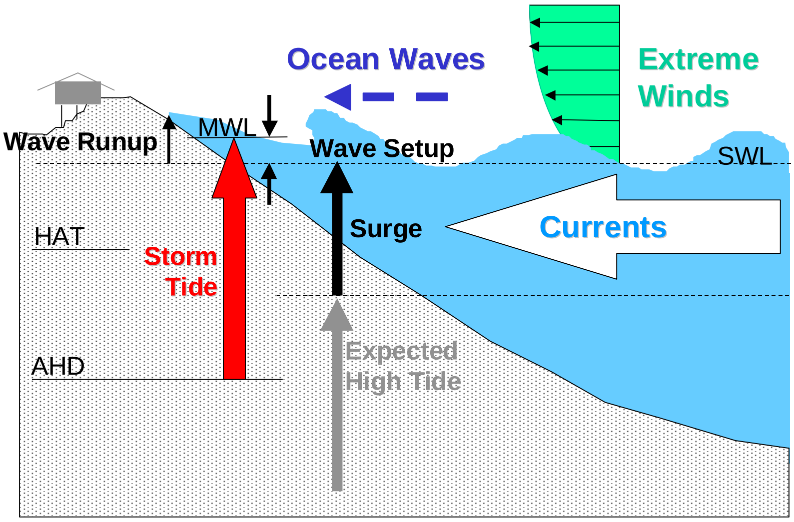


Figure 2 - Water level components of an extreme TC storm tide (after SEA 2005).

3 MRA (2014) Methodology

The basic philosophy of the provided MRA (2014) study is supported:

The limited availability of water level data means that an extreme analysis of peak recorded levels would not provide meaningful results. Consequently, there is the need to use numerical modelling techniques to create a synthetic water level record which can then be used to determine extreme water levels for Denham.

The overall modelling approach as stated in MRA (2014) is as summarised below.

1. Setup, calibrate and validate the Delft3D cyclone, wave and hydrodynamic model for the region.
2. Use the Delft3D model to simulate historical cyclones that have affected the region and interrogate cyclone tracks and predicted water levels to determine a first order storm surge approximation.
3. Use a Monte Carlo model to simulate 1,000 years of cyclone tracks and severity.
4. Rank the 1,000 years of synthetic cyclones using the first order storm surge approximation combined with the predicted tide to determine the top events.
5. Use the Delft3D model to simulate the top events and record the peak water levels at Denham.
6. Complete an extreme analysis of peak recorded water levels for Denham.

The veracity of each of the steps in the methodology is assessed below.

3.1 Setup, calibrate and validate

Unfortunately the report is lacking essential detail in a number of areas:

- There is no statement as to the spatial resolution of the coarse and fine hydrodynamic models nor any associated information such as assumed bottom fiction or if wetting/drying of the extensive shallow margins has been permitted;
- The bathymetry used is that from Geoscience Australia, which from personal experience is not very reliable in this area. It would be advisable for the model depths to be crosschecked against navigation charts, which show that the area is very shallow and likely to respond strongly to tropical cyclone forcing in the nearshore if the angle of attack is critical.
- The model development refers to hydrodynamic and **waves,** but no evidence of wave modelling is provided.

3.2 Simulate historical cyclones

MRA has made some effort to assemble a number of historical events to test the model performance, which is a function of the representation of the hydrodynamics plus the assigned wind and pressure fields. Only one of the events (Hazel) seems to have produced any significant response at Denham, which is corroborated only by anecdotal evidence, albeit apparently having some significant impact at the townsite.

There are a number of associated issues that have not received any commentary:

- The use of the Bureau of Meteorology (post-1960) storm dataset to represent the historical events does not provide essential information on storm scale (e.g. radius of maximum winds) and is known to contain artefacts that relate maximum estimated windspeed (Vmax) and minimum sea level pressure (pc) (e.g. Harper et al. 2008);
- It is noted that the Delft3d WES model (e.g. Deltares 2018) makes certain assumptions about the relationship between various model storm parameters (largely derived from model development for India) and that these might be at odds with the BoM dataset;
- It would have been more compelling to also see the comparisons of measured and modelled wind speeds and pressures for each modelled event (e.g. using winds at Carnarvon) to provide confidence in the hydrodynamic model results, noting that the BoM parameters in conjunction with a Holland (1980) model often do not match these well.

In closing, it is noted that the Deltares WES wind and pressure model makes no mention of the need for a boundary layer adjustment of the modelled winds to the surface.

3.3 Use a Monte Carlo storm event model to generate 1,000 years of synthetic storms

The report discusses the adoption of a statistical tropical cyclone climate model based on the approach by Emanuel et al. (2006) and provides extensive illustration of aspects of that model development that adds little to the documentation. The reliability of the developed model is limited to a comparison of input and output parameters and a display of spatial storm tracks. In line with previous comments, there are several issues regarding the applicability of the merging of the BoM track dataset on the one hand and the Emanuel method on the other.

The only way to demonstrate that the model has predictive skill for this region would be to generate the long-term winds for (say) Carnarvon and compare those with the measured winds (e.g. Harper and Mason 2016). Unfortunately, this is not done and so the reliability of the whole analysis remains unknown.

3.4 Rank the 1,000 years of synthetic cyclones

Section 4.4 also introduces the so-called "first order" or parametric storm tide model that is used to rank the 1,000-year event track set to reduce it to the "top 154" decided upon to be modelled through the hydrodynamic models. There is no way to assess the veracity of this model because there are no specific details provided, other than describing its principal parameters and the fact that it is combined with a simple harmonic tide generator. It is noted that a 150 km radius is also used to include any potentially significant events, which is supported.

3.5 Use the Delft3D model to simulate the top events

The "top 154" events (why this number was adopted is not stated but must be related to the Poisson inter-arrival frequency to achieve a lowest ARI of 20 y) are then modelled in detail. Whether this is done with tidal boundaries in a coupled-mode or simply retaining the associated parametric model astronomical tide sequence, which itself lacks specifically-localised tidal nuances, is not stated. It would have been instructive to show a comparison between the parametric and hydrodynamic storm tide response to gauge the effectiveness of the parametric model used in the initial ranking to select the 154 runs.

It is noted that the 154 storm's storm tide levels were then subject to an Extreme Value Analysis following Petrauskas & Aagaard (1971) but, given that P&A offer a wide range of possible EVAs with sometimes disparate outcomes, it would have been useful to show how well the modelled data points have been fitted and then subsequently extrapolated. P&A also enables confidence limits to be estimated for such extrapolation, but these are not provided.

4 Conclusions and Recommendations

While the overall study approach is supported, the lack of detail around the many essential steps needed to fulfil the benefits of the methodology is disappointing and does not allow a ready endorsement of the results.

Firstly, the method ignores the potential contribution of wave setup at Denham, which although not likely to be critical given the exposure and the shallow margins, is also not likely to be insignificant at higher ARI. Given the proximity of assets to the shoreline, wave setup and runup are likely important components of any tropical cyclone storm tide impact and should be estimated as part of the CHMRP.

Next, there is no validation of the Monte Carlo storm climatology against regional data. Given that storm tide is a complex function of wind-field scale, magnitude, speed of movement, frequency and track, the synthetic storms should be demonstrated to produce a similar statistical distribution to regionally-measured winds where they are available (Harper 2001). The need for this is compounded by the adoption of the US-based Emanuel approach combined with the lack of parameter information in the BoM dataset and the assumptions made in the WES model, which together leave a wide range of interpretation. Finally, there is a lack of disclosure of how the final 154 event extrapolation was performed and what likely range of uncertainty exists with that.

It is difficult to conclude the reliability of the final MRA Table 5.1 "Tide plus Surge" recommendations and so I can only point to the various uncertainties in the methodology to speculate that it may be no better than ± 0.5 m at the 500 y ARI. Wave setup allowances will add to the upper limit of this uncertainty by potentially another 0.5 m at the 500 y ARI. In contrast, the estimated 20 y ARI level of 1.9 m AHD seems relatively high given that HAT is only around 0.9 m AHD.

5 References

Harper B.A. (ed.), (2001) Queensland climate change and community vulnerability to tropical cyclones - ocean hazards assessment - stage 1, Report prepared by Systems Engineering Australia Pty Ltd in association with James Cook University Marine Modelling Unit, Queensland Government, March, 375pp.
[available from: http://www.longpaddock.qld.gov.au/about/publications/pdf/climatechange/vulnerabilitytotropicalcyclones/stage1/FullReportLowRes.pdf]

Harper B.A., Stroud S.A., McCormack M. and West S. (2008) A review of historical tropical cyclone intensity in north-western Australia and implications for climate change trend analysis. Australian Meteorological Magazine, Vol. 57, No. 2, June, 121-141. [Available online at: http://www.bom.gov.au/amoj/docs/2008/harper.pdf]

Harper B.A. and Mason L.B. (2016) A tropical cyclone wind event data set for Australia. Proc. 18th Australasian Wind Engineering Society Workshop, 6-8 July, McClaren Vale, SA.

Holland G.J. (1980) An analytic model of the wind and pressure profiles in hurricanes. Mon. Wea. Rev., 108, 1212-1218.

Deltares (2018) WES - Wind Enhance Scheme for cyclone modelling, User Manual, Version: 3.01. SVN Revision: 52614, April, 56pp.

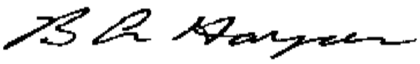
Emanuel K. A., Ravela S., Vivant E., and Risi C. (2006) A statistical deterministic approach to hurricane risk assessment. Bull. Amer. Meteor. Soc., 87, 299–314.

MRA (2014) Denham Inundation Levels -Storm Surge Modelling Report. Prepared by M.P. Rogers and Associates Pty Ltd for Shire of Shark Bay. R558 Rev 0, Dec, 35pp.

Petrauskas C. & Aagaard P. M. (1971) Extrapolation of Historical Storm Data for Estimating Design Wave Heights. American Institute of Mining, Metallurgical and Petroleum Engineers Inc.

WT (2018) Subcontractor agreement 5652_SC03V01. March.

WAPC (2014) Coastal hazard risk management and adaptation planning guidelines. Western Australian Planning Commission, Government of Western Australia, 38pp.



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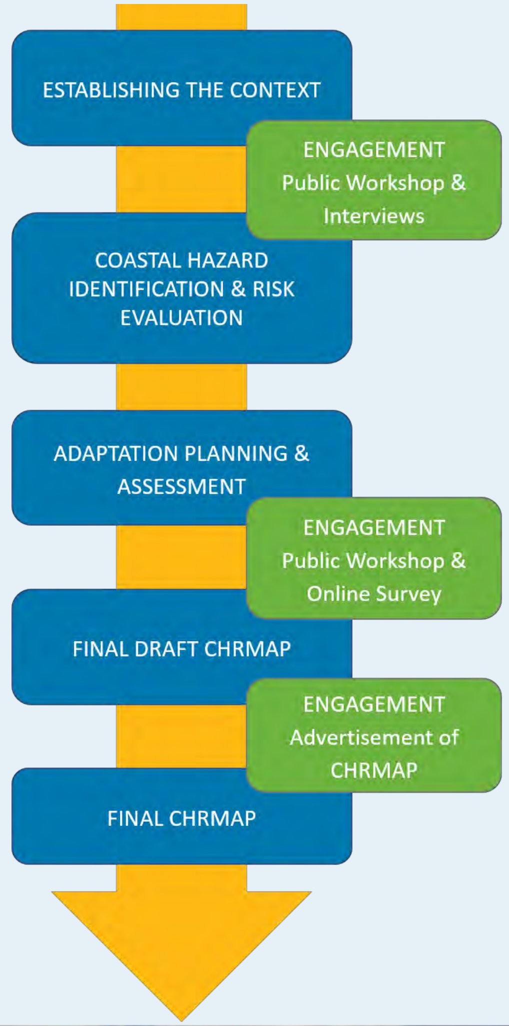
APPENDIX D
COMMUNITY INFORMATION SHEET

Coastal Hazard Planning for the Denham Townsite

The Shire of Shark Bay has engaged Water Technology to prepare a **Coastal Hazard Risk Management and Adaptation Plan (CHRMAP)** for the Denham Coast. Undertaking a CHRMAP is a recommendation of the Western Australian Planning Commission.

Information regarding this plan and its objectives, as well as details for the corresponding community consultation program are outlined in this information sheet.

CHRMAP Process



What is a CHRMAP?

A CHRMAP is a strategic plan that provides a framework for decision makers to meet the challenges associated with coastal hazards, including erosion, inundation and sea level rise.

Purpose:

- To identify vulnerable assets (public and private) and the risk posed to them by coastal hazards.
- To preserve community values for present and future generations.
- To develop a plan that will allow the Shire to respond to identified risks through adaptation planning activities.
- To recommend monitoring plans to ensure the risk management and adaptation plan activities are working into the future as expected.

Why Does Denham need a CHRMAP?

Residents of and visitors to Denham place a high value on the surrounding coastline. In addition, the town site has significant assets within 50 metres of the present day coastline. The processes that affect this area are multiple and complex.

Sea Level Rise

Sea levels in WA have risen 11cm in the past 40 years. By 2100 sea levels are expected to rise by a further 90cm. On sandy coastlines, a 1cm rise in sea level will result in a 1m movement of the shoreline inland.

Changing Coastlines

Much of Western Australia's coastline is sandy and low lying, and Denham is no exception. These coastlines can be variable in nature and may be highly susceptible to changing conditions, such as sea level rise.

CHRMAP Outcomes

- The development of adaptation options such as planning responses, erosion and inundation mitigation options, and recommendations.
- An evaluation of potential managed retreat options and trigger points to initiate retreat plans.
- A recommended monitoring plan that the Shire can implement to identify risks and evaluate the performance of the CHRMAP aims in the short and long term.

Community Involvement

Community and stakeholder involvement is a critical component of the CHRMAP process, as it defines what and how much value is placed on built and natural assets within the study area. This will inform the adaptation planning process and ensure all needs are considered.

How can I be involved?

- Community Workshop 1: **5:30 pm Thursday 3rd May 2018**
  - **Recreation Centre, Francis Street, Denham**
- Stakeholder Interviews Friday 4th May 2018, Denham
- Community Workshop 2 October 2018, Denham
- Community Survey: to be posted to the Shire's website in October (planned)

Contact Details

Shire of Shark Bay
Paul Anderson
Chief Executive Officer
Phone: (08) 9948 1218
Email: ceo@sharkbay.wa.gov.au

Water Technology
Joanna Garcia-Webb
Senior Coastal Engineer
Phone: (08) 6555 0105
Email: joanna.garcia-webb@watertech.com.au

APPENDIX E
ASSET & COMMUNITY VALUES MAPS

NOTE
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Denham Assets
Commercial
Public
Residential
Tourism

0 0.1 0.2 0.4 Kilometers

1:5,000 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Denham Assets

1/2

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DATE: 17/05/2018 | SHEET: 2 of 2 | DRAWING NUMBER:

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Denham Assets
Commercial
Residential
Public
Tourism

0 0.25 0.5 1 Kilometers

1:14,000 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Denham Assets

2/2

REFERENCE: M:\Jobs\5600-5699\5652_SharkBay\Spatial\ESRI\Mxds\5652_Assets2.mxd

DATE: 17/05/2018 | SHEET: 2 of 2 | DRAWING NUMBER:

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Community Values
Commercial
Environmental
Recreational
Cultural
Physical Infrastructure

0 0.1 0.2 0.4 Kilometers
1:5,000 at A3

WATER TECHNOLOGY

Community Values

1/2

REFERENCE: M:\Jobs\5600-5699\5652_SharkBay\Spatial\ESRI\Mxds\5652_CommunityValues1.mxd

DATE: 17/05/2018 | SHEET: 2 of 2 | DRAWING NUMBER:

Community Values
Commercial
Environmental
Recreational
Cultural
Physical Infrastructure

0 0.25 0.5 1 Kilometers

1:14,000 at A3

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WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Community Values

2/2

REFERENCE: M:\Jobs\5600-5699\5652_SharkBay\Spatial\ESRI\Mxds\5652_CommunityValues2.mxd

DATE: 17/05/2018 | SHEET: 2 of 2 | DRAWING NUMBER:

APPENDIX C
CHAPTER REPORT: COASTAL HAZARD & VULNERABILITY ASSESSMENT

Denham Townsite CHRMAP

Chapter Report: Coastal Hazard & Vulnerability Assessment

Shire of Shark Bay

16 August 2019

Document Status

Version	Doc type	Reviewed by	Approved by	Date issued
V01	DRAFT	Christine Arrowsmith	Christine Arrowsmith	27/07/2018
V02	FINAL	Paul O'Brien	Paul O'Brien	17/01/2019
V03	FINAL	Joanna Garcia-Webb	Joanna Garcia-Webb	16/08/2019

Project Details

Project Name	Chapter Report: Coastal Hazard & Vulnerability Assessment
Client	Shire of Shark Bay
Client Project Manager	Paul Anderson
Water Technology Project Manager	Joanna Garcia-Webb
Water Technology Project Director	Christine Lauchlan Arrowsmith
Authors	William Edge, Joanna Garcia-Webb
Document Number	5652_01_R04v03.docx

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Quality ISO 9001 SAI GLOBAL
Environment ISO 14001 SAI GLOBAL
Health & Safety AS 4801 SAI GLOBAL

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16 August 2019

Paul Anderson
Chief Executive Officer
Shire of Shark Bay
65 Knight Terrace Denham WA 6537
Via email ceo@sharkbay.wa.gov.au

Dear Paul

Chapter Report: Coastal Hazard & Vulnerability Assessment

We are pleased to present the Denham Townsite Coastal Hazard Risk Management and Adaptation Plan Chapter Report: Coastal Hazard & Vulnerability Assessment. If you have any queries, please do not hesitate to contact me on (03) 8526 0830.

Yours sincerely

Joanna Garcia-Webb
Principal Coastal Engineer **|** National Practice Lead – Coasts & Environment

joanna.garcia-webb@watertech.com.au

WATER TECHNOLOGY PTY LTD

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EXECUTIVE SUMMARY

It is internationally recognised that increasing sea levels and storm intensities will intensify coastal hazards such as coastal inundation (temporary coastal flooding), storm erosion and long-term shoreline recession (IPCC 2014). Consequently, State governments across Australia have introduced obligations that require local governments to consider and plan for the effects of these hazards over various planning timeframes. In Western Australia (WA), the governing policy is the Western Australian Planning Commission's State Coastal Planning Policy 2.6 (WAPC, 2013, herein referred to as "SPP2.6"). SPP2.6 recommends management authorities develop a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP). Specific guidelines have been developed to assist in this process (WAPC, 2014).

One of the key objectives of SPP2.6 is to establish coastal foreshore reserves which include allowances for the protection, conservation and enhancement of coastal values across the state. Risk assessment processes are then utilised to identify risks that are intolerable to the community, and other stakeholders such as the Shire of Shark Bay, indigenous and cultural interests, and private enterprise. Adaptation measures are then developed according to the preferential adaptation hierarchy outlined in SPP2.6.

The overall CHRMAP purpose is as follows:

- To identify vulnerable assets (public and private) and the risk posed to them by coastal hazards.
- To preserve community values for present and future generations.
- To develop a plan that will allow the Shire to respond to identified risks through adaptation planning activities.
- To recommend monitoring plans to ensure the risk management and adaptation plan activities are working into the future as expected.

This document presents the Coastal Hazard & Vulnerability Assessment Chapter Report. Hazard maps are produced defining the erosion and inundation extents for present day, 2030, 2050, 2118. The vulnerability of assets to the defined coastal hazards (exposure, sensitivity and adaptive capacity) is identified. The flow chart displayed in Figure 1-2 indicates where this component of the study sits with reference to the wider project; the 'Coastal Hazard Risk Identification' phase corresponds to the bubbles shaded in red, as replicated below.

Hazard Assessment – to understand coastal processes & hazards & identify areas at risk

(A) Review of available information and knowledge summary
   a. Water Level / inundation information
   b. Hydrographic surveys
   c. Aerial photography analysis
   d. Previous coastal hazard reporting

(B) Coastal Hazard Assessment on key coastal processes – coastal inundation, long-term and short-term erosion

1. Update previous assessments with most recent aerial photographs / historical where necessary; analyse accordingly
2. Inundation scenarios include - Present day, 2030, 2050, 2118 conditions, with Average Recurrence Interval of 20, 50, 100, 500 years
3. Erosion scenarios assessed as per SPP2.6, with SBEACH modelling at key points in the study area
4. Determine trigger events & responses

(C) Coastal Hazard Mapping
   a. 3D surface mapping of all coastal inundation and erosion scenarios.
   b. Split into sectors, as required, at the stipulated scales & generate maps
   c. Online mapping provided for all maps, all information within GIS system

Vulnerability Assessment

- Identify vulnerable assets, group by specified categories; implications on land use
- Identify function, services & values of each vulnerable asset
- Assess vulnerability of each asset (exposure, sensitivity and adaptive capacity)
  - Assets grouped with rationale; Sensitivity scaling considered
  - Results tabularised
- Online mapping of vulnerability, all information within GIS system

A summary of the findings of the hazard and vulnerability assessment is presented below:

- The hazard maps for the coastal inundation assessment are presented in Appendix C. These display the extent of the predicted inundation for present day, 2030, 2050 and 2118. The data is overlaid the 2017 aerial photograph; the identified assets are also displayed.
- The coastal processes allowance hazard maps are presented in and Appendix D. Similarly, these display the calculated erosion extent for the planning timeframes.
  - Note this is not necessarily the predicted extent of erosion, rather the area at risk of erosion following the methodology of SPP2.6.
- All hazards and assets are included in the online database:
  - https://watech.maps.arcgis.com/apps/webappviewer/index.html?id=6e092b4d0f044e038a721705e907c084
- A vulnerability assessment was undertaken for assets predicted to be exposed to inundation and erosion. The full vulnerability assessment is provided in Appendix E and Appendix F for inundation and erosion respectively. Table 0-1 and Table 0-2 below present the number of assets predicted to be vulnerable to coastal hazards.
- The vulnerability assessment considers the physical impact of the hazard, and to some extent assumes the hazard will definitely occur. The next phase of the study involves carrying out a risk assessment for all assets predicted to be exposed to coastal hazards. This will include applying the likelihood of the hazard occurring. The risk assessment will also consider the social, cultural and environmental impacts in the form of the success criteria already developed in previous phases of the study.
- Inundation vulnerability summary:
  - The number of assets exposed to inundation is almost the same for all planning timeframes. However, the exposure increases due to the relative increase in water depth.
  - All buildings (commercial, residential and tourism related) and utilities are given a high vulnerability rating, due to both their sensitivity and low adaptive capacity.
  - Public recreational items are considered to be less vulnerable, especially those that can easily moved
    - Assets that are connected to utilities (e.g. toilets, BBQs) are given a higher vulnerability
- Erosion vulnerability summary:
  - In the present day, only public recreational items are vulnerable,
    - The exception is the utility: marina fire hydrant. As this is located at the crest of the engineered seawall, it is unlikely to be compromised in a present-day erosion event.
  - No buildings are threatened until the 2050 timeframe
  - Utilities begin to be threatened by 2030
  - All buildings (commercial, residential and tourism related) and utilities are given a high vulnerability rating, due to both their sensitivity and low adaptive capacity.
  - Public recreational items are considered to be less vulnerable
    - Assets that are connected to utilities (e.g. toilets, BBQs) are given a higher vulnerability

TABLE 0-1 ASSETS EXPOSED TO INUNDATION

Asset Classification	Present Day	2030	2050	2118
Commercial	14	14	14	14
Public	74	74	74	74
Residential	43	43	43	44
Tourism Related	9	9	9	10

TABLE 0-2 ASSETS EXPOSED TO EROSION

Asset Classification	Present Day	2030	2050	2118
Commercial	0	1	5	14
Public	20	64	70	74
Residential	0	0	18	51
Tourism Related	0	1	4	10

To address ongoing knowledge and data gaps which increase uncertainty in the predicted inundation and erosion hazards assessed in this component of the project, the following recommendations are summarised below:

- Deployment of a nearshore water level and wave data logger as soon as possible (Section 6).
- Development of a trigger-based adaptation plan and corresponding coastal management action during the next phases of the CHRMAP. The use of triggers mitigates some of the uncertainty surrounding the accuracy of the modelling.
  - Inclusion of a photographic beach monitoring schedule and guideline
  - Beach surveys when possible.
  - Recording of any coastal development, dredging, or renourishment activity (including approximate volumes)
- A geotechnical investigation to determine the presence of bedrock, which would potentially limit the landward erosion, particularly in the areas of higher relief.

CONTENTS

APPENDICES

LIST OF FIGURES

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LIST OF TABLES

1 INTRODUCTION

It is internationally recognised that increasing sea levels and storm intensities will intensify coastal hazards such as coastal inundation (temporary coastal flooding), storm erosion and long-term shoreline recession (IPCC 2014). Consequently, State governments across Australia have introduced obligations that require local governments to consider and plan for the effects of these hazards over various planning timeframes. In Western Australia (WA), the governing policy is the Western Australian Planning Commission's State Coastal Planning Policy 2.6 (WAPC, 2013, herein referred to as "SPP2.6"). SPP2.6 recommends management authorities develop a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP). Specific guidelines have been developed to assist in this process (WAPC, 2014).

One of the key objectives of SPP2.6 is to establish coastal foreshore reserves which include allowances for the protection, conservation and enhancement of coastal values across the state. Risk assessment processes are then utilised to identify risks that are intolerable to the community, and other stakeholders such as the Shire of Shark Bay, indigenous and cultural interests, and private enterprise. Adaptation measures are then developed according to the preferential adaptation hierarchy outlined in SPP2.6.

The aim of the present study is to investigate and plan for coastal hazards which are likely to affect the Denham townsite. Denham is located within the local government area of the Shire of Shark Bay, approximately 800km north of Perth (refer Figure 1-1 for locality). Denham and its surrounds are used extensively for tourism, commercial and recreational purposes. Tourism is the primary industry in the Shire, with fishing and aquaculture also playing a major role.

Given the above, visitors to and residents of Denham and its surrounds place a high value on the coastline. Processes affecting the coastal zone are multiple and complex: storm surge; tidal movement; shoreline stability; stormwater drainage; and the interactions between surface and groundwater all contribute in differing degrees. Furthermore, the potential impacts of climate change, specifically increasing sea levels and storm intensities, will place increased pressure on the coastal zone, and threaten public infrastructure and assets, private property, foreshore reserves, coastal attractions and public open spaces.

This document presents the Coastal Hazard & Vulnerability Assessment Chapter Report. Hazard maps are produced defining the erosion and inundation extents for present day, 2030, 2050, 2118. Vulnerability of assets to the defined coastal hazards (exposure, sensitivity and adaptive capacity) is identified. The flow chart displayed in Figure 1-2 indicates where this component of the study sits with reference to the wider study; the 'Coastal Hazard Risk Identification' phase corresponds to the bubbles shaded in red.

FIGURE 1-1 EXTENT OF CHRMAP

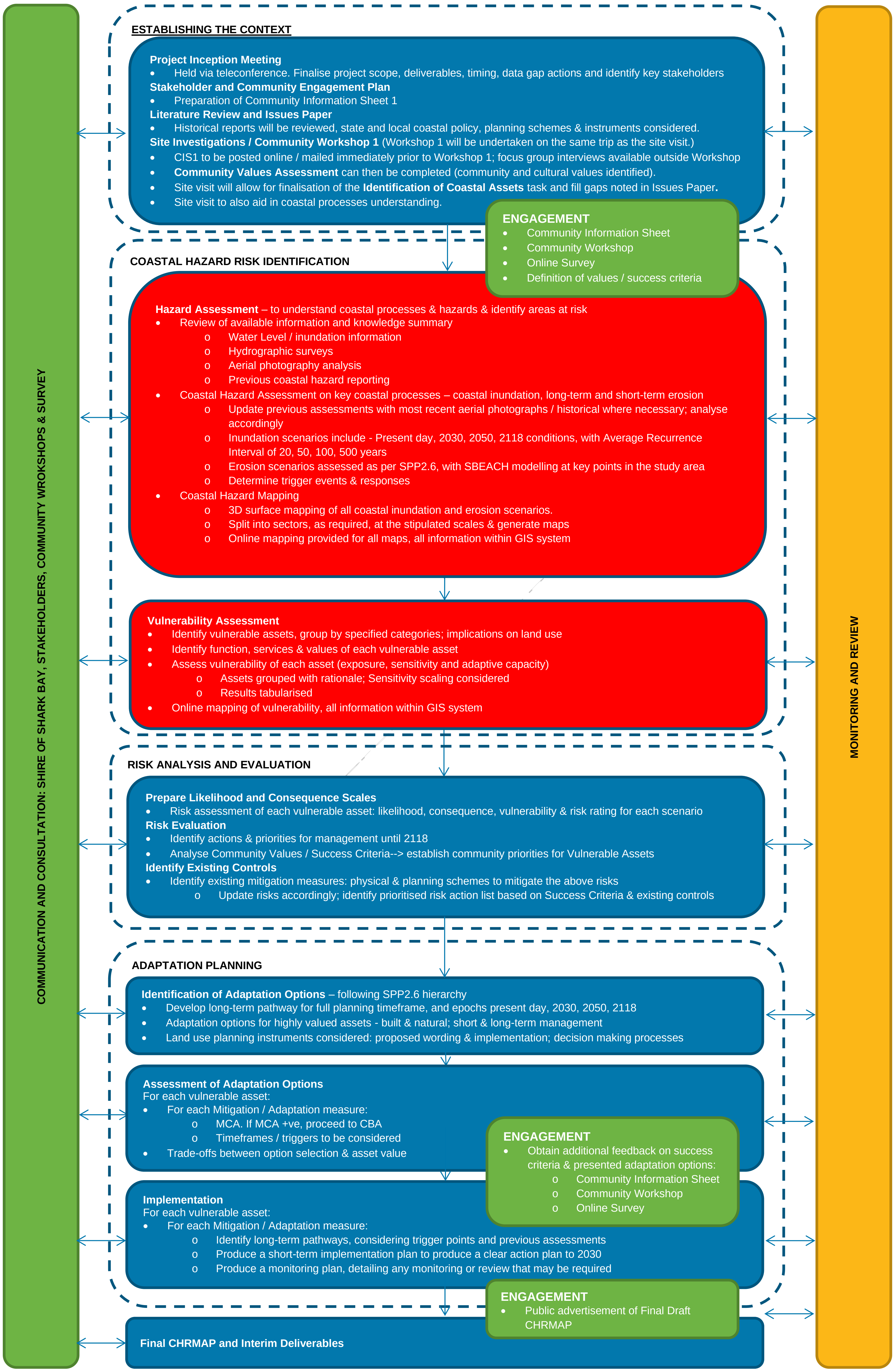

FIGURE 1-2 PROPOSED CHRMAP METHODOLOGY FLOW CHART (ADAPTED FROM WAPC CHRMAP GUIDELINES)

2 STUDY APPROACH

2.1 CHRMAP Objectives

As discussed in Chapter 1, the CHRMAP is a legislative recommendation from the state government.

The Denham CHRMAP aims to investigate and provide the blueprint for adapting and addressing coastal hazards which are likely to affect the Denham townsite over various planning timeframes. The CHRMAP will provide strategic guidance for coordinated, integrated and sustainable decision making by the Shire of Shark Bay in terms of future land use planning and management within the project area. The project will generate information on climate change and its impacts in the coastal zone within the Denham Townsite. This will enable the Shire to optimise its use of the coastal foreshore reserve in present day, and plan for how this may change in the future.

The overall CHRMAP purpose is as follows:

- To identify vulnerable assets (public and private) and the risk posed to them by coastal hazards.
- To preserve community values for present and future generations.
- To develop a plan that will allow the Shire to respond to identified risks through adaptation planning activities.
- To recommend monitoring plans to ensure the risk management and adaptation plan activities are working into the future as expected.

2.2 Coastal Foreshore Reserve

SPP2.6 provides guidance on the planning principles and guidelines required for coastal development in Western Australia. A key policy objective of SPP2.6 is the provision of a coastal foreshore reserve. The coastal foreshore reserve is essentially a 'space' between the ocean and coastal development. It accommodates a range of functions and values such as geomorphological integrity, biodiversity, heritage, public ownership and access.

Schedule One of SPP2.6 provides guidance for calculating the extent of the coastal foreshore reserve in terms of the physical processes alone. This reserve allows for coastal processes including present day erosion, historical shoreline movement, sea-level rise and storm surge inundation. However, as per the above, the coastal foreshore reserve should be determined on a case by case basis and include allowance for additional functions provided by the coastal foreshore associated with environmental, social and indigenous values.

The component of the coastal foreshore reserve to allow for coastal processes should be sufficient to mitigate the risks of coastal hazards by allowing for landform stability, natural variability and climate change. The coastal foreshore reserve is a critical input into the coastal hazard risk management and adaption planning framework outlined in SPP2.6. The assessment considers allowances for coastal erosion and storm surge inundation in parallel.

2.2.1 Allowance for Coastal Erosion

The allowance for erosion on sandy coasts is calculated as the sum of the S1, S2 and S3 Erosion components, plus 0.2 m per year allowance for uncertainty:

- (S1 Erosion) Allowance for the current risk of storm erosion

- (S2 Erosion) Allowance for historic shoreline movement trends
- (S3 Erosion) Allowance for erosion caused by future sea level rise

The coastal processes allowance is applied from a horizontal shoreline datum (HSD), defined as the active limit of the shoreline under storm activity. The Denham townsite is located in an area prone to tropical cyclones. SPP2.6 stipulates that a cyclone event corresponding to the 100-year Average Recurrence Interval (ARI) event should be selected to assess the erosion due to an extreme storm event, tracking to maximise its erosion and inundation potential.

2.2.2 Inundation Allowance

The allowance for current risk of inundation, according to SPP2.6, is calculated as the maximum extent of storm inundation, defined as the peak steady water level plus wave run-up. Consideration must be given to the likelihood of breaching any manmade structure or natural barriers, for example a dune system.

The allowance for the current risk of inundation is required to be based on a tropical cyclone storm event with a 500-year ARI. As per the erosion allowance, this cyclone should track to maximise its inundation potential.

2.2.3 Sea Level Rise

We have applied the sea-level rise scenarios presented in Table 2-1. This is a combination of DoT (2010) and IPCC (2014). The 2118 value matches that of DoT (2010) and is therefore consistent with SPP2.6. Figure SPM.6 within IPCC (2014) indicates the sea level rise prediction rates have been updated in the intervening years between the two reports. Whilst the 2118 predicted sea level rise is the same, the earlier epochs have a greater sea level rise. The more conservative interim values are adopted for this study, as presented in Table 2-1.

TABLE 2-1 PROPOSED SEA LEVEL RISE SCENARIOS

	2030	2050	2118
Sea Level Rise (m)	0.15	0.3	0.9

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3 SITE DESCRIPTION

The Denham townsite is located approximately 800 km north of Perth in the Shire of Shark Bay on Western Australia's Gascoyne Coast. The town's unique location (refer Figure 3-1) on the western flank of the Peron Peninsula, in the lee of Dirk Hartog Island, provides it with some protection from open ocean conditions. With the exception of the dredged channel, the nearshore bathymetry adjacent to the town remains within -3m AHD up to a distance 2km offshore, with significant portions of this area becoming exposed under regular tidal action.

The townsite itself is centred around the foreshore area and accompanying main street (Knight Terrace), which comprises new and old developments primarily under 5 m AHD. The low-lying foreshore area is part of a storm ridge and tidal flat system and is reported to be the original settlement location (Eliot et al. 2012). This area has experienced some seaward advancement due to reclamation works, the presence of built structures and periodic renourishment from dredged materials. The foreshore is bounded on the landward side by a scarp up to 25 m AHD, upon which much of the town's later development has occurred.

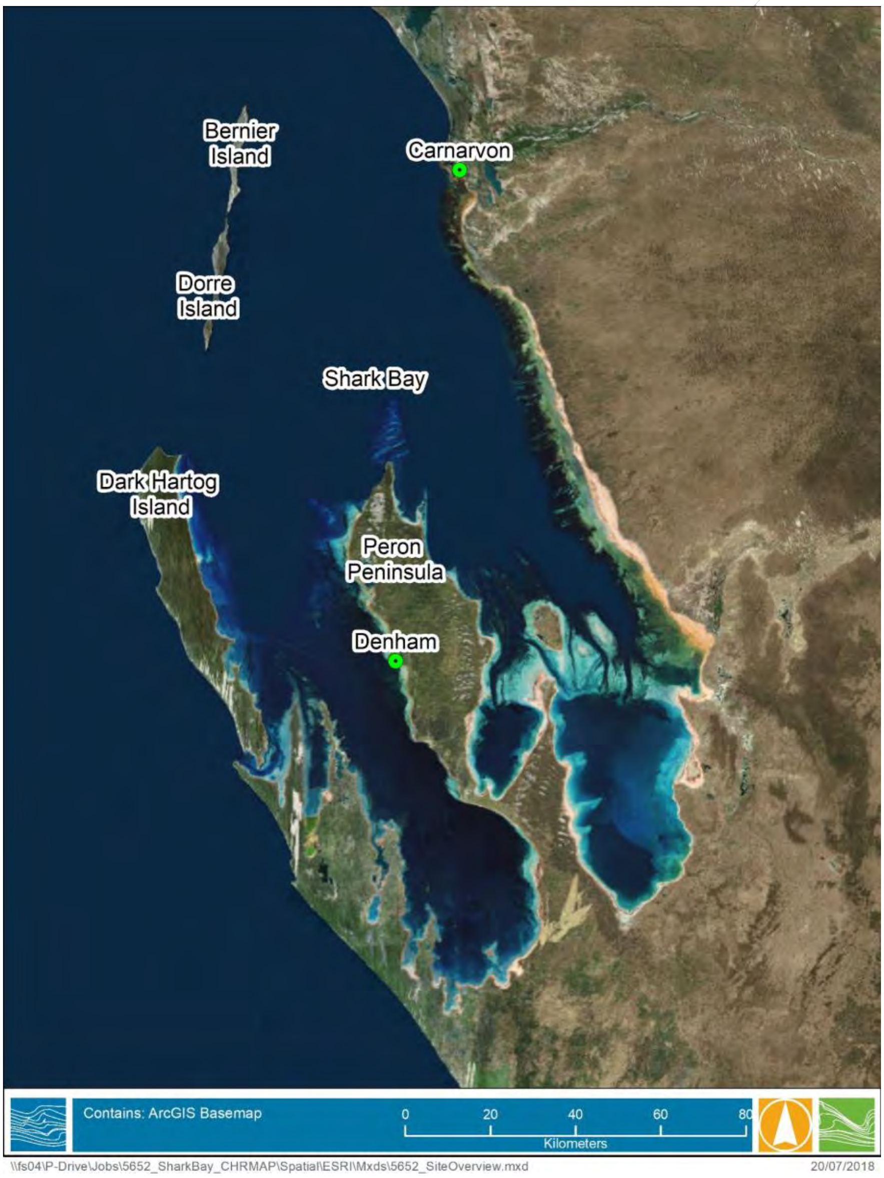

FIGURE 3-1 LOCATION OF THE STUDY SITE WITH WITHIN SHARK BAY

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3.1 Oceanographic Conditions

3.1.1 Climate & Wind

Denham sits at the northern end of the subtropical zone and as a result experiences distinct wet and dry seasonality, with 78% of the area's total rainfall (223.2 mm total per year) occurring in the low-sun half of the year (April to September). Despite the dominant winter rains, the study site is classified directly on the crossover between a hot desert climate (BWh) and a hot semi-arid climate (BSh) using the Köppen climate classification (BoM, 2018a).

A wind rose for Shark Bay Airport is displayed in Figure 3-2. The majority of the winds come from the southern sector; almost 45% of the time winds are from the south-southwest through to the south-southeast. Wind speeds are on average about 5 m/s (~17 km/hr), varying from 3.5 to 6.5 m/s. Extreme winds can be from 9 to 18 m/s (32 to 67 km/hr).

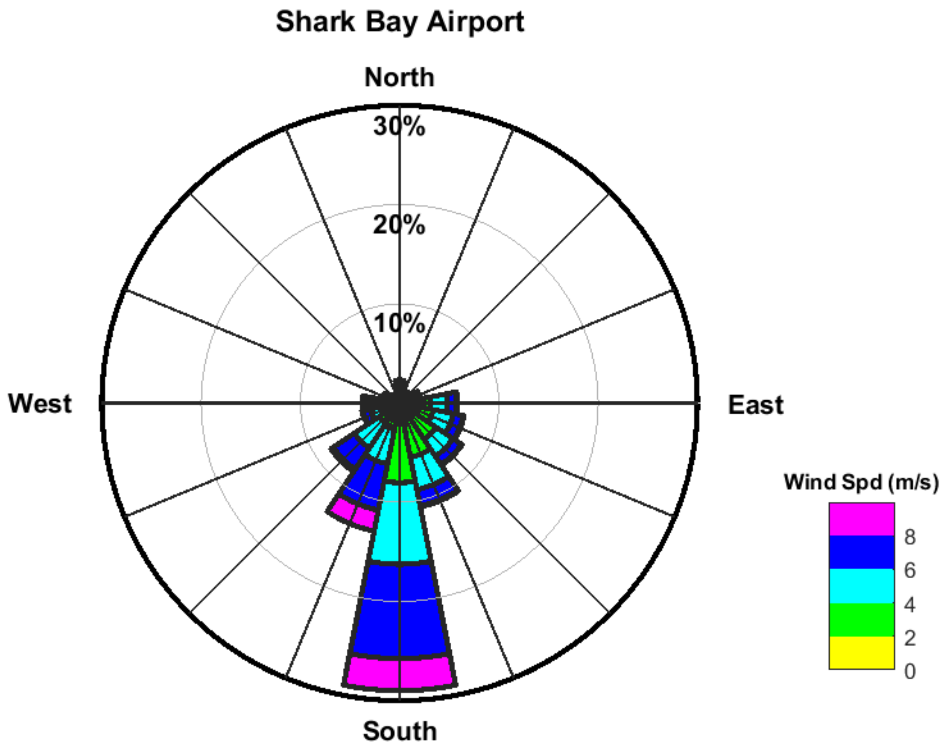

FIGURE 3-2 SHARK BAY AIRPORT WIND ROSE: 2000 TO 2018 (10-MINUTE MEAN)

3.1.2 Water Levels

The study area is located within a climatically transitional zone on the Western Australian coastline, experiencing mid-latitude and tropical weather systems and falling within the shift from diurnal to semi-diurnal tidal dominance (moving north). The townsite experiences a typical tidal range of 0.3 to 1.1 m (data from Australia National Tide Tables 2018).

TABLE 3-1 TIDAL PLANES AT DENHAM

Tidal Level	m CD	m MSL
Highest Astronomical Tide (HAT)	1.70	0.85
Mean Higher High Water (MHHW)	1.40	0.55
Mean Lower High Water (MLHW)	1.00	0.15
Mean Sea Level (MSL)	0.85	0
Australian Height Datum (AHD)	0.80	-0.05
Mean Higher Low Water (MHLW)	0.70	-0.15
Mean Lower Low Water (MLLW)	0.30	-0.55
Lowest Astronomical Tide (LAT) & Chart Datum (CD)	0	-0.85

3.1.3 Waves

Outside Shark Bay, waves are dominated by Southern and Indian Ocean swells. However, these have limited influence in Shark Bay (Eliot et al. 2012) due to the sheltering effects of Dirk Hartog and Dorre Islands. As such, waves approaching Denham are predominantly wind-driven, both from the ambient southerly sea breezes as well as during storms / cyclones.

These wind-generated waves are both fetch and depth limited. The dominant southerly winds mean the fetch is limited to about 40km. Shallow sand bars extending offshore limit the energy that does reach the foreshore. Therefore, the majority of the waves approaching Denham are likely to be less than 0.5m. Waves greater than this height, perhaps up to 1m, are only expected in the nearshore during extreme events.

3.1.4 Currents

Shark Bay is also sheltered from the offshore current system, which is dominated by the southward flowing Leeuwin Current (DEWHA, 2007). Currents inside Shark Bay are locally driven by wind and to some extent the tide. A seasonal, wind driven, northward flowing current known as the Shark Bay Current, exits the bay and enters the main flow of the Leeuwin Current (DEWHA, 2007).

Current speeds at Denham are expected to be quite small; waves are the dominant sediment transport mechanism.

3.2 Geomorphological Setting

The Gascoyne region contains a large portion of unconsolidated Holocene landforms overlying Quaternary rock layers, usually limestone or sandstone (Eliot et al. 2012). These layers support the overlying active sediment which interacts with coastal processes to continually develop the shoreline. This forms the basis of the coastal geomorphological setting for the region.

The lower local foreshore area appears to be a storm ridge structure (beach dunes) and remnant tidal flat (Eliot et al. 2012). Similar loose sedimentary structures would be likely to shift landwards back to the scarp line due to stresses from storm events and sea level rise. However, the engineered coastal interface along much of the town foreshore has altered natural evolution of the local geomorphology.

There is a scarp extending steeply upwards from around the 4m AHD contour. This appears to be the Quaternary rock layers, the presence of which may limit the level of erosion. This is particularly the case seaward of the Denham Seaside Caravan Park, and to the west around to the public lookout, where the scarp line is quite close to the existing shoreline.

3.3 Shoreline Description

Water Technology performed a site inspection of the townsite and greater study area on the 3rd of May 2018. A major aim of this visit was to document, photograph, and characterise the entire coastline to assist in the compartmentalisation and analysis of the area. For the purposes of the assessment, the coastline was divided into 5 distinct compartments based on natural and built features; these are displayed in Figure 3-3.

This separation into coastal precincts does not imply that the coastal processes within each section are in any way compartmentalised. They are by no means isolated or discrete sections of shoreline, since the processes affecting each have considerable influence on the others. However, this partitioning lends itself to a more concise explanation of natural processes affecting the shoreline.

Descriptions of each section, the features of note, and representative photographs have been included in the following chapters. Historical shoreline position data has been analysed and presented in Chapter 5.2 for all sections.

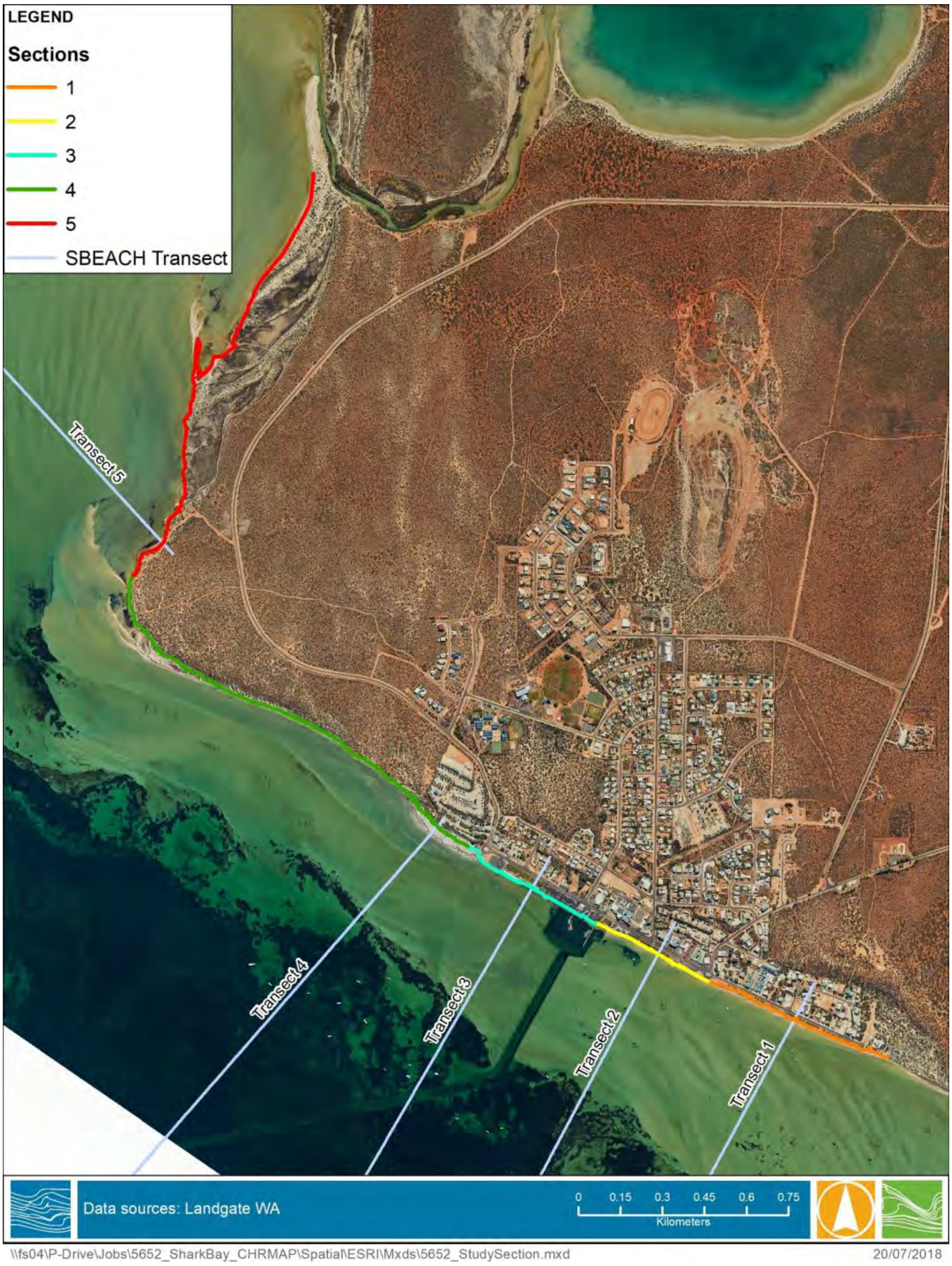

FIGURE 3-3 FIGURE OF STUDY AREA SECTIONS AND SBEACH TRANSECTS

3.3.1 Section 1

Section 1 extends from the south-eastern extent of the study area to the southern end of the ad-hoc seawall just south of the Denham-Hamelin Rd and Knight Terrace roundabout. This section is primarily composed of sandy beach and low vegetated foredunes seaward of the Terrace. The vegetated foredune is generally 10-20 m in width and is broken up by numerous drains, paths and an old boat loading area. The majority of the section appears to be close to its natural state, with no protection, reclamation or renourishment works between the road and the shoreline. However, it is difficult to know how this area has evolved without detailed records.

The section contains a small rock protection structure adjacent to and serving the turnaround at the southern end of Knight Terrace. The rest of the section comprises of a very low foredune primarily vegetated with grasses and occasional shrubs. Rarely does the beach face rise above the level of the adjacent road. At regular intervals, dedicated drainage channels collect the stormwater from the road and direct it across the foredune.

The sediment is reasonably fine and is studded with shells; seagrass wrack is present at the high tide mark. Evidence of aeolian transport is visible across the beach face.

FIGURE 3-4 ROCK SEAWALL WITH VARIABLE ARMOUR SIZING PROTECTING KNIGHT TERRACE TURNAROUND (LEFT); TYPICAL BEACH PROFILE IN SECTION 1 (RIGHT)

FIGURE 3-5 ROAD TO BEACH DRAINAGE INTERFACE ON KNIGHT TERRACE (LEFT); BEACH FACE SHOWING EVIDENCE OF AEOLIAN SEDIMENT TRANSPORT

3.3.2 Section 2

Section 2 extends from the commencement of the ad-hoc seawall or revetment at the southern roundabout to the southern commencement of the engineered seawall at the commercial jetty. The beach face is generally narrow with regular tidal action reaching the rock armour (evidenced by seagrass wrack position). The revetment in the southern half of this section comprises of variable armour size and exhibits significant signs of failure along its length. The structure rarely rises above the road level and does not appear to be sufficiently designed for long-term protection. The foreshore reserve in lee of the wall ranges from 5-15 m wide (to the Terrace and coastal pathway) and is sparsely vegetated.

The northern half of this section encompasses a revetment with a slightly higher crest level and wider setback to the Terrace, which has been used for public open space such as grassy areas, benches, and cooking areas. This second revetment structure appears to contain the same variable armour sizing, with an estimated diameter ranging from 0.15 – 0.8 m. Similar signs of damage and failure, such as slumping and armour fallout, are present along the entire structure. Loss of armour stability during energetic elevated water level events may engender significant risk that could remain concealed within the structure indefinitely until movement is triggered by additional loading (e.g.: movement due to children playing on the rocks). At the interface between these two walls is an area of eroded dune with some scattered small armour rocks present.

The Fibreglass Reinforced Plastic (FRP) sheet-pile groyne at the northern end of this section creates an area of wider beach face (40 m long on south side, 20 m long on north side). The 20 m north section has a vertical rock wall backing the small section of beach that is controlled by the groyne and rock revetment on either side.

FIGURE 3-6 TYPICAL SECTION OF BEACH AND ROCK ARMOUR STRUCTURE (LEFT); GAP BETWEEN TWO STRUCTURES CAUSING LOCALLY INCREASED EROSION (RIGHT)

FIGURE 3-7 WIDE BEACH AND IMPROVED ARMOUR STRUCTURE IMMEDIATELY ADJACENT TO FRP GROYNE (LEFT); LANDWARD END OF FRP GROYNE AND SMALL BEACH SECTION UP TO (RIGHT)

3.3.3 Section 3

Section 3 encompasses the dredged footprint with commercial and public boat launching facilities, and extends northwards to the tie in of the rock revetment directly seaward of the roundabout at Stella Rowley Dr and Knight Terrace. The coastal interface in the section is spanned by a large rock armour revetment intersected by three boat launching ramps. No dry beachface was evident during the site inspection and natural coastal processes appear modified due to the boating facility and associated works.

The coastal protection structures in the section were in good condition. The northern half of the revetment appears older and utliises a smaller average armour size. This section also appears to have a lower crest level and exhibits evidence of minor failure that was not expected to decrease structural effectiveness. Seagrass wrack buildup at the ramp locations appeared to inhibit boat launching somewhat. It is understoond this is perdiocially cleared manually using a tractor.

The area landward of the revetment is primarliy composed of boat launch parking and associated infrastructure, as well as public open space. The northern half of the section contains a section of sparsely vegetated sandy reclaimed land between the revetment and the coastal path that does not appear to be utilised for recreation.

FIGURE 3-8 TYPICAL SECTION OF ROCK ARMOUR REVETMENT ALONG SECTION 3 (LEFT); COMMERCIAL BOAT LAUNCHING RAMP WITH SOME SEAGRASS WRACK ACCUMULATION (RIGHT)

FIGURE 3-9 NORTHERN HALF OF SECTION WITH LOWER CRESTED SEAWALL AND SPARSELY VEGETATED BEACH

3.3.4 Section 4

Section 4 extends from the northern extent of the seawall to Lagoon Point where the shoreline convexity reaches its maximum. This section comprises a wide section of beach seaward of the caravan park and a narrow beach abutting steep dune faces up to 25 m AHD. A transient sediment spit presents outwards from the shoreline at the northern extent of the section, indicating long term net longshore drift through the section and around the headland towards the north.

The southern 300 m of the section has received a significant volume of sand renourishment in the past as advised by the Shire. The original shoreline interface and renourishment is clearly viewable from aerial photography and onsite, intersected by a line of low scarp (1-2 m in height) with sections of exposed loosely cemented sedimentary layers. This shoreline corresponds with the 1956 shoreline position supplied by the Department of Transport (DoT) (refer Chapter 5.2 and Appendix A). Sporadic vegetation has begun to consolidate the renourished area below this scarp. The seawall tied in at the southern extent of the section appears to have accented erosion immediately northwards, which pertains to the net sediment transport in the area. Renourishment in the area appears to be relatively stable but is likely to be slowly transported out of the area over time. More detailed information regarding the renourishment quantities and dates would be required to undertake a more detailed analysis of sediment processes in the area.

The north-western majority of the section does not directly interact with the built environment and has significant relief compared with other areas. It is not expected that erosion and inundation will have a significant impact at this site.

FIGURE 3-10 SOUTHERN EXTENT OF SECTION 4 VIEWED FROM THE REVETMENT TIE-IN. RECENT RENOURISHMENT AND PRE-NOURISHMENT SHORELINE VISIBLE (LEFT); SECTION OF EXPOSED SCARP REPRESENTATIVE OF THE 1956 SHORELINE LOCATION (RIGHT)

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FIGURE 3-11 THE NORTH-EASTERN EXTENT OF SECTION 4 AS VIEWED FROM THE NORTH-EASTERN EXTENT OF THE CARAVAN PARK

3.3.5 Section 5

Section 5 extends from Lagoon Point in the south to the entrance of Little Lagoon. This section of the study area is oriented facing north-northwest, in contrast with the rest of the study area, and has experienced minimal development. Stella Rowley Drive tracks along this section and provides access to some recreational vehicle tracks and a small car park along the shoreline just north of the point. The shoreline has several natural sediment and rocky/reef type structures presenting from the shoreline, most prominently the sandbar extending northwards over the lagoon entrance channel from the southern boundary.

The majority of this section is fronted by low lying sand dunes with low lying areas connected to the open water by tidal channels resulting in several small salt water marshes. Tyre tracks are visible throughout this area, especially at the northern end, where a track gives vehicles access to the length of the lagoon channel and the sandy area to its south, including the transient bar.

FIGURE 3-12 SOUTHERN HALF OF SECTION 5 SHOWING COASTAL ACCESS TRACK AND A TRANSIENT SEDIMENT FEATURE AT THE MIDPOINT OF THE SECTION

FIGURE 3-13 LOW LYING COASTAL FORESHORE IN SECTION 5 WITH INTERTIDAL MARSH AREAS VISIBLE

3.4 Sediment Transport

The townsite is located within the secondary sediment compartment from Goulet Bluff in the south to Cape Peron North (Eliot et al. 2012). This cell is divided by five headlands that influence the shape of the local coastline. The area is predominantly backed by low limestone scarps and fronted by sub-tidal shoals and rocky outcrops. Beaches are mostly said to be perched on rock overlain by sandy and shelly sediments, whose profiles differ depending on the protection provided by offshore structures and terraces (Eliot et al. 2012).

Anecdotal and observational evidence suggest that net sediment transport is to the north, driven largely by prevailing winds seen in Figure 3-2. Features such as the FRP sheet-pile groyne collect sediment on the southern side and are eventually bypassed. Indeed, this was the reasoning behind the location of the sheet-pile groyne updrift of the dredged jetty zone, to minimise the dredging frequency requirements. Significant tidal flats offshore and south of the Denham townsite likely provide sediment to the area. This agrees with the anecdotal evidence that Section 1 remains relatively wide and unsusceptible to energetic storm events.

The active coastal zone along the town's foreshore inhibits longshore sediment transport to the north. As a result, sediment supply to Section 4 is expected to be net negative (without renourishment) potentially causing erosion observed in the area. Town officials noted that infrequently maintenance dredge spoil has been utilised to satisfy the sediment deficit in this location, with acceptable success in recent years.

Aeolian sediment transport was witnessed during Water Technology's site visit in May 2018. The amount of wind-blown sediment transport depends on the sediment grain size as well as the wind speed. The D_{50} for the study site is estimated to be approximately 0.17 to 0.25 mm, based on observations at the site. Using the equations for initiation of motion of sediment in Hsu & Weggel (2002), the threshold wind speed at a height of 2 m above the beach is 4.3 to 5.5 ms^{-1}. To estimate the period of time this wind speed is exceeded at the study site, the threshold wind speed was converted to the wind record at Shark Bay Airport by applying both a height and wind-over-water factor as per CERC (1984). From this it was calculated that approximately 60-70% of the time sand can be transported by wind; a significant period of time. Dune vegetation would likely improve the sediment trapping function of the beach significantly.

3.4.1 Coastal Processes

The dominant sediment transport processes influencing the shoreline around Denham are:

- Net northwards longshore transport
- Cross-shore transport during cyclones / storms
- Seawall adjacent to the boat harbour limits cross-shore erosion
- Wind driven transport is a contributor to beach stability
- Low-lying dunes in Section 1 may be susceptible to erosion

4 COASTAL INUNDATION ASSESSMENT

4.1 Modelling Overview

For this assessment, hydrodynamic (HD) and spectral wave (SW) modules within MIKE by DHI software package have been used. The MIKE 21 Flexible Mesh (FM) HD/SW model is based on an unstructured flexible mesh and uses a finite volume solution technique. The hydrodynamic module simulates water level variations and flows in response to a variety of forcing functions such as:

- Momentum dispersion
- Bottom shear stress
- Coriolis force
- Wind shear stress

The modelling system is based on the numerical solution of the two-dimensional shallow water equations - the depth-integrated incompressible Reynolds averaged Navier-Stokes equations. Thus, the model consists of continuity, momentum, temperature, salinity and density equations.

The wave model simulates the growth, decay and transformation of wind-generated waves and swell in offshore and coastal areas. The model includes the following phenomena:

- Wave growth by action of wind
- Non-linear wave-wave interaction
- Dissipation due to white-capping
- Dissipation due to bottom friction
- Dissipation due to depth-induced wave breaking
- Refraction and shoaling due to depth variations
- Wave-current interaction
- Effect of time-varying water depth and flooding and drying

4.2 Modelling Scenarios

A range of cyclone events were simulated for this assessment, as per Table 4-1. The results from these simulations were used to generate the coastal inundation hazard maps. The sea level rise scenarios are as per those presented in Table 2-1.

TABLE 4-1 SCENARIO MATRIX

Cyclone Events	Water Levels			
	Present Day	2030	2050	2118
20-year ARI	✓	✓	✓	✓
50-year ARI	✓	✓	✓	✓
100-year ARI	✓	✓	✓	✓
500-year ARI	✓	✓	✓	✓

4.3 Model Bathymetry

A regional model was developed with an extent shown in Figure 4-1. As shown, the model boundary extends offshore into the Indian Ocean. This allows the model to include the effects caused by larger ocean circulations, as well as swell generated during cyclone events.

The mesh is comprised of triangular and quadrilateral elements. This approach enables a variation of the horizontal resolution of the model mesh within the model area, and therefore for a finer resolution in selected sub-areas. The computational triangular mesh of the model is made with sufficiently small cells to resolve the detailed conditions in the study area, especially along Denham townsite's coastline.

The model mesh was established as a compromise between computational time and sufficient resolution in the study area. The model resolution increases towards the project area, where the mesh size is approximately 15m. The model mesh applied for the simulation has 13,453 nodes. Figure 4-2 presents the mesh zoomed in closer to the Denham townsite.

The mesh was developed using the hydrographic surveys supplied by the Department of Transport (DoT), and the photogrammetry supplied by Landgate. The corresponding aerial photograph from 2017 was applied to supplement this data, and to assign the resolution of the model mesh to match the features of the area. Survey elevation/position data associated with the roads and pathways in Denham townsite was also provided by the Shire of Shark Bay and supplemented the available data to prepare the final model mesh.

4.4 Tidal Boundary Conditions

The HD model is driven by tidal water levels specified at its open boundaries, varying both in time and along the boundary. The locations of the model open boundaries are presented in Figure 4-1. These tidal boundaries were extracted from the Global Tide Model developed by DTU Space (a research institute of the Technical University of Denmark). The model is available on a 0.125° x 0.125° resolution grid for the major 10 constituents in the tidal spectra. The model utilises the latest 17 years' multi-mission measurements from TOPEX/Poseidon, Jason-1 and Jason-2 satellite altimetry for sea level residual analysis. The constituents cover the semidiurnal M2, S2, K2, N2, the diurnal S1, K1, Or, P1, Q1 and the shallow water constituents M4.

Time-varying tidal water levels at a point midway along the northern boundary are illustrated in Figure 4-3. For the simulation of the proposed sea level rise scenarios, the projected sea level rise was added to the tidal boundary conditions for each open boundary.

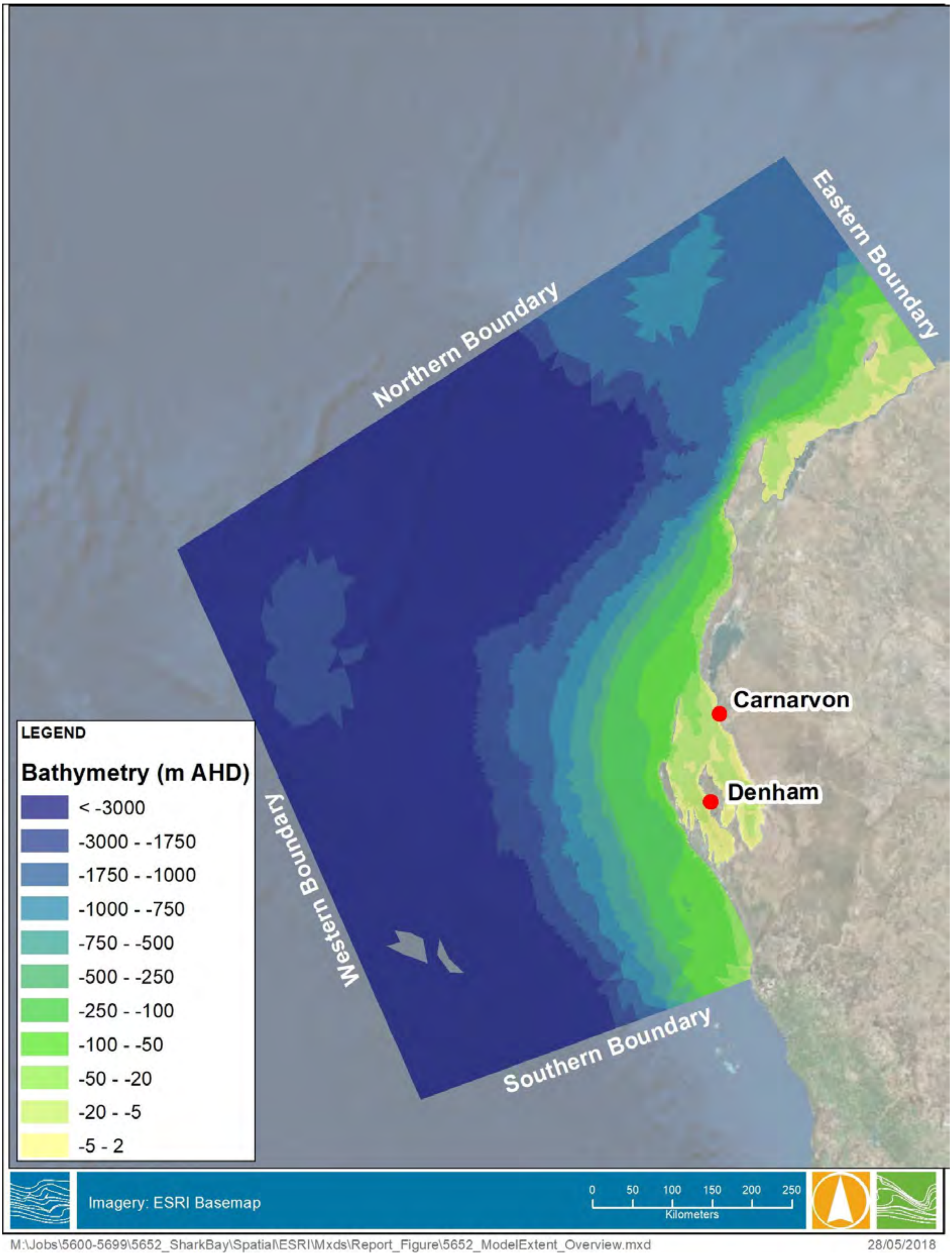

FIGURE 4-1 MODEL EXTENT OVERVIEW

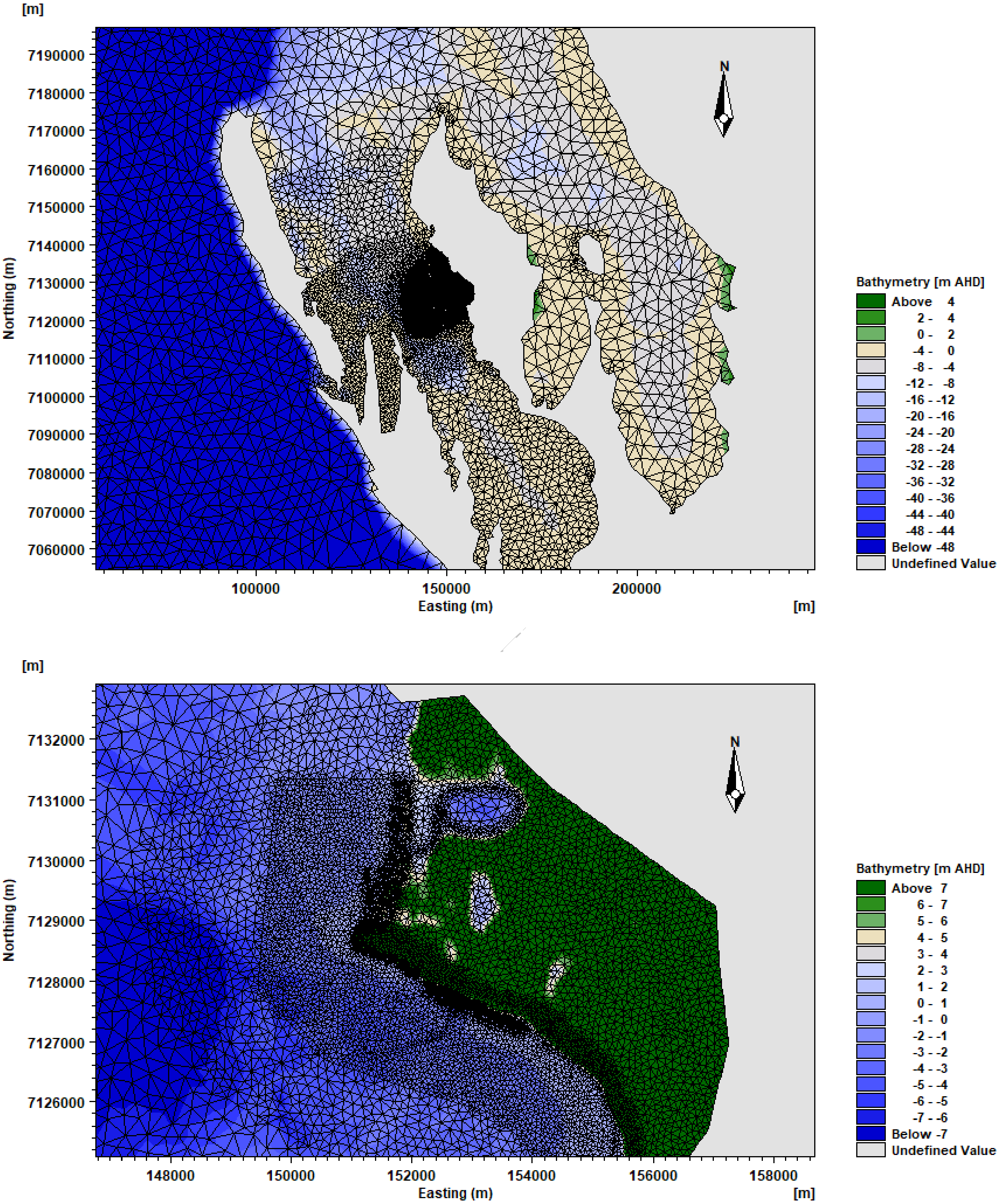

FIGURE 4-2 MODEL MESH – DENHAM AREA

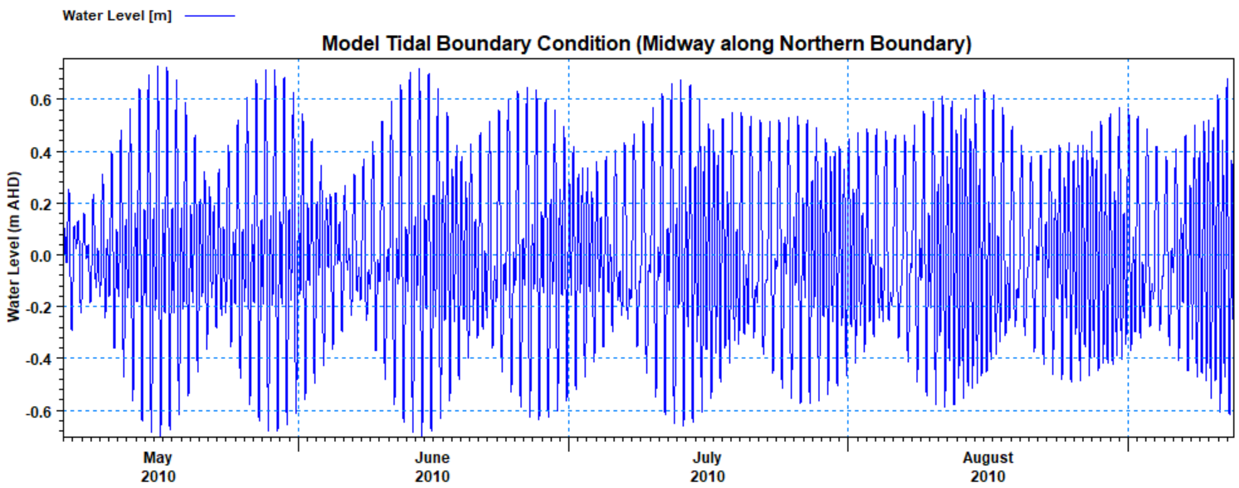

FIGURE 4-3 MODEL TIDAL BOUNDARY CONDITIONS (MIDWAY ALONG THE NORTHERN BOUNDARY)

4.5 Wind Forcing

The wind field generated under a moving cyclone, and the associated energy transfer between the ocean-atmosphere interface affects the local and far-field oceanographic conditions. In particular, wind stresses can have a significant effect on the water level in areas with shallow bathymetry.

As discussed in the Establishing the Context Chapter Report (Water Technology, 2018), MRA (2014) undertook a coastal inundation study for Denham. The wind field model used for the MRA (2014) study is the Holland (1980) parametric cyclone wind-field model which can be utilised directly in MIKE21's Cyclone Wind Generation Tool.

The model inputs required to generate cyclonic wind/pressure fields for the events listed in Table 4-1 are as follows:

- p_n – the ambient surrounding pressure field or neutral pressure
- p_c – the pressure at the storm centre or central pressure
- Cyclonic track (geographical coordinates)
- B – shape parameter added by Holland to match different kinds of storm pressure profiles. Hence, it is usually referred to as the Holland parameter or profile 'peakedness'. According to Holland, the range of B is: 1<B<2.5.
- R_{mw} – radius to maximum winds
- A timeframe must be applied, in order to assign the appropriate phasing of the tidal signal with the peak of the storm.

Cyclone track information was provided by MP Rogers & Associates Pty Ltd (MRA, 2014) for the events presented in Table 4-1. These were selected from a database of 1,000 years of synthetic cyclones developed using a Monte Carlo model by MRA (2014). Water Technology's project scope specified use of the design cyclones developed by MRA (2014). For detailed information on the development of the design cyclones please see MRA (2014).

The supplied track information was limited to time as an interval (rather than time stamp), geographic location, and pressure drop. To complete the model input requirements for the generation of the cyclonic wind/pressure fields, additional calculations and assumptions were undertaken and these are discussed below.

Historical data from the Bureau of Meteorology (BoM) was purchased and statistical analysis performed on this dataset. Data includes long-term wind speed and air pressure data at the following meteorological stations:

- Denham (Station ID: 006044)
- Shark Bay Airport (006105)
- Carnarvon Airport (006011)

The ambient air pressure (P_n) for each of the design events was calculated based on the Shark Bay Airport half-hourly dataset from 2000 to 2018. As the timing data for all the MRA (2014) events was unavailable, the pressure has been based on the mean historical atmospheric pressure at the airport for northwest cyclonic season (November to April). Details of the ambient air pressure from Shark Bay Airport are presented in Table 4-2.

As pressure differentials for each step of the design events were available, this allowed the calculation of the central air pressure (P_c) by subtraction from the calculated ambient air pressure.

TABLE 4-2 MONTHLY AVERAGES OF ATMOSPHERIC PRESSURE FROM SHARK BAY AIRPORT

Month	Mean Pressure (hPa)	Number of Observations
November	1012.13	17093
December	1009.35	18059
January	1007.79	17854
February	1008.31	16057
March	1011.19	16981
April	1014.87	16094
Seasonal Mean	**1010.6**	-

The B parameter was set at 1. This is based on the extensive work undertaken by Cardno (2015), and their earlier studies self-referenced within that report.

R_{mw} for each track was calculated as per the method described in Cardno (2015). R_{mw} can be calculated by applying the equation presented below; R_c is a fit coefficient. The fit coefficient can be calculated by analysing BoM's cyclone database for cyclones passing near to Denham. A radius of 500km was applied, both because the dataset contained few R_{mw} values, and there are not many cyclones that passed close to Denham in the record (compared to say Broome or Onslow, further north into the cyclone-prone region). A non-linear fit was assigned to the central pressure ./ R_{mw} relationship as per the equation below to calculate Rc. This relationship is presented in Figure 4-4.

$$R_{mw}(t) = \frac{Rc}{P_n - P_c(t)} \qquad \text{(Cardno,2015, adapted from Harper et al (1989 and 1993))}$$

Once R_c was determined (R_c = 802), the equation above could be applied to calculate R_{mw} for each P_c in the cyclone tracks.

Figure 4-5 presents an example wind field for one time-step from the 500-year ARI cyclone event; the cyclone track is overlain in the pink dots. This provides an indication of how wind forcing is applied over the hydrodynamic model grid, shown in Figure 4-1. The relevant track parameters for input into the model are provided in Appendix A. These are interpolated onto a 1-hour time step for the model input to ensure the wind field is relatively smooth in the model simulation. Tracks of all the 20, 50, 100 and 500-year ARI cyclones and their relative central pressures are presented in Figure 4-6.

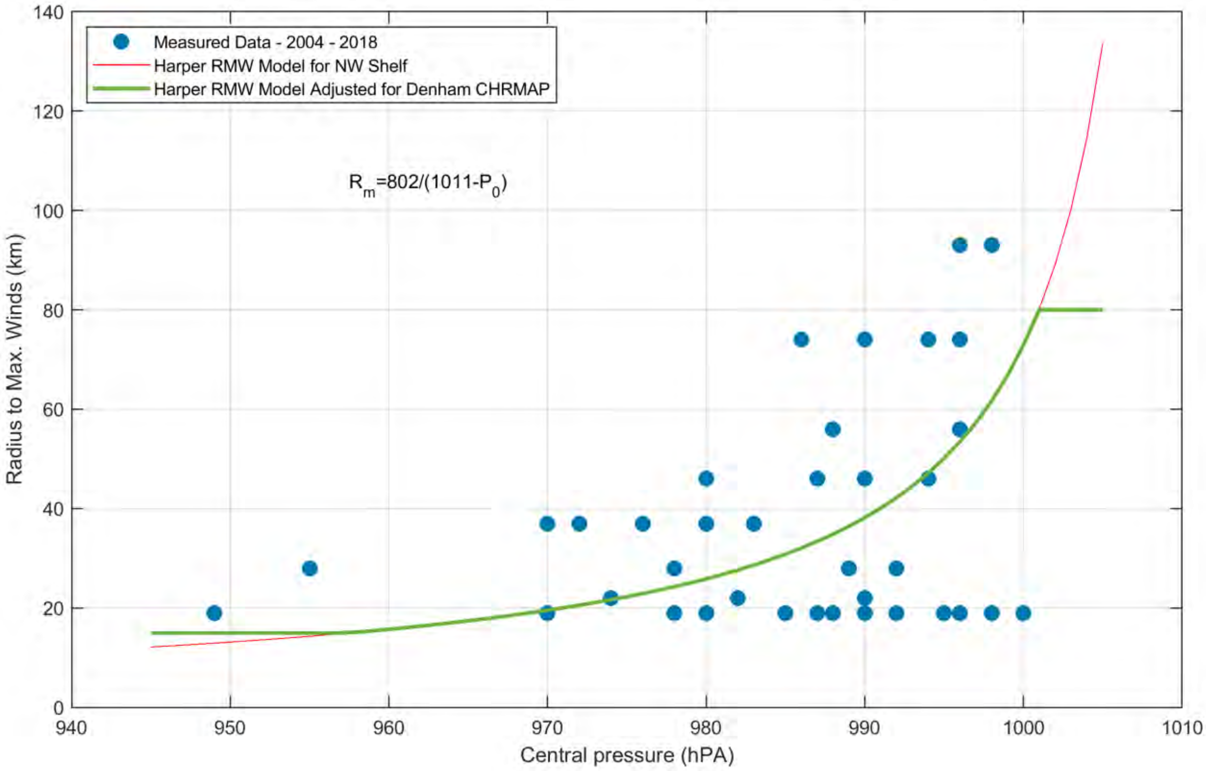

FIGURE 4-4 NON-LINEAR FIT ON RADIUS TO MAXIMUM WINDS VERSUS CENTRAL PRESSURE FOR CYCLONES PASSING WITHIN 500KM OF DENHAM

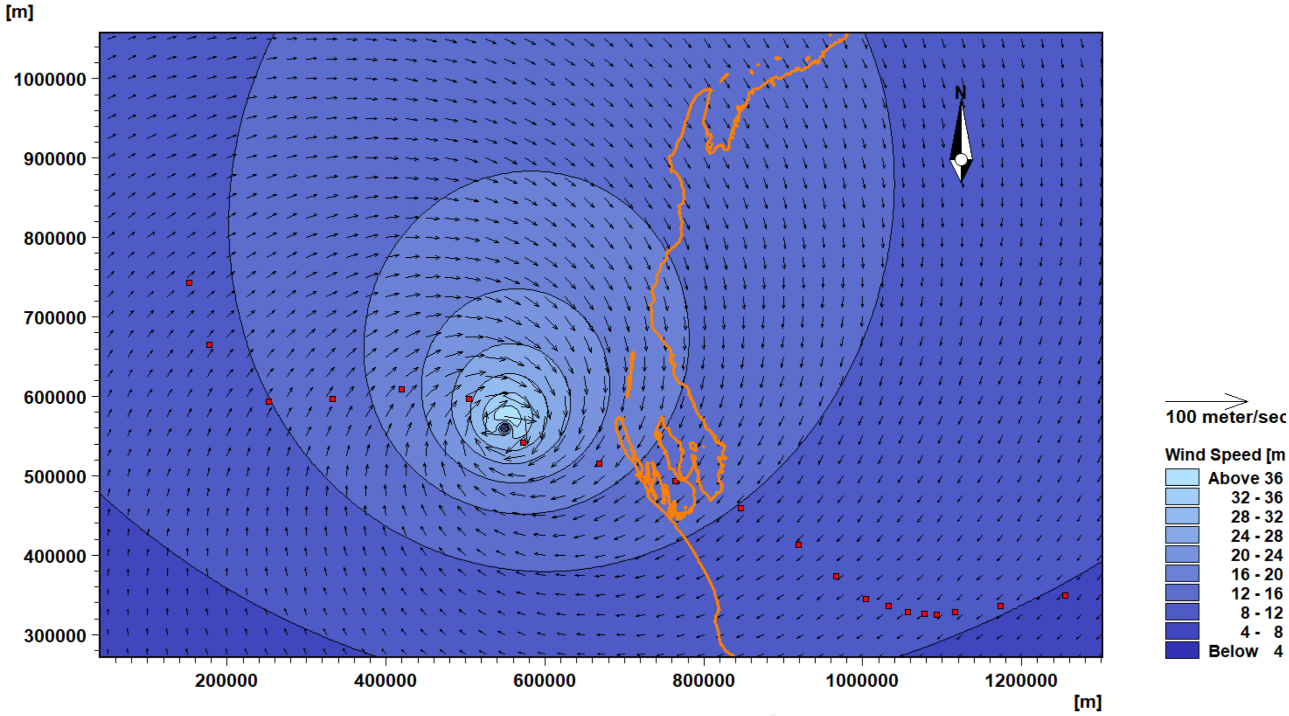

FIGURE 4-5 WIND FIELD: 500-YEAR ARI CYCLONE EVENT

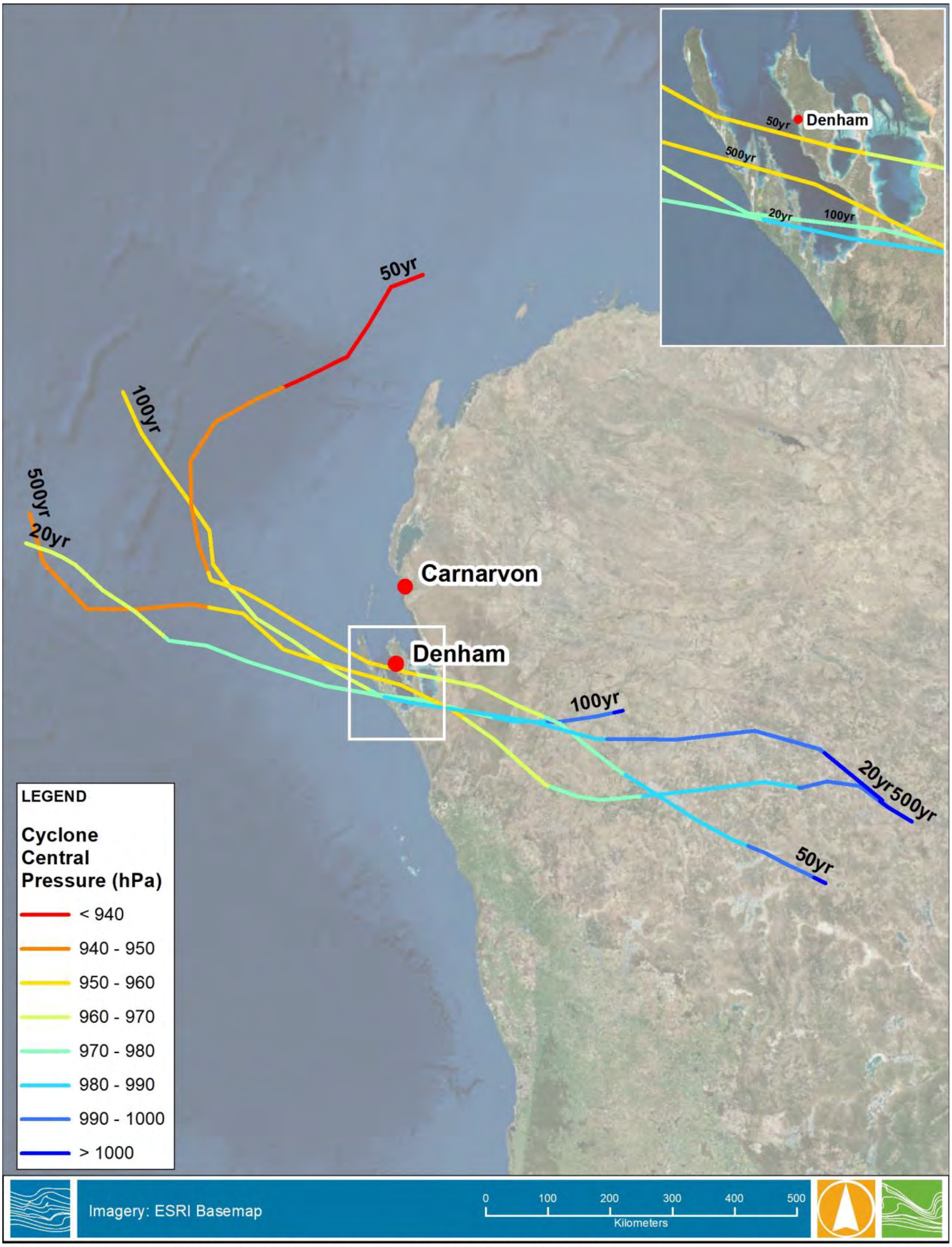

FIGURE 4-6 CYCLONE TRACKS FOR THE SELECTED EVENTS

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4.6 Simulation Period

For this assessment, spring tide conditions were selected to represent the combined effect of tides and cyclonic storm surge. The simulation period is between 10 June 2010 to 15 June 2010.

4.7 Model Setup

4.7.1 HD Model Parameters

4.7.1.1 Eddy Viscosity

The transfer of momentum through sub-grid scale turbulence is modelled through the inclusion of eddy viscosity in the horizontal extent. The eddy viscosity is given by a “Smagorinsky-type” formulation. This expresses the effects of sub-grid scale turbulence by an effective eddy viscosity related to a characteristic length scale and the local spatial current variations.

4.7.1.2 Bed Resistance

To include bed resistance a Manning M (reciprocal of Manning’s n) number of 50 $m^{1/3}/s$ is applied throughout the domain for the model domain. Land areas in Denham townsite are represented by a Manning number of 20 $m^{1/3}/s$.

4.7.1.3 Wind Friction

The air-sea momentum exchange, or the wind stress, is calculated based on the empirical formula proposed by Wu (1980, 1994) which is used for the parametrization of the drag coefficient:

$$c_d = \begin{cases} c_a, w_{10} < w_a \\ c_a + \dfrac{c_b - c_a}{w_b - w_a} \; w_a \leq w_{10} \leq w_b \\ c_b, w_{10} > w_b \end{cases}$$

Where c_a c_b, w_a and w_b are empirical factors and w_{10} is the wind speed at 10m above the sea surface. Here, wind friction is varying with the wind speed according to Table 4-3.

TABLE 4-3 WIND FRICTION VARYING WITH WIND SPEED

Wind Speed (m/s)	Wind Friction
$w_a = 7$	$c_a = 0.001255$
$w_b = 60$	$c_b = 0.005$

4.7.1.4 Flooding and Drying Parameters

Flooding and drying depths for this assessment are defined as follows:

- Drying Depth = 0.005m
- Flooding Depth = 0.05m
- Wetting Depth = 0.1m

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4.7.2 Spectral Wave Model Parameters

DHI's MIKE21 Spectral Wave (SW) model was coupled to the HD model for this assessment. The model is based on an unstructured flexible mesh comprising of triangular elements.

A fully spectral wave model has been used to simulate the propagation of waves. Wave breaking and diffraction are included in the model. Applied wave-breaking parameters in the model are gamma = 0.8 and alpha = 1. Bottom friction is a calibration parameter and the parameter selected is determined based on Water Technology experience in the study area. Model parameters are detailed in Table 4-4.

TABLE 4-4 SW MODEL PARAMETERS

Model Parameter	Parameter details
Simulation Period	10 June 2010 – 15 June 2010
Spectral Formulation	Fully Spectral Formulation
Time Formulation	Instationary Formulation
Spectral Discretization	Number of frequencies = 25 Minimum frequency = 0.035 Frequency Factor = 1.11 Directional discretization = 360 degrees Number of directions = 16 Separation of Wind sea and Swell = No separation
Energy Transfer	Quadruplet wave interaction included
Wave Breaking	gamma = 0.8 and alpha = 1
Bottom Friction	Nikuradse roughness, kn constant = 0.04
White Capping	Dissipation Coefficient, Cdis = 4.5 Dissipation Coefficient, Delta dis = 0.5 Power of mean angular frequency = -1 Power of mean wave number = -1

4.8 Model Validation

4.8.1 Water Levels

Water Technology (2018) investigated previous coastal inundation studies and noted that limited oceanographic data was available for model validation at the study site. As outlined previously, the scope of this project is to utilise information and water level values from the inundation study performed by MRA (2014). Hence, the peak steady water level (PSWL) in the coupled MIKE 21 HD/SW model was calibrated to match the PSWL for each corresponding design ARI event outlined in the MRA (2014) report. Track data for each design event (20, 50, 100, and 500-year ARI's) were supplied by MRA.

Despite utilising different hydrodynamic models, Water Technology's MIKE 21 model was able to replicate the PSWL results provided by MRA with minimal adjustment to key parameters, combined with adjusting the timing of the tidal signal. Matching these values does not necessarily reinforce the accuracy of MRA's results; in the absence of additional data it is not appropriate to suggest alternate values.

MRA (2014) noted that no cyclonic event was captured in the sporadic water level record at Denham and as such, site-specific calibration of an extreme water level event was not possible. Whilst every effort was made by MRA to calibrate their hydrodynamic model with TC's measured at other locations (Carnarvon, Useless Loop), uncertainties resulting from a lack of measured data are present in MRA's final PSWL which have been carried through to this project.

The MRA report noted that water level records within Shark Bay were a key data gap and more accurate calibration would require the collection of water level and wave data from within Shark Bay.

Tide only water level from Water Technology's MIKE 21 model was validated against predicted water level for Denham and Carnarvon. Figure 4-7 presents a comparison of predicted and modelled water level time series showing good agreement between the predicted water level at both Denham and Carnarvon and the water level output from a tide only model run.

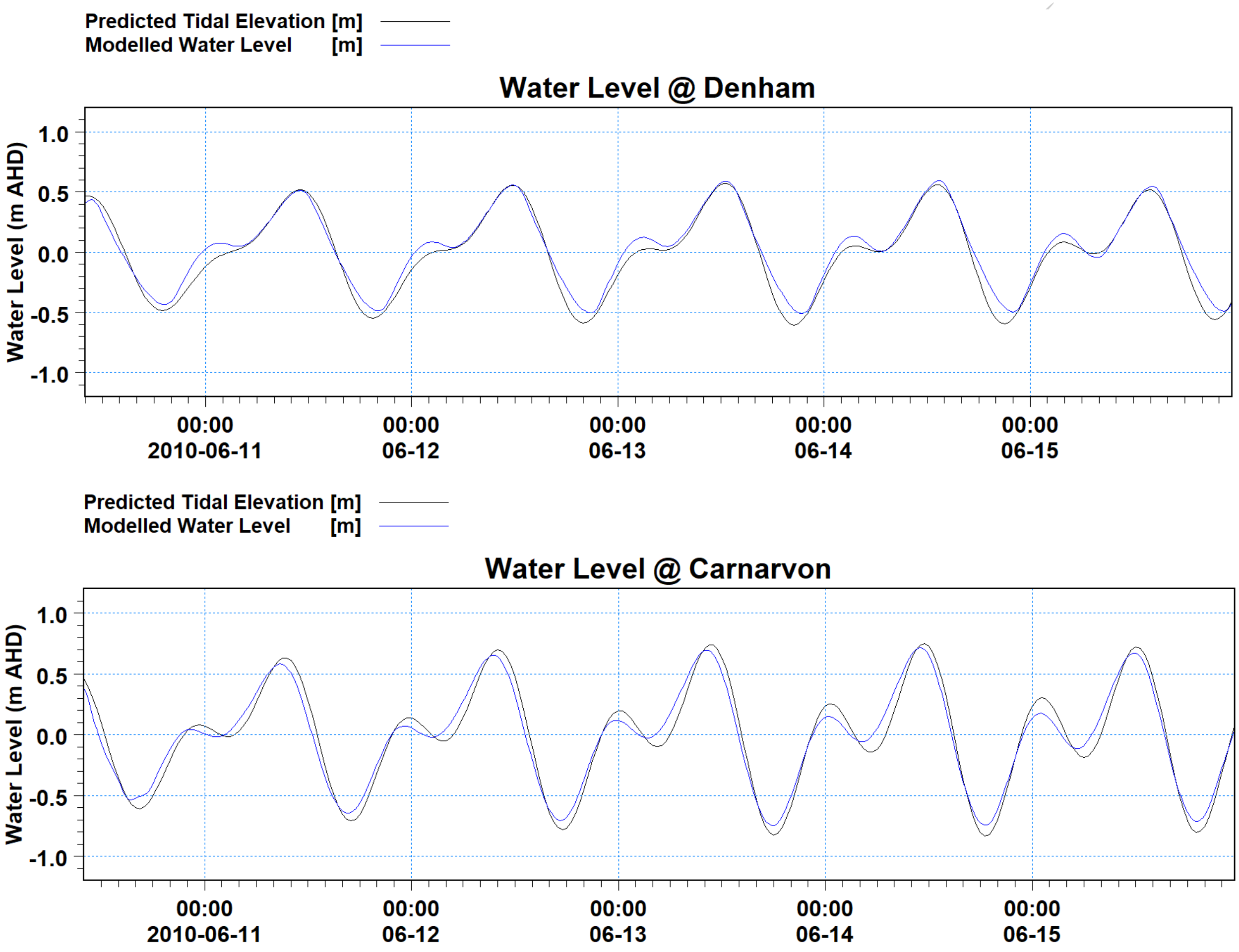

FIGURE 4-7 TIME SERIES OF PREDICTED AND MODELLED WATER LEVELS FOR A TIDE ONLY SIMULATION AT DENHAM & CARNARVON

4.8.2 Waves

Surface wave information was not supplied in MRA (2014) for comparison; little information is provided in the report regarding their calculation and impact on the final inundation level. Certainly, the scope of their study doesn't seem to require the output of wave information. As noted in Water Technology (2018), no wave data was available close enough to the study area to be utilised for model calibration. As a result, no calibration of surface wave heights has been performed.

4.8.3 Wind

The Holland wind-field model included in the MIKE 21 model was not calibrated for this project. The project scope was to replicate the design events PSWL as best as possible and did not allow for inclusion of historical Tropical Cyclone model runs to calibrate or validate the wind-field model. The same Holland wind-field model was utilised as part of the MRA (2014) report and Water Technology's matching storm surge outputs do not indicate any significant difference between the two models.

4.8.4 Summary for Decision Makers

TABLE 4-5 MODEL VALIDATION SUMMARY

- The model results from the present study match those of MRA (2014), as intended.
  - This is not a verification of MRA's results.
- It is strongly recommended that a local nearshore water level and wave data logger be installed to provide a better understanding as to the accuracy of the model results.
- This should be installed as soon as possible, and ideally take continuous measurements for at least a period of 5-years to maximise the chance of capturing a cyclone in the dataset.
- The inundation levels have a direct implication for finished floor levels of future development.
  - Raising finished floor levels to meet the design levels carries significant costs. If these are set higher than necessary due to modelling uncertainty, this represents costs the Shire could be spending elsewhere.
  - Similarly, if these levels are set too low, this poses a significant risk to infrastructure.

4.9 Water Level Design Criteria

4.9.1 Coastal Inundation Assessment Summary

The design water levels provided by MRA (2014) and matched by Water Technology's model are outlined in Table 4-6. It should be noted that the values supplied by MRA are only based on present day sea level tropical cyclone modelling plus an allowance for sea level rise at each epoch as required by the SPP2.6. No allowance has been made for the increase in cyclone intensity. As indicated by MRA (2014), the final inundation allowance, as specified by SPP2.6, is 4.2 m AHD as shown in bold. This value includes tidal, surge, and wave set-up components. It is noted that SPP2.6 requires the inclusion of wave runup for the final inundation allowance. The decision to exclude this from the table below is discussed in Section 4.9.2.

TABLE 4-6 DESIGN WATER LEVELS FOR THE TOWN OF DENHAM (M AHD); NUMBERS IN BOLD ARE THE ALLOWANCE FOR INUNDATION

ARI (years)	Present Day	2030	2050	2118
20	1.9	2.05	2.2	2.8
50	2.4	2.55	2.7	3.3
100	2.7	2.85	3	3.6
500	3.3	3.45	3.6	**4.2**

4.9.2 Wave Runup Allowance

SPP2.6 requires an allowance for wave run-up to be included in the definition of the design water levels, as indicated previously. Wave runup is the maximum elevation of wave uprush above still-water level (Smith, 2003). This is the combination of wave setup and swash, which is the fluctuation of the water level about the mean setup value. Wave set-up is the increase in steady water level near a coastline due to wave breaking and the conservation of the resultant momentum flux (Smith, 2003). This increase can be significant during extreme weather events due to the large waves generated.

Wave set-up was included in the coupled MIKE 21 HD/SW model, and the MRA (2014) modelling. For the purpose of this study wave runup was calculated using the SBEACH model utilised for the coastal erosion assessment. The model results from the SBEACH simulations (refer Chapter 5) indicate a runup of **0.3 m** should be allowed for a 500-year ARI design event for all sections of the study area.

To match the design water level values provided in MRA (2014), some scaling up of the results was required. Given the uncertainties in the modelling output, it is not recommended to add 0.3m to the 500-year ARI design event, the requirement of SPP2.6. Instead, as discussed in Section 6, a locally placed nearshore water level and wave data logger should be deployed to provide a better understanding as to the accuracy of the model results and thus accurately define the PSWL and wave runup allowance.

Once improved model calibration is achieved, the value can be updated with run-up included. Given the inundation level refers to the 500-year ARI in 2118, there is relatively low risk for this value to be updated over the next 5-years. It is recommended the specified Finished Floor Level in the Shire's Local Planning Scheme remain at 4.2m AHD until the relevant data has been obtained.

4.10 Tsunami Allowance

It is a requirement of SPP2.6, WAPC (2013), to include an allowance for inundation due to tsunami when planning for development in the coastal zone. We have undertaken a literature review of existing studies to provide this allowance for the study site.

Geoscience Australia has mapped the tsunami hazard at the 100m depth contour across the Australian coastline (Geoscience Australia, 2009). Figure 4-8 presents the predicted wave amplitude offshore from the study site for the 500-year ARI tsunami hazard. These hazard maps, and the corresponding probabilistic tsunami hazard assessment by Burbidge et al (2008), identify the coastline from Shark Bay to Dampier as the region with the highest level of hazard in Australia. This present study is south of the peak hazard at Exmouth; the hazard offshore from Shark Bay has an amplitude of approximately 0.7m at the 100m depth contour, and approximately 0.4m at the 50m depth contour (Figure 4-9). The maximum run-up ever recorded in Australia occurred at Steep Point (Shark Bay) in 2006, with a value of 9m.

The entrance to Shark Bay is approximately 27km wide between Dirk Hartog Island and Dorre Island, and 37km between Bernier Island and the mainland. Tsunami wavelengths typically would range from 10km to 500km (BoM, 2018b). It is therefore unlikely a high energy (wavelength) tsunami would be able to penetrate into Shark Bay.

Geoscience Australia (2006) undertook tsunami modelling to assess the vulnerability of the nearshore Onslow coastline from earthquake generated tsunamis originating on the Sunda Arc Subduction Zone. The simulation was run for an approximately 500-year ARI event at Highest Astronomical Tide (HAT), Lowest Astronomical Tide and Mean Sea Level. Local bathymetry played a large role in the measured tsunami water level in the nearshore. The resultant inundation levels varied from 0.5 to 5 m AHD.

Given the tsunami hazard at Denham is lower than at Onslow, a run-up similar to or slightly less than the 500-year ARI cyclonic water level can be expected for the 500-year ARI tsunami.

FIGURE 4-8 PREDICTED TSUNAMI WAVE AMPLITUDE AT 100M DEPTH CONTOUR FOR 500-YEAR ARI (GEOSCIENCE AUSTRALIA, 2009)

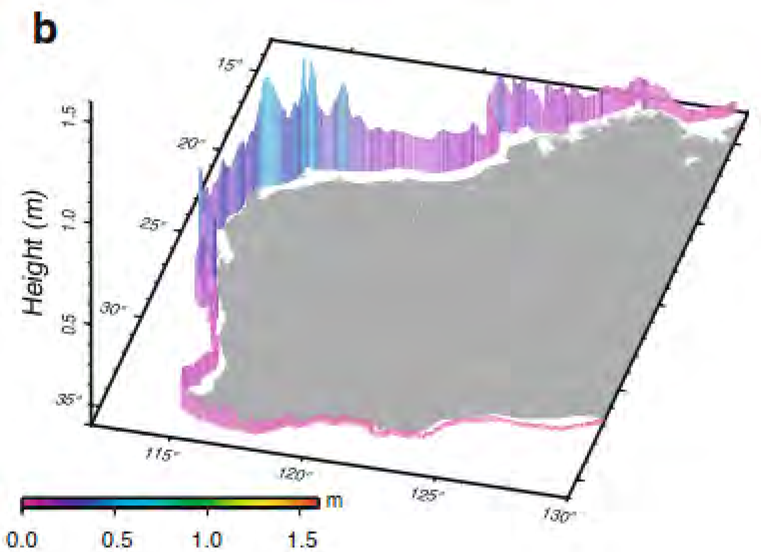

FIGURE 4-9 PREDICTED TSUNAMI WAVE AMPLITUDE AT 50M DEPTH CONTOUR FOR 500-YEAR ARI (BURBIDGE ET AL, 2008)

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5 COASTAL EROSION ASSESSMENT

The assessment of coastal processes affecting the study site has been undertaken based on available data and utilising the methodology specified in SPP2.6, as per the description in Chapter 2.2.1. This chapter details the calculation of the total erosive potential over the 100-year planning time frame to define the width of the coastal foreshore reserve that allows for coastal erosion processes.

Due to the limitations of this study it is assumed that the subsurface of the shoreline within the study site is of a uniform uncemented sandy constituency. However, the actual study area is likely to encompass a spatially variable and complex three-dimensional geologic support system that may make use of the Bruun Rule unnecessary (Eliot et all, 2012). Consideration of more complex geological features is beyond the scope of this report.

5.1 S1: Current Risk by Storm Erosion

5.1.1 Determination of Storm Events

The 100-year ARI cyclone track provided by MRA was utilised as the selected storm to model acute storm erosion. This design storm track moves past the study area to the west generating significant wave energy offshore that impacts the town site and meets SPP2.6 requirements. The wave field generated by the cyclone approaches shore normal for Sections 1 to 4 at approximately the same time as the peak water level is reached, maximising erosive potential of the storm. Section 5 has a different coastline orientation, so the storm approach is slightly different. However, significant wave energy is still directed towards the shoreline, and the cyclone is considered appropriate to use in the assessment.

5.1.2 SBEACH Set-up

The potential for storm-induced acute erosion was assessed using the SBEACH numerical model as recommended by SPP2.6. This model was developed to calculate idealised sediment dynamics under short term wave action (Wise et al, 1995) and has been utilised in a range of studies including shoreline stability assessments in the northwest of Western Australia (Cardno, 2015). It is recommended in SPP2.6 for use in calculating this component of the shoreline change.

A representative beach profile was determined for each of the five study sections extending from -5 m to 5 m AHD across the beach face (profile locations shown in Figure 3-3). The bathymetry used for the hydrodynamic model was used to generate nearshore seabed levels and beach face elevations for each transect. Data was then extracted from the hydrodynamic model at the offshore terminus of each profile to force the SBEACH model. The storm data for Transect 1 is displayed in Figure 5-1 as an example; data did not vary significantly between transects.

Critical input utilised for each profile included:

- Digital elevation data from +5 m AHD down to -5 m AHD offshore (from model bathymetry, see Chapter 4.3)
- Time-series of water level from the design cyclone (tide plus surge)
- Time-series of significant wave height (Hs) which encompasses the tide and cyclone-induced surge
- Peak wave period (Tp)
- Wave direction (Wdir)

SBEACH simulations were tested with variable wave direction, as per the hydrodynamic model results, and fixed shore normal wave direction; the most conservative response was applied. Each storm was repeated 3 times in succession as recommended by SPP2.6 to determine the S1 value. Hard structures have not been included in the model profiles. However, sections with engineered seawalls are not expected to incur any erosion and sections with old or ad-hoc structures are not expected to receive significant benefit from these during an extreme storm event.

Some limitations of the model that were noted include:

- Lack of particle size distribution information for the sediment at site. A D_{50} of 250 µm was used for the model runs based on visual observations of the sediment during the site visit. Whilst the observed sand grains are likely smaller than 250µm (expected closer to 200µm), the presence of shells through the matrix would increase this value of the overall system.
- No information available regarding the depth of the sediment layer, or presence of hard bed structures covered by loose sediment
- No inclusion of the built environment that may affect erosion (e.g.: roads, retaining walls).

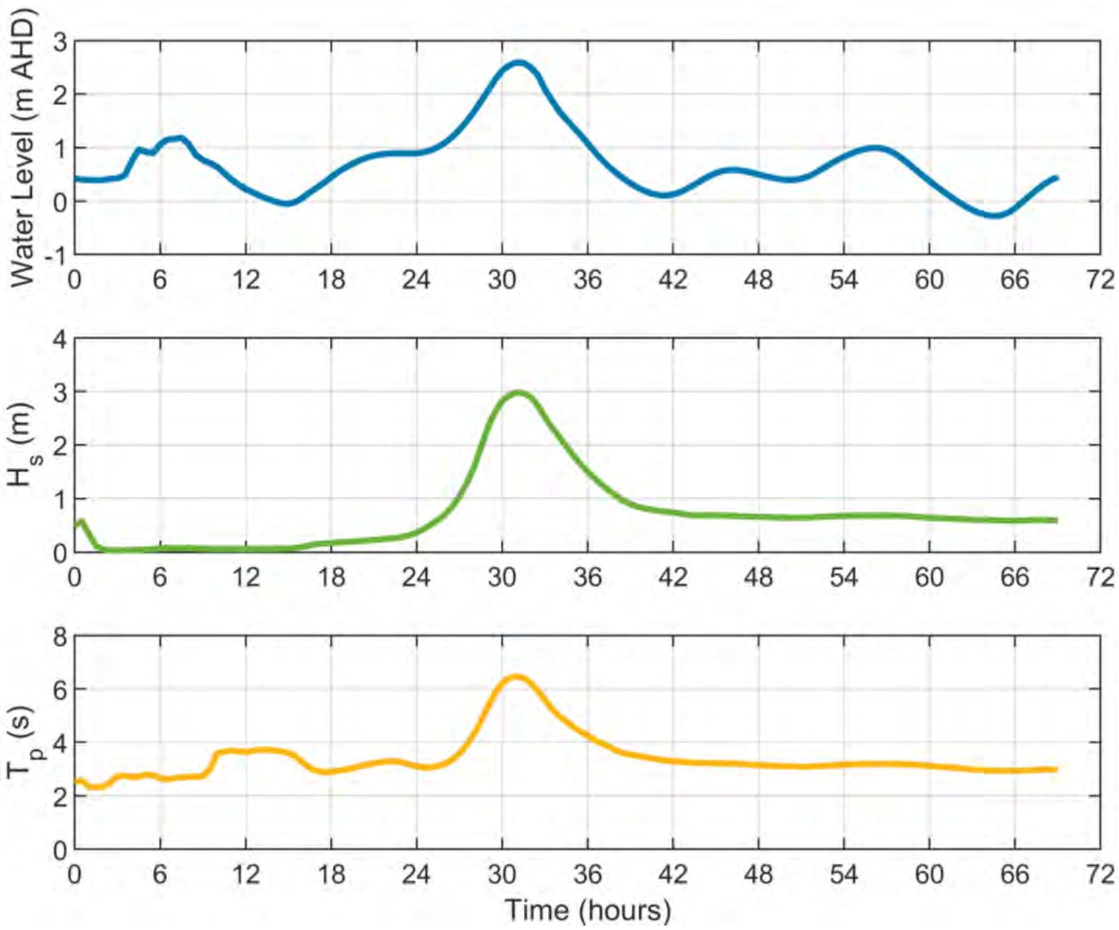

FIGURE 5-1 TIME SERIES OF DESIGN WATER LEVEL AND WAVES APPLIED IN SBEACH (STORM 1 OF 3)

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5.1.3 SBEACH Results & Storm Erosion Allowance

The S1 horizontal erosion distance is calculated as the maximum horizontal recession of the Horizontal Shoreline Datum HSD contour, as discussed in Chapter 2.2.1. The value for the HSD is 2.92m AHD. This corresponds to the 100-year ARI peak steady water level (PSWL) calculated for the design storm in SBEACH itself, which includes tidal, storm surge and wave set-up actions. The 2.9m AHD contour is located 70 to 100m landward of the dune / beach interface in Sections 1 to 3. The terrain at that location consists of roads and buildings; this is not appropriate to be modelled in SBEACH as storm-induced erosion. To conduct a more realistic assessment of the acute erosion due to storms, the aim behind S1 in SPP2.6, the HSD has been defined as follows:

- Section 1 to 3:
  - The maximum recession in the vicinity of the vegetation line. This is considered to represent the erosive effects during the event that would impact the study area. For example, in most areas, the retreat of the vegetation line by about 10m would lead to potential damage to Knight Terrace.
- Section 3 and 4:
  - HSD value of 2.92 m AHD, as per SPP2.6. This corresponds well with the vegetation and dune system in these beach sections.

The shoreline response to the storm events is displayed in Figure 5-2 for all transects. The HSD value of 2.9m AHD is shown on all transects, as is the location of the vegetation line. The shoreline recession S1 value is presented in Table 5-1. Whilst Section 3 contains the engineered seawall, it is still anticipated that some erosion could occur in the area to the west of the harbour, due to the low crest level in this location. The value calculated to the west of the harbour is applied across the whole section.

TABLE 5-1 ALLOWANCE FOR CURRENT RISK OF STORM EROSION , S1 (M)

Section 1	Section 2	Section 3	Section 4	Section 5
4.4	4.2	12.8	8.9	7.7

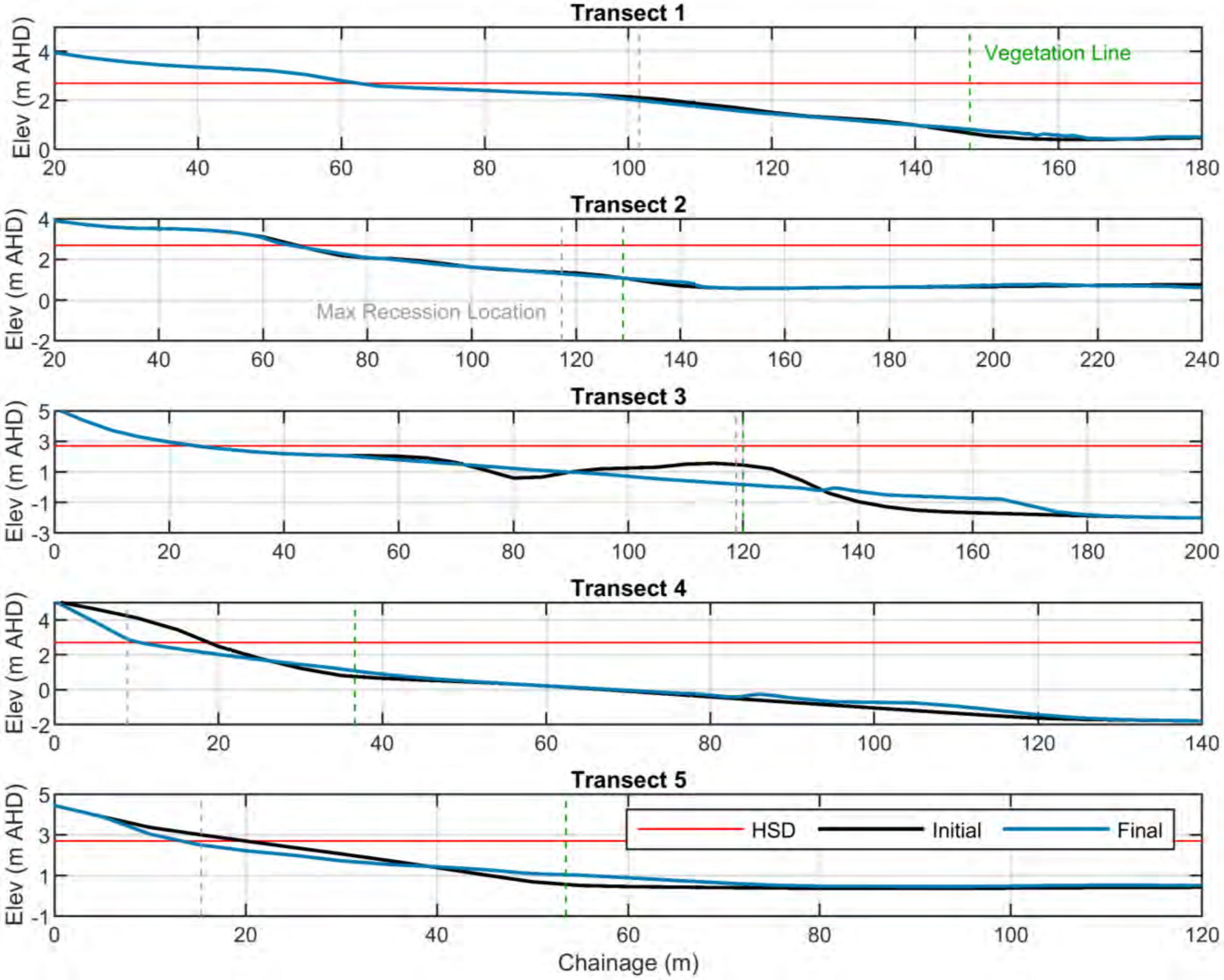

FIGURE 5-2 SBEACH RESULTS FOR EACH TRANSECT, REPRESENTING EACH COASTAL SECTION

5.2 S2: Historical Shoreline Evolution

5.2.1 Policy Requirements

The guidance provided in SPP2.6 for the calculation of shoreline evolution is based on historical shoreline trends. The policy recommends that a review of available shoreline records be conducted and that *"trends should be derived from shoreline movement timeseries and may include continuous erosion or accretion; erosion followed by accretion or vice versa; longshore evolution of features; or shoreline rotation. The allowance for historic shoreline movement trends should generally be calculated as 100 times the historic annual rate of erosion… Where the historic annual rate of shoreline movement is accretion less than 0.2 metres per year the allowance for historic shoreline movement trends should be zero."*

5.2.2 Historical Shoreline Change Calculations

Shoreline change for the study area at Denham has been calculated based on historical shoreline movement data and aerial imagery provided by the Department of Transport (DoT) and Landgate respectively. Data was available from 1957 to 2015 with an additional aerial for 2017 included by tracing the vegetation line. Comparison with the digital elevation model compiled for this project indicates that the vegetation line was generally at about 2.5 to 3 m AHD when the built environment did not significantly affect vegetation locations.

Recession per year was calculated as the average recession over the discrete section of coastline divided by the appropriate time period as discussed in Table 5-2 below. Care has been taken to remove reclamation and renourishment influences from the calculation of S2 where possible as it may result in legacy issues. Sections of coastline that have artificially accreted and been consolidated by designed seawalls will be given an S2 value of 0 m/year. This primarily applies to S3 and legacy issues due to this should be noted.

Section 4 appears to experience significant variability in the vegetation lines, however further analysis indicates that the majority of this movement is a result of changes to unstable low-lying sediment features that evolve over time. Sporadic vegetation of these features distorts a simple calculation of meaningful historical trends. It appears from aerial imagery that little significant changes occur to the high relief dunes fronting the coast here, although more spatial data is needed to increase confidence. It is recommended that an historical erosion rate of 0.2 m/year be applied to this section to ensure that any development close to the crest of the dunes in this area comes under the scrutiny of the active coastal zone requirements.

The eastern portion of Section 4 is significantly affected by renourishment from dredging works that occurred in 1997 and 2004. This obfuscation of natural historic trends is compounded by significant development and reclamation in the adjacent Section 3. It can be reasonably expected that sporadic renourishment will occur over the lifetime of the Denham port. However, it is recommended that the historic rate of 0.2 m/year applied to the rest of the section be applied here, due to low confidence in natural trends and to reduce liability of legacy issues.

Figure 5-3 to Figure 5-7 show the shoreline location overlain on the 2017 aerial photograph for 1957, 1990, 2006 and 2017 for Sections 1 to 5 respectively. All 9 sets of shoreline data are displayed in Appendix A. Table 5-3 presents the allowance due to historical shoreline movement for each section.

TABLE 5-2 HISTORICAL SHORELINE CHANGE

Section	Discussion
1	This section of shoreline has receded by an average distance of around 10m from 1957 to 2017, which is a rate of 0.17 m/year. The ability to utilise the full timeframe of data for this section increases confidence in the prediction, however, detailed records of renourishment in this area were not available and may have influenced the evolution during this period. The high variability of erosion observed in this area over shorter periods emphasises the need for a trigger-based adaptation plan.
2	Average recession distance from 2006 to 2017 is 3m, however this is probably due to different measuring techniques. This is a recession rate of 0.27 m/year. This section has undergone some development and contains some erosion control structures that appear to be old and/or insufficiently engineered for the site. For this reason, the shoreline trend was only estimated over the most recent period.
3	The shoreline trend for this section has been set to 0 m/year due to the engineered rock structure. Some sub-sections have receded by 8m and accreted by 3m from 2006 – 2017. However, this included data prior to the construction (or re-construction) of the seawall presently located in this area. This seawall is expected to limit erosion if maintained.
4	Average accretion distance for this section from 1957 to 2017 is approximately 7 m, which equates to a rate of 0.12 m/year. However, significant renourishment has occurred in this area as per the Shire's records. It was noted by the council that this area experiences erosion under long term conditions without the assistance of renourishment from dredging spoil. As a result, 0.12 m/year is not considered to be a true rate of accretion and the trend has instead been set to 0.2 m/year of recession.
5	Average recession distance is roughly 12m from 2006 to 2017 (no data available prior to 2006 in this section) which is a rate of 1.09 m/year. It was noted that a longer record of shoreline location may increase the accuracy of this predicted trend rate due to the high variability of the shoreline landforms in this section.

TABLE 5-3 HISTORICAL SHORELINE MOVEMENT ALLOWANCE, S2 (M)

Planning Timeframe	Section 1	Section 2	Section 3	Section 4	Section 5
Present Day	0	0	0	0	0
2030	2.0	3.2	0	2.4	13.1
2050	5.3	8.6	0	6.4	34.9
2118	16.7	27.0	0	20.0	109.1

FIGURE 5-3 SECTION 1 SHORELINE MOVEMENT: 1957, 1990, 2006 AND 2017

FIGURE 5-4 SECTION 2 SHORELINE MOVEMENT: 1957, 1990, 2006 AND 2017

FIGURE 5-5 SECTION 3 SHORELINE MOVEMENT: 1957, 1990, 2006 AND 2017

FIGURE 5-6 SECTION 4 SHORELINE MOVEMENT: 1957, 1990, 2006 AND 2017

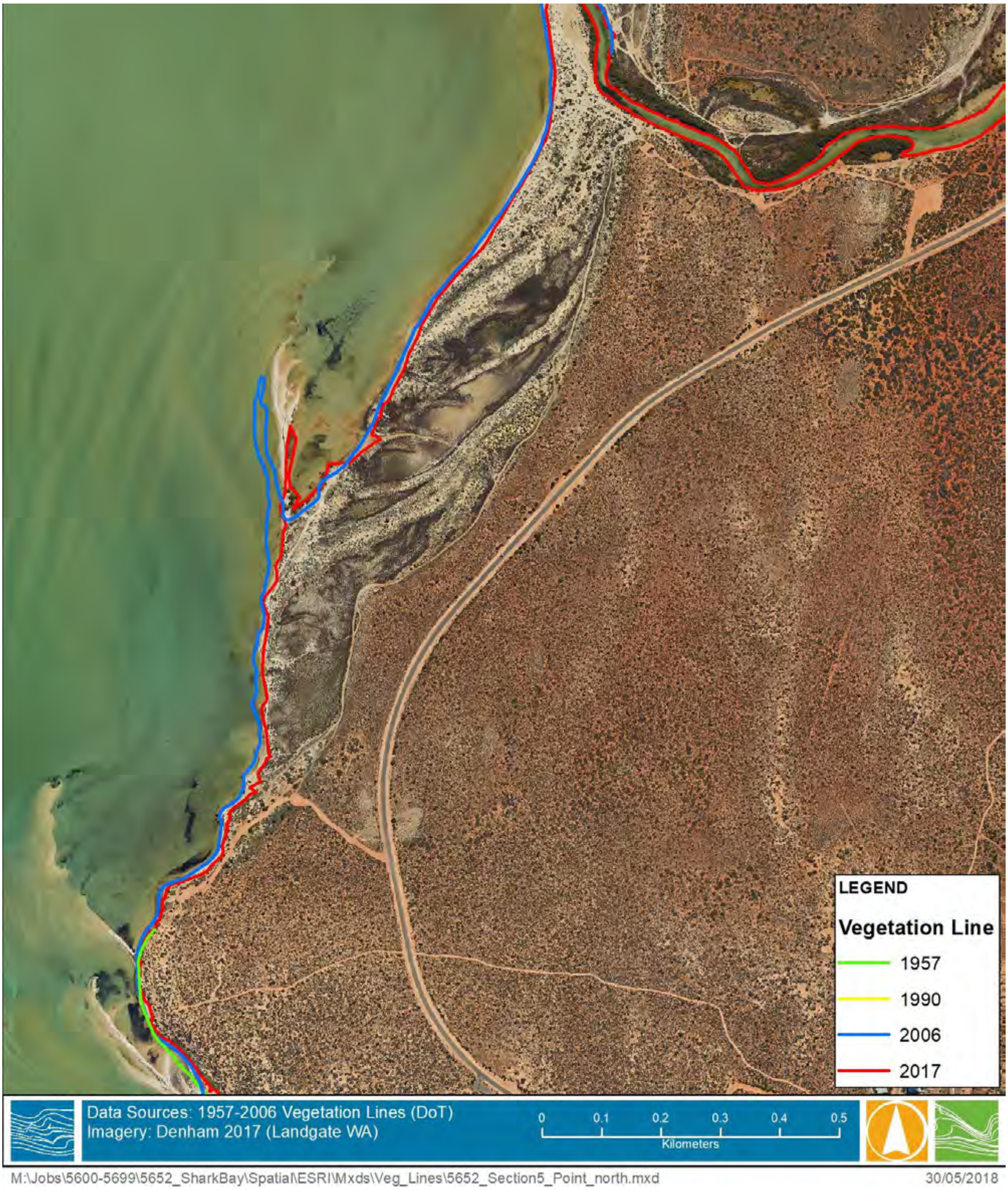

FIGURE 5-7 SECTION 5 SHORELINE MOVEMENT: 1957, 1990, 2006 AND 2017

5.3 S3: Erosion Due to Sea Level Rise

As indicated in Chapter 2.2.3, the policy requires the consideration of set levels of sea level rise over the given planning epochs. The policy recommends the use of the Bruun Rule which allows for the recession of sandy coastlines at a rate of 100 times the level of sea level rise. These values are shown in Table 5-4 below.

Whilst some sections of the shoreline are currently engineered with seawalls, this value has still been applied across the study area. This means the Shire is not necessarily committed to maintenance of the seawall for the full 100-year planning timeframe. In addition, the crest levels of the existing seawalls are such that they are fully overtopped in the present day 500-year ARI storm. Erosion forces are thus able to act on areas landward of the existing seawall.

TABLE 5-4 EROSION DUE TO SEA LEVEL RISE, S3 (M)

Planning Timeframe	Sea Level Rise (m)	S3 (m)
Present Day	0.00	0
2030	0.15	15
2050	0.30	30
2118	0.90	90

5.4 Summary of Coastal Erosion Allowance

The allowance for coastal processes is presented in Table 5-5 to Table 5-7 for 2030, 2050 and 2118 respectively. The Present Day coastal processes allowance is the S1 row in Table 5-5, highlighted in light blue.

These lines are plotted by study area Section in Appendix D. It should be noted that the vertical relief is not considered in the setback due to sea level rise. For example, the high elevation of the Denham Seaside Caravan Park means the 2118 coastal processes allowance is unlikely to occur to that extent, due to the significantly higher volume of sediment required to be eroded.

TABLE 5-5 COASTAL PROCESSES ALLOWANCE - 2030

Parameter	Section 1	Section 2	Section 3	Section 4	Section 5
S1	4.4	4.2	12.8	8.9	7.7
S2	2.0	3.2	0	2.4	13.1
S3	15.0	15.0	15.0	15.0	15.0
Uncertainty Allowance	2.4	2.4	2.4	2.4	2.4
TOTAL	**24**	**25**	**30**	**29**	**38**

TABLE 5-6 COASTAL PROCESSES ALLOWANCE - 2050

Parameter	Section 1	Section 2	Section 3	Section 4	Section 5
S1	4.4	4.2	12.8	8.9	7.7
S2	5.3	8.6	0	6.4	34.9
S3	30.0	30.0	30.0	30.0	30.0
Uncertainty Allowance	6.4	6.4	6.4	6.4	6.4
TOTAL	**46**	**49**	**49**	**52**	**79**

TABLE 5-7 COASTAL PROCESSES ALLOWANCE - 2118

Parameter	Section 1	Section 2	Section 3	Section 4	Section 5
S1	4.4	4.2	12.8	8.9	7.7
S2	16.7	27.0	0	20.0	109.1
S3	90.0	90.0	90.0	90.0	90.0
Uncertainty Allowance	20.0	20.0	20.0	20.0	20.0
TOTAL	**131**	**141**	**123**	**139**	**227**

6 STUDY LIMITATIONS

As discussed in Chapter 4.8, there is no appropriate locally measured water level or wave data with which to calibrate the models developed for this study. It is strongly recommended that a locally placed nearshore water level and wave data logger be deployed to provide a better understanding as to the accuracy of the model results. This should be installed as soon as possible, and ideally take continuous measurements for at least a period of 5 years with the aim of capturing a cyclone in the dataset. The data can be used to validate models under ambient conditions after a few months. However, to more confidently calibrate the model under cyclonic conditions, it is best that measured local cyclonic conditions are utilised.

The predicted inundation levels have a direct implication for recommended finished floor levels of future development. Raising finished floor levels to meet the design levels carries significant costs for the Shire, the community and stakeholders. If these are set higher than necessary due to modelling uncertainty, this represents costs the Shire and community could be spending elsewhere. Similarly, if these levels are set too low, this poses a significant risk to housing and infrastructure.

The impacts of the inaccuracies in the coastal processes allowance can be mitigated by the use of triggers in the adaptation plan and their corresponding coastal management action. An indicative likelihood and timeframe can be provided for guidance, but the ultimate adaptive action is driven by the triggers. However, photographic beach monitoring can be employed to improve the understanding of the beach erosion due to storms. This is especially important given the assumptions made regarding the location of the HSD in the S1 calculation.

Photographic beach monitoring can be conducted at 6-monthly intervals at the end of the summer and winter. Photos should also be taken immediately following severe storms. They should be undertaken from a set vantage point to allow accurate comparisons between images. The images can be used to supplement available data when undertaking adaptation option design. These images can also be used to support adaptation option funding applications, and in educating the community about natural fluctuations in beach shape. Coastal specialists should review the data every couple of years, or if erosion is causing an issue. This data can also be used to identify if a trigger has been reached.

Similarly, beach surveys can improve the understanding of coastal processes. These should be undertaken ideally every 6-months following the summer and winter periods and immediately following cyclones. Corresponding monitoring photos should be taken at the same time.

The study has assumed all material is unconsolidated sand. A geotechnical investigation could determine the presence of bedrock, which would potentially limit the landward erosion, particularly in the areas of higher relief. If located relatively near the surface, bedrock can act as a natural protection structure, and negate the need for other mitigation works. However, in low lying areas the presence of bedrock may not alter the level of risk to coastal hazards. If the area is inundated, the hard surface will not provide the expected protection to erosion.

7 VULNERABILITY ASSESSMENT - ASSETS

7.1 Asset Identification

In the Establish the Context Chapter Report (Water Technology, 2018), the assets in the coastal zone were identified. These were grouped as follows:

- Commercial
  - This includes shops, businesses, offices etc.
- Public
  - This item mainly relates to public infrastructure, and includes the boat ramp and jetty structures
- Tourism Related
  - This mainly includes tourist accommodation such as caravan parks, hostels and private rentals
  - Whilst tourism is a commercial venture, it is a key industry for the Shark Bay area, so is relevant as a category of its own
- Residential
  - Private houses, apartments and supporting structures such as sheds and garages

Each asset was colour coded based on its classification for ease of identification in the maps and online database. The online database can be found at the following link:

https://watech.maps.arcgis.com/apps/webappviewer/index.html?id=6e092b4d0f044e038a721705e907c084

7.2 Vulnerability Assessment Approach

The vulnerability of coastal assets to coastal hazards is related to its exposure to the hazard, its sensitivity to that exposure, and the ability of the asset to be modified or adapted to manage this exposure. This is displayed diagrammatically in Figure 7-1; the input components are displayed in blue.

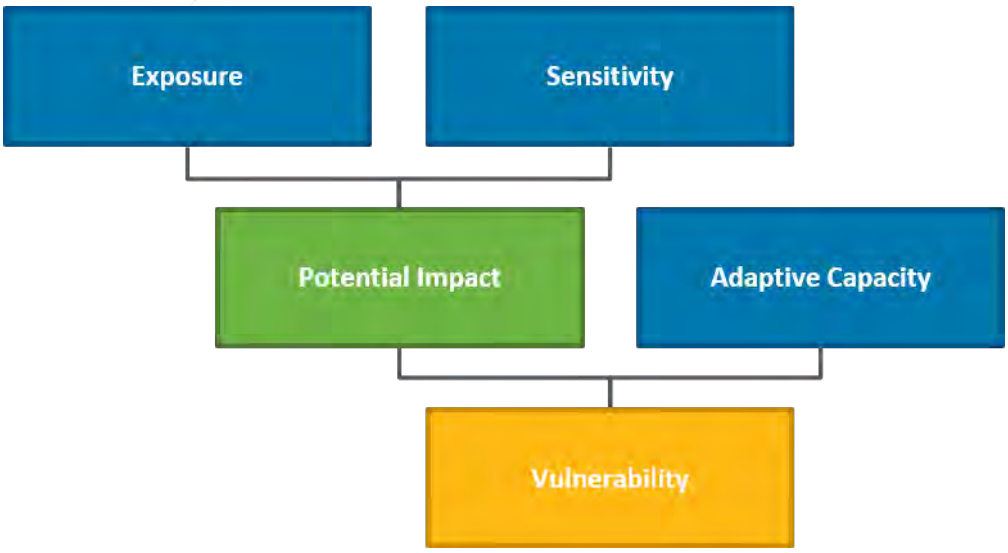

FIGURE 7-1 VULNERABILITY ASSESSMENT COMPONENTS (REPRODUCED FROM ALLEN CONSULTING, 2005)

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The **exposure** of identified assets to the inundation and erosion hazards are displayed in the hazard maps presented in Appendix C and Appendix D respectively, as well as the online database. In addition to the predicted 500-year ARI inundation extent that is displayed in Appendix C, the 20, 50 and 100-year ARI inundation extents are also included within the online database.

The **sensitivity** of an asset is its responsiveness to the coastal hazard. This could be a gradual response or a stepped change in response to discrete events (WAPC, 2014). The sensitivity can be applied to the asset itself, or to the asset's function and the criticality of the service it provides (CoastAdapt, 2017). For example, the inundation of the road leading into town would be highly sensitive as this would cut off access to the town. At this stage of the project, the sensitivity is limited to the physical response or impact to the asset. The social, cultural or environmental impacts are to be dealt with as part of the CHRMAP risk assessment (the next stage of the project), once the success criteria are incorporated. That is, they will be considered as part of the assessment of the tolerability of the physical risk to the asset, as defined by the community and stakeholders.

The **potential impact** is the **product** of the exposure and sensitivity. The **adaptive capacity** is the asset's ability to adjust / adapt to the identified hazard. **Vulnerability** is the **product** of potential impact and the adaptive capacity, as presented in Figure 7-2. Traditionally, a rating is assigned to the three inputs: exposure, sensitivity and adaptive capacity, and then the calculations carried out to determine the relative vulnerability.

The ratings for all components of the vulnerability assessment, together with their definitions, are presented in Table 7-1 and Table 7-2. For the purposes of the vulnerability assessment, the exposure is considered to be a relative assessment of the magnitude of the hazard. All assets have a minimum exposure rating of 'Moderate' because these assets are identified as being located within the hazard zone for that specific event. The probability or likelihood of the event occurring will be considered in the risk assessment component of the CHRMAP.

In the sub-chapters below, the asset ratings to the hazards are discussed and a vulnerability rating assigned. Inundation and erosion hazards are considered separately. Assets are also grouped according to classification for ease of interpretation. Ratings were discussed with the Steering Committee to ensure they are reflective of stakeholder knowledge.

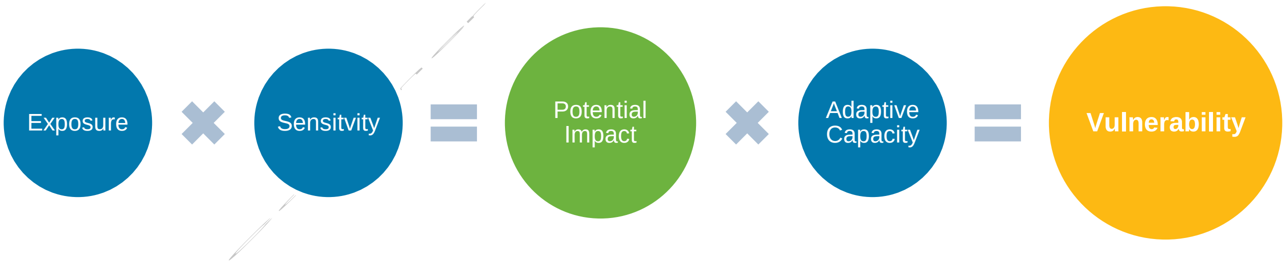

FIGURE 7-2 VULNERABILITY RELATIONSHIP

TABLE 7-1 VULNERABILITY ASSESSMENT RATINGS: SENSITIVITY, EXPOSURE & ADAPTIVE CAPACITY

Sensitivity / Exposure		Adaptive Capacity	
Rating	**Description**	**Rating**	**Description**
1	Very Low	1	No adaptation required
2	Low	2	Very High
3	Moderate	3	High
4	High	4	Moderate
5	Very High	5	Low

TABLE 7-2 VULNERABILITY ASSESSMENT RATINGS: POTENTIAL IMPACT & VULNERABILITY

Potential Impact		Vulnerability	
Rating	**Description**	**Rating**	**Description**
1-4	Very Low	1-24	Very Low
5-9	Low	25-49	Low
10-14	Moderate	50-74	Moderate
15-19	High	75-99	High
20-25	Very High	100-125	Very High

7.3 Inundation Vulnerability

Appendix E contains the full vulnerability assessment for all exposed assets for the planning timeframes Present Day, 2030, 2050 and 2118. Table 7-3 to Table 7-6 below present a summary of the vulnerability ratings, grouped by the asset classification.

The exposure of the assets is defined as follows:

- Present Day: Moderate
- 2030: Moderate - High
- 2050: High
- 2118: Very High

As discussed in Chapter 7.2, all assets have a minimum exposure rating of 'Moderate'. The higher ratings for the future timeframes are based on the increased relative inundation depth leading to greater sensitivity to the hazard.

Further sub-classifications were identified for each asset classification, defined according to their sensitivity. This breakdown was most detailed for the public assets. For example, a power substation ('Utility') has a much greater sensitivity to inundation than a park bench.

7.3.1 Commercial Assets

The commercial assets and their vulnerability are presented in Table 7-3. Despite the difference in sensitivity between buildings and the fuel assets, the vulnerability ratings are the same due to the perceived higher adaptive capacity of the fuel assets.

TABLE 7-3 COMMERCIAL ASSETS INUNDATION VULNERABILITY

Asset Classification	Number Affected	Present Day	2030	2050	2118
General buildings	11	60	70	80	100
Petrol Pumps	2	60	70	80	100
Fuel Tank	1	60	70	80	100

7.3.2 Public Assets

The public assets and their vulnerability are presented in Table 7-4. The greatest vulnerability ratings are assigned to the utilities and the public buildings such as the Shire offices. Assets connected to utilities are thought to be more sensitive and also more difficult to adapt / relocate.

TABLE 7-4 PUBLIC ASSETS INUNDATION VULNERABILITY

Asset Classification	Number Affected	Present Day	2030	2050	2118
Drain to beach	9	27	31.5	36	45
Utilities	6	75	87.5	100	125
Seawall - adhoc	4	12	28	32	40
Seawall - engineered	2	12	28	32	40
Picnic table / pergola	11	27	31.5	36	45
Universal beach access (removable)	2	12	14	16	20
Community resource centre	1	60	70	80	100
Public bench & reclaimed jetty posts	5	18	21	24	30
Car Park	5	18	21	24	30
Foreshore Path	1	18	21	24	30
Public Toilet	3	36	56	64	80
BBQ & Covered Structure	3	36	42	48	60
Limestone retaining wall	2	12	14	16	20
Playground	1	30	35	40	50
DBCA* Offices	1	60	70	80	100
Shire Offices	1	60	70	80	100
FRP Sheet-pile groyne	1	6	7	8	10
Grassed foreshore area	3	30	35	40	50
Public art	3	30	35	40	50
Jetty	3	6	7	8	10
Boat ramp	3	6	7	8	10
Fish cleaning station	1	12	21	24	30
Beach access	1	6	7	8	10
Road (Knight Tce & Stella Rowley Dve)	2	12	14	16	20

* Department of Biodiversity, Conservation & Attractions

7.3.3 Residential Assets

The residential assets and their vulnerability are presented in Table 7-5. Vacant blocks have a considerably lower vulnerability rating as their sensitivity is low, and adaptive capacity high.

TABLE 7-5 RESIDENTIAL ASSETS INUNDATION VULNERABILITY

Asset Classification	Number Affected	Present Day	2030	2050	2118
Houses	29 (30*)	60	70	80	100
Vacant blocks	14	6	7	8	10

* number of assets affected increases for the 2118 planning timeframe – value indicated in brackets

7.3.4 Tourism Related Assets

The tourism related assets and their vulnerability are presented in Table 7-6. These are assessed the same way as houses, public buildings and other commercial buildings.

TABLE 7-6 TOURISM RELATED ASSETS INUNDATION VULNERABILITY

Asset Classification	Number Affected	Present Day	2030	2050	2118
General sets of buildings	9 (10*)	60	70	80	100

* number of assets affected increases for the 2118 planning timeframe – value indicated in brackets

7.4 Erosion Vulnerability

The number of assets predicted to be impacted due to erosion varies between the planning timeframes, as displayed in Table 7-7. Appendix F contains the full vulnerability assessment for all exposed assets for the planning timeframes Present Day, 2030, 2050 and 2118. Table 7-8 to Table 7-11 present a summary of the vulnerability ratings, grouped by the asset classification.

The exposure of the assets is defined as 'Very High' for all assets and timeframes. This is selected as the definition of the erosion hazard is that the land is no longer present at that location.

As per the inundation assessment, each asset classification was further sub-divided for the assessment.

TABLE 7-7 ASSETS EXPOSED TO EROSION

Asset Classification	Present Day	2030	2050	2118
Commercial	0	1	5	14
Public	20	64	70	74
Residential	0	0	18	51
Tourism Related	0	1	4	10

7.4.1 Commercial Assets

The commercial assets and their vulnerability are presented in Table 7-8. Due to the high sensitivity and low adaptive capacity, all assets affected have a very high vulnerability rating. Assets are not predicted to be impacted until 2030.

TABLE 7-8 COMMERCIAL ASSETS EROSION VULNERABILITY

Asset Classification	Present Day	2030	2050	2118
General buildings	N/A	N/A	100	100
Petrol Pumps	N/A	N/A	100	100
Fuel Tank	N/A	100	100	100

7.4.2 Public Assets

The public assets and their vulnerability are presented in Table 7-9. For the public assets, the greatest vulnerability ratings are assigned to the utilities and the public buildings such as the Shire offices. Similar to the inundation assessment, assets connected to utilities are thought to be more sensitive and also more difficult to adapt / relocate.

The utility predicted to be in the coastal hazard zone is the marina fire hydrant. As this is located at the crest of the engineered seawall, the exposure is slightly reduced as the engineered seawall is unlikely to be compromised in a present-day erosion event.

TABLE 7-9 PUBLIC ASSETS EROSION VULNERABILITY

Asset Classification	Present Day	2030	2050	2118
Drain to beach	N/A	45	45	45
Utilities	80	125	125	125
Seawall - adhoc	40	40	40	40
Seawall - engineered	N/A	20	20	20
Picnic table / pergola	30	45	45	45
Universal beach access (removable)	20	20	20	20
Community resource centre	N/A	N/A	N/A	100
Public bench & reclaimed jetty posts	30	30	30	30
Car Park	45	45	45	45
Foreshore Path	45	45	45	45
Public Toilet	N/A	60	60	60
BBQ & Covered Structure	N/A	60	60	60
Limestone retaining wall	45	45	45	45
Playground	N/A	60	60	60
DBCA Offices	N/A	N/A	N/A	100
Shire Offices	N/A	N/A	100	100
FRP Sheet-pile groyne	N/A	10	10	10
Grassed foreshore area	N/A	30	30	30
Public art	30	30	30	30
Jetty	N/A	10	10	10
Boat ramp	N/A	10	10	10
Fish cleaning station	N/A	45	45	45
Beach access	20	20	20	20
Road (Knight Tce & Stella Rowley Dve)	N/A	60	60	60

7.4.3 Residential Assets

The residential assets and their vulnerability are presented in Table 7-10. Vacant blocks have a lower vulnerability rating as their adaptive capacity is slightly higher than an existing house.

TABLE 7-10 RESIDENTIAL ASSETS EROSION VULNERABILITY

Asset Classification	Present Day	2030	2050	2118
Houses	N/A	N/A	100	100
Vacant blocks	N/A	N/A	80	80

7.4.4 Tourism Related Assets

The tourism related assets and their vulnerability are presented in Table 7-11. These are assessed the same way as houses, public buildings and other commercial buildings.

The Denham Seaside Caravan Park is the asset predicted to be in the coastal hazard zone in 2030. However, only caravan / tent sites are located in the zone, so the sensitivity is reduced.

TABLE 7-11 TOURISM RELATED ASSETS EROSION VULNERABILITY

Asset Classification	Present Day	2030	2050	2118
General sets of buildings	N/A	60	100	100

* number of assets affected increases for the 2118 planning timeframe – value indicated in brackets

7.5 Vulnerability Assessment Summary

- Inundation vulnerability summary:
  - The number of assets exposed to inundation is almost the same for all planning timeframes. However, the exposure increases due to the relative increase in water depth.
  - All buildings (commercial, residential and tourism related) and utilities are given a high vulnerability rating, due to both their sensitivity and low adaptive capacity.
  - Public recreational items are considered to be less vulnerable, especially those that can easily moved
    - Assets that are connected to utilities (e.g. toilets, BBQs) are given a higher vulnerability
- Erosion vulnerability summary:
  - In the present day, only public recreational items are vulnerable,
    - The exception is the utility: marina fire hydrant. As this is located at the crest of the engineered seawall, it is unlikely to be compromised in a present-day erosion event.
  - No buildings are threatened until the 2050 timeframe
  - Utilities begin to be threatened by 2030
  - All buildings (commercial, residential and tourism related) and utilities are given a high vulnerability rating, due to both their sensitivity and low adaptive capacity.
  - Public recreational items are considered to be less vulnerable
    - Assets that are connected to utilities (e.g. toilets, BBQs) are given a higher vulnerability

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8 CONCLUSIONS & RECOMMENDATIONS

A summary of the findings of this component of the CHRMAP is presented below:

- The hazard maps for the coastal inundation assessment are presented in Appendix C. These display the extent of the predicted inundation for present day, 2030, 2050 and 2118. The data is overlaid on the 2017 aerial photograph; the identified assets are also displayed.
- The coastal processes allowance hazard maps are presented in Appendix D. Similarly, these display the calculated erosion extent for the planning timeframes.
  - Note this is not necessarily the predicted extent of erosion, rather the area at risk of erosion following the methodology of SPP2.6.
- All hazards and assets are included in the online database:
  - https://watech.maps.arcgis.com/apps/webappviewer/index.html?id=6e092b4d0f044e038a721705e907c084
- A vulnerability assessment was undertaken for assets predicted to be exposed to inundation and erosion. The full vulnerability assessment is provided in Appendix E and Appendix F for inundation and erosion respectively. Table 8-1 and Table 8-2 below present the number of assets predicted to be vulnerable to coastal hazards.
- The vulnerability assessment considers the physical impact of the hazard, and to some extent assumes the hazard will definitely occur. The next phase of the study involves carrying out a risk assessment for all assets predicted to be exposed to coastal hazards. This will include applying the likelihood of the hazard occurring. The risk assessment will also consider the social, cultural and environmental impacts in the form of the success criteria already developed in previous phases of the study.

TABLE 8-1 ASSETS EXPOSED TO INUNDATION

Asset Classification	Present Day	2030	2050	2118
Commercial	14	14	14	14
Public	74	74	74	74
Residential	43	43	43	44
Tourism Related	9	9	9	10

TABLE 8-2 ASSETS EXPOSED TO EROSION

Asset Classification	Present Day	2030	2050	2118
Commercial	0	1	5	14
Public	20	64	70	74
Residential	0	0	18	51
Tourism Related	0	1	4	10

A summary of the recommendations presented within this component of the CHRMAP is presented below:

- Deployment of a nearshore water level and wave data logger as soon as possible (Section 6).
- Development of a trigger-based adaptation plan and corresponding coastal management action during the next phases of the CHRMAP. The use of triggers mitigates some of the uncertainty surrounding the accuracy of the modelling.
  - Inclusion of a photographic beach monitoring schedule and guideline
  - Beach surveys when possible.
  - Recording of any coastal development, dredging, or renourishment activity (including approximate volumes)
- A geotechnical investigation to determine the presence of bedrock, which would potentially limit the landward erosion, particularly in the areas of higher relief.

9 REFERENCES

Allen Consulting, (2005). *Climate Change Risk and Vulnerability: Promoting an efficient adaptation response in Australia*, Australian Greenhouse Office, March 2005, 159pp

Bureau of Meteorology (BoM, 2018a). *Climate Statistics for Australian Locations*, accessed 26th June 2018, [http://www.bom.gov.au/climate/averages/tables/cw_006044.shtml]

Bureau of Meteorology (BoM, 2018b). *Tsunami Facts and Information*, accessed 20th July 2018, [http://www.bom.gov.au/tsunami/info/]

Cardno (2015). *Broome Coastal Vulnerability Study: Final Report*, report No 59914800, prepared for the Shire of Broome, available online: [http://www.broome.wa.gov.au/files/assets/public/building/major-projects/59914800_r04_rev2.pdf], accessed 21/05/2018

CoastAdapt (2017). *How to conduct a climate change risk assessment*, accessed 17th July 2018, [https://coastadapt.com.au/how-to-pages/how-to-conduct-a-climate-change-risk-assessment], developed by National Climate Change Adaptation Research Facility with funding from Department of the Environment and Energy

Coastal Engineering Research Center (1984). *Shore Protection Manual Volume I*, US Army Corps of Engineers

DEWHA (2007). 'A characterisation of the marine environment of the north-west marine region', *summary of an expert workshop convened in Perth, Western Australia, 5-6 September*, Department of the Environment, Water, Heritage and the Arts. Commonwealth of Australia, Barton. (http://www.environment.gov.au/resource/characterisation-marine-environment-north-west-marine-region)

Department of Transport (2010). *Sea Level Change in Western Australia: Application to Coastal Planning*, Coastal Infrastructure, Coastal Engineering Group

Eliot I, Gozzard JR, Eliot M, Stul T and McCormack G. (2012). *The Coast of the Shires of Shark Bay to Exmouth, Gascoyne, Western Australia: Geology, Geomorphology & Vulnerability*, prepared by Damara WA Pty Ltd and Geological Survey of Western Australia for the Department of Planning and the Department of Transport

Geoscience Australia. (2006). *Tsunami impact modelling for the North West Shelf: Onslow*.

Geoscience Australia (2009). *Offshore Tsunami Hazard for Australia*, website & downloadable files [http://www.ga.gov.au/scientific-topics/hazards/tsunami/australia], accessed 17th July 2018

Harper, B.A., Lovell, K.F., Chandler, B.D. and Todd D.J. (1989). 'The Derivation of Environmental Design Criteria for Goodwyn 'A' Platform', *Proceedings of the 9th Australian Conference on Coastal and Ocean Engineering*, Institution of Engineers, Australia, Adelaide, December 1989.

Harper B.A., Mason L.B. and Bode L., (1993). 'Tropical Cyclone Orson - A Severe Test for Modelling', *Proceedings of the 11th Australian Conference on Coastal and Ocean Engineering*, Institution of Engineers, Australia, Townsville, August 1993

Holland, G. J. (1980). 'An Analytical Model for the Wind and Pressure Profiles in Hurricanes', *Monthly Weather Review*, 108, pp 1212-1218

Hsu, S.A., and Weggel, J.R. (2002). *Coastal Engineering Manual: Chapter III-4 Wind-Blown Sediment Transport*, US Army Corp of Engineers, Report No: EM 1110-2-1100 (Part III)

Intergovernmental Panel on Climate Change (IPCC, 2014). *Climate Change 2014: Synthesis Report*, Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland, Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)], IPCC, Geneva, Switzerland, 151 pp.

MRA (2014). *Denham Inundation Levels Storm Surge Modelling Report*, report to the Shire of Shark Bay

Seashore Engineering Pty Ltd (2018). *Design Storms for Western Australian Coastal Planning: Tropical Cyclones*, report prepared for Department of Transport, report No SE015-01-RevB

Smith, J.M., (2003). *Coastal Engineering Manual: Chapter II-4 Surf Zone Hydrodynamics*, US Army Corps of Engineers, Report Nº. EM 1110-2-1100 (Part II)

Water Technology (2018). *Denham Townsite CHRMAP - Chapter Report: Establish the Context*, Report Nº 5562-01 R03v02, prepared for Shire of Shark Bay

Western Australian Planning Commission (WAPC, 2013). *State Planning Policy No. 2.6 – State Coastal Planning Policy*, prepared under the Planning and Development Act 2005.

Western Australian Planning Commission (WAPC, 2014). *Coastal Hazard Risk Management and Adaptation Planning Guidelines*

Wise, R. A., Smith, S. J., and Larson, M. (1995). ‘SBEACH: Numerical Model for Simulating Storm-Induced Beach Change. Report 4. Cross-Shore Transport Under Random Waves and Model Validation with SUPERTANK and Field Data’, *Technical Report CERC-95*, U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, Vicksburg, MS

Wu, Jin (1994). ‘The sea surface is aerodynamically rough even under light winds’, *Boundary Layer Meteorology*, 69, 149-158

Wu, Jin (1980). ‘Wind-stress Coefficients over sea surface and near neutral conditions - A revisit’, *Journal of Physical Oceanography*, 10, 727-740

APPENDIX A
CYCLONE TRACK PARAMETERS

TABLE A-1 CYCLONE TRACK PARAMETERS FOR THE 20-YEAR ARI EVENT

Time (hr)	Long (deg)	Lat (deg)	R_{mw} (km)	P_c [hPa]	P_n [hPa]	Holland B
0	107.6595	-24.1704	16.6	962.3	1010.6	1
3	108.0485	-24.3004	17.7	965.2	1010.6	1
6	108.2384	-24.3868	18.0	966.0	1010.6	1
9	108.4424	-24.5004	18.0	966.1	1010.6	1
12	108.8670	-24.8730	18.0	966.1	1010.6	1
15	109.3876	-25.1965	19.0	968.3	1010.6	1
18	109.9134	-25.6150	19.8	970.2	1010.6	1
21	110.5107	-25.6894	21.2	972.8	1010.6	1
24	111.1832	-25.9247	22.7	975.3	1010.6	1
27	111.8260	-26.1034	24.4	977.7	1010.6	1
30	112.4170	-26.2658	25.3	979.0	1010.6	1
33	113.0715	-26.3615	25.6	979.3	1010.6	1
36	113.8270	-26.4942	27.2	981.1	1010.6	1
39	114.7530	-26.5971	30.8	984.6	1010.6	1
42	115.7321	-26.7056	35.0	987.7	1010.6	1
45	116.8093	-26.9236	38.3	989.7	1010.6	1
48	118.1153	-26.8710	43.0	992.0	1010.6	1
51	119.3436	-26.6777	55.7	996.2	1010.6	1
54	120.4048	-26.8764	73.3	999.7	1010.6	1
57	121.4768	-27.5419	80.0	1003.7	1010.6	1

TABLE A-2 CYCLONE TRACK PARAMETERS FOR THE 50-YEAR ARI EVENT

Time (hr)	Long (deg)	Lat (deg)	R_{mw} (km)	P_c [hPa]	P_n [hPa]	Holland B
0	113.8594	-20.28977	15.0	934.9	1010.61	1
3	113.37127	-20.474129	15.0	935.8	1010.61	1
6	113.02588	-21.039507	15.0	936.7	1010.61	1
9	112.70808	-21.493122	15.0	937.5	1010.61	1
12	112.02503	-21.814197	15.0	938.8	1010.61	1
15	111.32303	-22.107917	15.0	941.5	1010.61	1
18	110.66333	-22.443865	15.0	941.2	1010.61	1
21	110.27075	-23.009865	15.0	941.6	1010.61	1
24	110.28049	-23.662506	15.0	947.1	1010.61	1
27	110.39714	-24.245979	15.0	948.3	1010.61	1
30	110.58684	-24.740583	15.0	950.5	1010.61	1
33	111.06855	-24.887594	15.0	950.7	1010.61	1
36	111.51169	-25.110512	15.0	952.8	1010.61	1
39	111.94605	-25.348049	15.0	955.3	1010.61	1
42	112.52365	-25.640505	15.3	958.3	1010.61	1
45	113.1009	-25.917177	15.6	959.3	1010.61	1
48	113.74718	-26.057634	15.7	959.5	1010.61	1
51	114.3371	-26.146726	16.3	961.3	1010.61	1
54	114.93086	-26.242581	16.5	961.9	1010.61	1
57	115.55315	-26.499969	17.3	964.4	1010.61	1
60	116.22031	-26.726662	21.5	973.4	1010.61	1
63	116.65829	-27.030086	22.5	974.9	1010.61	1
66	117.18234	-27.358638	25.9	979.6	1010.61	1
69	117.83769	-27.684629	27.8	981.7	1010.61	1
72	118.45368	-27.992977	29.7	983.6	1010.61	1
75	119.09057	-28.257972	35.4	988.0	1010.61	1
78	119.65586	-28.420203	43.2	992.1	1010.61	1
81	119.96095	-28.54105	51.3	995.0	1010.61	1
84	120.28053	-28.649373	62.4	997.8	1010.61	1
87	120.66614	-28.786893	80.0	1002.3	1010.61	1

TABLE A-3 CYCLONE TRACK PARAMETERS FOR THE 100-YEAR ARI EVENT

Time (hr)	Long (deg)	Lat (deg)	R_{mw} (km)	P_c [hPa]	P_n [hPa]	Holland B
0	109.22235	-22.000069	15.0	951.3	1010.61	1
3	109.50409	-22.599452	15.0	952.1	1010.61	1
6	109.85134	-23.083389	15.0	954.1	1010.61	1
9	110.22148	-23.563349	15.0	955.3	1010.61	1
12	110.56561	-24.025575	15.3	958.3	1010.61	1
15	110.6215	-24.514486	15.4	958.4	1010.61	1
18	110.90132	-24.859957	16.0	960.5	1010.61	1
21	111.30575	-25.294262	16.6	962.3	1010.61	1
24	111.90604	-25.625938	17.0	963.4	1010.61	1
27	112.5575	-26.044066	17.8	965.6	1010.61	1
30	113.27958	-26.38379	20.2	970.9	1010.61	1
33	114.00936	-26.449686	21.2	972.8	1010.61	1
36	114.89565	-26.63008	23.0	975.8	1010.61	1
39	115.46843	-26.718079	31.5	985.2	1010.61	1
42	115.94028	-26.708674	32.4	985.8	1010.61	1
45	116.02508	-26.703773	40.3	990.7	1010.61	1
48	116.02508	-26.703773	44.9	992.7	1010.61	1
51	116.02508	-26.703773	50.9	994.9	1010.61	1
54	116.07143	-26.703366	43.7	992.3	1010.61	1
57	116.12678	-26.703431	47.1	993.6	1010.61	1
60	116.24004	-26.692957	53.0	995.5	1010.61	1
63	116.43592	-26.660708	61.5	997.6	1010.61	1
66	116.79834	-26.596481	63.0	997.9	1010.61	1
69	117.21553	-26.497713	80.0	1001.1	1010.61	1

TABLE A-4 CYCLONE TRACK PARAMETERS FOR THE 500-YEAR ARI EVENT

Time (hr)	Long (deg)	Lat (deg)	R_{mw} (km)	P_c [hPa]	P_n [hPa]	Holland B
0	107.73162	-23.739398	15.0	943.5	1010.61	1
3	107.92659	-24.451307	15.0	947.1	1010.61	1
6	108.60795	-25.139246	15.0	948.7	1010.61	1
9	109.40572	-25.154017	15.0	949.0	1010.61	1
12	110.26675	-25.087449	15.0	949.1	1010.61	1
15	111.0971	-25.224459	15.0	951.7	1010.61	1
18	111.74687	-25.74359	15.0	952.0	1010.61	1
21	112.68293	-26.013248	15.0	953.4	1010.61	1
24	113.63936	-26.23744	15.0	955.0	1010.61	1
27	114.4501	-26.569162	15.5	958.9	1010.61	1
30	115.17375	-26.996777	16.7	962.5	1010.61	1
33	115.65322	-27.356474	18.6	967.5	1010.61	1
36	116.02207	-27.618609	19.5	969.5	1010.61	1
39	116.30956	-27.697983	20.3	971.1	1010.61	1
42	116.55869	-27.766282	20.6	971.7	1010.61	1
45	116.55869	-27.766282	21.6	973.4	1010.61	1
48	116.77464	-27.786817	22.4	974.8	1010.61	1
51	116.92812	-27.800474	22.6	975.1	1010.61	1
54	117.16067	-27.771224	23.6	976.7	1010.61	1
57	117.73974	-27.694991	27.1	981.0	1010.61	1
60	118.5617	-27.57337	28.0	982.0	1010.61	1
63	119.55558	-27.402678	31.7	985.3	1010.61	1
66	120.14681	-27.448995	39.5	990.3	1010.61	1
69	120.56016	-27.329092	46.8	993.5	1010.61	1
72	121.08119	-27.357269	58.3	996.9	1010.61	1
75	121.56915	-27.627043	80.0	1001.2	1010.61	1
78	121.97322	-27.80196	80.0	1006.1	1010.61	1

APPENDIX B
HISTORICAL SHORELINE MOVEMENT

Section 1 - Vegetation Lines

Data Source: 1957-2015 Vegetation Lines (DoT)
Imagery: Denham 2017 (Landgate WA)

0 20 40 80 Meters

1:2,000 at A3

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REFERENCE: M:\Jobs\5600-5699\5652_SharkBay\Spatial\ESRI\Mxds\Veg_Lines\5652_Section1_Southern_Study_area_A3.mxd

DATE: 30/05/2018 | SHEET: 1 of 1 | DRAWING NUMBER: 1

LEGEND

Vegetation Line

- 1957
- 1978
- 1980
- 1990
- 1999
- 2001
- 2006
- 2015
- 2017

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Data Source: 1957-2015 Vegetation Lines (DoT)
Imagery: Denham 2017 (Landgate WA)

0 15 30 60 Meters

1:1,500 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Section 2 - Vegetation Lines

REFERENCE: M:\Jobs\5600-5699\5652_SharkBay\Spatial\ESRI\Mxds\Veg_Lines\5652_Section2_SeaWall_to_Jetty_area_A3.mxd

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Data Source: 1957-2015 Vegetation Lines (DoT)
Imagery: Denham 2017 (Landgate WA)

0 20 40 80 Meters

1:1,720 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Section 3 - Vegetation Lines

REFERENCE: M:\Jobs\5600-5699\5652_SharkBay\Spatial\ESRI\Mxds\Veg_Lines\5652_Section3_Jetty_End_Seawall_A3.mxd

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Data Source: 1957-2015 Vegetation Lines (DoT)
Imagery: Denham 2017 (Landgate WA)

0 60 120 240 Meters

1:5,000 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Section 4 - Vegetation Lines

REFERENCE: M:\Jobs\5600-5699\5652_SharkBay\Spatial\ESRI\Mxds\Veg_Lines\5652_Section4_Seawal_to_Point_A3y.mxd

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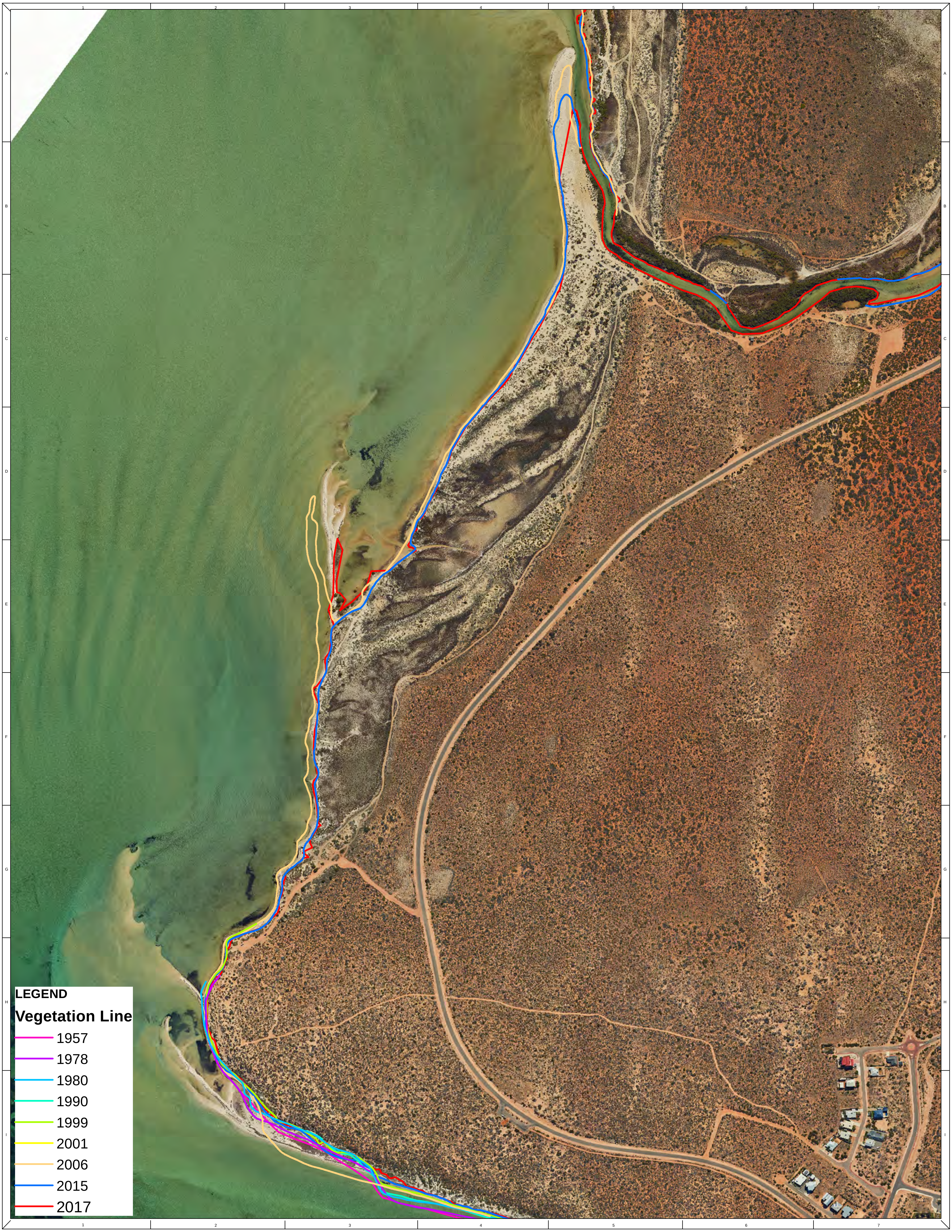

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Data Source: 1957-2015 Vegetation Lines (DoT)
Imagery: Denham 2017 (Landgate WA)

0 70 140 280 Meters

1:6,500 at A3

WATER TECHNOLOGY
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Section 5 - Vegetation Lines

REFERENCE: M:\Jobs\5600-5699\5652_SharkBay\Spatial\ESRI\Mxds\Veg_Lines\5652_Section5_Point_North_A3.mxd

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APPENDIX C
INUNDATION HAZARD MAPS

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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 205 410 820 Metres

1:15,000 at A3

WATER TECHNOLOGY
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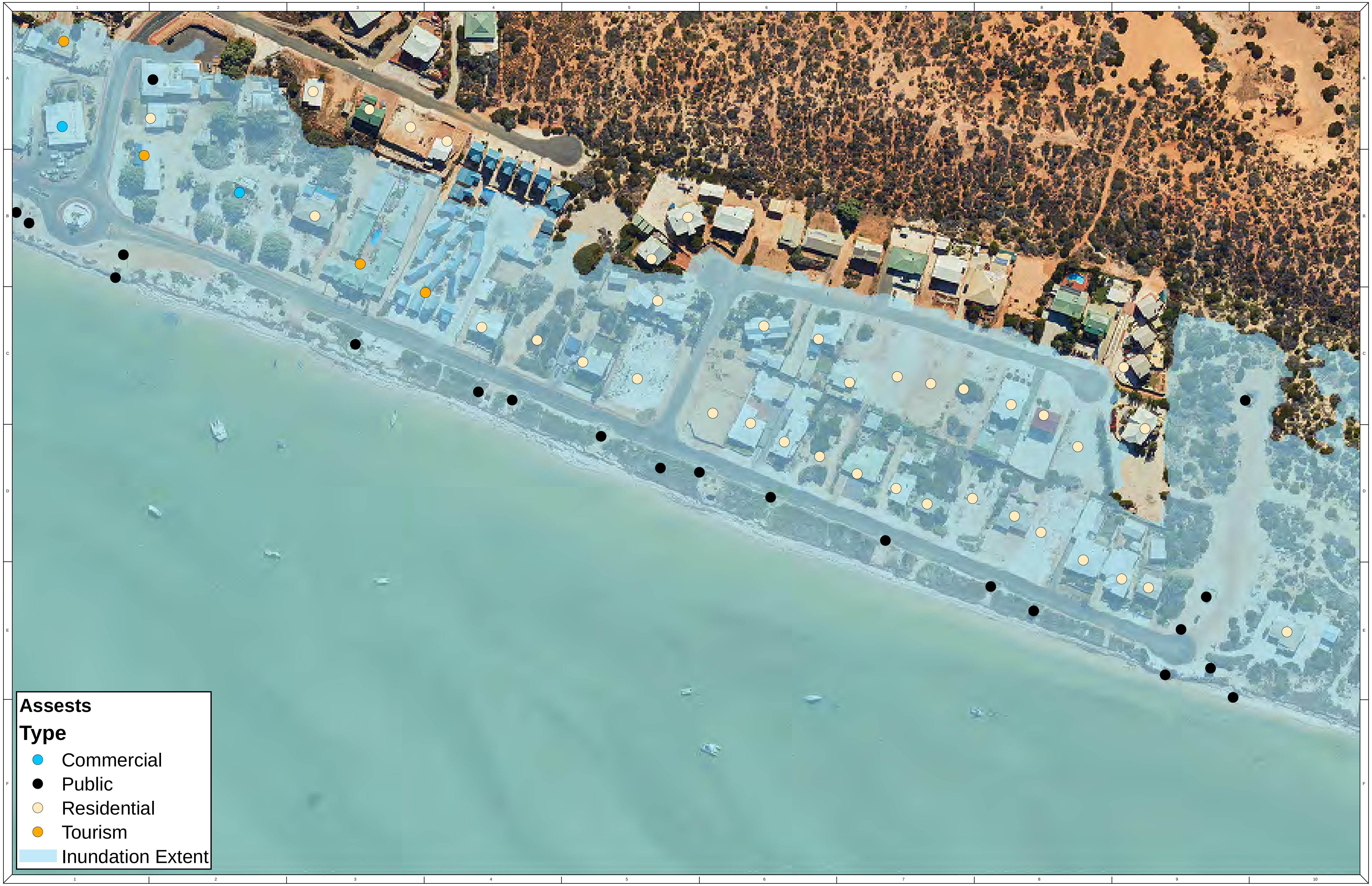
Map Location Key

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_PresentDay_all_A3.mxd

DATE: 30/05/2018 | SHEET: 1 of 1 | DRAWING NUMBER: 1



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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 25 50 100 Metres

1:2,000 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

500-yr ARI Inundation Assessment
Present Day
Section 1

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_PresentDay_A3.mxd

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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 20 40 80 Metres

1:1,500 at A3

500-yr ARI Inundation Assessment
Present Day
Section 2

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_PresentDay_A3.mxd

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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 20 40 80 Metres

1:1,725 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

500-yr ARI Inundation Assessment
Present Day
Section 3

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_PresentDay_A3.mxd

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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 30 60 120 Metres

1:2,500 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

500-yr ARI Inundation Assessment
Present Day
Section 4A

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_PresentDay_A3.mxd

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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 30 60 120 Metres

1:2,500 at A3

500-yr ARI Inundation Assessment
Present Day
Section 4B

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_PresentDay_A3.mxd

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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 50 100 200 Metres

1:4,000 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

500-yr ARI Inundation Assessment
Present Day
Section 5A

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_PresentDay_A3.mxd

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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 50 100 200 Metres

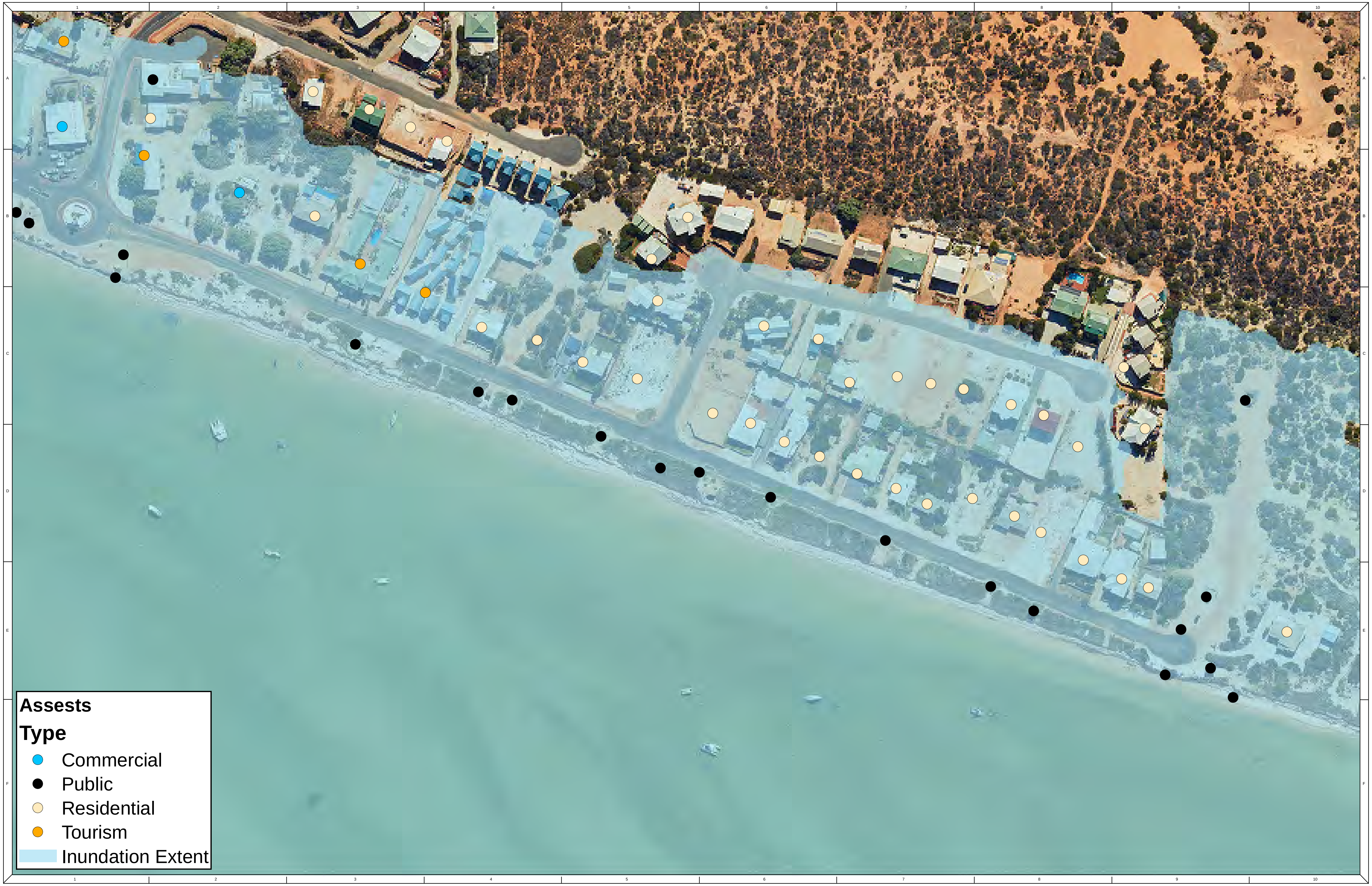
1:4,000 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

500-yr ARI Inundation Assessment
Present Day
Section 5B

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_PresentDay_A3.mxd

DATE: 30/05/2018 | SHEET: 1 of 1 | DRAWING NUMBER: 1



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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 25 50 100 Metres

1:2,000 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

500-yr ARI Inundation Assessment
2030
Section 1

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_2030_A3.mxd

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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 20 40 80 Metres

1:1,500 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

500-yr ARI Inundation Assessment
2030
Section 2

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_2030_A3.mxd

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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 20 40 80 Metres

1:1,725 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

500-yr ARI Inundation Assessment
2030
Section 3

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_2030_A3.mxd

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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 30 60 120 Metres

1:2,500 at A3

WATER TECHNOLOGY
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500-yr ARI Inundation Assessment
2030
Section 4A

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_2030_A3.mxd

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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 30 60 120 Metres

1:2,500 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

500-yr ARI Inundation Assessment
2030
Section 4B

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_2030_A3.mxd

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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 50 100 200 Metres

1:4,000 at A3

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WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

500-yr ARI Inundation Assessment
2030
Section 5A

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_2030_A3.mxd

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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 50 100 200 Metres

1:4,000 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

500-yr ARI Inundation Assessment
2030
Section 5B

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_2030_A3.mxd

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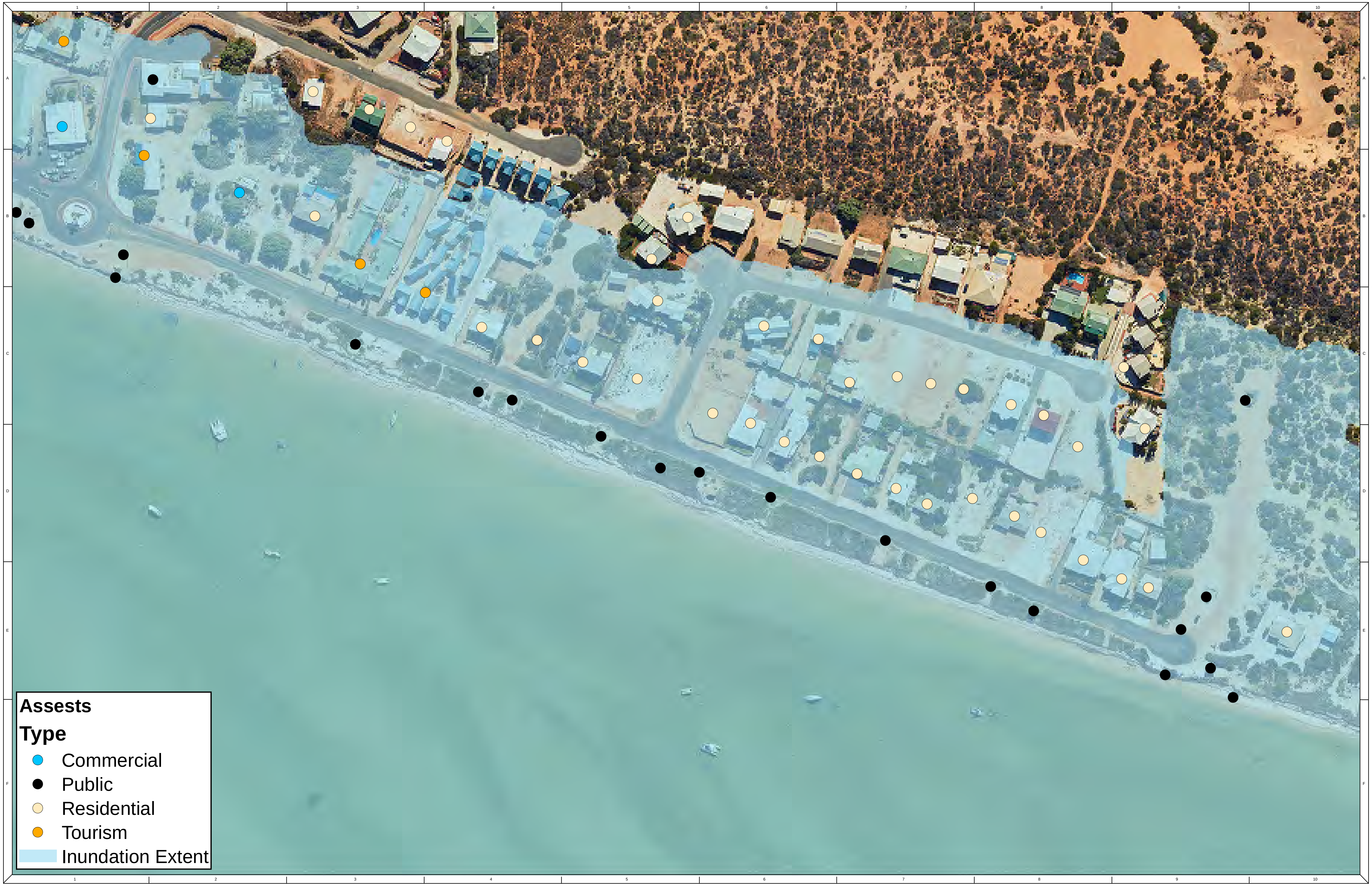

500-yr ARI Inundation Assessment
2050
Section 1

Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 25 50 100 Metres
1:2,000 at A3

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_2050_A3.mxd

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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 20 40 80 Metres

1:1,500 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

500-yr ARI Inundation Assessment
2050
Section 2

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_2050_A3.mxd

DATE: 30/05/2018	SHEET: 1 of 1	DRAWING NUMBER: 1

500-yr ARI Inundation Assessment
2050
Section 3

Denham Townsite CHRMAP

Imagery: Denham 2017 (Landgate WA)

0 20 40 80 Metres

1:1,725 at A3

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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 30 60 120 Metres

1:2,500 at A3

500-yr ARI Inundation Assessment
2050
Section 4A

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_2050_A3.mxd

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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 30 60 120 Metres

1:2,500 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

500-yr ARI Inundation Assessment
2050
Section 4B

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_2050_A3.mxd

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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 50 100 200 Metres

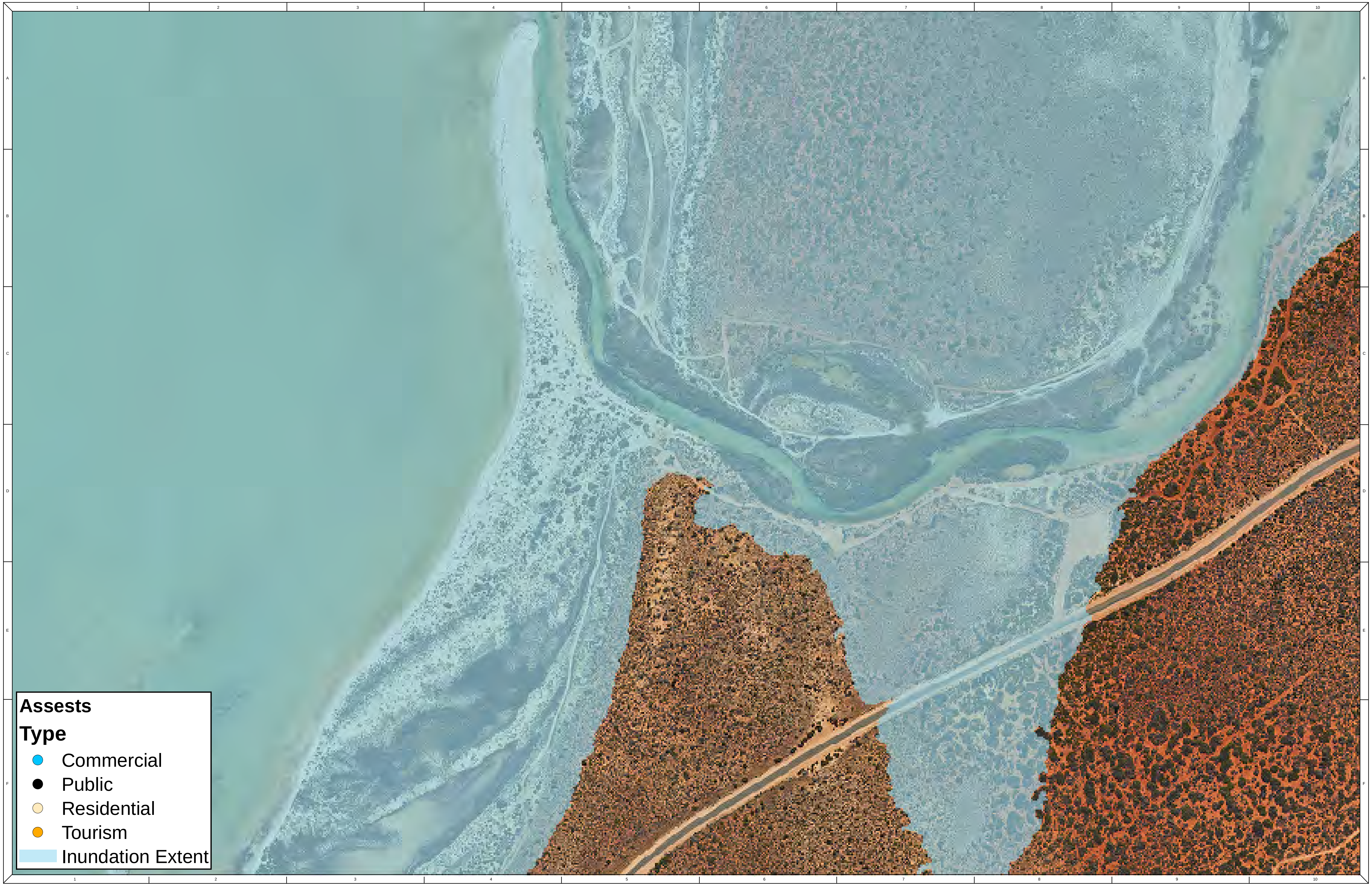
1:4,000 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

500-yr ARI Inundation Assessment
2050
Section 5A

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_2050_A3.mxd

DATE: 30/05/2018 | SHEET: 1 of 1 | DRAWING NUMBER: 1



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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 50 100 200 Metres

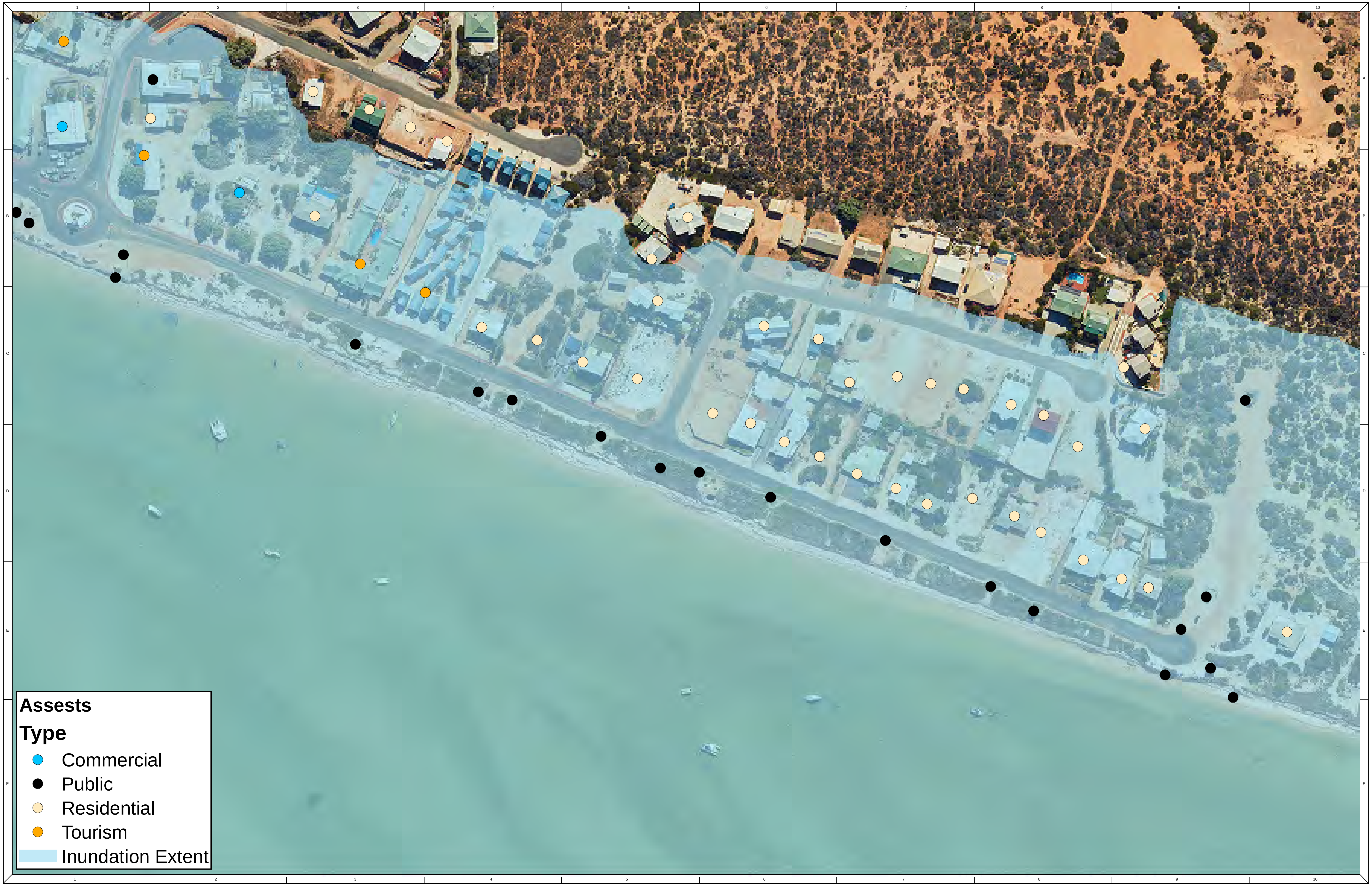
1:4,000 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

500-yr ARI Inundation Assessment
2050
Section 5B

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_2050_A3.mxd

DATE: 30/05/2018 | SHEET: 1 of 1 | DRAWING NUMBER: 1



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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 25 50 100 Metres

1:2,000 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

500-yr ARI Inundation Assessment
2118
Section 1

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_2118_A3.mxd

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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 20 40 80 Metres

1:1,500 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

500-yr ARI Inundation Assessment
2118
Section 2

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_2118_A3.mxd

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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 20 40 80 Metres

1:1,725 at A3

500-yr ARI Inundation Assessment
2118
Section 3

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_2118_A3.mxd

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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 30 60 120 Metres

1:2,500 at A3

500-yr ARI Inundation Assessment
2118
Section 4A

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_2118_A3.mxd

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N W E S

Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 30 60 120 Metres

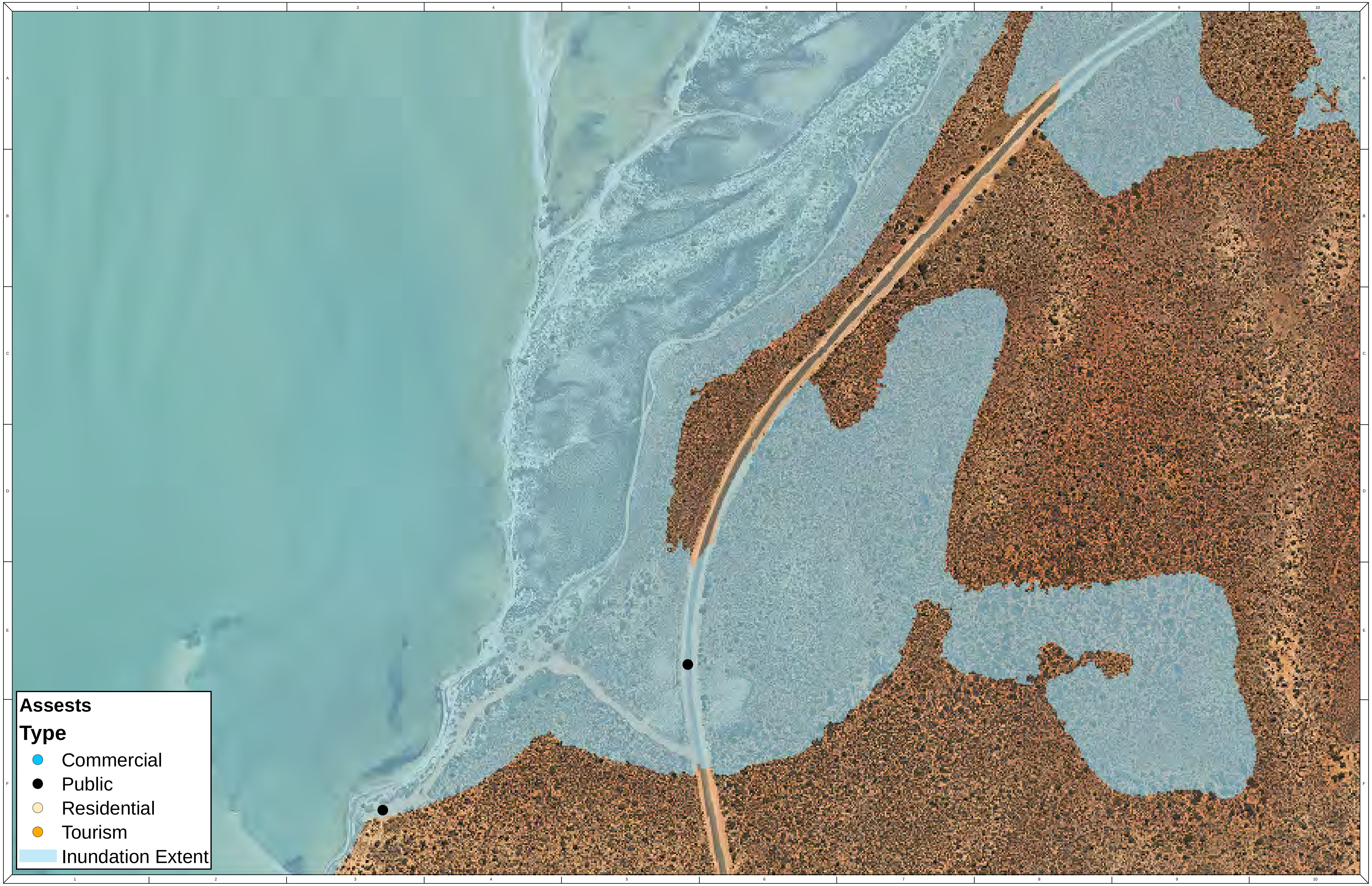
1:2,500 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

500-yr ARI Inundation Assessment
2118
Section 4B

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_2118_A3.mxd

DATE: 30/05/2018 | SHEET: 1 of 1 | DRAWING NUMBER: 1



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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

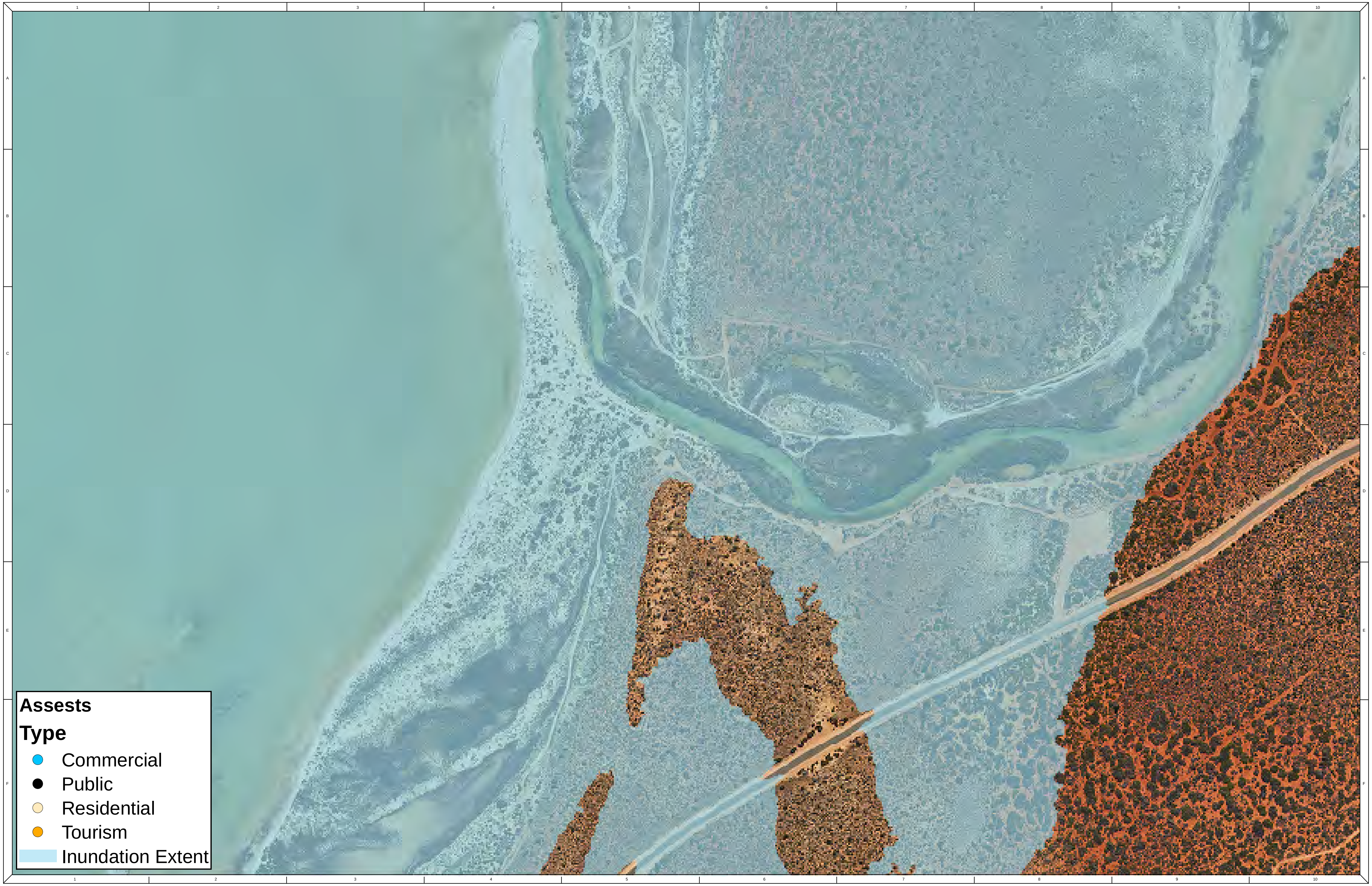
0 50 100 200 Metres

1:4,000 at A3

500-yr ARI Inundation Assessment
2118
Section 5A

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_2118_A3.mxd

DATE: 30/05/2018 | SHEET: 1 of 1 | DRAWING NUMBER: 1



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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 50 100 200
Metres

1:4,000 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

500-yr ARI Inundation Assessment
2118
Section 5B

REFERENCE: \\FS04\P-Drive\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Inundation\5652_500yrARI_2118_A3.mxd

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APPENDIX D
COASTAL PROCESSES HAZARD MAPS

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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 25 50 100 Metres

1:2,000 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Coastal Processes Assessment
Section 1

REFERENCE: P:\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Hazard\5652_HazardAssessment_A3.mxd

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1:1,500 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Coastal Processes Assessment
Section 2

REFERENCE: P:\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Hazard\5652_HazardAssessment_A3.mxd

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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 20 40 80 Metres

1:1,725 at A3

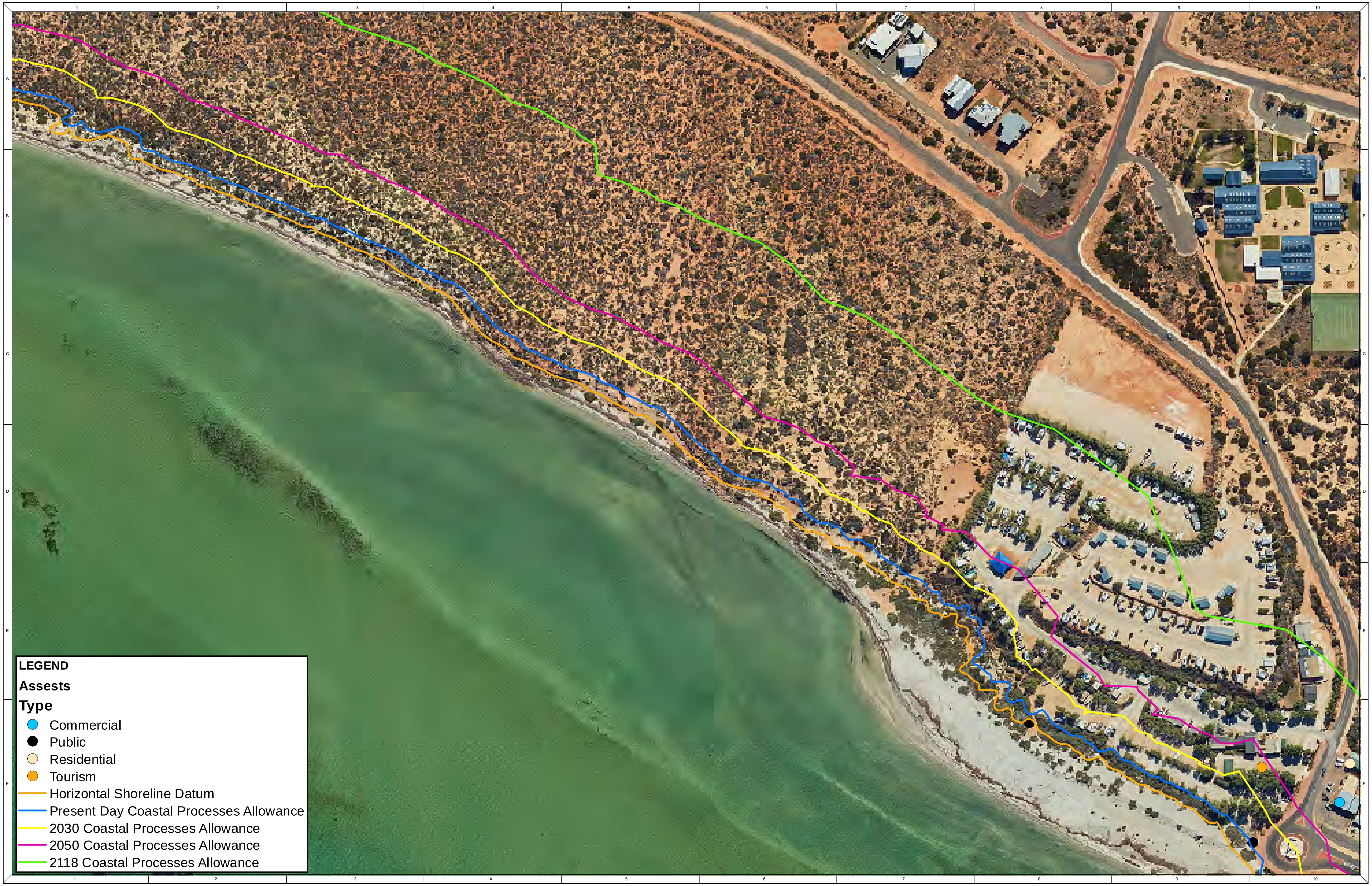
WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Coastal Processes Assessment

Section 3

REFERENCE: P:\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Hazard\5652_HazardAssessment_A3.mxd

DATE: 30/05/2018 | SHEET: 1 of 1 | DRAWING NUMBER: 1



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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 30 60 120 Metres

1:2,500 at A3

WATER TECHNOLOGY
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Coastal Processes Assessment
Section 4A

REFERENCE: P:\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Hazard\5652_HazardAssessment_A3.mxd

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Denham Townsite CHRMAP
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1:2,500 at A3

WATER TECHNOLOGY
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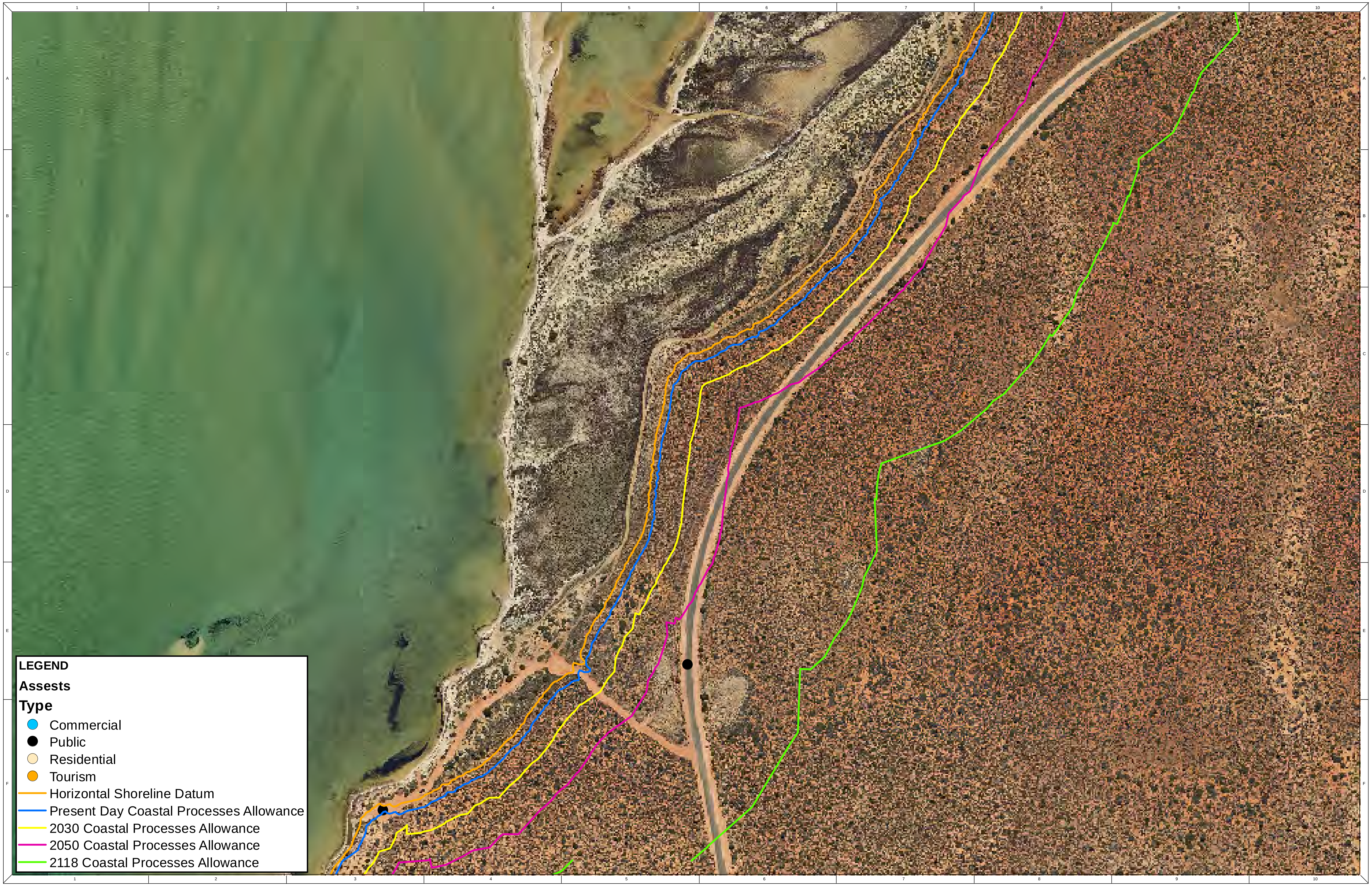
Coastal Processes Assessment
Section 4B

REFERENCE: P:\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Hazard\5652_HazardAssessment_A3.mxd

DATE: 30/05/2018 | SHEET: 1 of 1 | DRAWING NUMBER: 1



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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 50 100 200
Metres

1:4,000 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Coastal Processes Assessment

Section 5A

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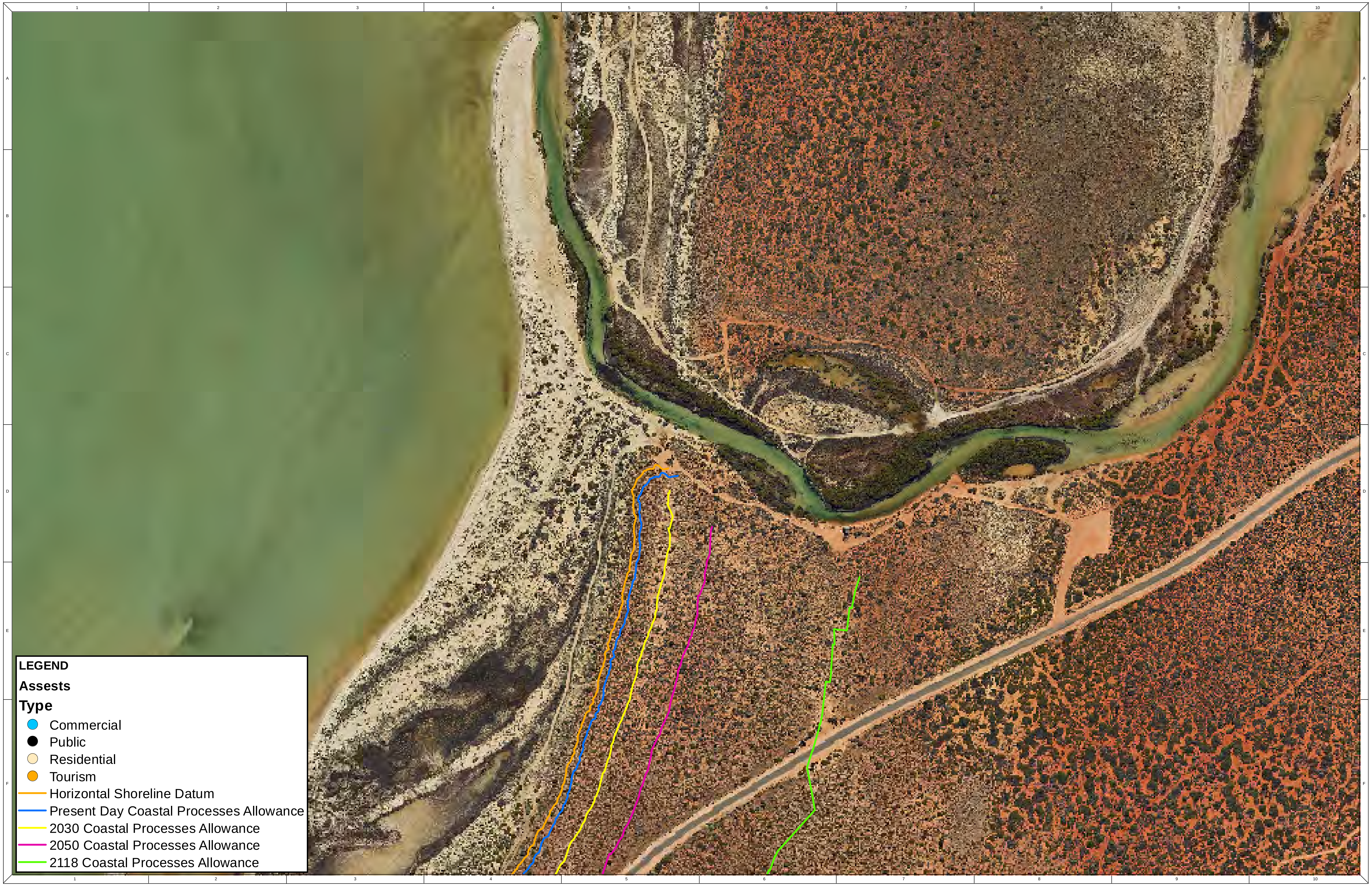

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Denham Townsite CHRMAP
Imagery: Denham 2017 (Landgate WA)

0 50 100 200 Metres

1:4,000 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Coastal Processes Assessment
Section 5B

REFERENCE: P:\Jobs\5652_SharkBay_CHRMAP\Spatial\ESRI\Mxds\Hazard\5652_HazardAssessment_A3.mxd

DATE: 30/05/2018 | SHEET: 1 of 1 | DRAWING NUMBER: 1

APPENDIX E
INUNDATION VULNERABILITY ASSESSMENT TABLES

TABLE E-1 INUNDATION VULNERABILITY – PRESENT DAY

Asset Classification	Number Affected	Exposure	Sensitivity	Potential Impacts	Adaptive Capacity	Vulnerability
Commercial						
General buildings	11	3	4	12	5	60
Petrol Pumps	2	3	5	15	4	60
Fuel Tank	1	3	5	15	4	60
Public						
Drain to beach	9	3	3	9	3	27
Utilities	6	3	5	15	5	75
Seawall - adhoc	4	3	2	6	2	12
Seawall - engineered	2	3	2	6	2	12
Picnic table / pergola	11	3	3	9	3	27
Universal beach access (removable)	2	3	2	6	2	12
Community resource centre	1	3	4	12	5	60
Public bench & reclaimed jetty posts	5	3	2	6	3	18
Car Park	5	3	2	6	3	18
Foreshore Path	1	3	2	6	3	18
Public Toilet	3	3	3	9	4	36
BBQ & Covered Structure	3	3	3	9	4	36
Limestone retaining wall	2	3	2	6	2	12
Playground	1	3	2	6	5	30
Department of Biodiversity & Attractions	1	3	4	12	5	60
Shire Offices	1	3	4	12	5	60
FRP Sheet-pile groyne	1	3	1	3	2	6
Grassed foreshore area / public park	3	3	2	6	5	30
Public art	3	3	2	6	5	30
Jetty	3	3	1	3	2	6
Boat ramp	3	3	1	3	2	6
Fish cleaning station	1	3	2	6	2	12
Beach access	1	3	1	3	2	6
Road (Knight Terrace & Stella Rowley Drive)	2	3	2	6	2	12
Residential						
Houses	29	3	4	12	5	60
Vacant blocks	14	3	1	3	2	6
Tourism Related						
General sets of buildings	9	3	4	12	5	60

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TABLE E-2 INUNDATION VULNERABILITY - 2030

Asset Classification	Number Affected	Exposure	Sensitivity	Potential Impacts	Adaptive Capacity	Vulnerability
Commercial						
General buildings	11	3.5	4	14	5	70
Petrol Pumps	2	3.5	5	17.5	4	70
Fuel Tank	1	3.5	5	17.5	4	70
Public						
Drain to beach	9	3.5	3	10.5	3	31.5
Utilities	6	3.5	5	17.5	5	87.5
Seawall - adhoc	4	3.5	4	14	2	28
Seawall - engineered	2	3.5	4	14	2	28
Picnic table / pergola	11	3.5	3	10.5	3	31.5
Universal beach access (removable)	2	3.5	2	7	2	14
Community resource centre	1	3.5	4	14	5	70
Public bench & reclaimed jetty posts	5	3.5	2	7	3	21
Car Park	5	3.5	2	7	3	21
Foreshore Path	1	3.5	2	7	3	21
Public Toilet	3	3.5	4	14	4	56
BBQ & Covered Structure	3	3.5	3	10.5	4	42
Limestone retaining wall	2	3.5	2	7	2	14
Playground	1	3.5	2	7	5	35
Department of Biodiversity & Attractions	1	3.5	4	14	5	70
Shire Offices	1	3.5	4	14	5	70
FRP Sheet-pile groyne	1	3.5	1	3.5	2	7
Grassed foreshore area	3	3.5	2	7	5	35
Public art	3	3.5	2	7	5	35
Jetty	3	3.5	1	3.5	2	7
Boat ramp	3	3.5	1	3.5	2	7
Fish cleaning station	1	3.5	3	10.5	2	21
Beach access	1	3.5	1	3.5	2	7
Road (Knight Terrace & Stella Rowley Dve)	2	3.5	2	7	2	14
Residential						
Houses	29	3.5	4	14	5	70
Vacant blocks	14	3.5	1	3.5	2	7
Tourism Related						
General sets of buildings	9	3.5	4	14	5	70

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TABLE E-3 INUNDATION VULNERABILITY - 2050

Asset Classification	Number Affected	Exposure	Sensitivity	Potential Impacts	Adaptive Capacity	Vulnerability
Commercial						
General buildings	11	4	4	16	5	80
Petrol Pumps	2	4	5	20	4	80
Fuel Tank	1	4	5	20	4	80
Public						
Drain to beach	9	4	3	12	3	36
Utilities	6	4	5	20	5	100
Seawall - adhoc	4	4	4	16	2	32
Seawall - engineered	2	4	4	16	2	32
Picnic table / pergola	11	4	3	12	3	36
Universal beach access (removable)	2	4	2	8	2	16
Community resource centre	1	4	4	16	5	80
Public bench & reclaimed jetty posts	5	4	2	8	3	24
Car Park	5	4	2	8	3	24
Foreshore Path	1	4	2	8	3	24
Public Toilet	3	4	4	16	4	64
BBQ & Covered Structure	3	4	3	12	4	48
Limestone retaining wall	2	4	2	8	2	16
Playground	1	4	2	8	5	40
Department of Biodiversity & Attractions	1	4	4	16	5	80
Shire Offices	1	4	4	16	5	80
FRP Sheet-pile groyne	1	4	1	4	2	8
Grassed foreshore area	3	4	2	8	5	40
Public art	3	4	2	8	5	40
Jetty	3	4	1	4	2	8
Boat ramp	3	4	1	4	2	8
Fish cleaning station	1	4	3	12	2	24
Beach access	1	4	1	4	2	8
Road (Knight Terrace & Stella Rowley Dve)	2	4	2	8	2	16
Residential						
Houses	29	4	4	16	5	80
Vacant blocks	14	4	1	4	2	8
Tourism Related						
General sets of buildings	9	4	4	16	5	80

TABLE E-4 INUNDATION VULNERABILITY - 2118

Asset Classification	Number Affected	Exposure	Sensitivity	Potential Impacts	Adaptive Capacity	Vulnerability
Commercial						
General buildings	11	5	4	20	5	100
Petrol Pumps	2	5	5	25	4	100
Fuel Tank	1	5	5	25	4	100
Public						
Drain to beach	9	5	3	15	3	45
Utilities	6	5	5	25	5	125
Seawall - adhoc	4	5	4	20	2	40
Seawall - engineered	2	5	4	20	2	40
Picnic table / pergola	11	5	3	15	3	45
Universal beach access (removable)	2	5	2	10	2	20
Community resource centre	1	5	4	20	5	100
Public bench & reclaimed jetty posts	5	5	2	10	3	30
Car Park	5	5	2	10	3	30
Foreshore Path	1	5	2	10	3	30
Public Toilet	3	5	4	20	4	80
BBQ & Covered Structure	3	5	3	15	4	60
Limestone retaining wall	2	5	2	10	2	20
Playground	1	5	2	10	5	50
Department of Biodiversity & Attractions	1	5	4	20	5	100
Shire Offices	1	5	4	20	5	100
FRP Sheet-pile groyne	1	5	1	5	2	10
Grassed foreshore area	3	5	2	10	5	50
Public art	3	5	2	10	5	50
Jetty	3	5	1	5	2	10
Boat ramp	3	5	1	5	2	10
Fish cleaning station	1	5	3	15	2	30
Beach access	1	5	1	5	2	10
Road (Knight Terrace & Stella Rowley Dve)	2	5	2	10	2	20
Residential						
Houses	30	5	4	20	5	100
Vacant blocks	14	5	1	5	2	10
Tourism Related						
General sets of buildings	10	5	4	20	5	100

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APPENDIX F
COASTAL EROSION VULNERABILITY TABLES

TABLE F-1 EROSION VULNERABILITY – PRESENT DAY

Asset Classification	Number Affected	Exposure	Sensitivity	Potential Impacts	Adaptive Capacity	Vulnerability
Commercial						
General buildings	0					
Petrol Pumps	0					
Fuel Tank	0					
Public						
Utilities	2	4	4	16	5	80
Seawall - adhoc	3	5	4	20	2	40
Picnic table / pergola	4	5	3	15	2	30
Universal beach access (removable)	1	5	2	10	2	20
Public bench & reclaimed jetty posts	4	5	3	15	2	30
Car Park	1	5	3	15	3	45
Foreshore Path	1	5	3	15	3	45
Limestone retaining wall	1	5	3	15	3	45
Public art	2	5	3	15	2	30
Beach access	1	5	2	10	2	20
Residential						
Houses	0					
Vacant blocks	0					
Tourism Related						
General sets of buildings	0					

TABLE F-2 EROSION VULNERABILITY – 2030

Asset Classification	Number Affected	Exposure	Sensitivity	Potential Impacts	Adaptive Capacity	Vulnerability
Commercial						
Fuel Tank	1	5	5	25	4	100
Public						
Drain to beach	9	5	3	15	3	45
Utilities	2	5	5	25	5	125
Seawall - adhoc	4	5	4	20	2	40
Seawall - engineered	2	5	2	10	2	20
Picnic table / pergola	10	5	3	15	3	45
Universal beach access (removable)	2	5	2	10	2	20
Public bench & reclaimed jetty posts	5	5	3	15	2	30
Car Park	5	5	3	15	3	45
Foreshore Path	1	5	3	15	3	45
Public Toilet	2	5	3	15	4	60
BBQ & Covered Structure	3	5	3	15	4	60
Limestone retaining wall	2	5	3	15	3	45
Playground	1	5	3	15	4	60
FRP Sheet-pile groyne	1	5	1	5	2	10
Grassed foreshore area	3	5	2	10	3	30
Public art	3	5	3	15	2	30
Jetty	3	5	1	5	2	10
Boat ramp	3	5	1	5	2	10
Fish cleaning station	1	5	3	15	3	45
Beach access	1	5	2	10	2	20
Road (Knight Terrace)	1	5	3	15	4	60
Residential						
Houses	0					
Vacant blocks	0					
Tourism Related						
General sets of buildings	1	5	3	15	4	60

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TABLE F-3 EROSION VULNERABILITY – 2050

Asset Classification	Number Affected	Exposure	Sensitivity	Potential Impacts	Adaptive Capacity	Vulnerability
Commercial						
General buildings	3	5	4	20	5	100
Petrol Pumps	1	5	5	25	4	100
Fuel Tank	1	5	5	25	4	100
Public						
Drain to beach	9	5	3	15	3	45
Utilities	4	5	5	25	5	125
Seawall - adhoc	4	5	4	20	2	40
Seawall - engineered	2	5	2	10	2	20
Picnic table / pergola	11	5	3	15	3	45
Universal beach access (removable)	2	5	2	10	2	20
Public bench & reclaimed jetty posts	5	5	3	15	2	30
Car Park	5	5	3	15	3	45
Foreshore Path	1	5	3	15	3	45
Public Toilet	3	5	3	15	4	60
BBQ & Covered Structure	3	5	3	15	4	60
Limestone retaining wall	2	5	3	15	3	45
Playground	1	5	3	15	4	60
Shire Offices	1	5	4	20	5	100
FRP Sheet-pile groyne	1	5	1	5	2	10
Grassed foreshore area	3	5	2	10	3	30
Public art	3	5	3	15	2	30
Jetty	3	5	1	5	2	10
Boat ramp	3	5	1	5	2	10
Fish cleaning station	1	5	3	15	3	45
Beach access	1	5	2	10	2	20
Road (Knight Terrace & Stella Rowley Drive)	2	5	3	15	4	60
Residential						
Houses	12	5	4	20	5	100
Vacant blocks	6	5	4	20	4	80
Tourism Related						
General sets of buildings	4	5	4	20	5	100

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TABLE F-4 EROSION VULNERABILITY – 2118

Asset Classification	Number Affected	Exposure	Sensitivity	Potential Impacts	Adaptive Capacity	Vulnerability
Commercial						
General buildings	11	5	4	20	5	100
Petrol Pumps	2	5	5	25	4	100
Fuel Tank	1	5	5	25	4	100
Public						
Drain to beach	9	5	3	15	3	45
Utilities	5	5	5	25	5	125
Seawall - adhoc	4	5	4	20	2	40
Seawall - engineered	2	5	2	10	2	20
Picnic table / pergola	12	5	3	15	3	45
Universal beach access (removable)	2	5	2	10	2	20
Community resource centre	1	5	4	20	5	100
Public bench & reclaimed jetty posts	5	5	3	15	2	30
Car Park	5	5	3	15	3	45
Foreshore Path	1	5	3	15	3	45
Public Toilet	3	5	3	15	4	60
BBQ & Covered Structure	3	5	3	15	4	60
Limestone retaining wall	2	5	3	15	3	45
Playground	1	5	3	15	4	60
Department of Biodiversity & Attractions	1	5	4	20	5	100
Shire Offices	1	5	4	20	5	100
FRP Sheet-pile groyne	1	5	1	5	2	10
Grassed foreshore area	3	5	2	10	3	30
Public art	3	5	3	15	2	30
Jetty	3	5	1	5	2	10
Boat ramp	3	5	1	5	2	10
Fish cleaning station	1	5	3	15	3	45
Beach access	1	5	2	10	2	20
Road (Knight Terrace & Stella Rowley Drive)	2	5	3	15	4	60
Residential						
Houses	36	5	4	20	5	100
Vacant blocks	15	5	4	20	4	80
Tourism Related						
General sets of buildings	10	5	4	20	5	100

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APPENDIX D
CHAPTER REPORT: RISK ASSESSMENT

Denham Townsite CHRMAP

Chapter Report: Risk Assessment

Shire of Shark Bay

06 March 2019

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Project Details

Project Name	Chapter Report: Risk Assessment
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06 March 2019

Paul Anderson
Chief Executive Officer
Shire of Shark Bay
65 Knight Terrace Denham WA 6537
Via email ceo@sharkbay.wa.gov.au

Dear Paul

Chapter Report: Risk Assessment

We are pleased to present the Denham Townsite Coastal Hazard Risk Management and Adaptation Plan Chapter Report: Risk Assessment. If you have any queries, please do not hesitate to contact me on (03) 8526 0830.

Yours sincerely

Joanna Garcia-Webb
Senior Coastal Engineer

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WATER TECHNOLOGY PTY LTD

EXECUTIVE SUMMARY

It is internationally recognised that increasing sea levels and storm intensities will intensify coastal hazards such as coastal inundation (temporary coastal flooding), storm erosion and long-term shoreline recession (IPCC 2014). Consequently, State governments across Australia have introduced obligations that require local governments to consider and plan for the effects of these hazards over various planning timeframes. In Western Australia (WA), the governing policy is the Western Australian Planning Commission's State Coastal Planning Policy 2.6 (WAPC, 2013, herein referred to as "SPP2.6"). SPP2.6 recommends management authorities develop a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP). Specific guidelines have been developed to assist in this process (WAPC, 2014).

One of the key objectives of SPP2.6 is to establish coastal foreshore reserves which include allowances for the protection, conservation and enhancement of coastal values across the state. Risk assessment processes are then utilised to identify risks that are intolerable to the community, and other stakeholders such as the Shire of Shark Bay, indigenous and cultural interests, and private enterprise. Adaptation measures are then developed according to the preferential adaptation hierarchy outlined in SPP2.6.

The overall CHRMAP purpose is as follows:

- To identify vulnerable assets (public and private) and the risk posed to them by coastal hazards.
- To preserve community values for present and future generations.
- To develop a plan that will allow the Shire to respond to identified risks through adaptation planning activities.
- To recommend monitoring plans to ensure the risk management and adaptation plan activities are working into the future as expected.

This document presents the Risk Assessment Chapter Report. The assets identified as being at risk of coastal hazards are assessed against the success criteria, as identified in the community values assessment. A prioritised list of risks is developed, allowing for existing controls that may provide some risk mitigation. The flow chart displayed in Figure 1-2 indicates where this component of the study sits with reference to the wider study; the 'Risk Analysis and Evaluation' phase corresponds to the bubble shaded in red, as replicated below.

Prepare Likelihood and Consequence Scales
- Risk assessment of each vulnerable asset: likelihood, consequence, vulnerability & risk rating for each scenario

Risk Evaluation
- Identify actions & priorities for management until 2118
- Analyse Community Values / Success Criteria--> establish community priorities for Vulnerable Assets

Identify Existing Controls
- Identify existing mitigation measures: physical & planning schemes to mitigate the above risks
    - Update risks accordingly; identify prioritised risk action list based on Success Criteria & existing controls

Community Values Assessment: Success Criteria

The stakeholder and community engagement strategy (Water Technology, 2018c) identified a workshop to collate the stakeholder and community's values. Upon discussion of the workshop outcomes with the project Steering Committee, it was decided the development of the success criteria could be further enhanced by the addition of an online survey to gain external stakeholder input.

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The outcomes of the workshop and the results of the survey were reviewed to develop the final adopted success criteria. These are presented in Table 1-1. These highlight the importance the community and stakeholders place on the environmental, social and cultural value of the study area.

TABLE 1-1 ADOPTED SUCCESS CRITERIA

- **Protection of the environmental assets of the study area / planning to retain environmental integrity**
- **Protection of the recreational value of the coastline**
- **Protection of the cultural values of the coastline & town centre**
- **Maintenance of a level of public recreational assets**
- **Development controls not to inhibit the landscape**

Risk Assessment

The risk assessment employs the suggested methods of WAPC (2014) and AS 5334-2013 “Climate change adaptation for settlements and infrastructure - A risk-based approach”. For the risk assessment process, the likelihood and consequence are combined to generate a risk classification. Likelihood examines the probability of an inundation or erosion event occurring, as well as its frequency (WAPC, 2014). The consequence ranking constitutes the physical impact of the event to the asset, as well as that of the values attributed to it by the success criteria.

The economic costs associated with the various consequences have not been considered at this time. The economic costs will be included in the cost benefit analysis as part of the adaptation options assessment component of the CHRMAP. This process aims to assess the risks in terms of the stakeholder and community values first, before assigning a monetary value.

Risk Evaluation

Risk evaluation of each asset is based on assigning a likelihood and consequence to inundation and erosion hazards to each asset separately. The consequence, and therefore the assessment of risk, is directly linked to the success criteria generated specifically for this project by the community and stakeholder engagement. The evaluation of risk focuses on providing the Shire with the ability to clearly prioritise coastal hazard risks across the study area and assist in the development of appropriate adaptation options.

The full risk assessment for all exposed assets for the planning timeframes Present Day, 2030, 2050 and 2118 is presented in Appendix C and Appendix D for inundation and coastal processes (erosion) respectively. Chapter 6 presents the prioritised risk list for erosion and inundation hazards. Table 1-2 presents some discussion points around these lists.

The next phase of the project identifies adaptation options to address the risks.

TABLE 1-2 ASSET RISK PRIORITY DISCUSSION

Inundation	Erosion
Present Day	
Whilst 140 assets are at risk in the present day, due to the low likelihood of the event occurring, the risk classification is low for all assets except the utilities. These may require additional maintenance if significantly inundated.	Only the adhoc seawall is considered a medium risk. This would require additional maintenance / formal design and construction.
2030	
▪ Most assets are at medium risk. This means additional maintenance / repair will be required if significantly inundated. ▪ Public, commercial, tourism and residential buildings may need to consider mechanisms for minimising the impact of flood damage.	Utility connected foreshore infrastructure, marina fuel tank, utilities and Knight Terrace may require additional maintenance / repair
2050	
▪ Utilities and foreshore recreational infrastructure may require significant repair. ▪ The drains to beach may need to be modified to continue to function. ▪ Public, commercial, tourism and residential buildings should consider mechanisms for minimising the impact of flood damage. ▪ There may be some flood related damage to Knight Terrace, car parks and grassed foreshore area leading to increased maintenance requirements.	▪ Utilities, marina fuel tank, petrol pumps and utility connected foreshore infrastructure may require significant repairs. ▪ Public, commercial, tourism and residential buildings may sustain damage. Knight Terrace, Stella Rowley Drive and foreshore recreational infrastructure may require additional maintenance.
2118	
▪ Utilities, foreshore recreational infrastructure, Knight Terrace, Stella Rowley Drive and the adjacent car parking areas and drains may require significant repair or relocation. ▪ Public, commercial, tourism and residential buildings may need significant repairs or relocation. ▪ Flood related damage to public open space, beach access, boat ramps and marine infrastructure may require significant repairs	▪ Utilities, marina fuel tank, petrol pumps, utility connected foreshore infrastructure, public, commercial, tourism and residential buildings, Knight Terrace and a section of Stella Rowley Drive may require relocation ▪ Foreshore recreational infrastructure may require significant repair or relocation ▪ Beach access, boat ramps and marine infrastructure may require significant repairs

CONTENTS

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APPENDICES

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

It is internationally recognised that increasing sea levels and storm intensities will intensify coastal hazards such as coastal inundation (temporary coastal flooding), storm erosion and long-term shoreline recession (IPCC 2014). Consequently, State governments across Australia have introduced obligations that require local governments to consider and plan for the effects of these hazards over various planning timeframes. In Western Australia (WA), the governing policy is the Western Australian Planning Commission's State Coastal Planning Policy 2.6 (WAPC, 2013, herein referred to as "SPP2.6"). SPP2.6 recommends management authorities develop a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP). Specific guidelines have been developed to assist in this process (WAPC, 2014).

One of the key objectives of SPP2.6 is to establish coastal foreshore reserves which include allowances for the protection, conservation and enhancement of coastal values across the state. Risk assessment processes are then utilised to identify risks that are intolerable to the community, and other stakeholders such as the Shire of Shark Bay, indigenous and cultural interests, and private enterprise. Adaptation measures are then developed according to the preferential adaptation hierarchy outlined in SPP2.6.

The aim of the present study is to investigate and plan for coastal hazards which are likely to affect the Denham townsite. Denham is located within the local government area of the Shire of Shark Bay, approximately 800km north of Perth (refer Figure 1-1 for locality). Denham and its surrounds are used extensively for tourism, commercial and recreational purposes. Tourism is the primary industry in the Shire, with fishing and aquaculture also playing a major role.

Given the above, visitors to and residents of Denham and its surrounds place a high value on the coastline. Processes affecting the coastal zone are multiple and complex: storm surge; tidal movement; shoreline stability; stormwater drainage; and the interactions between surface and groundwater all contribute in differing degrees. Furthermore, the potential impacts of climate change, specifically increasing sea levels and storm intensities, will place increased pressure on the coastal zone, and threaten public infrastructure and assets, private property, foreshore reserves, coastal attractions and public open spaces.

This document presents the Risk Assessment Chapter Report. The assets identified as being at risk of coastal hazards will be assessed against the success criteria, as identified in the community values assessment. A prioritised list of risks is developed, allowing for existing controls that may provide some risk mitigation. The flow chart displayed in Figure 1-2 indicates where this component of the study sits with reference to the wider study; the 'Risk Analysis and Evaluation' phase corresponds to the bubble shaded in red.

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FIGURE 1-1 EXTENT OF CHRMAP

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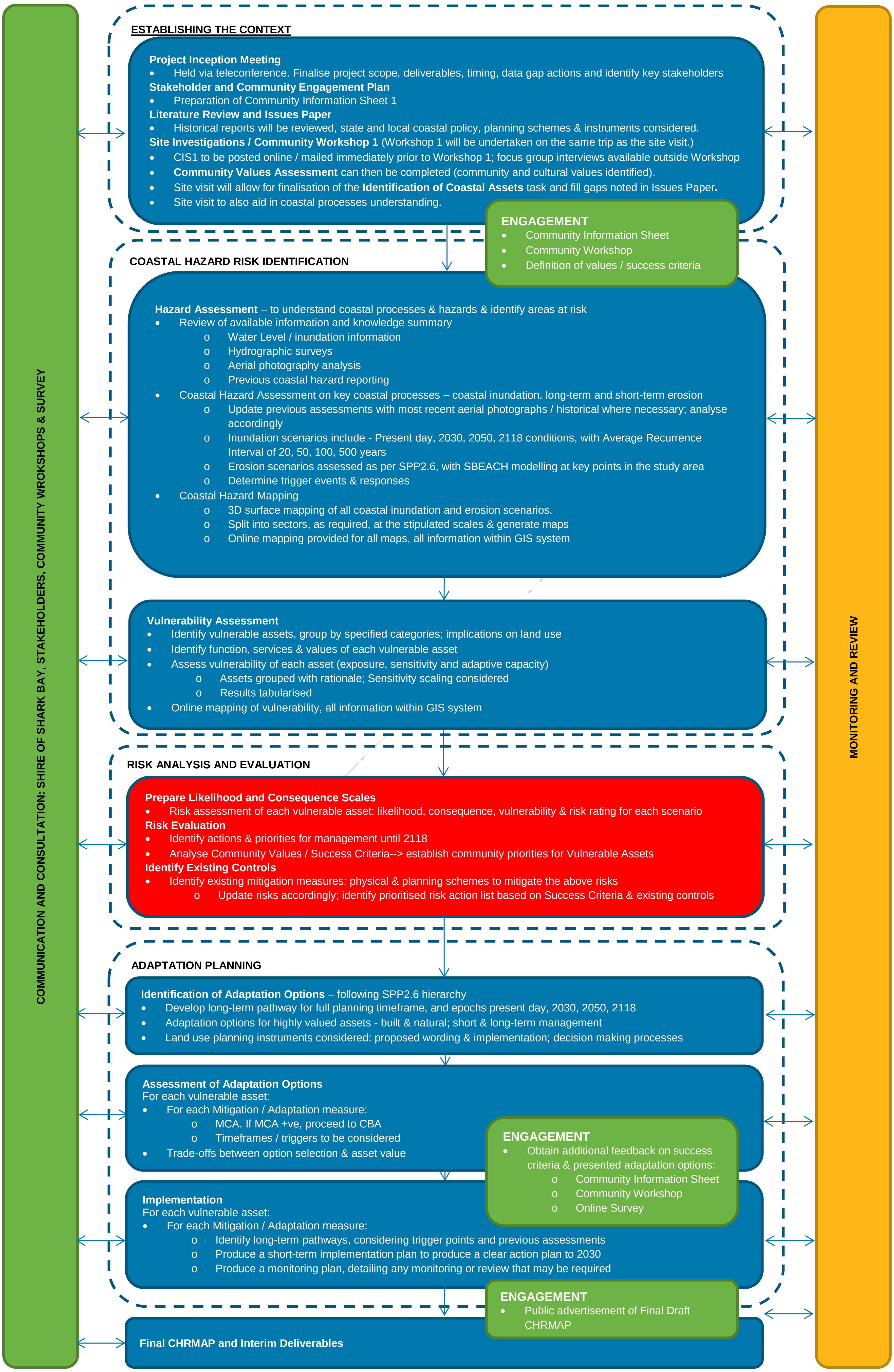

FIGURE 1-2 PROPOSED CHRMAP METHODOLOGY FLOW CHART (ADAPTED FROM WAPC CHRMAP GUIDELINES)

2 SUCCESS CRITERIA

Community and stakeholder involvement are a critical component of the CHRMAP process, as it defines what and how much value is placed on assets within the study area. This will inform the adaptation planning process and ensure all needs are considered. A Community Values assessment was conducted as part of the Establish the Context Chapter Report (Water Technology, 2018b). This aimed to determine the success criteria for the risk assessment component of the CHRMAP. Success criteria represent stakeholders' tolerance and acceptability of the impact to assets from the identified coastal hazards.

As defined in Water Technology (2018c), stakeholders for the project can be split into two categories:

- Internal Stakeholders:
  - Part of the decision-making team. Predominantly, these will be Shire of Shark Bay Councillors and staff, although state government will also play a role. A Steering Committee has been established to oversee preparation and completion of the CHRMAP, including review of project deliverables. This includes representatives from state government.
- External Stakeholders:
  - Not decision-makers but are affected by the project outcomes. They might live near the coast, use an asset or resource located in the coastal zone, or simply have an interest in the coastal foreshore reserve.

The Community Values Assessment aimed to engage both internal and external stakeholders.

2.1 Community Workshop Values

The engagement strategy (Water Technology, 2018c) identified a workshop to collate the stakeholder and community's values. The workshop was held on 3rd May 2018 and consisted of internal stakeholders only. The values collated from the workshop were used to generate preliminary success criteria for the risk assessment; these are defined in Table 2-1.

The success criteria are key to the whole CHRMAP as it is these that will ultimately drive the selection of adaptation options. It is important that a comprehensive approach be applied at this stage of the project, in order to provide a CHRMAP applicable to the Shire and stakeholders.

TABLE 2-1 PRELIMINARY SUCCESS CRITERIA

• **Protection of the environmental assets of the study area / planning to retain environmental integrity** • **Protection of the recreational value of the coastline** • **Protection of the cultural values of the coastline** • **Maintenance of the culture of the Denham Town Centre** • **Maintenance of a level of public infrastructure** • **Development controls not to inhibit the landscape**

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2.2 Community Values Survey

Upon discussion of the workshop outcomes with the project Steering Committee, it was decided the development of the success criteria could be further enhanced by the addition of external stakeholder input. This was undertaken in the form of an online survey. The survey was posted online for a period of 3 weeks: from 12th July to 2nd August 2018. A total of 36 responses were received; all had a 100% completion rate.

The survey questions are displayed in Appendix A. The full results are presented in Appendix B. A summary and discussion of the results is as follows:

- Most of the responses were from residents or ratepayers of Denham.
- Most people were concerned about the permanent impacts of sea level rise.
  - There is some opportunity for further information to be provided at the next workshop in order to improve understanding of coastal erosion and coastal inundation.
- Values of the Denham townsite coastline were ranked in the following order:
  - Recreational opportunities, e.g. boating, fishing, swimming
  - Public access to the beach
  - Recreational assets, e.g. parks, beach shade / picnic structures
  - Environmental landscape / natural ecosystems
  - Work / education opportunities
  - Commercial / business opportunities
- When asked to rate values in the terms of what to protect, the results were slightly different. The protection of coastal values is listed in the order as rated in the survey:
  - Protecting environmental assets
  - Protecting the recreational value of the coastline
  - Maintenance of a level of public infrastructure
  - Planning controls so coastal development does not inhibit the landscape
  - Protection of the cultural values of the coastline
  - Maintenance of the culture of the Denham town centre
- All survey responders considered it important to access the coastline. The majority would have their way of life impacted if the opportunity to access the coastline was lost, as they could not conveniently access these elsewhere.
- Some responders had observed impacts of both coastal erosion and inundation
- Adaptation options were ranked as follows. All adaptation options were selected by at least 11 respondents as appropriate:
  - Avoid development within the coastal hazard zone.
  - Adapt structures to accommodate coastal hazards
  - Protection of at-risk assets
  - Planned / managed retreat of at-risk assets

Overall, the survey indicated respondents placed a high value on the recreational and environmental value of the coastline.

2.3 Adopted Success Criteria

The outcomes of the workshop and the results of the survey were reviewed to develop the final adopted success criteria. These are presented in Table 2-2. These highlight the importance the community and stakeholders place on the environmental, social and cultural value of the study area.

TABLE 2-2 ADOPTED SUCCESS CRITERIA

- **Protection of the environmental assets of the study area / planning to retain environmental integrity**
- **Protection of the recreational value of the coastline**
- **Protection of the cultural values of the coastline & town centre**
- **Maintenance of a level of public recreational assets**
- **Development controls not to inhibit the landscape**

3 RISK ASSESSMENT PROCESS

The risk assessment process adopted for this CHRMAP is described in Figure 3-1. Also included in the figure is how the risk assessment relates back to the vulnerability assessment conducted in Water Technology (2018a). In that report, the vulnerability for all coastal assets was assessed by rating the exposure, sensitivity, and adaptive capacity. For the risk assessment, the likelihood and consequence ratings are assigned, which determines the preliminary risk classification. Existing controls are then examined in a similar way to adaptive capacity to generate the unmitigated risk classification. Future stages of the CHRMAP will investigate possible adaptation options, as shown by the grey boxes in Figure 3-1. These adaptation options aim to bring any risks identified as intolerable back into the tolerable range.

The risk assessment employs the suggested methods of WAPC (2014) and AS 5334-2013 “Climate change adaptation for settlements and infrastructure - A risk-based approach”.

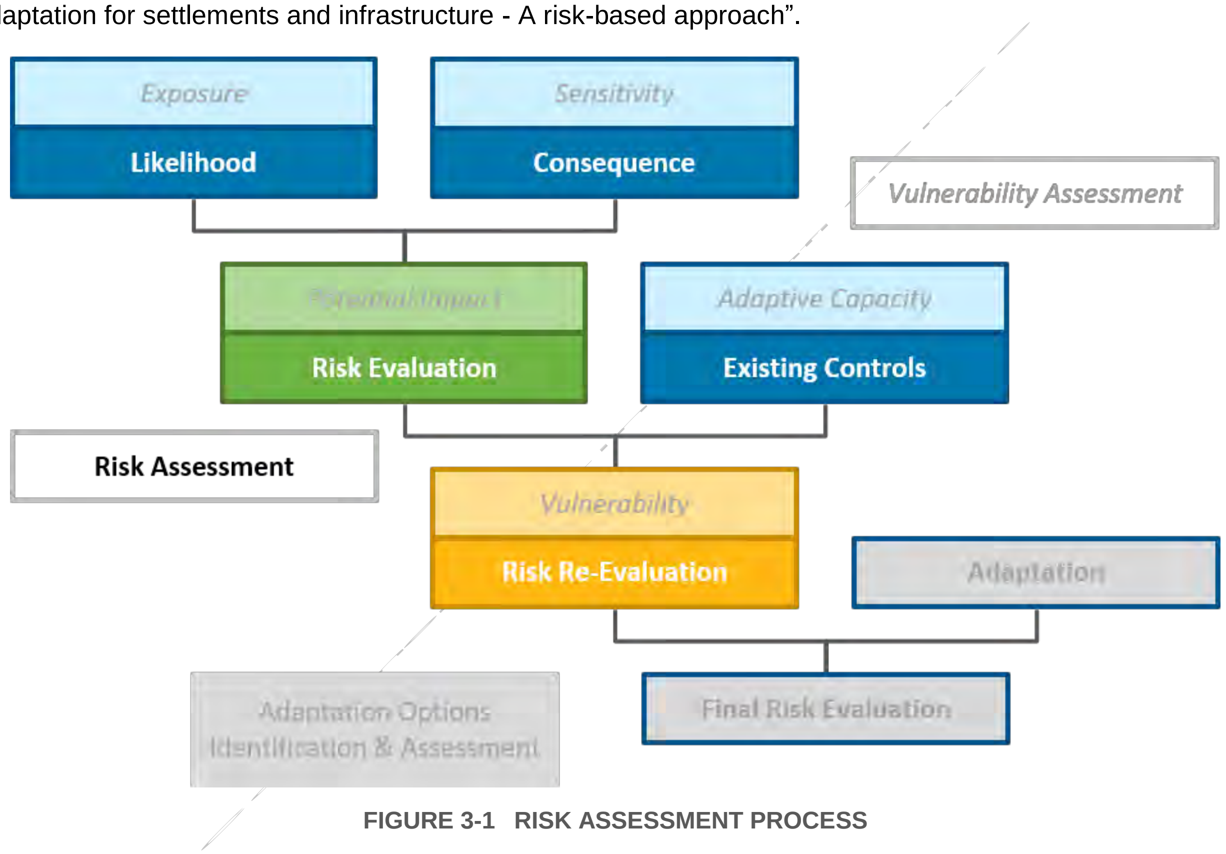

FIGURE 3-1 RISK ASSESSMENT PROCESS

3.1 Likelihood & Consequence Scales

As described in Figure 3-1, defining the likelihood and consequence of a coastal hazard is the precursor to understanding the risk to any coastal asset. Determining the risk level of the coastal assets will allow the Shire to prioritise future adaptation actions. Likelihood examines the probability of an inundation or erosion event occurring, as well as its frequency (WAPC, 2014). Consequence examines the impact to the assets as a result of the coastal hazard.

3.1.1 Likelihood Ranking

Table 3-1 presents the likelihood ranking to be applied to each hazard in the risk assessment in terms of annual exceedance probability and frequency. Table 3-2 presents the various probabilities of the 100-year ARI erosion event and 500-year ARI inundation event occurring during the planning timeframes. The calculation of these

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probabilities is extremely complex. For the purposes of this risk assessment it was necessary to make a series of simplifying assumptions. Any adaptation measures will consider applying triggers before implementation which reduces the risk of this simplification process. For example, a trigger might be reached by an inundation event with certain consequences occurring twice in a given year.

To determine the probability of the erosion event occurring, it is assumed that the 100-year ARI storm event corresponding to the short-term erosion component happens once rather than 3 times in succession, as was actually modelled in the coastal hazard assessment (Water Technology, 2018a). It is assumed that the long-term shoreline rates of change are fixed and will occur; the probability is connected purely to the likelihood of the present-day short-term erosion event.

The present day 500-year ARI inundation event has a 0.2% chance of occurring in any given year. By 2118, it is 18% likely that this event will have occurred once. However, in 2118, there is also a 0.2% chance the 2118 500-year ARI event will occur, which has a higher water level and therefore greater consequence. To take this into account, the combined probability of the inundation events occurring over the planning timeframes was calculated. For example, the 2050 inundation probability presented in Table 3-2 considers the likelihood that one of the present day, 2030 and 2050 500-year ARI inundation events would have occurred by 2050.

The inundation likelihood was calculated in this way due to the real risk of inundation for the town. The present day 20-year, 50-year and 100-year ARI events also show inundation extents similar to the 500-year ARI extent. By calculating the combined probability of the 500-year ARI event, the likelihood of inundation is more realistically captured in the risk assessment.

TABLE 3-1 LIKELIHOOD RANKING DEFINITION

Likelihood Level	Frequency	Annual Exceedance Probability
1 – Rare	Recurrent events are unlikely to occur more than once per century. Single events are not expected to occur but are possible.	< 1%
2 – Unlikely	Recurrent events are expected to occur only 1-2 times per century. Single events are unlikely.	1-10%
3 – Possible	Recurrent events are expected to occur every decade or so. Single events are less likely than not.	10 – 50%
4 – Likely	Recurrent events are expected several times each decade. Single event more likely to occur than not.	50 - 90%
5 – Almost Certain	Recurrent events expected to happen several times per year. Single event highly likely.	> 90% probability

TABLE 3-2 EVENT PROBABILITIES OVER PLANNING TIMEFRAMES

Timeframe	500-year ARI Inundation Event Probability	100-year ARI Erosion Event Probability
Present Day	0.2%	1%
2030	2.6%	11.4%
2050	10.1%	27.5%
2118	40.2%	63.4%

3.1.2 Consequence Ranking

The consequence ranking presented in Table 3-3 constitutes the physical impact of the event to the asset, as well as that of the values attributed to it by the success criteria defined in Chapter 2.3. The second column of Table 3-3 considers the physical impact; columns 3 and 4 include the application of the success criteria. The economic costs associated with the various consequences have not been considered at this time. The economic costs will be included in the cost benefit analysis as part of the adaptation options assessment component of the CHRMAP. The process aims to assess the risks in terms of the stakeholder and community values first, before assigning a monetary value.

For each hazard, the consequence is assessed against the criteria. Inundation hazards use the flood hazard curve presented in Figure 3-2 to gain an understanding of the impact to the specific structure or asset. This combines the water depth and current velocity for assessing the flood hazard to people, vehicles and structures / buildings. Erosion hazard is assessed in a more qualitative manner, based on experience of the impacts of coastal erosion, and the examples presented in the consequence scale.

TABLE 3-3 CONSEQUENCE RANKING

Consequence Level	Physical Impact	Environment	Community, Culture & Lifestyle
1 – Insignificant Minimal, if any, impact which has an overall negligible net effect	Minor damage requiring increased maintenance	Negligible to no impact to flora and fauna	Minor instances in which the asset is unable to maintain its services. Short-term inconvenience, <5% community affected
2 – Minor Localised, reversible short-term events with minor effects which are contained to an onsite level	Damage to assets resulting in restrictions in capability	Short term loss of flora and fauna. Recovery will be strong.	Isolated but noticeable examples of disruption in asset function; <10% community affected
3 – Moderate Localised long term but reversible event with moderate impact on a local level	Damage to assets resulting in isolated loss of capability	Medium term loss of flora and fauna. Recovery is likely.	General appreciable decline in assets & their function; <25% of community affected
4 – Major Extensive, long term, but reversible event with high impacts on a regional level	Significant damage to many assets resulting in very limited capability	Major damage to flora and fauna. Limited chance of recovery.	Severe decline in asset services and corresponding quality of life within the community; <50% of community affected
5 – Catastrophic Long term, extensive, irreversible with high level impacts, potentially at state wide levels	Significant damage to most assets resulting in loss of capability	Permanent damage to flora and fauna. No chance of recovery	Asset services failure; no chance of repair; >75% of community affected

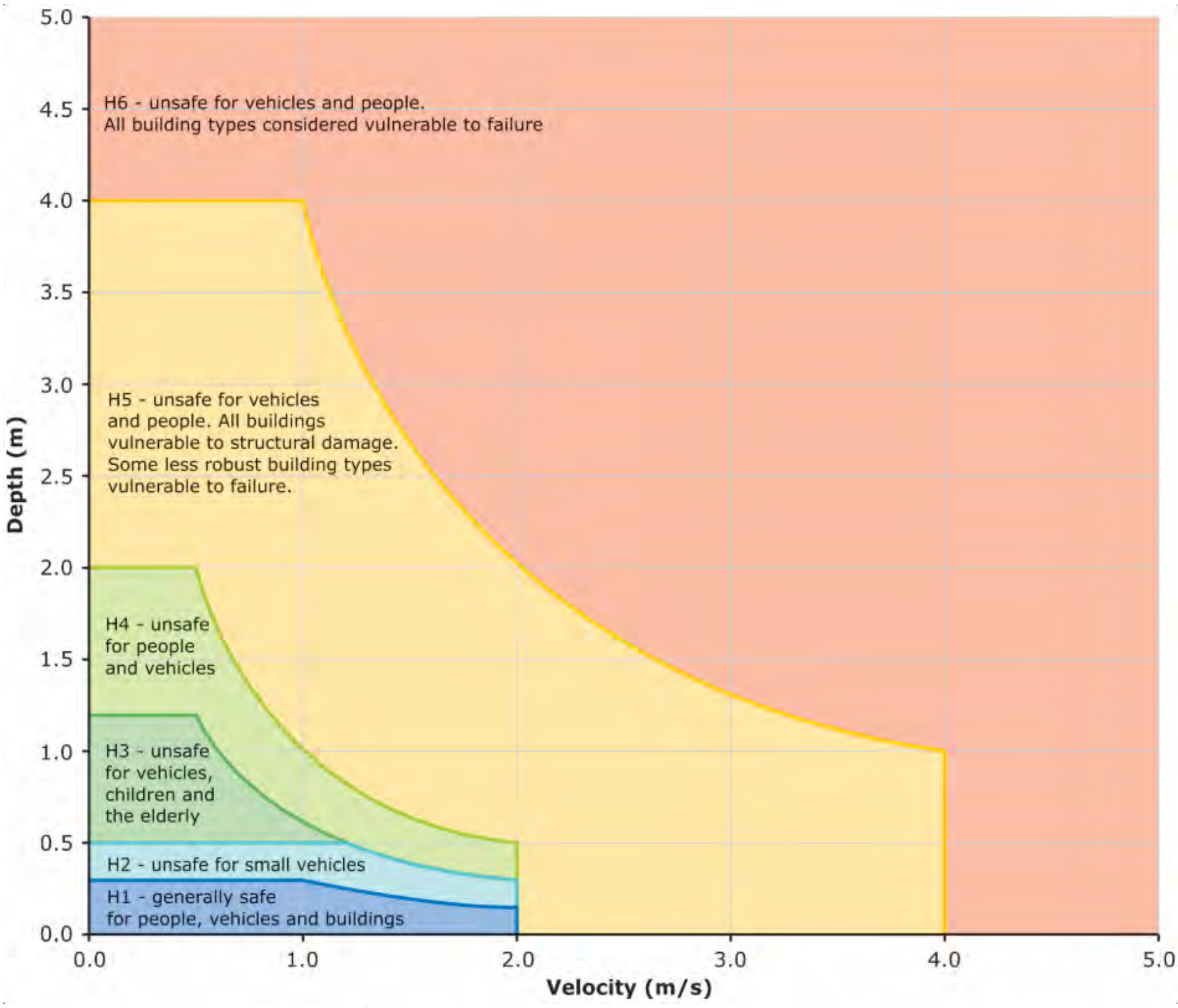

FIGURE 3-2 FLOOD HAZARD CURVE (SMITH ET AL, 2014)

3.2 Risk Classification

For the risk assessment process, the likelihood and consequence are combined to generate a risk classification. The risk classification corresponding to each likelihood and consequence is presented in Table 3-4. The risk classification definitions are presented in Table 3-5.

TABLE 3-4 RISK ASSESSMENT MATRIX

Likelihood	Consequence				
	1 - Insignificant	2 - Minor	3 - Moderate	4 - Major	5 - Catastrophic
5 – Almost Certain	**Low**	**Medium**	**High**	**Extreme**	**Extreme**
4 – Likely	**Low**	**Medium**	**Medium**	**High**	**Extreme**
3 – Possible	**Low**	**Low**	**Medium**	**High**	**Extreme**
2 – Unlikely	**Low**	**Low**	**Medium**	**Medium**	**High**
1 – Rare	**Low**	**Low**	**Low**	**Medium**	**Medium**

TABLE 3-5 RISK PROFILE DEFINITION

Risk Profile	Definition
Low	Tolerable risk. A level of risk that is low and manageable without intervention outside routine asset maintenance.
Medium	A level of risk that may require intervention to mitigate, such as changes to design standards or asset maintenance.
High	A level of risk requiring significant intervention to mitigate.
Extreme	Immediate action required

4 RISK EVALUATION

Risk evaluation of each asset is based on assigning a likelihood and consequence for inundation and erosion hazards to each asset separately. The consequence, and therefore the assessment of risk, is directly linked to the success criteria generated specifically for this project by the community and stakeholder engagement.

The evaluation of risk focuses on providing the Shire with the ability to clearly prioritise coastal hazard risks across the study area and assist in the development of appropriate adaptation options.

4.1 Asset Identification

In the Establish the Context Chapter Report (Water Technology, 2018b), the assets in the coastal zone were identified. These were grouped as follows:

- Commercial
  - This includes shops, businesses, offices etc.
- Public
  - This item mainly relates to public infrastructure, and includes the boat ramp and jetty structures
- Tourism Related
  - This mainly includes tourist accommodation such as caravan parks, hostels and private rentals
  - Whilst tourism is a commercial venture, it is a key industry for the Shark Bay area, so is relevant as a category of its own
- Residential
  - Private houses, apartments and supporting structures such as sheds and garages

Each asset was colour coded based on its classification for ease of identification in the maps and online database. The online database can be found at the following link:

https://watech.maps.arcgis.com/apps/webappviewer/index.html?id=6e092b4d0f044e038a721705e907c084

4.2 Inundation Risk Evaluation

Appendix C contains the full risk assessment for all exposed assets for the planning timeframes Present Day, 2030, 2050 and 2118. Table 4-1 to Table 4-4 below present a summary of the risk ratings, grouped by the asset classification.

The likelihood of the assets is defined as follows, based on the probability of the 500-year ARI inundation events:

- Present Day: Rare
- 2030: Unlikely
- 2050: Possible
- 2118: Possible
  - The exception to this assignment is for inundation of the drains to the beach and adhoc seawall. Due to the predicted sea level rise of 0.9m, these assets would be ‘Likely’ to be inundated most of the time.

As discussed in Chapter 3.1.2, assets are assigned a consequence rating based on the flood hazard curve presented in Figure 3-2. This allows for a consistent approach across assets and planning timeframes.

As per the vulnerability assessment (Water Technology, 2018a), further sub-classifications were identified for each asset classification, defined according to their sensitivity to the coastal hazard. This breakdown was most detailed for the public assets. For example, a power substation ('Utility') has a much greater sensitivity to inundation than a park bench. The risks are sorted within each asset category from the greatest to lowest risk. This presents the prioritised list of risks before the identification of existing controls.

4.2.1 Commercial Assets

The commercial assets and their risk are presented in Table 4-1. The petrol pumps and fuel tank have a slightly higher risk in 2050 due to the higher consequence of damage.

TABLE 4-1 COMMERCIAL ASSETS INUNDATION RISK

Asset Classification	Number Affected	Present Day	2030	2050	2118
Above ground fuel tank	1	Low	Medium	High	High
Fuel stations and below ground fuel tanks	2	Low	Medium	High	High
General buildings	11	Low	Medium	Medium	High

4.2.2 Public Assets

The public assets and their risk are presented in Table 4-2. The greatest risk rating is assigned to the utilities. The drains to the beach rely on gravity flow from the streets down to the beach. Under increased sea levels and storm frequency, the ability of the drains to function will be reduced as they may be more frequently inundated. Under the 2118 predicted sea level rise, the drains may be completely inundated most of the time.

Similarly, the adhoc seawall will have limited function if inundated permanently.

Assets with a low structural stability and / or connected to utilities are considered to be sensitive, and therefore also have a high risk rating.

4.2.3 Residential Assets

The residential assets and their risks are presented in Table 4-3. Vacant blocks have a lower risk rating as the consequence of inundation is also lower.

TABLE 4-2 PUBLIC ASSETS INUNDATION RISK

Asset Classification	Number Affected	Present Day	2030	2050	2118
Utilities	6	Medium	Medium	High	Extreme
Drain to beach	9	Low	Medium	High	High
Seawall - adhoc	4	Low	Medium	High	High
Fish cleaning station	1	Low	Medium	High	High
BBQ & Covered Structure	3	Low	Medium	High	High
Public Toilet	3	Low	Medium	High	High
Public art	3	Low	Medium	High	High
Playground	1	Low	Medium	High	High
Limestone retaining wall	2	Low	Medium	High	High
Foreshore Path	1	Low	Medium	High	High
Public bench & reclaimed jetty posts	5	Low	Medium	High	High
Picnic table / pergola	11	Low	Medium	High	High
Shire Offices	1	Low	Medium	Medium	High
DBCA*	1	Low	Medium	Medium	High
Shark Bay Discovery Centre	1	Low	Medium	Medium	High
Community resource centre	1	Low	Medium	Medium	High
Road (Knight Terrace & Stella Rowley Dve)	2	Low	Medium	Medium	High
Car Park	5	Low	Medium	Medium	High
Grassed foreshore area / public park	3	Low	Medium	Medium	Medium
Beach access	1	Low	Low	Medium	Medium
Boat ramp	3	Low	Low	Low	Medium
Universal beach access (removable)	2	Low	Low	Low	Medium
FRP Sheet-pile groyne	1	Low	Low	Low	Medium
Seawall - engineered	2	Low	Low	Low	Medium
Jetty	3	Low	Low	Low	Medium

- * Department of Biodiversity, Conservation & Attractions

TABLE 4-3 RESIDENTIAL ASSETS INUNDATION RISK

Asset Classification	Number Affected	Present Day	2030	2050	2118
Houses	29 (30*)	Low	Medium	Medium	High
Vacant blocks	14	Low	Low	Low	Medium

* number of assets affected increases for the 2118 planning timeframe – value indicated in brackets

4.2.4 Tourism Related Assets

The tourism related assets and their risks are presented in Table 4-4. These are assessed the same way as houses, public buildings and other commercial buildings.

TABLE 4-4 TOURISM RELATED ASSETS INUNDATION VULNERABILITY

Asset Classification	Number Affected	Present Day	2030	2050	2118
General sets of buildings	8 (9*)	Low	Medium	Medium	High

* number of assets affected increases for the 2118 planning timeframe – value indicated in brackets

4.3 Erosion Risk Evaluation

The number of assets predicted to be impacted due to erosion varies between the planning timeframes, as displayed in Table 4-5. Appendix D contains the full risk assessment for all exposed assets for the planning timeframes Present Day, 2030, 2050 and 2118. Table 4-6 to Table 4-9 present a summary of the risk ratings, grouped by the asset classification. In each table, 'N/A' means Not Affected.

The likelihood of the assets is defined as follows, based on the probability of the 100-year ARI erosion event:

- Present Day: Unlikely
- 2030: Possible
- 2050: Possible
- 2118: Likely

The consequence is selected based on the definition of the erosion hazard: the land is either no longer present at that location, or severely eroded and unstable.

As per the inundation risk assessment, each asset classification was further sub-divided for the assessment.

TABLE 4-5 ASSETS EXPOSED TO EROSION

Asset Classification	Present Day	2030	2050	2118
Commercial	0	1	5	14
Public	20	64	70	74
Residential	0	0	18	51
Tourism Related	0	1	4	9

As stated above, in each of the risk rating tables Table 4-6 to Table 4-9, 'N/A' means Not Affected. In some cases, an asset is listed as Not Affected for present day through to 2050, and then the rating is assigned as Extreme for the 2118 planning timeframe. For example, the public assets Shark Bay Discovery Centre, and Department of Biodiversity, Conservation & Attractions (DBCA). Whilst this appears to be a sudden change in the risk rating, in fact the risk of the asset exposed to erosion would be increasing steadily over the 68 years between these two planning timeframes. The hazard maps presented in the online database, and in Water Technology (2018a), indicate these buildings to be located between the 2050 and 2118 hazard line. As per the definition of erosion risk, at some point between 2050 and 2118, if the erosion risk is realised, the land in this zone will either no longer be present at that location, or severely eroded and unstable. The likelihood assigned for this is 4 (likely, at 63.4% annual exceedance probability), and the consequence is 5 (catastrophic: long term, extensive, irreversible with high level impacts; significant damage to asset resulting in loss of capability). As per the risk classification matrix in Table 3-4, these assignations result in the extreme risk rating. That is, immediate action is required. In reality, the trigger for an adaptation option would occur prior to 2118, as part of the CHRMAP actions would be to re-assess the risk profile every 5 years or so.

4.3.1 Commercial Assets

The commercial assets and their risks are presented in Table 4-6. Assets are not predicted to be impacted until 2030.

TABLE 4-6 COMMERCIAL ASSETS EROSION RISK

Asset Classification	Present Day	2030	2050	2118
Above ground fuel tank	N/A	Medium	High	Extreme
Fuel stations and below ground fuel tanks	N/A	N/A	High	Extreme
General buildings	N/A	N/A	High	Extreme

4.3.2 Public Assets

The public assets and their risks are presented in Table 4-7. For the public assets, the greatest risk ratings are assigned to the utilities and the public buildings such as the Shire offices. Similar to the inundation assessment, public assets connected to utilities are thought to be more sensitive than those without.

4.3.3 Residential Assets

The residential assets and their risks are presented in Table 4-8. Vacant blocks have a lower risk rating as the consequence is lower than an existing house.

TABLE 4-7 PUBLIC ASSETS EROSION RISK

Asset Classification	Present Day	2030	2050	2118
Utilities	Medium	Medium	High	Extreme
Seawall - adhoc	Medium	Medium	High	Extreme
Public Toilet	N/A	Medium	High	Extreme
BBQ & Covered Structure	N/A	Medium	High	Extreme
Fish cleaning station	N/A	Medium	High	Extreme
Shire Offices	N/A	N/A	High	Extreme
DBCA	N/A	N/A	N/A	Extreme
Shark Bay Discovery Centre	N/A	N/A	N/A	Extreme
Community resource centre	N/A	N/A	N/A	Extreme
Road (Knight Terrace & Stella Rowley Drive)	N/A	Medium	High	Extreme
Drain to beach	N/A	Low	Medium	High
Foreshore Path	Low	Low	Medium	High
Limestone retaining wall	Low	Low	Medium	High
Playground	N/A	Low	Medium	High
Grassed foreshore area / public park	N/A	Low	Medium	High
Public art	Low	Low	Medium	High
Picnic table / pergola	Low	Low	Medium	High
Public bench & reclaimed jetty posts	Low	Low	Medium	High
Car Park	Low	Low	Medium	High
Seawall - engineered	N/A	Low	Low	Medium
FRP Sheet-pile groyne	N/A	Low	Low	Medium
Jetty	N/A	Low	Low	Medium
Boat ramp	N/A	Low	Low	Medium
Beach access	Low	Low	Low	Medium
Universal beach access (removable)	Low	Low	Low	Low

TABLE 4-8 RESIDENTIAL ASSETS EROSION RISK

Asset Classification	Present Day	2030	2050	2118
Houses	N/A	N/A	High	Extreme
Vacant blocks	N/A	N/A	High	High

4.3.4 Tourism Related Assets

The tourism related assets and their risks are presented in Table 4-9. These are assessed the same way as houses, public buildings and other commercial buildings.

The Denham Seaside Caravan Park is the asset predicted to be in the coastal hazard zone in 2030. However, only caravan / tent sites are located in the zone, so the consequence is reduced.

TABLE 4-9 TOURISM RELATED ASSETS EROSION RISK

Asset Classification	Present Day	2030	2050	2118
General sets of buildings	N/A	Low	High	Extreme

5 EXISTING CONTROL IDENTIFICATION

5.1 Planning Controls

Planning in Western Australia is guided and regulated by the State Planning Framework, which ranges from overarching strategic planning strategies, to specific planning policies and supportive guidelines. Figure 5-1 explains the framework, which includes planning at the state, regional, and local levels and demonstrates how strategic planning is implemented through statutory planning controls (e.g. local planning schemes) and local planning policies. This Framework sits within the *Planning and Development Act 2005*.

The Establish the Context Chapter Report (Water Technology, 2018b) reviewed the planning documents within this Framework which are relevant to coastal hazard planning in the project area. The review aimed to:

- Assess the adequacy of the existing planning documents for addressing coastal hazards.
- Identify gaps that need to be addressed through the CHRMAP process.
- Identify any potential planning issues that may constrain the CHRMAP process.
- Ensure that the Shire's adaptation plan aligns with state, regional and local planning frameworks.

Through this review, existing development controls relating to the impacts of coastal hazards for land use and development were identified. The following sub-chapters summarise the controls relevant to this study.

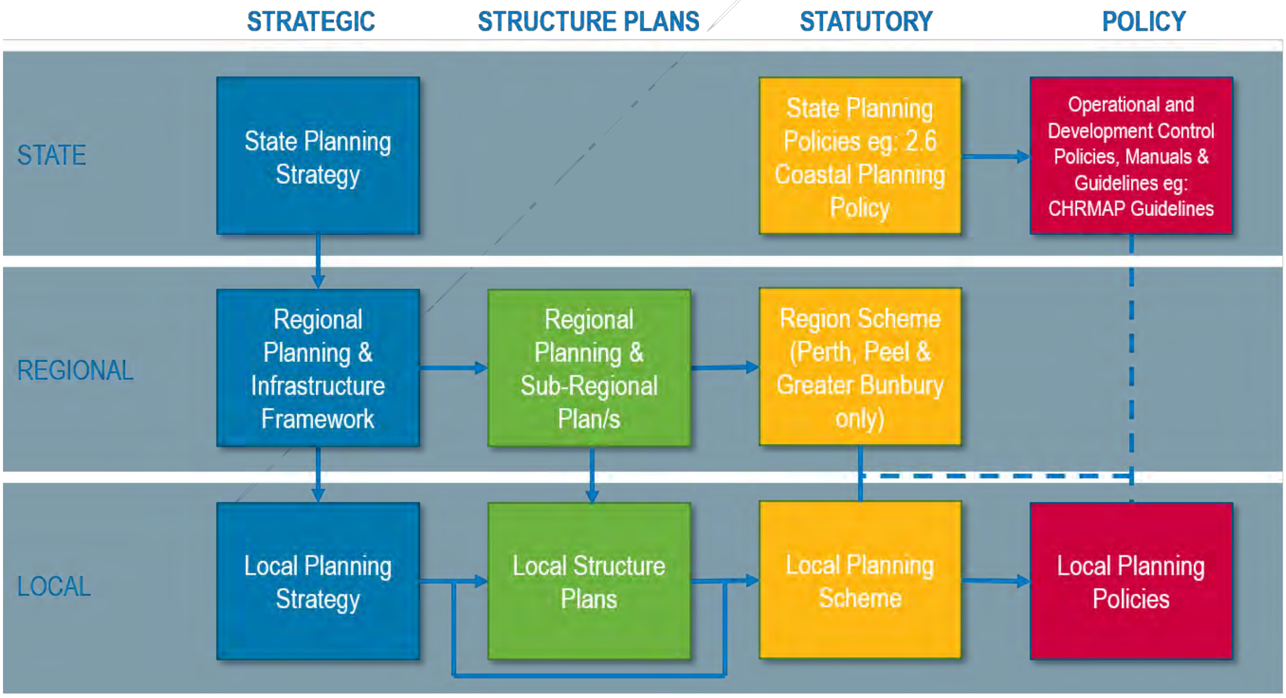

FIGURE 5-1 STATE PLANNING FRAMEWORK FOR WESTERN AUSTRALIA

5.1.1 Shire of Shark Bay Local Planning Strategy

The *Shire of Shark Bay Local Planning Strategy 2013* (*Local Planning Strategy)* outlines the local government's intentions and objectives for development of the district over a timeframe of around 15 years. It informs the content of the local planning scheme to provide the statutory controls and guidance to direct development towards achieving these longer-term objectives. The local planning strategy is an important guiding document for the exercise of discretion in determining planning applications within the district as it provides context and enunciates the intentions behind various planning strategies, scheme provisions and local planning policies.

The local planning strategy has several stated objectives that are directly or indirectly related to planning for coastal areas. These objectives are reproduced in Table 5-1, with remarks as to the relevance to coastal planning. Whilst these aren't formal controls that will impact the risk assessment, they are still relevant to the CHRMAP process.

TABLE 5-1 LOCAL PLANNING STRATEGY OBJECTIVES - COASTAL AREAS

Objective	Comment
To identify key components of the long-term direction for the Shire of Shark Bay that are crucial to orderly growth and development of the Denham townsite, and to recommend strategies to pursue these.	Orderly growth and development of the townsite require a considered and strategic response to coastal processes, given the vulnerability of some areas and assets.
Ensure that there is sustainable provision of land to meet existing and future needs for housing, business, community facilities, recreation, open space, industry, tourist accommodation, foreshore facilities, and civic uses.	Sustainable provision implies the ability to use the land in the long term, without undue economic, social or environmental cost. New development should therefore be located or built to minimise or avoid impacts from coastal processes if possible.
To provide a range of quality services and amenities to meet the existing and future needs of the local community and support local tourism in a manner that enhances the existing townsite and does not adversely impact on local character and amenity.	A balance will be required between mitigating inundation from storm surges and an acceptable town centre amenity.
Support ongoing improvements and expansion of infrastructure and provide a basis for coordinated decision making on future servicing of the local government area by local, state government, and service providers.	This will require clarity about coastal processes and requirements to ensure assets are not put at unacceptable risk from inundation or erosion.
Protect the natural environment, resources and coastal areas from inappropriate development that may have any undesirable or negative impact in terms of amenity, social, environmental, or visual.	Inappropriate development would include any that could exacerbate the impact of coastal processes on assets.
Give direction to the Shire of Shark Bay, the DPLH, WAPC, the Minister, and the State Administrative Tribunal in assessment of Scheme Amendments, subdivision, applications, development, applications for review, and provide strategic planning support for this decision making.	To achieve this requires clear statutory and policy support in relation to what is acceptable for development on land vulnerable to coastal processes.

The strategy acknowledges that there are key constraints of cyclonic storm and coastal processes. It identifies the following physical constraint challenges relevant to coastal processes:

- The proximity of development to the coast and lack of coastal setbacks. Coastal risks are a planning implication and constraints can be associated with storm surge, coastal processes and setbacks.
- Flooding in the Town Centre resulting from major and intense storm events and the need to implement minimum floor levels, which causes streetscape and design challenges for interaction between existing and new development.

The Local Planning Strategy suggests that increased flexibility could be examined to allow lower levels for detached non-habitable buildings such as outbuildings. This is in recognition that increased floor levels applied to new development will represent a challenge in dealing with streetscape and interfaces between existing buildings and new development of Knight Terrace, the main street. This is difficult when the visual impact of development on land adjacent to the coast is also an important consideration.

5.1.2 Local Planning Scheme

The Shire's current scheme, *Local Planning Scheme No. 3* (LPS 3) will be superseded in due course by *Local Planning Scheme No. 4* (LPS 4), which is currently in draft form. The content of draft LPS 4 follows the recommendations of the *Scheme Review* prepared in November 2016. The *Scheme Review* documents various changes to LPS 3 to be reflected in LPS 4, largely to implement the *Local Planning Strategy.*

One of the stated aims of draft LPS 4 is to impose special conditions for development of land within Denham to mitigate the adverse effects of land subject to inundation and other physical constraints.

Clause 29 of the *Model Scheme Text* provides local government the option to give statutory effect to any relevant State Planning Policy (SPP) in whole or in part, in a similar way as the R-Codes are linked to a Scheme. The Shire has not elected to do this with *SPP 2.6 State Coastal Policy*, although some proposed zones do make reference to the requirement for preparation of foreshore management plans and to have regard to SPP 2.6. Mostly, it is proposed to include provisions relating to requirements for development approval and minimum floor levels in areas identified as being vulnerable to coastal storm surge inundation.

As at April 2018 draft LPS 4 contains the following clause of relevance to land subject to inundation from coastal processes.

31.1 Land Subject to Inundation

a. *No development shall be constructed upon any land within an area considered by the local government as being vulnerable to coastal storm surge inundation unless granted specific planning approval by the local government.*

a. *The local government shall require any new development within an area as being vulnerable to coastal storm surge inundation to comply with a minimum finished floor level not less than RL 4.2 metres AHD.*

b. *Notwithstanding Clause 32.1(b), Council has discretion to consider a minimum finished floor level less than RL 4.2 metres AHD for non-habitable development that is detached from any single house or dwelling unit on the same lot in the Denham townsite and / or any minor non-habitable development that is ancillary to existing tourist development in the Scheme Area.*

c. *In considering applications for development in areas vulnerable to coastal storm surge inundation, the local government may have regard to any Local Planning Policy, or any site-specific coastal storm surge inundation report acceptable to the local government.*

d. *Notwithstanding Clause 32.1(b), the local government has discretion to consider and require alternative minimum finished floor levels where:*

   i. *The proponent provides a site-specific coastal storm surge inundation report by a suitably qualified professional coastal engineer that is acceptable to the local government and clearly identifies appropriate alternative minimum finished floor levels and / or;*

   ii. *Approval of the development is consistent with variations allowable under the relevant State Coastal Planning Policy; and /or*

   iii. *the proposed development only involves refurbishment of or a minor extension to an existing development.*

It is noted that this clause relates only to vulnerability to coastal storm surge inundation. Other potential impacts such as erosion are not addressed in the Scheme. This is an important distinction because whilst infrastructure may recover from temporary inundation, erosion can be much more devastating. It is further noted that there is no Local Planning Policy relating to development on land vulnerable to coastal processes which could provide guidance as to appropriate ways of addressing the risk from coastal processes.

Application of the recommended FFL of 4.2m AHD will be recommended as an adaptation option in the next phase of the CHRMAP. However, the Scheme at present does not give consideration to the method of achieving the elevated FFL. That is, landfill, or raised buildings that allow water to flow beneath them and how this will impact other sites.

There are a number of planning zones located in the coastal foreshore reserve defined in Water Technology (2018a). One such zone is the Special Control Area (SCA) which is described in more detail below in Chapter 5.1.2.1.

Although some special use zones require coastal processes to be addressed in development applications, these controls do not apply universally to land identified as being impacted by coastal processes to 2118.

5.1.2.1 Special Control Area

An SCA is an overlay that applies in addition to the underlying classification of the land and specifies special controls in addition to any other requirements relevant to the underlying zone. An SCA could be applied to relate specifically to land subject to coastal processes, as recommended in WAPC (2017): *Draft Planned or Managed Retreat Guidelines*. This will be analysed in the Adaptation Options Chapter report, the next phase of the CHRMAP.

There is just one proposed SCA located in the study area, the Shark Bay World Heritage Property. However, this is located in the nearshore waters to the north of Nicholson Point, so not directly applicable to the study. For land-based development applications in these areas:

35.1 Application Requirements

a. *The local government may require applicants to provide a professional coastal report by a suitably qualified coastal engineer to determine appropriate coastal setbacks, minimum floor areas, and address coastal hazard risk management adaption planning to comply with relevant state planning coastal policy and guidelines.*

35.2 Relevant Considerations

In considering any proposal including and not limited to a development application, structure plan, local development plan, scheme amendment, strata or subdivision the local government will have regard to:

a. *Requirements for referral of proposals to the Environmental Protection Authority (EPA) under Part IV of the Environmental Protection act 1986.*

b. *Relevant State Planning Policies including and not limited to state Coastal Planning*

c. *Any recommendations and advice provided by relevant government agencies.*

d. *Recommendations and advice by the Shark Bay World Heritage Advisory Committee or any replacement of that Committee.*

5.2 Structural Controls

A formally designed seawall was constructed along a 250m length of the town's foreshore in 2016. For the purposes of the coastal processes assessment (Water Technology, 2018a), the coastline was divided into 5 distinct compartments based on natural and built features. The seawall is located across the eastern half of Section 3; refer Figure 5-3 for location.

A design report reviewed in an earlier stage of the project (Worley Parsons (WP), 2016) indicates the revetment design has a recommended crest level of 3.4 m AHD, with a width of three armour stones at the crest to minimise damage due to overtopping. Water Technology were subsequently provided with the As-Constructed drawings, by the Department of Transport. These detail the crest level as varying around 2.15m AHD, with three armour stones at the crest to minimise overtopping damage. This matches the levels identified in the 2017 Landgate photogrammetry of approximately 2 to 2.5m AHD. This elevation is not enough to prevent overtopping from occurring (known during design and construction and resultant damage levels reduced by crest width) during the present day 100-year and 500-year ARI design event, and possibly the 50-year ARI event. The presence of multiple boat ramps along this seawall also allows a flooding flow path for more frequent storm events behind the wall.

Whilst the revetment will not prevent inundation of the site, its presence will act to prevent cross-shore erosion. Assets in its lee will may therefore have a reduced risk when analysed taking this control into account. Figure 5-2 presents photographs of the seawall, together with some landward assets.

FIGURE 5-2 ENGINEERED SEAWALL ALONG FORESHORE

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FIGURE 5-3 EXTENT OF ENGINEERED SEAWALL – SECTION 3

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6 RISK RE-EVALUATION

As discussed in Chapter 5, the existing risk management controls and measures are as follows:

- New development is required to have a finished floor level (FFL) of 3.2m AHD
  - Draft Local Planning Scheme No. 4 includes a requirement for FFL of 4.2m AHD, however this has not yet come into effect.
- A formal seawall is in place across the eastern half of Section 3. This limits the level of erosion that will occur at the site.

The sub-chapters below discuss the implications of applying these controls to the risk evaluation. Appendix C and Appendix D present the full risk assessment for all assets.

6.1 Inundation Risk Re-Evaluation

Local Planning Scheme No. 3 (LPS 3) was gazetted in 2008. The clause regarding land subject to inundation was modified in 2012. It is not clear from the document's quality control panel if the land subject to inundation clause was added in 2012, or if it was already in place at document gazettal. Similarly, it is not known if the Local Planning Scheme pre-2008 also had a clause regarding finished floor levels. If it is new to LPS 3, buildings older than 6-10 years may not have an FFL of 3.2m AHD. As such, reassessing all buildings assuming this control is in place may lead to lower than actual risks.

For a conservative approach, the risk assessment has been left as assessed in Chapter 4. Appendix C does contain additional columns indicating the revised risk rating if buildings do have an FFL of 3.2m AHD. If applied, the risk level of all buildings drops from 'High' to 'Medium' by 2118. However, the adaptation planning will be determined from the higher risk rating.

6.2 Erosion Risk Re-Evaluation

For the risk assessment, the assets are grouped by type such that there are multiples of the same asset type along the foreshore. For example, toilet blocks, foreshore path and limestone retaining walls occur throughout the foreshore area. It is unsuitable to revise the risk rating for individual instances of these assets that happen to be located landward of the engineered seawall without also revising those that are not protected. Therefore, only the likelihood for assets singularly located in the protected area have been adjusted. The assets with a reduced risk due to the presence of the seawall are as follows:

- Utilities: marina and dock fire hydrants reduced to 'Low' for the present day and a lower 'Medium' by 2030.
- Fuel tank at the marina reduced within the 'Medium' category in 2030.
- Boat ramp and jetty scores are reduced, but this does not change their risk rating within each planning timeframe.
- Fish cleaning station has a reduced risk rating that changes the risk rating in 2050 from 'High' to 'Medium'. This risk is still considered 'Extreme' by 2118.

It is noted that individual asset management plans may take the specific location into account and thus the individual asset's risk, however the adaptation plans developed in the next phase of the CHRMAP will consider each group as a whole.

6.3 Risk Priority List

The risk assessment has allowed the identification of a set of risks that require action, specifically targeting assets that are highly valued by the community. This involves consideration of the success criteria presented in Table 2-2 (Chapter 2.3).

The main area at risk for the town is the length of Knight Terrace. Moving from there to the west along the study area, the remaining at-risk assets include the lookout at Nicholson Point, the car park to the north of Nicholson Point, and a section of Stella Rowley Drive at that location.

Table 6-1 and Table 6-2 present the coastal hazard risks in order of priority for each planning timeframe, due to inundation and coastal erosion respectively. Each asset's risk is presented along each row; risk classification is indicated by colour, as defined in Table 3-4 (Chapter 3.2). Only risks from medium and above are presented; low risks are considered manageable without intervention, as per the risk profile definition.

Some discussion on the risk priority lists are discussed below in Table 6-3.

TABLE 6-1 PRIORITISED ASSETS - INUNDATION RISKS

Present Day	2030	2050	2118
Utilities consist of: ▪ Electrical box, the water pumping station and the water well located at the south-eastern end of Knight Terrace ▪ Electrical substation on Durlacher St near the corner of Knight Terrace ▪ Fire hydrants located at the marina facility			
	Drain to beach, foreshore recreational infrastructure such as benches, picnic tables, BBQs, toilets, public art		
	Fuel tank at marina		
	Petrol pumps / tanks at the 2 petrol stations		
	Public buildings: Shire Offices, DBCA, Shark Bay Discovery Centre, Community resource centre		
	Knight Terrace, car parks, parks		
	Commercial, tourism and residential buildings		
			Vacant blocks

TABLE 6-2 PRIORITISED ASSETS - EROSION RISKS

Present Day	2030	2050	2118
Adhoc seawall			
	Utilities: ▪ Fire hydrants located at the marina facility	Utilities: ▪ Electrical box and water pumping station located at south-eastern end of Knight Terrace ▪ Fire hydrants located at the marina facility	Utilities: ▪ Electrical box and water pumping station located at south-eastern end of Knight Terrace ▪ Fire hydrants located at the marina facility ▪ Electrical substation on Durlacher St near the corner of Knight Terrace
	Foreshore recreational infrastructure: BBQs, toilets, fish cleaning station	Foreshore recreational infrastructure: BBQs, public toilets	Foreshore recreational infrastructure: BBQs, public toilets, fish cleaning station
	Knight Terrace	Knight Terrace & Stella Rowley Drive	
	Fuel tank at marina		
		Public buildings: Shire Offices	Public buildings: Shire Offices, DBCA, Shark Bay Discovery Centre, Community resource centre
		Commercial, tourism and residential buildings	
		Petrol pumps / tanks at the 2 petrol stations	
		Vacant blocks	
		Foreshore recreational infrastructure: foreshore path, limestone retaining wall, playground, parks, car parks, drain to beach, public art, public bench, pergola	
			Marine infrastructure: Engineered seawall, FRP sheet-pile groyne, jetty, boat ramp, beach access

TABLE 6-3 ASSET RISK PRIORITY DISCUSSION

Inundation	Erosion
Present Day	
Whilst 140 assets are at risk in the present day, due to the low likelihood of the event occurring, the risk classification is low for all assets except the utilities. These may require additional maintenance if significantly inundated.	Only the adhoc seawall is considered a medium risk. This would require additional maintenance / formal design and construction.
2030	
▪ Most assets are at medium risk. This means additional maintenance / repair will be required if significantly inundated. ▪ Public, commercial, tourism and residential buildings may need to consider mechanisms for minimising the impact of flood damage.	Utility connected foreshore infrastructure, marina fuel tank, utilities and Knight Terrace may require additional maintenance / repair
2050	
▪ Utilities and foreshore recreational infrastructure may require significant repair. ▪ The drains to beach may need to be modified to continue to function. ▪ Public, commercial, tourism and residential buildings should consider mechanisms for minimising the impact of flood damage. ▪ There may be some flood related damage to Knight Terrace, car parks and grassed foreshore area leading to increased maintenance requirements.	▪ Utilities, marina fuel tank, petrol pumps and utility connected foreshore infrastructure may require significant repairs. ▪ Public, commercial, tourism and residential buildings may sustain damage. Knight Terrace, Stella Rowley Drive and foreshore recreational infrastructure may require additional maintenance.
2118	
▪ Utilities, foreshore recreational infrastructure, Knight Terrace, Stella Rowley Drive and the adjacent car parking areas and drains may require significant repair or relocation. ▪ Public, commercial, tourism and residential buildings may need significant repairs or relocation. ▪ Flood related damage to public open space, beach access, boat ramps and marine infrastructure may require significant repairs	▪ Utilities, marina fuel tank, petrol pumps, utility connected foreshore infrastructure, public, commercial, tourism and residential buildings, Knight Terrace and a section of Stella Rowley Drive may require relocation ▪ Foreshore recreational infrastructure may require significant repair or relocation ▪ Beach access, boat ramps and marine infrastructure may require significant repairs

7 SUMMARY

This document presents the Risk Assessment Chapter Report of the Denham Townsite CHRMAP. The assets identified as being at risk of coastal hazards were assessed against the success criteria, as identified in the community values assessment. A prioritised list of risks was developed, allowing for existing controls that may provide some risk mitigation.

Community Values Assessment: Success Criteria

The stakeholder and community engagement strategy (Water Technology, 2018c) identified a workshop to collate the stakeholder and community's values. Upon discussion of the workshop outcomes with the project Steering Committee, it was decided the development of the success criteria could be further enhanced by the addition of an online survey to gain external stakeholder input.

The outcomes of the workshop and the results of the survey were reviewed to develop the final adopted success criteria. These are presented in Table 7-1. These highlight the importance the community and stakeholders place on the environmental, social and cultural value of the study area.

TABLE 7-1 ADOPTED SUCCESS CRITERIA

- **Protection of the environmental assets of the study area / planning to retain environmental integrity**
- **Protection of the recreational value of the coastline**
- **Protection of the cultural values of the coastline & town centre**
- **Maintenance of a level of public recreational assets**
- **Development controls not to inhibit the landscape**

Risk Assessment & Evaluation

The risk assessment employs the suggested methods of WAPC (2014) and AS 5334-2013 "Climate change adaptation for settlements and infrastructure - A risk-based approach". For the risk assessment process, the likelihood and consequence are combined to generate a risk classification. Likelihood examines the probability of an inundation or erosion event occurring, as well as its frequency (WAPC, 2014). The consequence ranking constitutes the physical impact of the event to the asset, as well as that of the values attributed to it by the success criteria.

The economic costs associated with the various consequences have not been considered at this time. The economic costs will be included in the cost benefit analysis as part of the adaptation options assessment component of the CHRMAP. This process aims to assess the risks in terms of the stakeholder and community values first, before assigning a monetary value.

Risk evaluation of each asset is based on assigning the likelihood and consequence to inundation and erosion hazards to each asset separately. The consequence, and therefore the assessment of risk, is directly linked to the success criteria generated specifically for this project by the community and stakeholder engagement. The evaluation of risk focuses on providing the Shire with the ability to clearly prioritise coastal hazard risks across the study area and assist in the development of appropriate adaptation options.

The full risk assessment for all exposed assets for the planning timeframes Present Day, 2030, 2050 and 2118 is presented in Appendix C and Appendix D for inundation and coastal processes (erosion) respectively.

Chapter 6 presents the prioritised risk list for erosion and inundation hazards separately. Table 6-3 presents some discussion points around these lists. The next phase of the project identifies adaptation options to address the risks

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8 REFERENCES

Intergovernmental Panel on Climate Change (IPCC, 2014). *Climate Change 2014: Synthesis Report*, Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland, Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)], IPCC, Geneva, Switzerland, 151 pp.

Standards Australia (2013). *Australian Standard: Climate change adaptation for settlements and infrastructure - A risk-based approach*, AS 5334-2013, published by Standards Australia, Australia

Smith G P, Davey E K, and Cox R J (2014). *Flood Hazard*, UNSW Australia Water Research Laboratory Technical Report 2014/07, 30 September 2014

Water Technology (2018a). *Denham Townsite CHRMAP Chapter Report: Coastal Hazard & Vulnerability Assessment*, Report Nº 5652-01 R04v01, prepared for Shire of Shark Bay

Water Technology (2018b). *Denham Townsite CHRMAP Chapter Report: Establish the Context*, Report Nº 5652-01 R03v02, prepared for Shire of Shark Bay

Water Technology (2018c). *Denham Townsite CHRMAP: Stakeholder and Community Engagement Plan*, Report Nº 5562-01 R01v01, prepared for Shire of Shark Bay

Western Australian Planning Commission (WAPC, 2013). State Planning Policy No. 2.6 – State Coastal Planning Policy, prepared under the Planning and Development Act 2005.

Western Australian Planning Commission (WAPC, 2014). Coastal Hazard Risk Management and Adaptation Planning Guidelines

Western Australian Planning Commission (WAPC, 2017). Draft Planned or Managed Retreat Guidelines, published by WAPC, Department of Planning, Lands and Heritage

Worley Parsons (WP, 2016). *Denham Foreshore Revitalisation Stage 1A: Design Report*, Report Nº 301012-02233 – GE-REP-002, prepared for Department of Transport

APPENDIX A
COMMUNITY VALUES SURVEY QUESTIONS

TABLE A-1 COMMUNITY VALUES SURVEY QUESTIONS

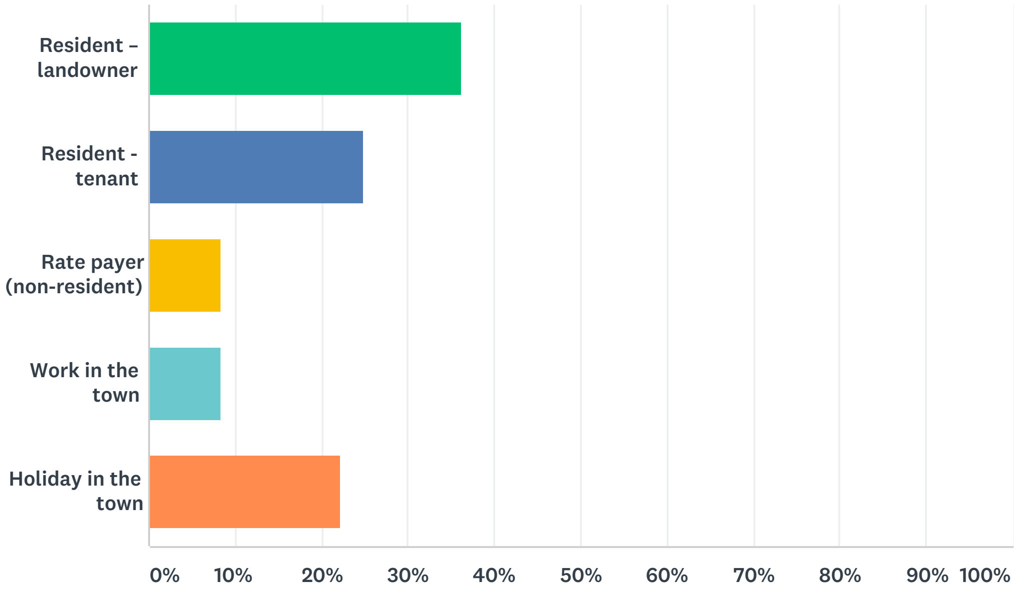
Question	Response Prompts
1. How would you describe your connection to the Denham Townsite?	▪ Resident – landowner ▪ Resident - tenant ▪ Rate payer (non-resident) ▪ Work in the town ▪ Holiday in the town ▪ Other / special interest (please specify)
2. What is your age?	▪ <20 ▪ 20-39 ▪ 40-59 ▪ >60
3. How would you describe your understanding of coastal erosion and coastal flooding due to storm surge inundation?	▪ Very good understanding ▪ Good understanding ▪ General awareness ▪ Uncertain ▪ Not aware
4. How would you describe your concern about the permanent impacts of sea level rise? For example, permanent coastal erosion and frequent coastal inundation.	▪ Very concerned ▪ Somewhat concerned ▪ Unconcerned ▪ No opinion
5. What do you consider to be the most important values of the Denham Townsite coastline? Please rank the following in order of their significance to you	▪ Recreational opportunities (e.g. boating, fishing, swimming) ▪ Public access to the beach ▪ Recreational assets (e.g. parks, beach shade / picnic structures) ▪ Commercial / business opportunities ▪ Work / education opportunities ▪ Environmental landscape / natural ecosystems
6. Please rate the following as they demonstrate their importance to you. A rating of 0 is completely unimportant and 10 is of significant importance	▪ Protection of the environmental assets of the Denham Townsite ▪ Protection of the recreational value of the coastline ▪ Protection of the cultural values of the coastline ▪ Maintenance of the culture of the Denham Town Centre ▪ Maintenance of a level of public infrastructure ▪ Planning Controls so coastal development does not inhibit the landscape

Question	Response Prompts
7. How important is it to you to be able to access the following aspects of the Denham townsite coastline? ▪ Recreational opportunities (e.g. ocean recreation, fishing, exercising) ▪ Coastal amenity (e.g. beach access, natural vegetation views) ▪ Entertainment and socialising (e.g. picnics/BBQs, events, cafes) ▪ Employment and economic (tourism, small and local business) ▪ Private benefit (e.g. living nearby, property values) ▪ Cultural amenity (e.g. historical sites, informational markers)	▪ Very important ▪ Somewhat important ▪ Unimportant ▪ No opinion
8. How much would the loss of these experiences/opportunities impact your way of life?	▪ I can conveniently access this elsewhere ▪ I cannot conveniently access this elsewhere ▪ This is not important to me
9. Have you experienced any coastal erosion or inundation events within the Denham Townsite?	▪ Yes, several times ▪ Yes, once or twice ▪ No impacts observed ▪ Uncertain
10. If you have witnessed impacts within the Denham Townsite from coastal erosion or inundation events, please share your experiences with us. For example, event date, location flooding lasted 4 hours, etc	▪ Space for text – AND/OR ▪ Provide an email address so they can send photos / additional information
11. Identify any areas and assets in the Denham Townsite and surrounds that are of high social, environmental and / or cultural value to you	▪ Space for text – AND/OR ▪ Provide an email address so they can send photos / additional information
12. What options would you like the Shire to consider in order to adapt to coastal hazards (i.e. erosion and inundation) over the next 50 years (Please tick all relevant)?	▪ **Avoid** development in areas identified to be impacted by potential future coastal hazards ▪ **Planned or managed retreat** of assets at the coast exposed to coastal assets (i.e. relocation of assets) ▪ Adaptation of structures to **accommodate** coastal hazards ▪ **Protection** of assets at the coast exposed to coastal hazards (e.g. construction of sea walls)
13. Please provide any comments or feedback on this survey	▪ Space for text – AND/OR ▪ Provide an email address so they can send photos / additional information

APPENDIX B
COMMUNITY VALUE SURVEY RESULTS

Q1 How would you describe your connection to the Denham Townsite?

Answered: 36   Skipped: 0

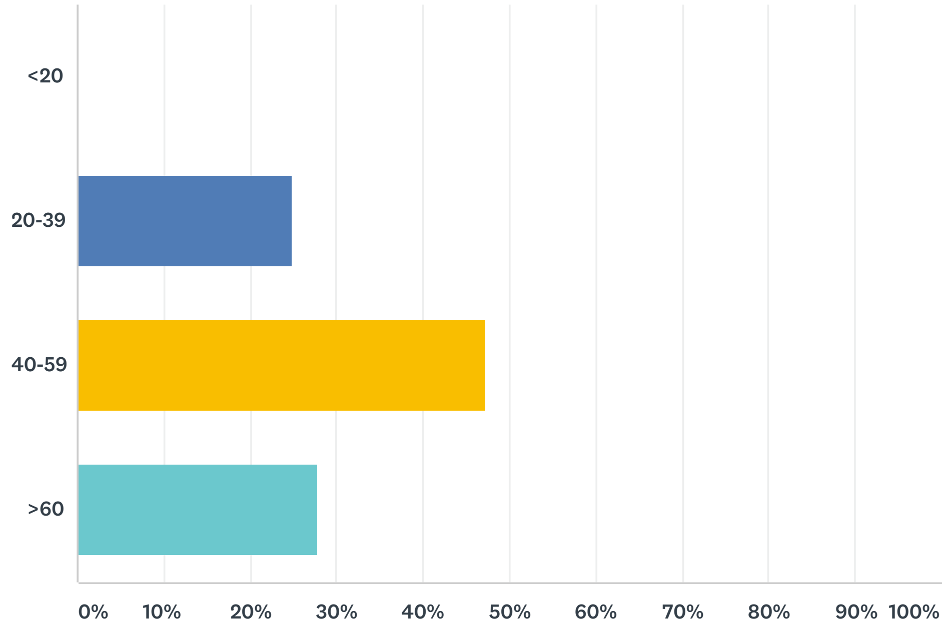


ANSWER CHOICES	RESPONSES	
Resident – landowner	36.11%	13
Resident - tenant	25.00%	9
Rate payer (non-resident)	8.33%	3
Work in the town	8.33%	3
Holiday in the town	22.22%	8
TOTAL		36

#	OTHER / SPECIAL INTEREST (PLEASE SPECIFY)	DATE
1	Family lives there	7/20/2018 8:54 AM
2	Malgana person with connection to country	7/16/2018 4:13 PM
3	Traditional owner	7/13/2018 3:19 PM
4	Lifetime resident	7/13/2018 7:15 AM
5	parents born here and I grew up here as a small child.	7/12/2018 6:05 PM

Q2 What is your age?

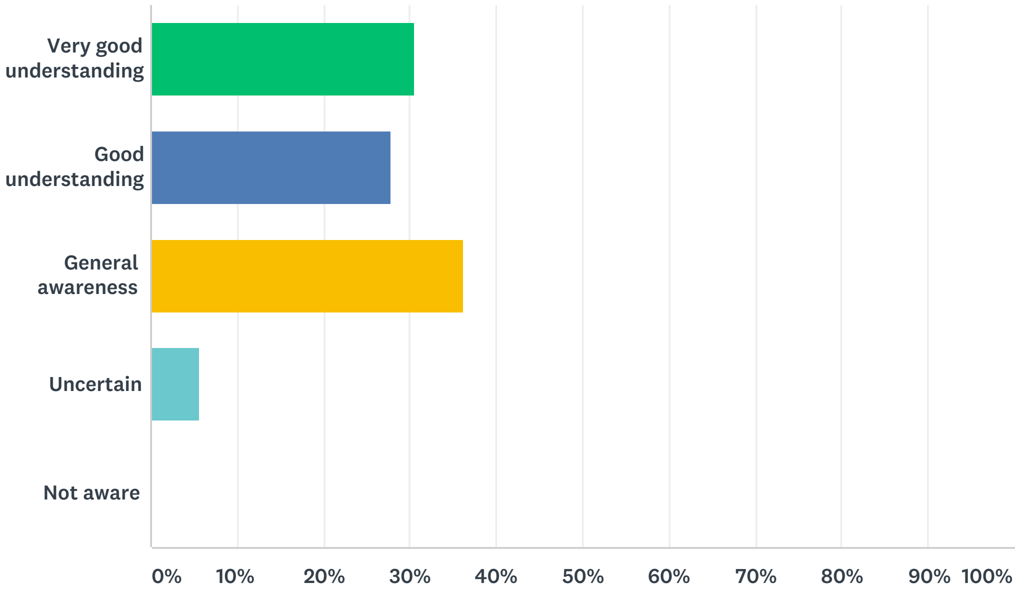
Answered: 36 Skipped: 0



ANSWER CHOICES	RESPONSES	
<20	0.00%	0
20-39	25.00%	9
40-59	47.22%	17
>60	27.78%	10
TOTAL		36

Q3 How would you describe your understanding of coastal erosion and coastal flooding due to storm surge inundation?

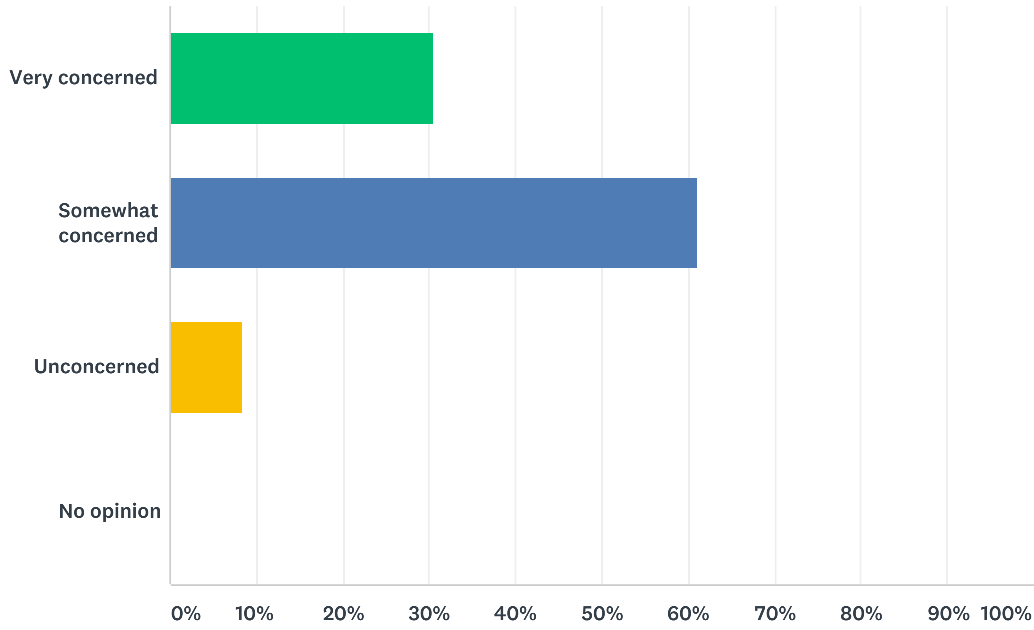
Answered: 36 Skipped: 0



ANSWER CHOICES	RESPONSES	
Very good understanding	30.56%	11
Good understanding	27.78%	10
General awareness	36.11%	13
Uncertain	5.56%	2
Not aware	0.00%	0
TOTAL		36

Q4 How would you describe your concern about the permanent impacts of sea level rise? For example, permanent coastal erosion and frequent coastal inundation

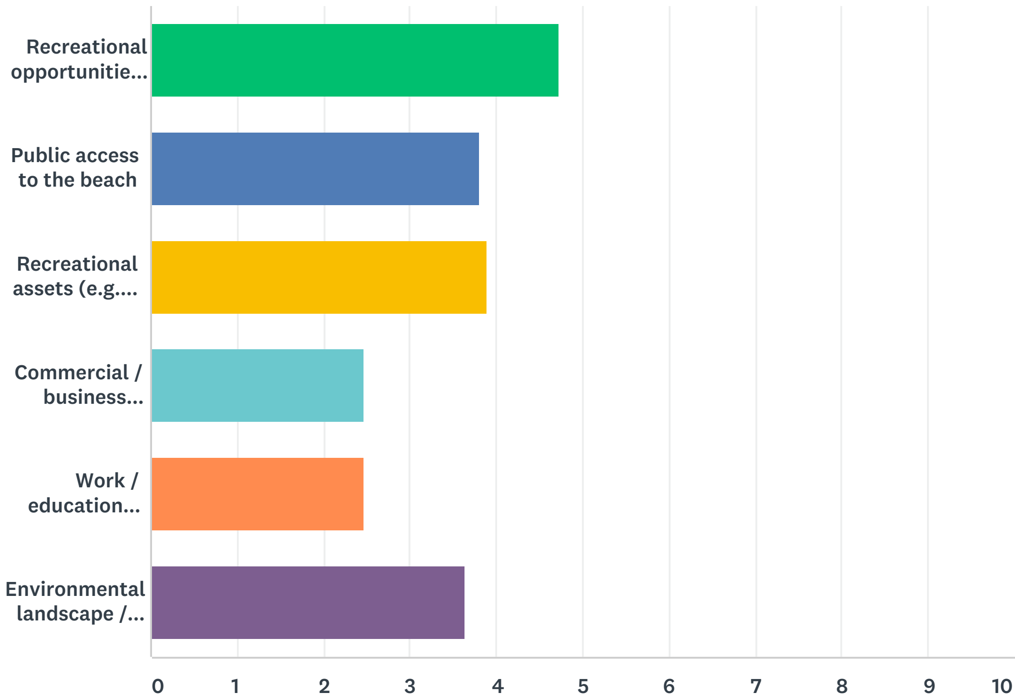
Answered: 36   Skipped: 0



ANSWER CHOICES	RESPONSES	
Very concerned	30.56%	11
Somewhat concerned	61.11%	22
Unconcerned	8.33%	3
No opinion	0.00%	0
TOTAL		36

Q5 What do you consider to be the most important values of the Denham Townsite coastline? Please rank the following in order of their significance to you

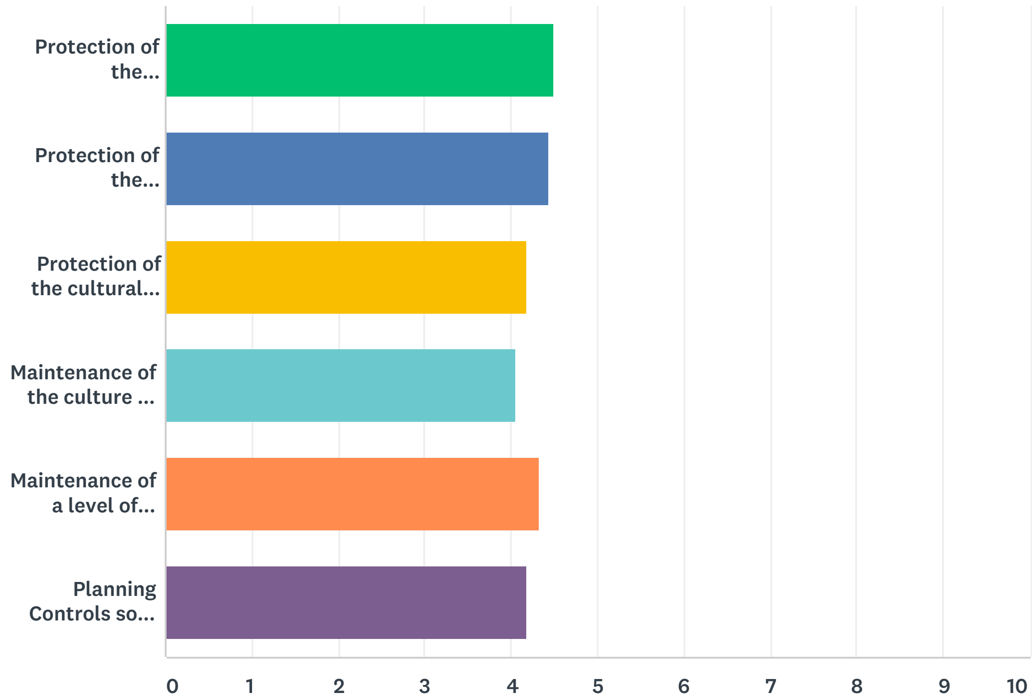
Answered: 36 Skipped: 0



	1	2	3	4	5	6	TOTAL	SCORE
Recreational opportunities (e.g. boating, fishing, swimming)	41.67% 15	27.78% 10	8.33% 3	8.33% 3	11.11% 4	2.78% 1	36	4.72
Public access to the beach	5.56% 2	33.33% 12	30.56% 11	11.11% 4	5.56% 2	13.89% 5	36	3.81
Recreational assets (e.g. parks, beach shade / picnic structures)	11.11% 4	19.44% 7	27.78% 10	33.33% 12	5.56% 2	2.78% 1	36	3.89
Commercial / business opportunities	2.78% 1	8.33% 3	11.11% 4	19.44% 7	27.78% 10	30.56% 11	36	2.47
Work / education opportunities	5.56% 2	2.78% 1	13.89% 5	11.11% 4	44.44% 16	22.22% 8	36	2.47
Environmental landscape / natural ecosystems	33.33% 12	8.33% 3	8.33% 3	16.67% 6	5.56% 2	27.78% 10	36	3.64

Q6 Please rate the following as they demonstrate their importance to you. A rating of 1 is completely unimportant and 5 is of significant importance

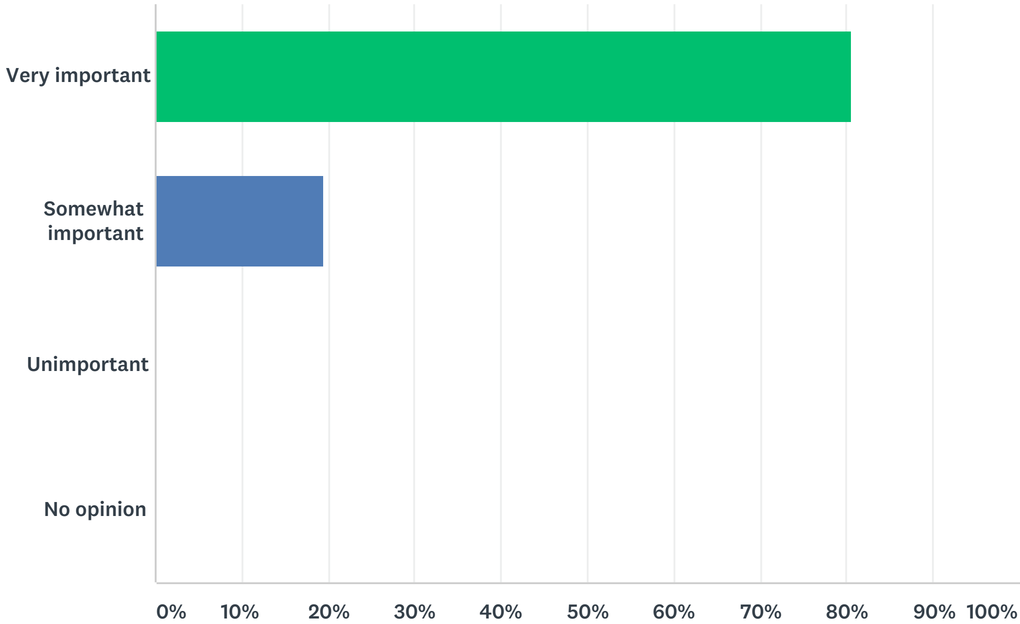
Answered: 36 Skipped: 0



	1 - COMPLETELY UNIMPORTANT	2	3 - SOMEWHAT IMPORTANT	4	5 - SIGNIFICANT IMPORTANCE	TOTAL	WEIGHTED AVERAGE
Protection of the environmental assets of the Denham Townsite	2.86% 1	5.71% 2	2.86% 1	17.14% 6	71.43% 25	35	4.49
Protection of the recreational value of the coastline	0.00% 0	2.78% 1	8.33% 3	30.56% 11	58.33% 21	36	4.44
Protection of the cultural values of the coastline	2.78% 1	5.56% 2	13.89% 5	25.00% 9	52.78% 19	36	4.19
Maintenance of the culture of the Denham Town Centre	2.78% 1	2.78% 1	22.22% 8	30.56% 11	41.67% 15	36	4.06
Maintenance of a level of public infrastructure	0.00% 0	2.78% 1	19.44% 7	19.44% 7	58.33% 21	36	4.33
Planning Controls so coastal development does not inhibit the landscape	2.78% 1	8.33% 3	8.33% 3	27.78% 10	52.78% 19	36	4.19

Q7 How important is it to you to be able to access the following aspects of the Denham townsite coastline? - Recreational opportunities (e.g. ocean recreation, fishing, exercising); - Coastal amenity (e.g. beach access, natural vegetation, views); - Entertainment and socialising (e.g. picnics/BBQs, events, cafes); - Employment and economic (tourism, small and local business); - Private benefit (e.g. living nearby, property values); - Cultural amenity (e.g. historical sites, informational markers);

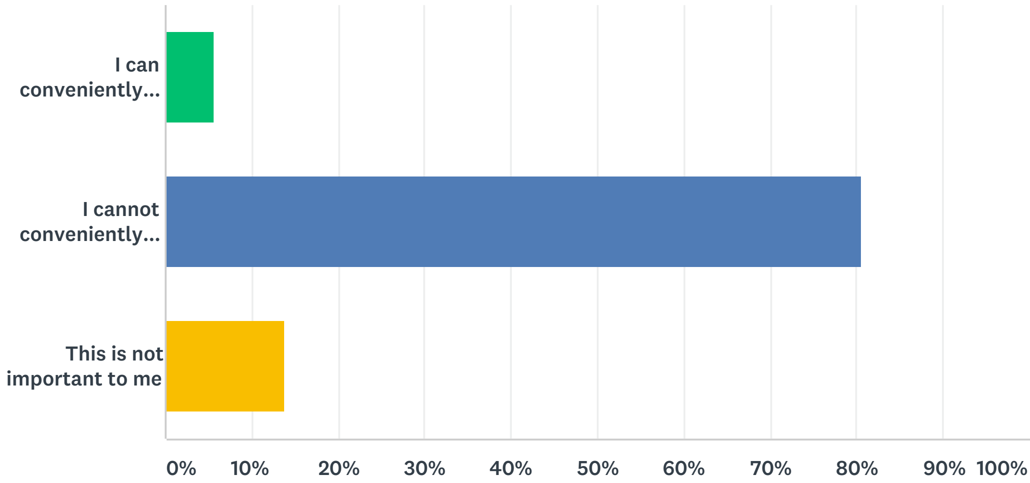
Answered: 36 Skipped: 0



ANSWER CHOICES	RESPONSES	
Very important	80.56%	29
Somewhat important	19.44%	7
Unimportant	0.00%	0
No opinion	0.00%	0
TOTAL		36

Q8 How much would the loss of these experiences/opportunities impact your way of life?

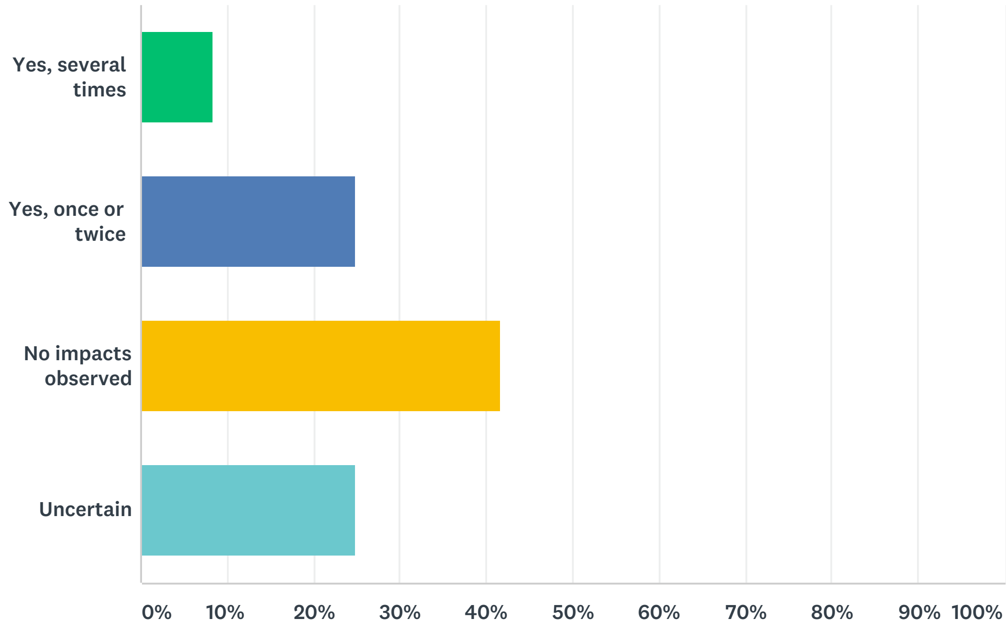
Answered: 36 Skipped: 0



ANSWER CHOICES	RESPONSES	
I can conveniently access this elsewhere	5.56%	2
I cannot conveniently access this elsewhere	80.56%	29
This is not important to me	13.89%	5
TOTAL		36

Q9 Have you experienced any coastal erosion or inundation events within the Denham Townsite?

Answered: 36 Skipped: 0



ANSWER CHOICES	RESPONSES	
Yes, several times	8.33%	3
Yes, once or twice	25.00%	9
No impacts observed	41.67%	15
Uncertain	25.00%	9
TOTAL		36

Q10 If you have witnessed impacts within the Denham Townsite from coastal erosion or inundation events, please share your experiences with us. For example, event date, location flooding lasted 4 hours, etc

Answered: 21 Skipped: 15

#	RESPONSES	DATE
1	none	7/20/2018 8:54 AM
2	cyclone olwyn may 2015	7/19/2018 11:59 AM
3	No am a visitor but not regularly	7/17/2018 8:40 AM
4	Unable to comment	7/16/2018 4:13 PM
5	Last severe storm we had the banks at the CP collapsed	7/16/2018 8:31 AM
6	0	7/16/2018 6:49 AM
7	Cyclones, Herbie 1988 and 2 others since, damage to fences only, some erosion but nothing unfixable	7/15/2018 4:40 PM
8	Beachfront erosion in front of denham seaside caravan park	7/13/2018 10:08 PM
9	Uncertain	7/13/2018 3:19 PM
10	Waterfront reduced in town and along night terrace	7/13/2018 3:08 PM
11	Cyclone olwin	7/13/2018 10:43 AM
12	the last cyclone,the wet winter when the budgies died the following summer, etc.	7/13/2018 9:48 AM
13	Cyclone 2015	7/13/2018 8:49 AM
14	Coastal erosion 2017 on the west side of beach due to extreme high tides	7/13/2018 7:15 AM
15	Cyclones	7/12/2018 9:36 PM
16	.	7/12/2018 8:17 PM
17	Cyclone Olwyn 2015	7/12/2018 7:01 PM
18	Na	7/12/2018 6:33 PM
19	Nil	7/12/2018 5:02 PM
20	the last cyclone	7/12/2018 3:22 PM
21	Nill	7/12/2018 2:33 PM

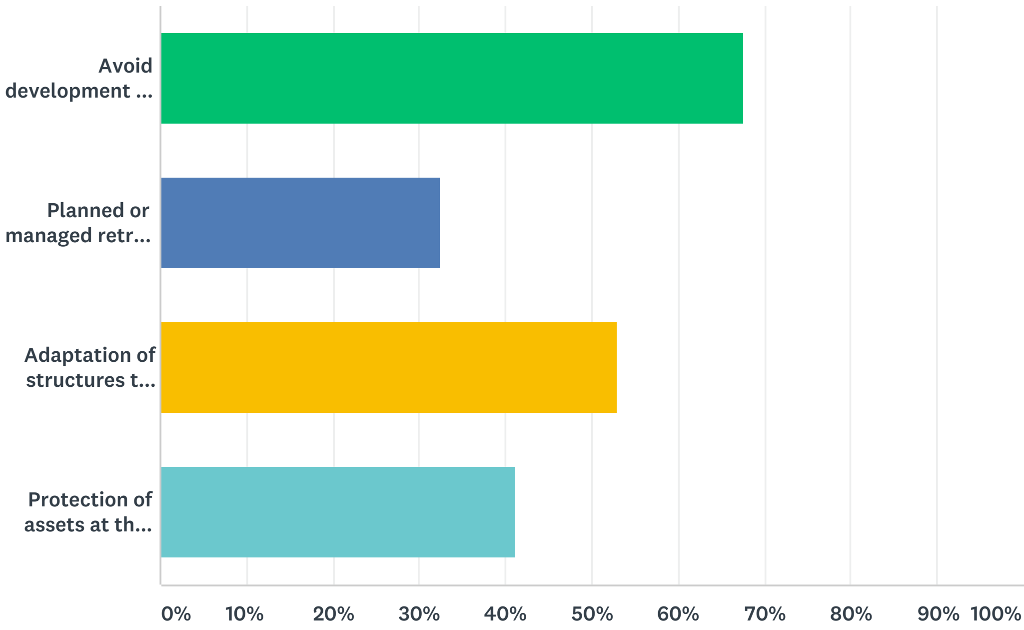
Q11 Identify any areas and assets in the Denham Townsite and surrounds that are of high social, environmental and / or cultural value to you

Answered: 25 Skipped: 11

#	RESPONSES	DATE
1	All	7/25/2018 9:07 PM
2	Caravan park	7/20/2018 8:54 AM
3	all areas	7/19/2018 11:59 AM
4	The whole gathaagudu area is of value to me	7/16/2018 4:13 PM
5	Main Street and foreshore	7/16/2018 8:31 AM
6	Speedway	7/16/2018 6:57 AM
7	Beach front	7/16/2018 6:49 AM
8	The nursing post is very significant along with the airport if an emergency arises	7/15/2018 4:40 PM
9	Beachfront and Jetty	7/13/2018 10:08 PM
10	All of DENHAM townsite	7/13/2018 9:13 PM
11	Public art piece. Accessibility to uninterruptedviews	7/13/2018 4:30 PM
12	The whole of the shark Bay Area is of cultural significance too me	7/13/2018 3:19 PM
13	Little lagoon, town oval	7/13/2018 3:08 PM
14	Denham foreshore beach or lack off due to weed ingretion	7/13/2018 10:43 AM
15	all of Shark Bay, there are so few areas where there is such natural beauty, that what is left needs to be protected for future generations of people AND flora and fauna	7/13/2018 9:48 AM
16	The whole area	7/13/2018 8:49 AM
17	Denham main foreshore, little lagoon, peron nation park,	7/13/2018 7:15 AM
18	Low sand dunes above high tide	7/12/2018 9:36 PM
19	Jetties	7/12/2018 8:17 PM
20	Nicholson Point beach access Camps beach access, rocky point big lagoon red bluff nettas beach to lookout	7/12/2018 7:47 PM
21	Nicholson Point to the Lagoon inlet is in need of urgent protection from erosion due to vehicle damage	7/12/2018 7:01 PM
22	Little lagoon. Nicholson point. Town oval. Nettas beach.	7/12/2018 6:33 PM
23	Keep Knight Tce single residential east of IGA	7/12/2018 5:02 PM
24	Foreshore	7/12/2018 3:54 PM
25	Little lagoon and all the tracks that are there	7/12/2018 2:33 PM

Q12 What options would you like the Shire to consider in order to adapt to coastal hazards (i.e. erosion and inundation) over the next 50 years (Please tick all relevant)?

Answered: 34 Skipped: 2



ANSWER CHOICES	RESPONSES	
Avoid development in areas identified to be impacted by potential future coastal hazards	67.65%	23
Planned or managed retreat of assets at the coast exposed to coastal assets (i.e. relocation of assets)	32.35%	11
Adaptation of structures to accommodate coastal hazards	52.94%	18
Protection of assets at the coast exposed to coastal hazards (e.g. construction of sea walls)	41.18%	14
Total Respondents: 34		

Q13 Please provide any comments or feedback on this survey

Answered: 12 Skipped: 24

#	RESPONSES	DATE
1	None	7/20/2018 8:54 AM
2	Some of the questions are hypothetical for instance if a cyclone hits the town erosion etc is unavoidable	7/15/2018 4:40 PM
3	It may never happen, ask the Dutch for advise if it does.	7/14/2018 1:41 PM
4	NA	7/13/2018 3:19 PM
5	All good for now. Thanks for asking. Looking forward to the new development. If the quality is anything like the town centre waterfront.. it will be fabulous!!	7/13/2018 3:08 PM
6	I do not know enough to comment on 12, but I think future assets and business should be very carefully managed to protect the area.	7/13/2018 9:48 AM
7	None	7/13/2018 8:49 AM
8	I think the recent high tides in 2017/2018 have been extreme however not constistent over the last 10 years enough to make too many drastic measures or changes to our foreshore amenities which for our town and tourism purposes are extremely important asset to the townsite of Denham	7/13/2018 7:15 AM
9	No	7/12/2018 9:36 PM
10	.	7/12/2018 8:17 PM
11	Sea Walls, groynes or any ocean barrier have a long history of causing additional problems	7/12/2018 7:01 PM
12	Nil	7/12/2018 5:02 PM

APPENDIX C
INUNDATION RISK EVALUATION

TABLE C-1 INUNDATION RISK EVALUATION – PRESENT DAY. RE-EVALUATION CONSIDERING EXISTING CONTROLS SHOWN IN LAST 3 COLUMNS

Asset Classification	Number Affected	Likelihood	Consequence	Risk	Risk Classification	Consequence	Risk	Risk Classification
Commercial								
Fuel Tank	1	1	3	3	Low	3	3	Low
Petrol Pumps	2	1	3	3	Low	3	3	Low
General buildings	11	1	3	3	Low	1	1	Low
Public								
Utilities	6	1	4	4	Medium	4	4	Medium
Drain to beach	9	1	3	3	Low	3	3	Low
Seawall - adhoc	4	1	3	3	Low	3	3	Low
Fish cleaning station	1	1	3	3	Low	3	3	Low
BBQ & Covered Structure	3	1	3	3	Low	3	3	Low
Public Toilet	3	1	3	3	Low	3	3	Low
Public art	3	1	3	3	Low	3	3	Low
Playground	1	1	3	3	Low	3	3	Low
Limestone retaining wall	2	1	3	3	Low	3	3	Low
Foreshore Path	1	1	3	3	Low	3	3	Low
Public bench & reclaimed jetty posts	5	1	3	3	Low	3	3	Low
Picnic table / pergola	11	1	3	3	Low	3	3	Low
Shire Offices	1	1	3	3	Low	1	1	Low
Department of Biodiversity & Attractions	1	1	3	3	Low	1	1	Low
Shark Bay Discovery Centre	1	1	3	3	Low	1	1	Low
Community resource centre	1	1	3	3	Low	1	1	Low
Road (Knight Terrace & Stella Rowley Drive)	2	1	2	2	Low	2	2	Low
Car Park	5	1	2	2	Low	2	2	Low
Grassed foreshore area / public park	3	1	2	2	Low	2	2	Low
Beach access	1	1	2	2	Low	2	2	Low
Boat ramp	3	1	2	2	Low	2	2	Low
Universal beach access (removable)	2	1	2	2	Low	2	2	Low
FRP Sheet-pile groyne	1	1	1	1	Low	1	1	Low
Seawall - engineered	2	1	1	1	Low	1	1	Low
Jetty	3	1	1	1	Low	1	1	Low
Residential								
Houses	29	1	3	3	Low	1	1	Low
Vacant blocks	14	1	1	1	Low	1	1	Low
Tourism Related								
General sets of buildings	8	1	3	3	Low	1	1	Low

TABLE C-2 INUNDATION RISK EVALUATION - 2030. RE-EVALUATION CONSIDERING EXISTING CONTROLS SHOWN IN LAST 3 COLUMNS

Asset Classification	Number Affected	Likelihood	Consequence	Risk	Risk Classification	Consequence	Risk	Risk Classification
Commercial								
Fuel Tank	1	2	4	8	Medium	4	8	Medium
Petrol Pumps	2	2	3	6	Medium	3	6	Medium
General buildings	11	2	3	6	Medium	1	2	Low
Public								
Utilities	6	2	4	8	Medium	4	8	Medium
Drain to beach	9	2	3	6	Medium	3	6	Medium
Seawall - adhoc	4	2	3	6	Medium	3	6	Medium
Fish cleaning station	1	2	3	6	Medium	3	6	Medium
BBQ & Covered Structure	3	2	3	6	Medium	3	6	Medium
Public Toilet	3	2	3	6	Medium	3	6	Medium
Public art	3	2	3	6	Medium	3	6	Medium
Playground	1	2	3	6	Medium	3	6	Medium
Limestone retaining wall	2	2	3	6	Medium	3	6	Medium
Foreshore Path	1	2	3	6	Medium	3	6	Medium
Public bench & reclaimed jetty posts	5	2	3	6	Medium	3	6	Medium
Picnic table / pergola	11	2	3	6	Medium	3	6	Medium
Shire Offices	1	2	3	6	Medium	1	2	Low
Department of Biodiversity & Attractions	1	2	3	6	Medium	1	2	Low
Shark Bay Discovery Centre	1	2	3	6	Medium	1	2	Low
Community resource centre	1	2	3	6	Medium	1	2	Low
Road (Knight Terrace & Stella Rowley Dve)	2	2	3	6	Medium	3	6	Medium
Car Park	5	2	3	6	Medium	3	6	Medium
Grassed foreshore area / public park	3	2	3	6	Medium	3	6	Medium
Beach access	1	2	2	4	Low	2	4	Low
Boat ramp	3	2	2	4	Low	2	4	Low
Universal beach access (removable)	2	2	2	4	Low	2	4	Low
FRP Sheet-pile groyne	1	2	1	2	Low	1	2	Low
Seawall - engineered	2	2	1	2	Low	1	2	Low
Jetty	3	2	1	2	Low	1	2	Low
Residential								
Houses	29	2	3	6	Medium	1	2	Low
Vacant blocks	14	2	2	4	Low	2	4	Low
Tourism Related								
General sets of buildings	8	2	3	6	Medium	1	2	Low

TABLE C-3 INUNDATION RISK EVALUATION - 2050. RE-EVALUATION CONSIDERING EXISTING CONTROLS SHOWN IN LAST 3 COLUMNS

Asset Classification	Number Affected	Likelihood	Consequence	Risk	Risk Classification	Consequence	Risk	Risk Classification
Commercial								
Fuel Tank	1	3	4	12	High	4	12	High
Petrol Pumps	2	3	4	12	High	4	12	High
General buildings	11	3	3	9	Medium	2	6	Low
Public								
Utilities	6	3	4	12	High	4	12	High
Drain to beach	9	3	4	12	High	4	12	High
Seawall - adhoc	4	3	4	12	High	4	12	High
Fish cleaning station	1	3	4	12	High	4	12	High
BBQ & Covered Structure	3	3	4	12	High	4	12	High
Public Toilet	3	3	4	12	High	4	12	High
Public art	3	3	4	12	High	4	12	High
Playground	1	3	4	12	High	4	12	High
Limestone retaining wall	2	3	4	12	High	4	12	High
Foreshore Path	1	3	4	12	High	4	12	High
Public bench & reclaimed jetty posts	5	3	4	12	High	4	12	High
Picnic table / pergola	11	3	4	12	High	4	12	High
Shire Offices	1	3	3	9	Medium	2	6	Low
Department of Biodiversity & Attractions	1	3	3	9	Medium	2	6	Low
Shark Bay Discovery Centre	1	3	3	9	Medium	2	6	Low
Community resource centre	1	3	3	9	Medium	2	6	Low
Road (Knight Terrace & Stella Rowley Dve)	2	3	3	9	Medium	3	9	Medium
Car Park	5	3	3	9	Medium	3	9	Medium
Grassed foreshore area / public park	3	3	3	9	Medium	3	9	Medium
Beach access	1	3	3	9	Medium	3	9	Medium
Boat ramp	3	3	2	6	Low	2	6	Low
Universal beach access (removable)	2	3	2	6	Low	2	6	Low
FRP Sheet-pile groyne	1	3	2	6	Low	2	6	Low
Seawall - engineered	2	3	2	6	Low	2	6	Low
Jetty	3	3	2	6	Low	2	6	Low
Residential								
Houses	29	3	3	9	Medium	2	6	Low
Vacant blocks	14	3	2	6	Low	2	6	Low
Tourism Related								
General sets of buildings	8	3	3	9	Medium	2	6	Low

TABLE C-4 INUNDATION RISK EVALUATION - 2118. RE-EVALUATION CONSIDERING EXISTING CONTROLS SHOWN IN LAST 3 COLUMNS

Asset Classification	Number Affected	Likelihood	Consequence	Risk	Risk Classification	Consequence	Risk	Risk Classification
Commercial								
Fuel Tank	1	3	4	12	High	4	12	High
Petrol Pumps	2	3	4	12	High	4	12	High
General buildings	11	3	4	12	High	3	9	Medium
Public								
Utilities	6	3	5	15	Extreme	5	15	Extreme
Drain to beach	9	4	4	16	High	4	16	High
Seawall - adhoc	4	4	4	16	High	4	16	High
Fish cleaning station	1	3	4	12	High	4	12	High
BBQ & Covered Structure	3	3	4	12	High	4	12	High
Public Toilet	3	3	4	12	High	4	12	High
Public art	3	3	4	12	High	4	12	High
Playground	1	3	4	12	High	4	12	High
Limestone retaining wall	2	3	4	12	High	4	12	High
Foreshore Path	1	3	4	12	High	4	12	High
Public bench & reclaimed jetty posts	5	3	4	12	High	4	12	High
Picnic table / pergola	11	3	4	12	High	4	12	High
Shire Offices	1	3	4	12	High	3	9	Medium
Department of Biodiversity & Attractions	1	3	4	12	High	3	9	Medium
Shark Bay Discovery Centre	1	3	4	12	High	3	9	Medium
Community resource centre	1	3	4	12	High	3	9	Medium
Road (Knight Terrace & Stella Rowley Dve)	2	3	4	12	High	4	12	High
Car Park	5	3	4	12	High	4	12	High
Grassed foreshore area / public park	3	3	3	9	Medium	3	9	Medium
Beach access	1	3	3	9	Medium	3	9	Medium
Boat ramp	3	3	3	9	Medium	3	9	Medium
Universal beach access (removable)	2	3	3	9	Medium	3	9	Medium
FRP Sheet-pile groyne	1	3	3	9	Medium	3	9	Medium
Seawall - engineered	2	3	3	9	Medium	3	9	Medium
Jetty	3	3	3	9	Medium	3	9	Medium
Residential								
Houses	30	3	4	12	High	3	9	Medium
Vacant blocks	14	3	3	9	Medium	3	9	Medium
Tourism Related								
General sets of buildings	9	3	4	12	High	3	9	Medium

APPENDIX D
COASTAL PROCESSES RISK EVALUATION

TABLE D-1 COASTAL PROCESSES RISK EVALUATION - PRESENT DAY. RE-EVALUATION CONSIDERING EXISTING CONTROLS SHOWN IN LAST 3 COLUMNS

Asset Classification	Number Affected	Likelihood	Consequence	Risk	Risk Classification	Likelihood	Risk	Risk Classification
Commercial								
Petrol Pumps	0							
General buildings	0							
Fuel Tank	0							
Public								
Utilities	2	2	3	6	Medium	1	3	Low
Seawall - adhoc	3	2	3	6	Medium	2	6	Medium
Public Toilet	0							
BBQ & Covered Structure	0							
Shire Offices	0							
Department of Biodiversity & Attractions	0							
Shark Bay Discovery Centre	0							
Community resource centre	0							
Road (Knight Terrace)	0							
Fish cleaning station	0							
Drain to beach	0							
Foreshore Path	1	2	2	4	Low	2	4	Low
Limestone retaining wall	1	2	2	4	Low	2	4	Low
Playground	0							
Grassed foreshore area / public park	0							
Public art	2	2	2	4	Low	2	4	Low
Picnic table / pergola	4	2	2	4	Low	2	4	Low
Public bench & reclaimed jetty posts	4	2	2	4	Low	2	4	Low
Car Park	1	2	2	4	Low	2	4	Low
Seawall - engineered	0							
FRP Sheet-pile groyne	0							
Jetty	0							
Boat ramp	0							
Beach access	1	2	2	4	Low	2	4	Low
Universal beach access (removable)	1	2	1	2	Low	2	2	Low
Residential								
Houses	0							
Vacant blocks	0							
Tourism Related								
General sets of buildings	0							

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TABLE D-2 COASTAL PROCESSES RISK EVALUATION - 2030. RE-EVALUATION CONSIDERING EXISTING CONTROLS SHOWN IN LAST 3 COLUMNS

Asset Classification	Number Affected	Likelihood	Consequence	Risk	Risk Classification	Likelihood	Risk	Risk Classification
Commercial								
Petrol Pumps	0							
General buildings	0							
Fuel Tank	1	3	3	9	Medium	2	6	Medium
Public								
Utilities	2	3	3	9	Medium	2	6	Medium
Seawall - adhoc	4	3	3	9	Medium	3	9	Medium
Public Toilet	2	3	3	9	Medium	3	9	Medium
BBQ & Covered Structure	3	3	3	9	Medium	3	9	Medium
Shire Offices	0							
Department of Biodiversity & Attractions	0							
Shark Bay Discovery Centre	0							
Community resource centre	0							
Road (Knight Terrace)	1	3	3	9	Medium	3	9	Medium
Fish cleaning station	1	3	3	9	Medium	2	6	Medium
Drain to beach	9	3	2	6	Low	3	6	Low
Foreshore Path	1	3	2	6	Low	3	6	Low
Limestone retaining wall	2	3	2	6	Low	3	6	Low
Playground	1	3	2	6	Low	3	6	Low
Grassed foreshore area / public park	3	3	2	6	Low	3	6	Low
Public art	3	3	2	6	Low	3	6	Low
Picnic table / pergola	10	3	2	6	Low	3	6	Low
Public bench & reclaimed jetty posts	5	3	2	6	Low	3	6	Low
Car Park	5	3	2	6	Low	3	6	Low
Seawall - engineered	2	3	1	3	Low	3	3	Low
FRP Sheet-pile groyne	1	3	1	3	Low	3	3	Low
Jetty	3	3	1	3	Low	2	2	Low
Boat ramp	3	3	1	3	Low	2	2	Low
Beach access	1	3	2	6	Low	3	6	Low
Universal beach access (removable)	2	3	1	3	Low	3	3	Low
Residential								
Houses	0							
Vacant blocks	0							
Tourism Related								
General sets of buildings	1	3	2	6	Low	3	6	Low

TABLE D-3 COASTAL PROCESSES RISK EVALUATION - 2050. RE-EVALUATION CONSIDERING EXISTING CONTROLS SHOWN IN LAST 3 COLUMNS

Asset Classification	Number Affected	Likelihood	Consequence	Risk	Risk Classification	Likelihood	Risk	Risk Classification
Commercial								
Petrol Pumps	1	3	4	12	High	3	12	High
General buildings	3	3	4	12	High	3	12	High
Fuel Tank	1	3	4	12	High	2	8	Medium
Public								
Utilities	4	3	4	12	High	3	12	High
Seawall - adhoc	4	3	4	12	High	3	12	High
Public Toilet	3	3	4	12	High	3	12	High
BBQ & Covered Structure	3	3	4	12	High	3	12	High
Shire Offices	1	3	4	12	High	3	12	High
Department of Biodiversity & Attractions	0							
Shark Bay Discovery Centre	0							
Community resource centre	0							
Road (Knight Terrace & Stella Rowley Drive)	2	3	4	12	High	3	12	High
Fish cleaning station	1	3	4	12	High	2	8	Medium
Drain to beach	9	3	3	9	Medium	3	9	Medium
Foreshore Path	1	3	3	9	Medium	3	9	Medium
Limestone retaining wall	2	3	3	9	Medium	3	9	Medium
Playground	1	3	3	9	Medium	3	9	Medium
Grassed foreshore area / public park	3	3	3	9	Medium	3	9	Medium
Public art	3	3	3	9	Medium	3	9	Medium
Picnic table / pergola	11	3	3	9	Medium	3	9	Medium
Public bench & reclaimed jetty posts	5	3	3	9	Medium	3	9	Medium
Car Park	5	3	3	9	Medium	3	9	Medium
Seawall - engineered	2	3	2	6	Low	3	6	Low
FRP Sheet-pile groyne	1	3	2	6	Low	3	6	Low
Jetty	3	3	2	6	Low	2	4	Low
Boat ramp	3	3	2	6	Low	2	4	Low
Beach access	1	3	2	6	Low	3	6	Low
Universal beach access (removable)	2	3	1	3	Low	3	3	Low
Residential								
Houses	12	3	4	12	High	3	12	High
Vacant blocks	6	3	4	12	High	3	12	High
Tourism Related								
General sets of buildings	4	3	4	12	High	3	12	High

TABLE D-4 COASTAL PROCESSES RISK EVALUATION - 2118. RE-EVALUATION CONSIDERING EXISTING CONTROLS SHOWN IN LAST 3 COLUMNS

Asset Classification	Number Affected	Likelihood	Consequence	Risk	Risk Classification	Likelihood	Risk	Risk Classification
Commercial								
Petrol Pumps	2	4	5	20	Extreme	4	20	Extreme
General buildings	11	4	5	20	Extreme	4	20	Extreme
Fuel Tank	1	4	5	20	Extreme	3	15	Extreme
Public								
Utilities	5	4	5	20	Extreme	4	20	Extreme
Seawall - adhoc	4	4	5	20	Extreme	4	20	Extreme
Public Toilet	3	4	5	20	Extreme	4	20	Extreme
BBQ & Covered Structure	3	4	5	20	Extreme	4	20	Extreme
Shire Offices	1	4	5	20	Extreme	4	20	Extreme
Department of Biodiversity & Attractions	1	4	5	20	Extreme	4	20	Extreme
Shark Bay Discovery Centre	1	4	5	20	Extreme	4	20	Extreme
Community resource centre	1	4	5	20	Extreme	4	20	Extreme
Road (Knight Terrace & Stella Rowley Drive)	2	4	5	20	Extreme	4	20	Extreme
Fish cleaning station	1	4	5	20	Extreme	3	15	Extreme
Drain to beach	9	4	4	16	High	4	16	High
Foreshore Path	1	4	4	16	High	4	16	High
Limestone retaining wall	2	4	4	16	High	4	16	High
Playground	1	4	4	16	High	4	16	High
Grassed foreshore area / public park	3	4	4	16	High	4	16	High
Public art	3	4	4	16	High	4	16	High
Picnic table / pergola	12	4	4	16	High	4	16	High
Public bench & reclaimed jetty posts	5	4	4	16	High	4	16	High
Car Park	5	4	4	16	High	4	16	High
Seawall - engineered	2	4	3	12	Medium	4	12	Medium
FRP Sheet-pile groyne	1	4	3	12	Medium	4	12	Medium
Jetty	3	4	3	12	Medium	3	9	Medium
Boat ramp	3	4	3	12	Medium	3	9	Medium
Beach access	1	4	3	12	Medium	4	12	Medium
Universal beach access (removable)	2	4	1	4	Low	4	4	Low
Residential								
Houses	36	4	5	20	Extreme	4	20	Extreme
Vacant blocks	15	4	4	16	High	4	16	High
Tourism Related								
General sets of buildings	9	4	5	20	Extreme	4	20	Extreme

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APPENDIX E
CHAPTER REPORT: IDENTIFICATION OF ADAPTATION OPTIONS

Denham Townsite CHRMAP

Chapter Report: Adaptation Option Identification

Shire of Shark Bay

12 March 2019

Document Status

Version	Doc type	Reviewed by	Approved by	Date issued
V01	DRAFT	Christine Arrowsmith	Christine Arrowsmith	05/10/2018
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Project Details

Project Name	Chapter Report: Adaptation Option Identification
Client	Shire of Shark Bay
Client Project Manager	Paul Anderson
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12 March 2019

Paul Anderson
Chief Executive Officer
Shire of Shark Bay
65 Knight Terrace Denham WA 6537
Via email ceo@sharkbay.wa.gov.au

Dear Paul

Chapter Report: Adaptation Option Identification

We are pleased to present the Denham Townsite Coastal Hazard Risk Management and Adaptation Plan Chapter Report: Adaptation Option Identification. If you have any queries, please do not hesitate to contact me on (03) 8526 0830.

Yours sincerely

Joanna Garcia- Webb
Principal Coastal Engineer | National Practice Lead – Coasts & Environment

joanna.garcia-webb@watertech.com.au

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WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

EXECUTIVE SUMMARY

It is internationally recognised that increasing sea levels and storm intensities will intensify coastal hazards such as coastal inundation (temporary coastal flooding), storm erosion and long-term shoreline recession (IPCC 2014). Consequently, State governments across Australia have introduced obligations that require local governments to consider and plan for the effects of these hazards over various planning timeframes. In Western Australia (WA), the governing policy is the Western Australian Planning Commission's State Coastal Planning Policy 2.6 (WAPC, 2013, herein referred to as "SPP2.6"). SPP2.6 recommends management authorities develop a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP). Specific guidelines have been developed to assist in this process (WAPC, 2014).

One of the key objectives of SPP2.6 is to establish coastal foreshore reserves which include allowances for the protection, conservation and enhancement of coastal values across the state. Risk assessment processes are then utilised to identify risks that are intolerable to the community, and other stakeholders such as the Shire of Shark Bay, indigenous and cultural interests, and private enterprise. Adaptation measures are then developed according to the preferential adaptation hierarchy outlined in SPP2.6.

The overall CHRMAP purpose is as follows:

To identify vulnerable assets (public and private) and the risk posed to them by coastal hazards.

To preserve community values for present and future generations.

To develop a plan that will allow the Shire to respond to identified risks through adaptation planning activities.

To recommend monitoring plans to ensure the risk management and adaptation plan activities are working into the future as expected.

This document presents the Identification of Adaptation Options Chapter Report. This identifies potential adaptation options for the prioritised list of assets at risk of coastal hazards developed during the risk assessment phase of the project. The flow chart displayed in Figure 1-2 indicates where this component of the study sits with reference to the wider study; the 'Adaptation Options Identification' phase corresponds to the bubble shaded in red, as replicated below.

Identification of Adaptation Options – following SPP2.6 hierarchy
- Develop long-term pathway for full planning timeframe, and epochs present day, 2030, 2050, 2118
- Adaptation options for highly valued assets - built & natural; short & long-term management
- Land use planning instruments considered: proposed wording & implementation; decision making processes

The Shire's responsibility is limited to preserving public interests by minimising risks to public assets where possible. As per the WA Coastal Zone Strategy 2017, it is not the Shire's responsibility to address risks to private assets.

SPP2.6 provides a hierarchy of adaptation pathways to guide decision making in coastal areas. This should be used by planning authorities and development proponents when considering adaptation options to minimise coastal hazard risks at the local level. The hierarchy indicates a clear preference against the adoption of 'protect' as a long-term adaptation pathway. This preference is re-emphasised in SPP26, the policy guidelines, and the WA Coastal Zone Strategy.

Management options are presented in detail in Sections 4 and 5. Options considered include the following:

- Incorporate SPP 2.6 into Local Planning Scheme No. 4
- Special Control Area to restrict development in the coastal hazard zone

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  - Develop a Local Planning Policy that provides guidance on coastal development
- Notifications on Title
- Revegetation / sand fencing of dune
- Renourishment with dredged material
- Monitoring of beach and seawalls
- Manage 4WD and quad bike activities

The adaptation options presented within this report have followed the coastal hazard risk management hierarchy, as per SPP2.6. The aim of the adaptation is to provide a planning framework that the Shire can follow that allows sustainable development, but also allows the continued use of the land until the risk is realised, and there is a plan on what to do if it is.

The final management options will include the continued revision of the CHRMAP and update of the recommended options at regular intervals (i.e. every five to ten years). This is due to corresponding future updates in climate change science, coastal engineering methodology, changes to the town's success criteria, triggers reached, and so on.

The next stage of the project will assess the adaptation options discussed within this report with a multi-criteria analysis. Options receiving a positive score from this will be assessed in a cost benefit analysis. All adaptation options come with a financial cost. We recommend investigating funding avenues based on the town's high tourism value, and the World Heritage listing. Maintaining the culture and recreational value of the Denham townsite is strongly linked to the continuation of both tourism and environmental protection of the region.

In addition to the recommendations of the CHRMAP, local foreshore management plans should consider broader issues such as biodiversity and environmental impacts.

The identification and assessment of the adaptation options will be reviewed by the community and stakeholders, as recommended in WAPC (2014). Similarly, the community and stakeholders may have suggestions for alternate adaptation options. The Stakeholder and Community Engagement Strategy (Water Technology, 2018d) identified a review period that included a workshop and online survey to complete this process.

CONTENTS

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LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

It is internationally recognised that increasing sea levels and storm intensities will intensify coastal hazards such as coastal inundation (temporary coastal flooding), storm erosion and long-term shoreline recession (IPCC 2014). Consequently, State governments across Australia have introduced obligations that require local governments to consider and plan for the effects of these hazards over various planning timeframes. In Western Australia (WA), the governing policy is the Western Australian Planning Commission's State Coastal Planning Policy 2.6 (WAPC, 2013, herein referred to as "SPP2.6"). SPP2.6 recommends management authorities develop a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP). Specific guidelines have been developed to assist in this process (WAPC, 2014).

One of the key objectives of SPP2.6 is to establish coastal foreshore reserves which include allowances for the protection, conservation and enhancement of coastal values across the state. Risk assessment processes are then utilised to identify risks that are intolerable to the community, and other stakeholders such as the Shire of Shark Bay, indigenous and cultural interests, and private enterprise. Adaptation measures are then developed according to the preferential adaptation hierarchy outlined in SPP2.6.

The aim of the present study is to investigate and plan for coastal hazards which are likely to affect the Denham townsite. Denham is located within the local government area of the Shire of Shark Bay, approximately 800km north of Perth (refer Figure 1-1 for locality). Denham and its surrounds are used extensively for tourism, commercial and recreational purposes. Tourism is the primary industry in the Shire, with fishing and aquaculture also playing a major role.

Given the above, visitors to and residents of Denham and its surrounds place a high value on the coastline. Processes affecting the coastal zone are multiple and complex: storm surge; tidal movement; shoreline stability; stormwater drainage; and the interactions between surface and groundwater all contribute in differing degrees. Furthermore, the potential impacts of climate change, specifically increasing sea levels and storm intensities, will place increased pressure on the coastal zone, and threaten public infrastructure and assets, private property, foreshore reserves, coastal attractions and public open spaces.

This document presents the Identification of Adaptation Options Chapter Report. This identifies potential adaptation options for the prioritised list of assets at risk of coastal hazards developed during the risk assessment phase of the project. The flow chart displayed in Figure 1-2 indicates where this component of the study sits with reference to the wider study; the 'Adaptation Options Identification' phase corresponds to the bubble shaded in red.

The Shire's responsibility is limited to preserving public interests by minimising risks to public assets where possible. As per the WA Coastal Zone Strategy 2017, it is not the Shire's responsibility to address risks to private assets.

FIGURE 1-1 EXTENT OF CHRMAP

COMMUNICATION AND CONSULTATION: SHIRE OF SHARK BAY, STAKEHOLDERS, COMMUNITY WROKSHOPS & SURVEY

MONITORING AND REVIEW

ESTABLISHING THE CONTEXT

Project Inception Meeting
- Held via teleconference. Finalise project scope, deliverables, timing, data gap actions and identify key stakeholders

Stakeholder and Community Engagement Plan
- Preparation of Community Information Sheet 1

Literature Review and Issues Paper
- Historical reports will be reviewed, state and local coastal policy, planning schemes & instruments considered.

Site Investigations / Community Workshop 1 (Workshop 1 will be undertaken on the same trip as the site visit.)
- CIS1 to be posted online / mailed immediately prior to Workshop 1; focus group interviews available outside Workshop
- **Community Values Assessment** can then be completed (community and cultural values identified).
- Site visit will allow for finalisation of the **Identification of Coastal Assets** task and fill gaps noted in Issues Paper**.**
- Site visit to also aid in coastal processes understanding.

ENGAGEMENT
- Community Information Sheet
- Community Workshop
- Definition of values / success criteria

COASTAL HAZARD RISK IDENTIFICATION

Hazard Assessment – to understand coastal processes & hazards & identify areas at risk
- Review of available information and knowledge summary
  - Water Level / inundation information
  - Hydrographic surveys
  - Aerial photography analysis
  - Previous coastal hazard reporting
- Coastal Hazard Assessment on key coastal processes – coastal inundation, long-term and short-term erosion
  - Update previous assessments with most recent aerial photographs / historical where necessary; analyse accordingly
  - Inundation scenarios include - Present day, 2030, 2050, 2118 conditions, with Average Recurrence Interval of 20, 50, 100, 500 years
  - Erosion scenarios assessed as per SPP2.6, with SBEACH modelling at key points in the study area
  - Determine trigger events & responses
- Coastal Hazard Mapping
  - 3D surface mapping of all coastal inundation and erosion scenarios.
  - Split into sectors, as required, at the stipulated scales & generate maps
  - Online mapping provided for all maps, all information within GIS system

Vulnerability Assessment
- Identify vulnerable assets, group by specified categories; implications on land use
- Identify function, services & values of each vulnerable asset
- Assess vulnerability of each asset (exposure, sensitivity and adaptive capacity)
  - Assets grouped with rationale; Sensitivity scaling considered
  - Results tabularised
- Online mapping of vulnerability, all information within GIS system

RISK ANALYSIS AND EVALUATION

Prepare Likelihood and Consequence Scales
- Risk assessment of each vulnerable asset: likelihood, consequence, vulnerability & risk rating for each scenario

Risk Evaluation
- Identify actions & priorities for management until 2118
- Analyse Community Values / Success Criteria--> establish community priorities for Vulnerable Assets

Identify Existing Controls
- Identify existing mitigation measures: physical & planning schemes to mitigate the above risks
  - Update risks accordingly; identify prioritised risk action list based on Success Criteria & existing controls

ADAPTATION PLANNING

Identification of Adaptation Options – following SPP2.6 hierarchy
- Develop long-term pathway for full planning timeframe, and epochs present day, 2030, 2050, 2118
- Adaptation options for highly valued assets - built & natural; short & long-term management
- Land use planning instruments considered: proposed wording & implementation; decision making processes

Assessment of Adaptation Options
For each vulnerable asset:
- For each Mitigation / Adaptation measure:
  - MCA. If MCA +ve, proceed to CBA
  - Timeframes / triggers to be considered
- Trade-offs between option selection & asset value

ENGAGEMENT
- Obtain additional feedback on success criteria & presented adaptation options:
  - Community Information Sheet
  - Community Workshop
  - Online Survey

Implementation
For each vulnerable asset:
- For each Mitigation / Adaptation measure:
  - Identify long-term pathways, considering trigger points and previous assessments
  - Produce a short-term implementation plan to produce a clear action plan to 2030
  - Produce a monitoring plan, detailing any monitoring or review that may be required

ENGAGEMENT
- Public advertisement of Final Draft CHRMAP

Final CHRMAP and Interim Deliverables

FIGURE 1-2 PROPOSED CHRMAP METHODOLOGY FLOW CHART (ADAPTED FROM WAPC CHRMAP GUIDELINES)

2 ADAPTATION: THE CONTEXT

2.1 Planning Timeframes

This study considers a 100-year planning timeframe. Interim epochs considered are present day, 2030, 2050, 2118. The predicted erosion and inundation extents for these epochs were defined in the Coastal Hazard & Vulnerability Assessment Chapter Report (Water Technology, 2018b). These extents are utilised to develop corresponding adaptation options. However, planning and adaptation actions should be undertaken and reviewed more frequently than these timeframes and epochs.

2.2 Planning Controls

Planning in Western Australia is guided and regulated by the State Planning Framework. This framework includes overarching strategic planning strategies, and specific planning policies and supportive guidelines. Figure 2-1 explains this framework, which includes planning at the state, regional, and local levels and indicates how strategic planning documents can be implemented through statutory planning controls (e.g. local planning schemes) and local planning policies. This Framework sits within the *Planning and Development Act 2005*.

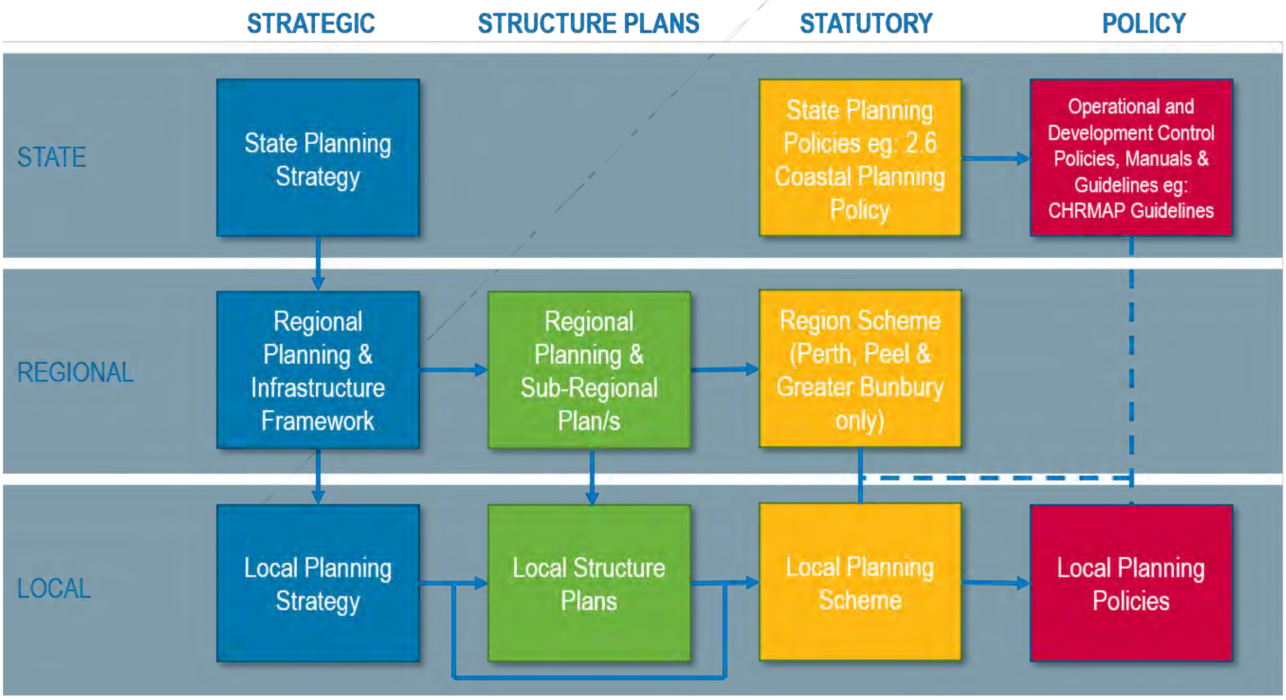

FIGURE 2-1 STATE PLANNING FRAMEWORK FOR WESTERN AUSTRALIA

The Establish the Context Chapter Report (Water Technology, 2018c) reviewed the planning documents within this Framework which are relevant to coastal hazard planning in the project area. The review aimed to:

- Assess the adequacy of the existing planning documents for addressing coastal hazards.
- Identify gaps that need to be addressed through the CHRMAP process.
- Identify any potential planning issues that may constrain the CHRMAP process.

- Ensure that the Shire's adaptation plan aligns with state, regional and local planning frameworks.

Figure 2-2 presents the identified and reviewed planning documents in order of their application within the state and local planning framework. Table 2-1 describes specifically how adaptation planning in the study area aligns with this planning framework. Figure 2-3 (on page 13) presents the planning and adaptation hierarchy referred to in Table 2-1. The following sub-sections provide further information regarding the context of the study area and development of adaptation options within the planning framework.

FIGURE 2-2 SITE-SPECIFIC PLANNING INSTRUMENTS IN ORDER OF PRIORITY

TABLE 2-1 EXISTING PLANNING CONTROLS

Documentation	Items of Relevance
State Planning Strategy	Seeks to achieve development and adoption of risk management strategies for natural hazards in the context of climate change patterns and trends. These include: ▪ Retaining natural bushland and coastal areas that are publicly accessible. This is essential to human health and a sense of wellbeing. ▪ All decisions about sustained growth and prosperity must strike the appropriate balance between environmental issues, economic conditions and community wellbeing
WA Coastal Zone Strategy	Planning framework to ensure that coastal development is sustainable in the long term, and meets community, economic, environmental and cultural needs. The stated goals of the strategy are to: 1. Conserve the State's natural coastal values and assets through sustainable use 2. Ensure safe public access to the coast and involve the community in coastal planning and management activities 3. Provide for the sustainable use of natural coastal resources 4. Ensure the location of facilities and infrastructure in the coastal zone is sustainable and suitable 5. Build community confidence in coastal planning and management **All levels of government, as well as individuals, businesses, and the community, each have important and complementary roles in adapting to coastal hazards**. Particular principles of relevance: ▪ Private parties are responsible for managing risks to their private assets; ▪ **Governments (i.e.: the Shire) are responsible for managing risks to public assets and any assets they manage**. They should also: – Develop local policies and regulations consistent with state adaptation approaches – Facilitate building resilience and adaptive capacity within the local community – Work in partnership with community to identify and manage risks / impacts Adaptation options should minimise coastal process interference and legacy issues; the adaptation hierarchy is presented in Figure 2-3. **Management strategies that preserve the natural coastline and move development away from the active coastal zone are considered ideal**. Of particular relevance to the CHRMAP process is the **user pays principle**, whereby those who benefit most from protection must provide the greatest financial contribution.
SPP2.6	WA's guideline for making decisions within the coastal zone. Goal is to avoid future development within areas identified to be at risk within the 100-year planning timeframe. Stipulates the requirement for a CHRMAP. The ultimate aims for the policy are: ▪ To ensure all future development considers coastal hazards, climate change, and landform stability. ▪ To ensure appropriate areas are identified for necessary stakeholders. ▪ To provide public coastal foreshore reserves. ▪ To conserve coastal values (landscape, biodiversity, ecosystems, indigenous and cultural) **Potential adaptation options to be identified under the coastal hazard risk management and adaptation planning hierarchy, as presented in Figure 2-3**.
Gascoyne PIF	Provides an overall strategic regional context for land-use planning within the region and identifies several priority initiatives required to facilitate comprehensive regional planning and guide local planning processes.
Gascoyne Coast Sub-Regional Strategy	**Aims to guide local planning processes, including the preparation of and amendments to local planning schemes and strategies.** It identifies coastal processes and hazards as an issue and recognises that these may compromise the suitability of proximate areas for development, noting that coastal foreshore reserves are generally required. Coastal processes are not mentioned specifically in relation to the ongoing development and expansion of the Denham townsite; however, the importance of tourism to the local economy is strongly tied to the sustainability of environmental tourist attractions and the tourism services provided within Denham.
Local Planning Strategy	The local planning strategy has several stated objectives that are directly or indirectly related to planning for coastal areas. Key objectives are as follows: ▪ Ensure that there is **sustainable provision of land to meet existing and future needs** for housing, business, community facilities, recreation, open space, industry, tourist accommodation, foreshore facilities, and civic uses ▪ To provide a range of quality services and amenities to meet the existing and future needs of the local community and support local tourism in a manner that enhances the existing townsite and does not adversely impact on local character and amenity ▪ **Protect the natural environment, resources and coastal areas from inappropriate development** that may have any undesirable or negative impact in terms of amenity, social, environmental, or visual The strategy acknowledges that there are key constraints of cyclonic storm and coastal processes. It identifies the following physical constraint challenges relevant to coastal processes: ▪ The proximity of development to the coast and lack of coastal setbacks. ▪ Flooding in the Town Centre resulting from major and intense storm events and the need to implement minimum floor levels.
Local Planning Scheme	*Local Planning Scheme No. 4* (LPS 4), has just been gazetted. One of the stated aims of LPS 4 is to impose special conditions for development of land within Denham to mitigate the adverse effects of land subject to inundation. New development will be required to have a minimum finished floor level not less than 4.2 m AHD. No allowances are made for coastal erosion hazards.

2.3 Risk Management & Adaptation Hierarchy

As discussed in Table 2-1, SPP2.6 provides a hierarchy of adaptation pathways to guide decision making in coastal areas. This should be used by planning authorities and development proponents when considering adaptation options to minimise coastal hazard risks at the local level. The hierarchy, presented in Figure 2-3, indicates a clear preference against the adoption of ‘protect’ as a long-term adaptation pathway. This preference is re-emphasised in SPP26, the policy guidelines, and the WA Coastal Zone Strategy. This hierarchy is discussed further below.

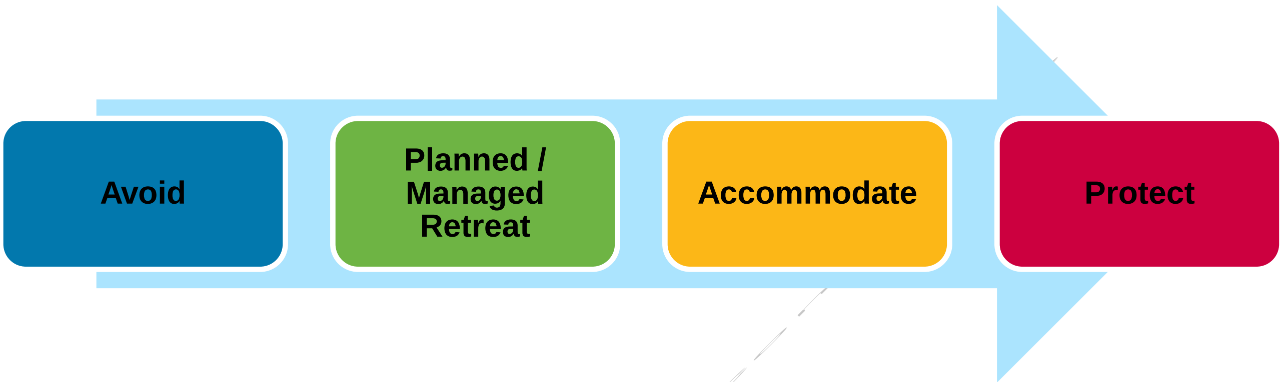

FIGURE 2-3 COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING HIERARCHY (ADAPTED FROM WAPC, 2013)

2.3.1 Avoid

This option aims to avoid the construction of new public and private assets within areas identified to be affected by coastal hazards. The project lifetime of a new asset should be a key consideration in deciding the suitability of locating new assets in coastal hazard areas. For example, the construction of new public assets, such as picnic facilities and public toilets, should be avoided where these assets are likely to be impacted by coastal hazards within the lifetime of the asset. Similarly, the construction of new private assets which are likely to be affected by coastal hazards over their projected lifetimes should not be permitted. The option of Avoid can be applied to manage coastal erosion and inundation hazard risks.

2.3.2 Planned or Managed Retreat

This option aims to relocate or remove assets which are located in hazard areas, in an orderly manner, where hazard risks are likely to be intolerable over relevant planning timeframes. In recognition of the increased risk to assets in the coastal zone, the Department of Planning, Lands and Heritage (DPLH), together with the Western Australian Planning Commission, recently prepared the Draft Planned or Managed Retreat Guidelines (WAPC, 2017). This document provides guidance on how to implement a policy of planned or managed retreat through property acquisitions.

Planned or managed retreat is mostly applicable to developed areas , where there is less potential to adapt to coastal hazards through development planning controls, such as setbacks in Greenfield areas. The strategy of retreat is based on social, environmental and economic sustainability, and ties into the SPP2.6 objectives and adaptation hierarchy (refer Figure 2-3). It allows for continuing public access to beaches, beach amenity, and the provision of a coastal foreshore reserve.

The Guidelines suggest a range of mechanisms for achieving managed retreat in developed areas, using compulsory or voluntary acquisition provisions outlined in state legislation. Alternatively, planned or managed Retreat can be achieved through the early acquisition and leaseback of private property. This alternative can help to reduce overall implementation costs.

Planned or managed retreat is an option that can be applied to manage coastal erosion and inundation hazards; however, this option requires a significant investment of public resources to fund acquisitions. From a practical perspective, implementation of managed retreat may require the State or Commonwealth to provide the majority of funding to acquire property. Funding programs offered at the State level do not currently provide amounts which facilitate property acquisitions, and there has been no indication to date that this situation will change in the near future. Therefore, landholders and the broader public should be aware of the risks in any decisions they make about purchasing or developing lands in coastal areas.

Given the values of the Denham townsite presented in the form of the success criteria (refer Section 2.4), together with the existing asset locations in proximity to the coastal hazard extents, a managed retreat option may be the most appropriate for the foreshore area. A planned or managed retreat option would allow for the continued public amenity of the foreshore and meet tourism sector needs. It is important to note that existing land uses would continue until the coastal hazard risk becomes unacceptable. The trigger for retreat is to be defined during the CHRMAP process. It is further discussed in Chapters 3.3 and 5.

The suitability and extent of the managed retreat option will be fully assessed in the next chapter report: Assessment of Adaptation Options. It is noted the above discussion focuses on potential acquisition of freehold land. Planned/managed retreat may also be applied to other type of assets; the level of investment depends on the type of assets to retreat. For example, removing / relocating a public bench or pergola / picnic table represents a much lower investment than the relocation of a residential property.

2.3.3 Accommodate

This option aims to utilise design and management strategies which render the risks from identified coastal hazards as acceptable. Design and management strategies include: minimum finished floor levels and elevated electrical circuitry, to minimise inundation risks; or, relocatable structures which can be moved to a different location on- or off-site, as shorelines recede, or regular inundation events make the provision of critical services unviable. In this way, the ‘Accommodate’ option allows landholders to continue to use land until hazard risks become intolerable, while minimising the current and future risk of legal and financial liability for Council.

Accommodate design and management strategies can be facilitated through modifications to local planning frameworks. These modified planning frameworks need to provide clear direction for planning authorities when assessing applications for new development and for affected landholders. Planning frameworks might include the introduction or modification of the following instruments:

- Special control areas, to ensure planning discretion over new development
- Clear development assessment criteria, to ensure that new development gives due regard to coastal processes
- Notifications on title, to inform current and future property owners of hazard risks
- Time or event limited planning permits, to allow the continued use of land until hazards become intolerable

Accommodate is an option that can be applied to help minimise the effect of coastal erosion and inundation hazards on new development and infrastructure. A key concern with the accommodate option, particularly in regard to managing coastal erosion, is that the current State legislative framework means that permanently inundated private land does not become Crown land, unlike in other Australian states (Robb et al 2017, Robb et all 2018). Therefore, where the shoreline is allowed to recede beyond private property boundaries, issues of public access and trespass may arise. This should be a key consideration when assessing the appropriateness of the Accommodate option.

2.3.4 Protect

This option aims to stabilise the position of the shoreline using hard or soft coastal protection measures such as seawalls, groynes, offshore breakwaters, geotextile sand-containers, sand renourishment and levee banks. Protection is an option that can be applied to manage coastal erosion and inundation hazards.

The adaptation hierarchy considers the construction of new protection measures as the least preferred option of all potential options listed in the hierarchy. Protection measures, particularly hard measures such as rock groynes and seawalls, interfere with local coastal processes and can have detrimental effects on local ecological systems. Protection measures can also inflate property values in hazard areas, create expectations that protection measures will be maintained into the future, and may limit the capacity of future decision makers to change strategies as situations change.

Over the short to medium term, public authorities may need to consider the appropriateness of using interim protection measures to delay shoreline recession. This might be achieved through measures such as geotextile sand containers which can be less costly to remove than rock structures, regular sand renourishment, and revegetating coastal dunes. Where public and private assets are proposed to be constructed inland of interim protection measures, the design life of the protection measure should be a key factor in determining the appropriateness of the proposed asset or development.

2.3.5 Hierarchy Summary

Maintaining public access to the coast in developed areas is one of the main objectives of SPP2.6 and identified as a key value of the Denham community. As discussed, the current State legislative framework means that where the shoreline recedes beyond private property boundaries, issues of public access and trespass are likely to arise. . This situation means that public authorities have two main adaptation options available to them for preserving public coastal access:

- **Planned or Managed Retreat** i.e. maintaining a foreshore reserve through public acquisition of private property; or,
- **Protect** i.e. preventing the shoreline from receding beyond private property boundaries by stabilising the current shoreline position using various protection measures (e.g. rock groynes, offshore breakwaters).

Where public authorities cannot commit to either of these options over the long term, it is likely that public authorities will need to **Accommodate**, by modifying local planning frameworks to help ensure that new development is appropriately designed and located. Public authorities in this situation may also choose to consider the appropriateness of interim Protection measures to preserve public interests by delaying shoreline recession and minimising the effect of regular nuisance inundation events on existing development and infrastructure.

A modified local planning framework, to facilitate the Accommodate and interim Protection options is discussed in Section 3.3.

2.4 Site Constraints

The success criteria for the study identified in the Risk Assessment Chapter Report (Water Technology, 2018a) are presented in Table 2-2. These criteria demonstrate that the stakeholder and community values in the study area reflect the requirements of the state, regional and local planning controls. The success criteria highlight the need for continuing public access to beaches, beach amenity, and the provision of a coastal foreshore reserve. They also identify protecting the natural environment. The importance of tourism to Denham's local economy is strongly tied to the sustainability of environmental tourist attractions. The public amenity and culture of the foreshore area is thus directly linked back to the economic values of the town.

TABLE 2-2 ADOPTED SUCCESS CRITERIA

- **Protection of the environmental assets of the study area / planning to retain environmental integrity**
- **Protection of the recreational value of the coastline**
- **Protection of the cultural values of the coastline & town centre**
- **Maintenance of a level of public recreational assets**
- **Development controls not to inhibit the landscape**

2.5 Summary for Decision Makers

Table 2-3 presents a summary of the relevant information provided in this chapter. It is important to note that there is no law requiring public authorities to provide protection of private property from natural hazards, nor compensation when land is lost due to coastal hazards. The CHRMAP process aims to minimise coastal hazard risks and maximise beneficial use of the coast.

TABLE 2-3 ADAPTATION CONSIDERATION SUMMARY

- Adaptation options should minimise coastal process interference and legacy issues
  - The adaptation hierarchy is presented in Figure 2-3.
- Coastal development must be sustainable in the long term, and must balance the community, economic, environmental and cultural needs
- Local Governments are responsible for managing risks to **public assets** and any assets they manage. They should also:
  - Develop local policies and regulations consistent with state legislation and policy
  - Facilitate building resilience and adaptive capacity within the local community
  - Work in partnership with community to identity and manage risks / impacts
- Management strategies that preserve the natural coastline and move development away from the active coastal zone in an orderly manner are considered ideal. Of particular relevance to the CHRMAP process is the user pays principle, whereby those who benefit most from protection must provide the greatest financial contribution
- Adaptation options should maintain future flexibility, in order to build resilient coastal communities.
- A key adaptation option will be the use of planning instruments, including managed retreat.

3 ADAPTATION OPTIONS

3.1 Assets at Risk

In the Establish the Context Chapter Report (Water Technology, 2018c), the assets in the coastal zone were identified. Each asset was colour coded based on its classification (commercial, public, tourism related and residential) for ease of identification in the hazard maps and online database. The online database displays the identified assets, as well as the spatial extent of the various coastal hazards. The present planning scheme zoning is also included as a layer. The online database can be found at the following link:

https://watech.maps.arcgis.com/apps/webappviewer/index.html?id=6e092b4d0f044e038a721705e907c084

The prioritised assets at risk of inundation are presented in Table 3-1, and for erosion in Table 3-2. These are as per the analysis undertaken in Water Technology (2018a). The inundation assessment investigated the 500-year ARI inundation event for the different planning timeframes: Present Day, 2030, 2050 and 2118. This event has a predicted level of 3.3m AHD in the present day, and 4.2 m AHD by 2118.

The erosion assessment calculated a coastal processes allowance. This is a setback distance from the horizontal shoreline datum, roughly equivalent to the present location of the dune vegetation line. This setback distance ranged from 4 to 13m in the present day, and 123 to 230m by 2118.

Along Knight Terrace, the extent of the hazard area in 2118 is similar for both inundation and erosion.

3.2 General Options

Table 3-3 below presents a list of generally available adaptation options suitable for most coastal sites. These relate to both short term and long-term adaptation to coastal hazards in general, not just in relation to planning for climate change impacts. The column on the right-hand side provides some discussion as to the possibility of its application in Denham. Chapters 3.3 and 5 provide some discussion and selection of these options over the planning timeframe for inundation and erosion respectively.

Whilst the risks and their corresponding adaptation options are assessed separately, triggers to adapt can occur at any time from either erosion or inundation.

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TABLE 3-1 PRIORITISED ASSETS - INUNDATION RISKS

Present Day	2030	2050	2118
Utilities consist of: ▪ Electrical box, the water pumping station and the water well located at the south-eastern end of Knight Terrace ▪ Electrical substation on Durlacher St near the corner of Knight Terrace ▪ Fire hydrants located at the marina facility			
	Drains to beach, foreshore recreational infrastructure such as benches, picnic tables, BBQs, toilets, public art		
	Fuel tank at marina		
	Petrol pumps / tanks at the 2 petrol stations		
	Public buildings: Shire Offices Department of Biodiversity, Conservation & Attractions, Shark Bay Discovery Centre, Community resource centre		
	Knight Terrace, car parks, parks		
	Commercial, tourism and residential buildings		
			Vacant blocks

TABLE 3-2 PRIORITISED ASSETS - EROSION RISKS

Present Day	2030	2050	2118
Adhoc seawall			
	Utilities: ▪ Fire hydrants located at the marina facility	Utilities: ▪ Electrical box and water pumping station located at south-eastern end of Knight Terrace ▪ Fire hydrants located at the marina facility	Utilities: ▪ Electrical box and water pumping station located at south-eastern end of Knight Terrace ▪ Fire hydrants located at the marina facility ▪ Electrical substation on Durlacher St near the corner of Knight Terrace
	Foreshore recreational infrastructure: BBQs, toilets, fish cleaning station	Foreshore recreational infrastructure: BBQs, public toilets	Foreshore recreational infrastructure: BBQs, public toilets, fish cleaning station
	Knight Terrace	Knight Terrace & Stella Rowley Drive	
	Fuel tank at marina		
		Public buildings: Shire Offices	Public buildings: Shire Offices, Department of Biodiversity, Conservation & Attractions, Shark Bay Discovery Centre, Community resource centre
		Commercial, tourism and residential buildings	
		Petrol pumps / tanks at the 2 petrol stations	
		Vacant blocks	
		Foreshore recreational infrastructure: foreshore path, limestone retaining wall, playground, parks, car parks, drain to beach, public art, public bench, pergola	
			Marine infrastructure: Engineered seawall, FRP sheet-pile groyne, jetty, boat ramp, beach access

TABLE 3-3 AVAILABLE ADAPTATION OPTIONS (ADAPTED FROM WAPC, 2014)

Option Nº	Option Name	Option Type	Asset	Discussion
1	Locating new assets outside of vulnerable areas	Avoid	This applies to future assets in the coastal zone, as those assets already in the zone do not apply by definition	Requires no financial resources to be spent on coastal management and adaptation.
2.1	'Do Nothing'	Planned / Managed Retreat	All assets in the hazard zone	This is managed retreat at its most basic form. The asset will be lost after a hazard event. Repairs are carried out for public safety purposes only.
2.2	Demolition or removal / relocation of assets from inside hazard area	Planned / Managed Retreat	All low cost / temporary assets, or those that are easily relocatable such as recreational amenities	Relevant for low value assets where it is impractical technically and financially to design asset to withstand hazard rather than relocating. Allows amenities to be retained until relocation is required. This meets social and economic values. Relocation can coincide with asset replacement to save on costs.
2.3	Prevention of further development / expansion of existing use rights	Planned / Managed Retreat	All assets that are impractical to protect	Enables existing development and use rights to continue without increasing them, until such time as impacts arise. This would be specified in the Local Planning Scheme. It is generally applicable if protecting the assets is not viable.
3.1	Notification on title	Accommodate	All assets located within an area vulnerable to the adverse impacts of coastal erosion and inundation within the planning timeframe	Indicates to current and future land owners that an asset is likely to be affected by coastal erosion and/or inundation over the planning timeframe, and that risk management and adaptation is likely to be required at some stage within the planning timeframe. Helps current and future owners make informed decisions about level of risk and tolerability. Low cost implementation; can guide sub-division and development.
3.2	Emergency evacuation plans	Accommodate	Roads (with particular regard to managing traffic flows during an event), car parks, residential property, hospitals, aged care facilities, schools, child care facilities, surf life-saving clubs etc.	Where assets may be affected by inundation and are not already identified in an existing emergency evacuation management plan. Such plans are important in managing the safety of community and stakeholders. Low cost option in addressing the consequences of inundation with regard to safety to lives as the impact occurs.
3.3	Design assets to withstand hazards	Accommodate	Roads, car parks, residential property, hospitals, aged care facilities, schools, child care facilities, surf life-saving clubs etc	When avoiding or relocating an asset is not an option, design of assets to withstand the impact of inundation. Aimed at retaining assets in existing locations but reducing the consequences of the inundation hazard. It is cheaper to mitigate the impacts with initial design outcomes as opposed to retrofitting existing assets in the future.
3.4	Revegetation	Accommodate / Protect	Primary and secondary dunes	This is a cross between designing assets to withstand hazards (in that the asset is the dune system) and protect, in that the vegetation will provide some resilience to coastal erosion and inundation events, and thus protect assets located landward of the dune.
4.1	Renourishment & revegetation	Protect	High use beaches and foreshore reserves where retreat is not an option.	Involves placement of sand on the upper beach face and dunes to re-establish the sandy beach and provide a sediment supply. Availability of suitable sand sources needs to be investigated. Where suitable sources are not readily available or a considerable distance away, costs are increased. If the nourishment sand is significantly finer than the existing beach sand the nourishment sand will be lost quickly.
4.2	Groynes	Protect	High use beaches and foreshore reserves where retreat is not an option. Where assets values are high, and relocation is not an option.	Construction of groynes to stop or restrict the movement of sand around the end of the structure, to provide protection to assets behind the beach/foreshore reserve. They are primarily effective where there is longshore sand supply. Groynes form a cross-shore barrier that traps sand that moves alongshore. Groynes are not effective as a means of managing short-term storm erosion. Groynes could be expensive and change the nature and appearance of the coast. This needs to be weighed up against the value of the assets being protected.
4.3	Seawalls	Protect	High use beaches and foreshore reserves where retreat is not an option. Where assets values are high, and relocation is not an option.	Construction of a seawall, usually along an entire section of shoreline. Where a beach is to be retained, this option should generally be accompanied with beach nourishment or replenishment. Seawalls are expensive and change the nature and appearance of the coast. Seawalls protect the land not the beaches. Needs to be accompanied by greater beach nourishment/replenishment, which adds to the cost of option. This needs to be weighed up against the value of the assets being protected.

3.3 Planning Options

This section outlines the key planning instruments which should be considered for incorporation into the Shire's local planning framework. These instruments are particularly useful for implementing Accommodate and Planned or Managed Retreat options.

3.3.1 Incorporate SPP 2.6 into Local Planning Scheme Nº. 4

Amend Clause 29 (1) to include SPP 2.6 as a State Planning Policy to be read as part of the Scheme. No amendments to SPP 2.6 under clause 30 are suggested.

It is possible for local governments to nominate any State Planning Policy to be read as part of the local planning scheme under clause 29, with or without modification. If modifications are proposed, these are specified under clause 30. In this way, the policy provisions are given statutory effect, and any modifications made to the State Planning Policy are automatically included into the scheme. It should be noted that modifications to State Planning Policies are infrequent and always subject to a public referral stage before adoption. This means that if future amendments to SPP 2.6 are proposed that the Shire does not wish to include in the scheme there will be time to identify the appropriate modifications by amendment to the scheme in clause 30.

3.3.2 Special Control Area

Amend the local planning scheme to introduce a Special Control Area (SCA) over all land identified as being at risk of coastal erosion and/or inundation. The SCA would be delimited by the position of either the 2118 coastal processes setback line or the inundation extent of the 500-year ARI event in the year 2118, whichever is the more landward.

An SCA is an overlay that applies in addition to the underlying classification of the land and identifies planning controls that apply in addition to any other requirements relevant to the underlying zone. Development that might otherwise be exempt from development approval would then be required to obtain a planning approval in addition to building approval. An SCA can facilitate land use changes and development control within that area.

An SCA should be applied to relate specifically to land subject to coastal processes (as recommended in the Draft Planned or Managed Retreat Guidelines).

Each SCA is allocated a number and depicted on the Scheme Map.

The Draft Planned or Managed Retreat Guidelines provide draft amendment text including the purpose, objectives and provisions (see below). The purpose of the SCA is to provide guidance as to the appropriate scope of land use and development to be permitted within a coastal erosion and inundation hazard risk area. Its objectives would be:

a. To ensure land in the coastal zone is continuously provided for coastal foreshore management, public access, recreation and conservation.

b. To ensure public safety and reduce risk associated with coastal erosion and inundation.

c. To avoid inappropriate land use and development of land at risk from coastal erosion and inundation.

d. To ensure land use and development does not accelerate coastal erosion or inundation risks; or have a detrimental impact on the functions of public reserves.

e. To ensure that development addresses the Denham Townsite CHRMAP prepared in accordance with SPP 2.6 and prepared in accordance with the Denham Townsite CHRMAP.

The SCA would include additional provisions (over and above or overriding provisions for development not within the SCA), such as:

a. All proposed development within the SCA requires approval. (This would include development that would not ordinarily require development approval under the scheme).

b. Approval to be issued on a temporary or time limited basis. (The applicant could later apply for a further approval, which could be granted if the risk from coastal processes was still considered acceptable).

c. Referral of applications. (Any planning application should be referred to the Department of Transport, the Western Australian Planning Commission and any other relevant authority for advice and comment on the coastal risk.)

d. Minimum finished floor levels and/or other development standards. (4.2 metres AHD has been identified as the appropriate minimum FFL).

3.3.3 Coastal Development Local Planning Policy

Prepare a local policy to clarify its attitude and expectations in relation to coastal development including the type of permanent or temporary assets it is prepared to accept within the coastal reserve and/or on land subject to coastal processes.

Local Planning Policies (LPP) are prepared and adopted according to the provisions Division 2 of Part 2 of the Deemed Provisions of LPS 4. The Deemed Provisions comprise Schedule 2 of the Planning and Development (Local Planning Schemes) Guidelines 2015.

A Coastal Development LPP can provide more detail and guidance on what sort of development would be acceptable and will also assist the Council in making planning decisions on coastal development requiring the exercise of discretion. For example, on land at risk of erosion within the life of a proposed development the LPP may encourage use of structures that can be disassembled and/or transported should erosion come within a specified distance of the structure. The policy would also identify the Council's intention to require notifications on title as a condition of development approval.

3.3.4 Notifications on Title

All freehold land identified as being at risk of impact from coastal processes should have a notification placed on its certificate of title/s to make the owner and future landholders aware of the potential for the land to be impacted.

Section 70A of the Transfer of Land Act 1893 and Section 165 of the Planning and Development Act 2005 enables a local government or public authority to cause a notification to be placed on the certificate of title of land to make owners and future owners of land aware of a factor that may affect the use and enjoyment of the land. The process requires the written consent of the landholder and payment of a fee, so it is usual for the requirement for placement of a notification to be a condition of development or subdivision approval. However, placement of a notification on the title does not have to be tied to an application and could take place at any time with owner consent.

Indicative wording is as follows, as per SPP2.6:

VULNERABLE COASTAL AREA – This lot is located in an area likely to be subject to coastal erosion and/or inundation over the next 100 years.

3.3.5 Other Instruments

Other instruments may be useful for implementing adaptation options. These include:

- Restrictive Covenants, which can be used to restrict present and future landholders from constructing protection structures and, to internalise the risk of building in inherently hazardous locations.
- Special Area Rates, which can be used to ensure that the costs associated with protection options are equitably distributed across beneficiaries.
- The requirement for a structure plan could be considered, setting out development provisions and planning controls consistent with SPP2.6 for vulnerable areas with new development/subdivision proposed.
- Update of Shire of Shark Bay Local Planning Strategy to be considered as part of amendments to other planning instruments.

The intent of these instruments aligns with guidance provided in the WA Coastal Zone Strategy, noting that private parties are responsible for managing risks to their private assets and incomes which might arise from coastal erosion and inundation hazards.

4 INUNDATION ADAPTATION OPTIONS

This section discusses adaptation options identified to respond to inundation hazards.

4.1 Present Day

Whilst 140 identified assets are at some level of risk in the present day, due to the low likelihood of the 500-year ARI inundation event occurring (0.2%), the resulting risk classification is low for all assets except the critical utilities. These utilities may require additional maintenance if significantly inundated. Depending on their specific construction details, the Shire and responsible authorities may consider planning for the relocation of these assets in the present day, or adapting designs to ensure inundation does not cause asset failure. This may apply to the electrical box, the water pumping station and the water well located at the south-eastern end of Knight Terrace, as well as the electrical substation on Durlacher St near the corner of Knight Terrace.

Due to the number of assets already at risk in the present day, there are additional options that will facilitate flexible adaptation in the future:

- Prevention of further development / limiting existing use rights
  - Introduce 'Special Control Area - Coastal Hazard' with a requirement for new development to achieve a minimum finished floor level of 4.2m AHD for habitable areas of buildings. Depending on the nature of development proposed, approval may be time limited or require structures to be removed by a specified date or when a specified trigger is reached.
  - Introduce a local planning policy outlining the Shire's requirements for building construction, land fill, and other relevant matters within the Special Control Area.
  - Incorporate SPP 2.6 into Local Planning Scheme
- Any new assets should avoid the coastal zone.
  - If they must be located within the coastal zone, they should be designed to withstand the inundation hazard. For example, new buildings to be constructed with permeable lower levels (e.g. a stilt arrangement), and services located above the flood level. This avoids the need to use fill to raise the (FFL). Fill is expensive, and also alters the flood flow, which could lead to increased hazards.
- Emergency evacuation plans for the affected areas
  - It is noted that access to the town is not predicted to be blocked in the event of a hazard.
- Commence investigations to determine options for appropriate longer-term relocation of affected parts of the town

4.2 Future Timeframes

The adaptation options discussed below are in addition to or add to those discussed for the Present Day above. Economically, relocation or managed retreat options may be triggered by the physical costs of repair exceeding the relocation costs. As per the success criteria and adaptation hierarchy, consideration should be given to the continued allowance for a recreational reserve. This may mean relocating buildings ahead of their risk rating in order to continue to allow this space.

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4.2.1 2030

The modelling has indicated that by 2030, inundation places most assets at medium risk. This means additional maintenance or repair will be required if significantly inundated. The multi-criteria analysis (MCA) / cost benefit analysis (CBA) to be conducted in the next chapter report: Assessment of Adaptation Options should investigate the timeframe when (if) relocating the foreshore recreational infrastructure is the most appropriate.

Public, commercial, tourism and residential buildings may need to consider mechanisms for minimising the impact of flood damage. The Shire is not responsible for preventing damage to private assets. Therefore, where relevant, landholders might consider the following measures in their own responses to minimise coastal hazard risk:

- Services moved so as to be located above the recommended FFL
- Commercial stock or important possessions stored above the flood level
- Installation of false (raised) floors
- Use of materials that are water resistant
- Floorplate / wall arrangements to allow flow of water (and therefore minimise damage)
- Building evacuation requirements

The fuel tank at the marina, and the petrol tanks / pumps at the two petrol stations should be investigated as to their resilience under an inundation event. Potentially adaptation of the waterproofing / footings could be carried out to ensure spills do not occur.

The following planning mechanisms are also recommended:

- Ensure that appropriately zoned land is available for relocation of the town as necessary. Structure planning of the land may be required.
- Amend the provisions (and boundaries, if necessary) of the Special Control Area to manage development in locations at risk of permanent inundation.

4.2.2 2050

Utilities and foreshore recreational infrastructure may require significant repair. Relocation may be a viable option by this timeframe. As per the 2030 timeframe, the CBA will provide a clearer understanding of the actions in this timeframe.

At this time, the drains and drainage system to the beach may need to be modified to continue to function. The drains rely on gravity flow from the streets down to the ocean. Under increased sea levels and storm frequency, the ability of the drains to function will be reduced as they may be more frequently inundated from the ocean side, such that there is nowhere for the landward-side water to go.

Public, commercial, tourism and residential buildings should consider mechanisms for minimising the impact of flood damage, as per the recommendations in 2030 above.

There may be some flood related damage to Knight Terrace, car parks, and grassed foreshore area leading to increased maintenance requirements.

Structure plans for relocation areas should have been completed and the Scheme Map amended as necessary.

4.2.3 2118

Utilities, foreshore recreational infrastructure, Knight Terrace, Stella Rowley Drive and the adjacent car parking areas and drains may require significant repair or relocation.

Under the 2118 predicted sea level rise, the drains may be completely inundated during a tidal cycle, leading to the inability to drain rainwater at high tide.

Public, commercial, tourism and residential buildings may need significant repairs or relocation.

Flood related damage to public open space, beach access, boat ramps and marine infrastructure may require significant repairs.

5 COASTAL EROSION ADAPTATION OPTIONS

5.1 Present Day

The evolution of the Denham townsite is such that much of the recreational infrastructure, and Knight Terrace itself, is located where the primary dune would have been historically. The foreshore from the Denham Seaside Tourist Village on Stella Rowley Drive, to the intersection of Denham Hamelin Road, is on reclaimed land. In an unmodified, undeveloped beach system, the primary dune acts as a natural buffer for erosion events. During storm events the dune face is eroded, and over time, is built back up again naturally. In the study area, as the dune has been converted to recreational and infrastructure space, erosion events will have a greater impact as the system has little tolerance to the erosion / accretion cycle. In addition to storm events, human foot traffic and stormwater run-off can also be significant contributors to erosion.

As indicated by the history of reclamation, the shoreline plan has changed significantly since European settlement. A 1987 aerial photograph displayed in the Shire's office shows some early reclamation works at the present-day marina site. The 2001 image available to view on the Landgate website shows the extension of this reclamation either side of the marina to the west and east. In this image, the beach area to the west of the marina extends some 16 m seaward of the beach location in the 2017 aerial image, noting the present-day beach is held in place by a low seawall. This movement is reflected in the historical shoreline movement chapter within Water Technology (2018b).

The 2017 planform (that is, the present-day planform) is likely more stable in shape than that of 1987 and 2001, due to its smoother profile. Unless rock is present, the shoreline will generally evolve to be parallel to the incoming wave crests. Sharp changes in beach planform shape due to reclamation works would be reworked to an equilibrium shape. It is expected that is what has happened along the Denham foreshore.

The present condition of the foreshore is summarised in Table 5-1, split by the study area sections defined in the Coastal Hazard & Vulnerability Assessment Chapter Report (Water Technology, 2018b, refer Figure 5-1). Also included in the table are each section's vulnerability to erosion, and potential coastal management actions that could improve stability in the present day.

In the present day, only the adhoc seawall is considered a medium risk according to the risk assessment (Water Technology, 2018a). To mitigate this risk fully would require formal design and construction. However, the upgrade of a seawall constitutes a protect option, which is not preferred under the adaptation hierarchy. It is also contrary to the feedback received during the project that has formed the success criteria. The presence of a formal seawall would significantly reduce the public amenity of the beaches from the marina to the eastern end of Knight Terrace. We note this could simply extend from the marina to the intersection of Denham Hamelin Road.

Revegetation in the adhoc seawall's lee with some minor renourishment to stabilise the profile may be an alternative, in addition to an initial re-placement of the existing rocks into a more stable shape. Maintenance of this vegetation will provide a natural resilience to the narrow 'dune' between the beach and recreational infrastructure.

Groynes are not a suitable option at the site unless multiple groynes are in place, together with significant renourishment and bypassing works. This would require ongoing maintenance in the long term and thus constitute a 'legacy' adaptation option. Groynes can also lead to unintended consequences.

TABLE 5-1 PRESENT DAY CONDITIONS

	Section 1	Section 2	Section 3	Section 4	Section 5
Condition	▪ Last remaining 'natural' shoreline within the townsite ▪ Primarily composed of sandy beach and low vegetated foredunes seaward of Knight Terrace ▪ Small basic rock protection structure adjacent to and serving the turnaround at the southern end of Knight Terrace ▪ The vegetated foredune is generally 10-20 m in width and is broken up by numerous drains, paths and an informal boat loading area	▪ Reclaimed foreshore. 1957 vegetation line is approximately 20m landward of the present-day vegetation line ▪ Revetment along most of section appears un-designed. Signs of damage and failure; amour fallout and slumping has occurred ▪ The structure's crest rarely rises above the road level ▪ The beach face is generally narrow, with regular tidal action reaching the rock armour ▪ Essentially no dune present, in its place is recreational infrastructure such as playground, car parks, paths etc.	▪ Reclaimed, armoured foreshore; approximately 40-60m seaward of 1957 shoreline ▪ Revetment intersected by three boat launching ramps. ▪ No dry beachface evident during site inspection; natural coastal processes modified due to boating facility and associated works ▪ Revetments in the section were in good condition during site visit ▪ Northern half of revetment appears older and utilises a smaller average armour size and lower crest level. ▪ Northern half contains a section of sparsely vegetated sandy reclaimed land between revetment and coastal path	▪ Reclaimed land seaward of the Denham Seaside Tourist Village; receives ongoing nourishment from dredge disposal ▪ Rest of section comprises a narrow beach abutting steep dune faces up to 25 m AHD ▪ Some terminal scour at the beach / seawall interface ▪ Some historical recession in west of section, however this could be due in part to the interference of the system updrift	▪ Minimal development in this section ▪ Majority of this section is fronted by low lying sand dunes ▪ Low lying areas connected to the open water by tidal channels resulting in several small salt water marshes. ▪ Recreational vehicle tracks and car park located about 10m landward of vegetation line ▪ Tyre tracks visible across much of the vegetation
Vulnerability	▪ Recreational infrastructure vulnerable in present day ▪ Gaps in vegetation increase erosive impact during storm. Reduces capacity of dune to retain sediment ▪ Overall recession in shoreline between 1957 and 2017 of ~10m ▪ Low lying; inundated in the present day 20-year ARI event	▪ Recreational infrastructure vulnerable in present day ▪ Low lying; inundated in the present day 20-year ARI event ▪ The shoreline has receded since the reclamation	▪ Low lying; inundated in the present day 20-year ARI event ▪ Erosion could occur in northern half which could damage the limestone retaining wall	▪ Most of the section predicted to be unaffected by inundation ▪ The section is vulnerable to erosion which affects Denham Seaside Tourist Village, a lookout and beach access path. Rest of section is undeveloped	▪ The car parks and connecting gravel road are vulnerable to erosion in the present day, and inundation under the 100-year ARI event. ▪ Stella Rowley Drive inundated in present day 500-year ARI event ▪ Foreshore well vegetated
Management Options	▪ Stability could be improved through modification of the stormwater drainage and revegetation of the dune ▪ Possibility of sand fencing to build the dune system vertically and laterally ▪ Possibility of dredge material placement to increase beach width ▪ Beach monitoring to regularly document changes to the shoreline and understand system; enables better prediction of management trigger timeframes	▪ Stability could be improved by reshaping the existing seawall and revegetating the crest seaward of the foreshore path ▪ Possibility of dredge material placement to increase beach width ▪ Beach monitoring to regularly document changes to the shoreline and understand system; enables better prediction of management trigger timeframes	▪ Sandy section in the north could be revegetated to promote stability. This could protect limestone retaining wall somewhat during an event – Beach monitoring to define trigger timeframes ▪ Monitoring of seawall to trigger maintenance requirements	▪ Consolidated / rocky shoreline may limit the erosion along this section ▪ Stability seaward of Denham Seaside Tourist Village could be improved through vegetation and send fencing – Beach monitoring to define trigger timeframes	▪ Environmental impacts of 4WD and quad bikes could be mitigated through management of these activities ▪ If the car parks are to be redeveloped, they should be located approximately 30m landward of their present location ▪ Beach monitoring would precipitate trigger timeframes of this shift

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FIGURE 5-1 STUDY AREA SECTIONS

As per the inundation adaptation options, planning mechanisms are recommended. These are as follows:

- Introduce Special Control Area - Coastal Hazard with a requirement for new development to achieve a minimum finished floor level of 4.2m AHD (in line with the present Scheme revisions) for habitable areas of buildings. Depending on the nature of development proposed, approval may be time limited or require structures to be removed by a specified date or when a specified trigger is reached.
- Require notification on Title for all land located seaward of the 100-year hazard line for coastal erosion. This should be made a condition of any approval for development or subdivision/amalgamation of land. The Shire should also negotiate with landholders whose land is not subject to an application for planning approval to place such a notification on the title with their consent.
- Introduce a local planning policy outlining the Shire's requirements for building construction, land fill, and other relevant matters within the Special Control Area.
- Commence investigations to determine options for appropriate longer-term relocation of affected parts of the town.

5.2 Future Timeframes

The modelling has provided an indicative timeframe as to when adaptation will be required. However, it is recommended to employ the use of triggers for adaptation, including for relocation or managed retreat purposes. These are as per those of WAPC (2017).

- **Trigger 1**: Where the most landward part of the Horizontal Shoreline Datum (HSD) is within 40 metres of the most seaward point of a development / structure / foreshore reserve area.
  - Due to the high value placed on the foreshore coastal reserve, the recreational area would itself be considered the asset in this case
- **Trigger 2**: Where a public road is no longer available or able to provide legal access to the property
  - This may occur for Knight Terrace, particularly to the east of Denham Hamelin Road. The Shire may choose to investigate access options from the landward side of these properties.
- **Trigger 3**: When water, sewage or electricity to the lot is no longer available as they have been removed/decommissioned by the relevant authority due to coastal hazards.

As per the inundation discussion, the management measures discussed in Table 5-1 and Chapter 5.1 above apply in the addition to those discussed below.

5.2.1 2030

Amend the provisions (and boundaries, if necessary) of the Special Control Area to limit development in locations at risk of erosion.

Continue to require notification on title as a condition of planning approval and/or on a voluntary basis.

Ensure that appropriately zoned land is available for relocation of the town as necessary. Structure planning of the land may be required.

Utility connected foreshore infrastructure, marina fuel tank, utilities and Knight Terrace may require additional maintenance / repair by this timeframe.

5.2.2 2050

Utilities, marina fuel tank, petrol pumps and utility connected foreshore infrastructure may require significant repairs.

Public, commercial, tourism and residential buildings may sustain damage.

Knight Terrace, Stella Rowley Drive and foreshore recreational infrastructure may require additional maintenance.

Structure plans for relocation areas should have been completed and the Scheme Map amended as necessary.

5.2.3 2118

Utilities, marina fuel tank, petrol pumps, utility connected foreshore infrastructure, public, commercial, tourism and residential buildings, Knight Terrace and a section of Stella Rowley Drive may require relocation.

Foreshore recreational infrastructure may require significant repair or relocation.

Beach access, boat ramps and marine infrastructure may require significant repairs.

6 CONCLUSIONS

The adaptation options presented within this report have followed the coastal hazard risk management hierarchy, as per SPP2.6. The aim of the adaptation is to provide a planning framework that the Shire can follow that allows sustainable development, but also allows the continued use of the land until the risk is realised, and there is a plan on what to do if it is.

The final management options will include the continued revision of the CHRMAP and update of the recommended options at regular intervals (i.e. every five to ten years). This is due to corresponding future updates in climate change science, coastal engineering methodology, changes to the town's success criteria, triggers reached, and so on.

The next stage of the project will assess the adaptation options discussed within this report with a multi-criteria analysis. Options receiving a positive score from this will be assessed in a cost benefit analysis. All adaptation options come with a financial cost. We recommend investigating funding avenues based on the town's high tourism value, and the World Heritage listing. Maintaining the culture and recreational value of the Denham townsite is strongly linked to the continuation of both tourism and environmental protection of the region.

In addition to the recommendations of the CHRMAP, local foreshore management plans should consider broader issues such as biodiversity and environmental impacts.

The identification and assessment of the adaptation options will be reviewed by the community and stakeholders, as recommended in WAPC (2014). Similarly, the community and stakeholders may have suggestions for alternate adaptation options. The Stakeholder and Community Engagement Strategy (Water Technology, 2018d) identified a review period that included a workshop and online survey to complete this process.

7 REFERENCES

Intergovernmental Panel on Climate Change (IPCC, 2014). *Climate Change 2014: Synthesis Report*, Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland, Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)], IPCC, Geneva, Switzerland, 151 pp.

Robb, A., Stocker, L., Payne M., & Middle, G., (2017). 'Planning for coastal erosion and inundation in Western Australia: Practices and perceptions from the local level', *Environmental and Planning Law Journal*, Volume 34

Robb, A., Payne, M., Stocker, L., Middle G. & Trosic, A. (2018). 'Development Control And Vulnerable Coastal Lands: Examples Of Australian Practice', *Urban Policy and Research*, DOI: 10.1080/08111146.2018.1489791

Water Technology (2018a). *Denham Townsite CHRMAP Chapter Report: Risk Assessment*, Report Nº 5652-01 R05v01, prepared for Shire of Shark Bay

Water Technology (2018b). *Denham Townsite CHRMAP Chapter Report: Coastal Hazard & Vulnerability Assessment*, Report Nº 5652-01 R04v01, prepared for Shire of Shark Bay

Water Technology (2018c). *Denham Townsite CHRMAP Chapter Report: Establish the Context*, Report Nº 5652-01 R03v02, prepared for Shire of Shark Bay

Water Technology (2018d). *Denham Townsite CHRMAP: Stakeholder and Community Engagement Plan*, Report Nº 5562-01 R01v01, prepared for Shire of Shark Bay

Western Australian Planning Commission (WAPC, 2013). State Planning Policy No. 2.6 – State Coastal Planning Policy, prepared under the Planning and Development Act 2005.

Western Australian Planning Commission (WAPC, 2014). Coastal Hazard Risk Management and Adaptation Planning Guidelines

Western Australian Planning Commission (WAPC, 2017). Draft Planned or Managed Retreat Guidelines, published by WAPC, Department of Planning, Lands and Heritage

APPENDIX F
CHAPTER REPORT: ASSESSMENT OF ADAPTATION OPTIONS

Denham Townsite CHRMAP

Chapter Report: Adaptation Option Assessment

Shire of Shark Bay

02 April 2019

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Project Name	Chapter Report: Adaptation Option Assessment
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02 April 2019

Paul Anderson
Chief Executive Officer
Shire of Shark Bay
65 Knight Terrace Denham WA 6537
Via email ceo@sharkbay.wa.gov.au

Dear Paul

Chapter Report: Adaptation Option Assessment

We are pleased to present the Denham Townsite Coastal Hazard Risk Management and Adaptation Plan Chapter Report: Adaptation Option Assessment. If you have any queries, please do not hesitate to contact me on (08) 6555 0105.

Yours sincerely

Joanna Garcia-Webb
Principal Coastal Engineer – National Practice Lead – Coasts & Environment

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WATER TECHNOLOGY PTY LTD

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EXECUTIVE SUMMARY

It is internationally recognised that increasing sea levels and storm intensities will intensify coastal hazards such as coastal inundation (temporary coastal flooding), storm erosion and long-term shoreline recession (IPCC 2014). Consequently, State governments across Australia have introduced obligations that require local governments to consider and plan for the effects of these hazards over various planning timeframes. In Western Australia (WA), the governing policy is the Western Australian Planning Commission's State Coastal Planning Policy 2.6 (WAPC, 2013, herein referred to as "SPP2.6"). SPP2.6 recommends management authorities develop a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP). Specific guidelines have been developed to assist in this process (WAPC, 2014).

One of the key objectives of SPP2.6 is to establish coastal foreshore reserves which include allowances for the protection, conservation and enhancement of coastal values across the state. Risk assessment processes are then utilised to identify risks that are intolerable to the community, and other stakeholders such as the Shire of Shark Bay, indigenous and cultural interests, and private enterprise. Adaptation measures are then developed according to the preferential adaptation hierarchy outlined in SPP2.6.

The overall CHRMAP purpose is as follows:

- To identify vulnerable assets (public and private) and the risk posed to them by coastal hazards.
- To preserve community values for present and future generations.
- To develop a plan that will allow the Shire to respond to identified risks through adaptation planning activities.
- To recommend monitoring plans to ensure the risk management and adaptation plan activities are working into the future as expected.

This document presents the Assessment of Adaptation Options Chapter Report. This assesses the identified potential adaptation options for the prioritised list of assets at risk of coastal hazards developed during the previous project phases. The flow chart displayed in Figure 1-2 indicates where this component of the study sits with reference to the wider study; the 'Adaptation Options Assessment' phase corresponds to the bubble shaded in red, as replicated below.

The Shire's responsibility is limited to preserving public interests by minimising risks to public assets where possible. As per the WA Coastal Zone Strategy 2017, it is not the Shire's responsibility to address risks to private assets.

Assessment of Adaptation Options
For each vulnerable asset:
- For each Mitigation / Adaptation measure:
    - Multi-Criteria Analysis (MCA). If +ve, proceed to CBA
    - Timeframes / triggers to be considered
- Trade-offs between option selection & asset value

This assessment has further defined the hazard mitigation options identified in the options identification report (Water Technology, 2018a) and applied them to the coastal hazards faced within the Denham townsite and surrounds. As discussed in the Water Technology (2018a), WAPC (2014) strongly recommend a tiered preference system geared towards managed retreat for existing assets, then accommodation and finally protection when no other strategy is plausible.

This report adheres to those guidelines, recommending avoid, managed retreat and some accommodation options in all areas. Through a multi-criteria assessment and a cost-benefit analysis, various adaptation options were scored and compared to the alternative of doing nothing. A summary of the final recommended options from this report are presented in Table 1-1.

From this table some recommendations for the Shire are as follows:

- All new ***non-infill permanent*** development within the identified hazard zones should be avoided
- A special control area (SCA) should be created including, but not limited to the following:
  - All proposed development within the SCA requires approval. (This would include development that would not ordinarily require development approval under the scheme).
    - Referral of applications (any planning application should be referred to the Department of Transport, the Western Australian Planning Commission and any other relevant authority for advice and comment on the coastal risk).
  - Placement of Section 70A notification on appropriate land titles (notifying of coastal hazard risk)
  - Prevention of further development for lots within the erosion hazard zone of the next epoch (i.e.: staged prevention of development, initially for lots at risk by 2030, then later for lots at risk by 2050 if hazard triggers are reached). This criterion may be relaxed for lots inland of protection structures as long as the new development and protection structure design lives are taken into account.
  - Requirement of houses damaged or otherwise triggered (see Section 2.2) by coastal hazards to be relocated or rebuilt out of the hazard zone.
  - Minimum finished floor levels and/or other development standards (4.2 metres AHD has been identified as the appropriate minimum FFL).
- Land developers should also be made aware of the risks from inundation at present and in the future and be educated of the steps they can take to minimise damage from such events.

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TABLE 1-1 SUMMARY OF ADAPTATION OPTIONS ASSESSMENT (*POINTS BELOW)

Option Nº.	Option Name	Section 1	Section 2	Section 3	Section 4	Section 5
1.1	Avoid (where possible)		NA	NA		
2.2	Relocate					
2.3	Prevent further development		*2	*1		
3.1	Notification on land titles					
3.3I	Minor re-design to help accommodate inundation (where possible)					
4.1	Renourishment	*3				
4.2/3	Hard structure protection		*4			

1. Potential to continue development behind seawall protection as long as the finished floor level requirements are met, and developers are made aware of the potential for long-term retreat when marina facilities are retired (could be implemented with a timeframe limit to the development). Note that the marina facility has a design life of 25 years (WP, 2016) and is managed by the DoT so the Shire should carefully consider allowing significant development with a design life longer than 25 years in this area based on the assumption that facility's life span will be extended.
2. Restriction of further development dependent on the final adaptation pathway chosen for this area. If protection is chosen, then a similar strategy to Point 1 could be implemented.
3. Renourishment to limit erosion may be viable for Section 1 and could be based on a monitoring and trigger-based strategy.
4. Potential to install some form of coastal protection structure in Section 2 to allow more time for assets inland to be relocated over time. Potential options to be discussed with stakeholders

If Section 70A notifications were to be implemented for all residential and commercial lots within the 2118 hazards zone, a total of 51 residential and 14 commercial properties would be impacted. If a policy of managed retreat were adopted, Table 1-2 (adapted from the Water Technology, 2018) shows the number of assets that would be affected. Assets vulnerable between the present day and 2030 are considered extreme risk and relocation should be considered. Assets vulnerable by 2050 are considered high risk and monitoring and consideration of long-term options should occur. Assets at risk by 2118 should also monitor the progress of erosion and sea level rise and consider their options as the risk of hazards increases. Note that most of these assets are already exposed to inundation risks.

TABLE 1-2 ASSETS EXPOSED TO EROSION UNDER MANAGED RETREAT PREDICTIONS

Asset Classification	Present day to 2030 (extreme risk)	By 2050 (high risk)	By 2118 (moderate risk)
Commercial	1	5	14
Public	64	70	74
Residential	0	18	51
Tourism Related	1	4	10

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The Denham townsite is situated close to or within the active coastal zone, especially high value areas such as the hub of Knight Terrace and the marina facilities. This makes some interaction with coastal processes unavoidable. This has already been observed through the placement of various coastal protection structures over time, ranging from the new marina rock revetment to old ad-hoc erosion guards near vulnerable assets. The upgrade of marina facilities has somewhat cemented a section of the town's coastline in place for the next few decades. Both the MCA and the CBA recommended this protection be maintained for the time being.

Given the results of the assessment, three primary adaptation pathways for the next 50-years are presented below. These options were discussed with stakeholders with feedback implemented into the final recommended adaptation pathways. Stakeholders should note that while the assessment indicated that certain protection options may be viable, they do not include all the potential costs. Implementation of a protection strategy may encourage developers to commit to areas at risk of inundation and may increase difficulty of a successful managed retreat in the future.

1. **Managed retreat for all areas except Section 3**
2. **Construction of more formal seawall in Section 2; managed retreat for all other areas except Section 3.**
3. **Renourishment for protection of Section 1; independent of whether Option 1 or 2 is selected, managed retreat for all other areas except Section 3**.

Whilst erosion may be locally restricted in the near future if a protection strategy is pursued, it is clear from inundation hazard mapping that as sea level rise progresses, the feasibility of development in low lying areas will decline. The Shire should begin to prepare for long-term adaptation pathways that potentially involve managed retreat of significant parts of the town, mainly Knight Terrace and associated lots. While the above options under the managed retreat and accommodation groupings aim to make this process easier in the long run, such a significant shift will require a clear and collaborative vision for Denham's future. It is recommended that the Shire investigate potential town structure plans that can achieve this goal over the next decade. Staged infill to raise low lying parts of the town between new and old developments may be expensive and require coastal protection indefinitely, which will be very difficult to justify.

The next stage of the project considers implementation of the selected options. An implementation plan will be prepared for each vulnerable group of assets, identifying long-term pathways, considering trigger points and all components of the CHRMAP to date. A short-term implementation plan to produce a clear action plan to 2030 will be developed, as well as a monitoring plan, detailing any monitoring or review that may be required over the full 100-year planning timeframe.

CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

It is internationally recognised that increasing sea levels and storm intensities will intensify coastal hazards such as coastal inundation (temporary coastal flooding), storm erosion and long-term shoreline recession (IPCC 2014). Consequently, State governments across Australia have introduced obligations that require local governments to consider and plan for the effects of these hazards over various planning timeframes. In Western Australia (WA), the governing policy is the Western Australian Planning Commission's State Coastal Planning Policy 2.6 (WAPC, 2013, herein referred to as "SPP2.6"). SPP2.6 recommends management authorities develop a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP). Specific guidelines have been developed to assist in this process (WAPC, 2014).

One of the key objectives of SPP2.6 is to establish coastal foreshore reserves which include allowances for the protection, conservation and enhancement of coastal values across the state. Risk assessment processes are then utilised to identify risks that are intolerable to the community, and other stakeholders such as the Shire of Shark Bay, indigenous and cultural interests, and private enterprise. Adaptation measures are then developed according to the preferential adaptation hierarchy outlined in SPP2.6.

The aim of the present study is to investigate and plan for coastal hazards which are likely to affect the Denham townsite. Denham is located within the local government area of the Shire of Shark Bay, approximately 800km north of Perth (refer Figure 1-1 for locality). Denham and its surrounds are used extensively for tourism, commercial and recreational purposes. Tourism is the primary industry in the Shire, with fishing and aquaculture also playing a major role.

Given the above, visitors to and residents of Denham and its surrounds place a high value on the coastline. Processes affecting the coastal zone are multiple and complex: storm surge; tidal movement; shoreline stability; stormwater drainage; and the interactions between surface and groundwater all contribute in differing degrees. Furthermore, the potential impacts of climate change, specifically increasing sea levels and storm intensities, will place increased pressure on the coastal zone, and threaten public infrastructure and assets, private property, foreshore reserves, coastal attractions and public open spaces.

This document presents the Assessment of Adaptation Options Chapter Report. This assesses the identified potential adaptation options for the prioritised list of assets at risk of coastal hazards developed during the previous project phases. The flow chart displayed in Figure 1-2 indicates where this component of the study sits with reference to the wider study; the 'Adaptation Options Assessment' phase corresponds to the bubble shaded in red.

The Shire's responsibility is limited to preserving public interests by minimising risks to public assets where possible. As per the WA Coastal Zone Strategy 2017, it is not the Shire's responsibility to address risks to private assets.

FIGURE 1-1 EXTENT OF CHRMAP

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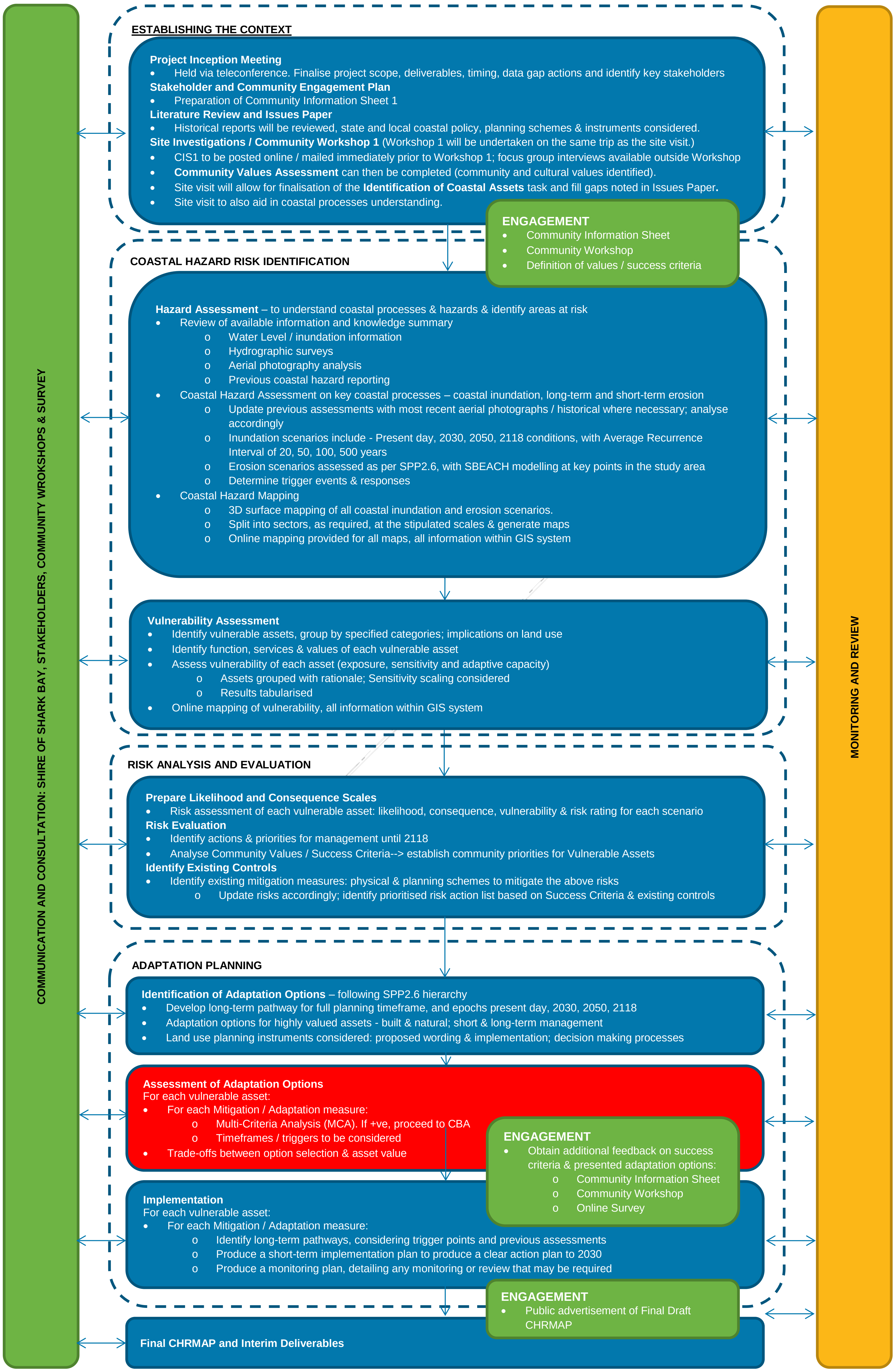

FIGURE 1-2 PROPOSED CHRMAP METHODOLOGY FLOW CHART (ADAPTED FROM WAPC CHRMAP GUIDELINES)

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2 POTENTIAL ADAPTATION OPTIONS

As per the Options Identification Chapter Report (Water Technology, 2018a), general adaptation options to mitigate coastal hazards are presented below. These options have been adapted from the CHRMAP Guidelines (WAPC, 2014) for this project. Note that the 'Do Nothing' approach here means applying no additional options to assets within the hazard zone, and simply repairing or condemning and removing assets after damage is incurred.

TABLE 2-1 AVAILABLE ADAPTATION OPTIONS (WATER TECHNOLOGY 2018A, TABLE 3-3; ADAPTED FROM WAPC, 2014)

Option Nº	Option Name	Option Type	Asset
1.1	Locating new assets outside of vulnerable areas	Avoid	This applies to future assets in the coastal zone, as those assets already in the zone do not apply by definition
2.1	'Do Nothing'	Planned / Managed Retreat	All assets in the hazard zone
2.2	Demolition or removal / relocation of assets from inside hazard area	Planned / Managed Retreat	All assets in the hazard zone
2.3	Prevention of further development / expansion of existing use rights	Planned / Managed Retreat	All assets that are impractical to protect
3.1	Notification on title	Accommodate	All assets located within an area vulnerable to the adverse impacts of coastal erosion and inundation within the planning timeframe
3.2	Emergency evacuation plans	Accommodate	Roads (with particular regard to managing traffic flows during an event), car parks, residential property, hospitals, aged care facilities, schools, child care facilities, surf life-saving clubs etc.
3.3	Design assets to withstand hazards	Accommodate	Roads, car parks, residential property, hospitals, aged care facilities, schools, child care facilities, surf life-saving clubs etc
3.4	Revegetation	Accommodate / Protect	Primary and secondary dunes
4.1	Renourishment & revegetation	Protect	High use beaches and foreshore reserves where retreat is not an option.
4.2	Groynes	Protect	High use beaches and foreshore reserves where retreat is not an option. Where assets values are high, and relocation is not an option.
4.3	Seawalls	Protect	High use beaches and foreshore reserves where retreat is not an option. Where assets values are high, and relocation is not an option.

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2.1 Do Nothing

Implementation of a 'Do Nothing' approach means the Shire allows coastal processes to occur unhindered. If and when these processes impact a private property, the Shire will seek to reclaim the lot by way of condemning the property on the grounds of safety (Health Act 1911). The lot would then become assimilated into the public foreshore reserve and provide protection to assets further inland.

Publicly owned assets would undergo a similar lifecycle, with relocation of each asset only required when damaged or absolutely necessary. Protection structures such as seawalls shall be left in place but not significantly maintained (public safety only) until they too are condemned and removed.

For this option the cost is the complete value of each asset as it is removed.

2.2 Planned or Managed Retreat

The 'Planned Retreat' option is very similar to 'Do Nothing' except assets are relocated or removed prior to the occurrence of irreparable damage and returned to public foreshore reserve. Under this option the Shire would purchase privately owned properties when a set trigger is reached.

Triggers recommended for this study are as per those of WAPC (2017):

- **Trigger 1**: Where the most landward part of the Horizontal Shoreline Datum (HSD, defined as the active limit of the shoreline under storm activity) is within 40 metres of the most seaward point of a development / structure / foreshore reserve area.
  - Due to the high value placed on the foreshore coastal reserve, the recreational area would itself be considered the asset in this case
- **Trigger 2**: Where a public road is no longer available or able to provide legal access to the property
  - This may occur for Knight Terrace, particularly to the east of Denham Hamelin Road. The Shire may choose to investigate access options from the landward side of these properties.
- **Trigger 3**: When water, sewerage or electricity to the lot is no longer available as they have been removed/decommissioned by the relevant authority due to coastal hazards.

Under the WA Planning Framework, a land parcel may be recovered by voluntary or compulsory acquisition based on the value of its land and improvements. Public property would utilise the same trigger-based relocation strategy.

Costs for this option are the same as 'Do Nothing', however the burden of cost for private assets is passed from the asset holder to the Shire.

2.2.1 Development Restrictions – Planning Instruments

The use of planning instruments to restrict development in the coastal hazard zone was discussed in Water Technology (2018a). These include the following:

- Incorporate SPP2.6 into Local Planning Scheme
- Special Control Area
- Coastal Development Local Planning Policy
- Notifications on Title
- Structure Plan
- Restrictive Covenants

- Special Area Rates

These options facilitate planned / managed retreat. These are considered as part of the 'Prevent further development' option in the Multi-Criteria analysis (MCA).

2.3 Renourishment

To protect against the increased erosive pressure forecast to occur as sea level rises, some beach areas could be renourished with sediment on a regular basis. This is a 'soft' protection option that allows for continued utility of the beach for stakeholders and aims to slow the landward movement of the HSD. This option can be expensive and sediment requirements can increase over time. Also, without supplemental design structures holding the renourishment in place, the shoreline will naturally return to its equilibrium position and renourishment may be transported away from the area faster than desired. This option does not reduce the risk of inundation to properties inland.

Whilst this option could initiate some legacy issues by requiring future spending to provide continued protection, it could also be used to delay the onset of erosion until structures at risk have been relocated.

2.4 Protection Structures

Construction of a seawall is likely to result in the loss of the beach seaward of its toe. It will therefore score poorly in certain MCA criteria, given the high value of beach area for stakeholders.

The construction of a groyne or multiple groynes on the town's foreshore is a protection option that seeks to limit erosion risk and maintain beach amenity. There are several different options that could meet these aims (groynes, offshore breakwaters), all of which are generally expensive and will convey legacy issues to future generations. The 'groyne' option included in the MCA is representative of the general costs and benefits that such an option would result in, and further pursuit of this kind of strategy would require detailed design and careful consideration beyond the scope of this study. Strategies of this kind can result in significant and unforeseen detrimental impacts to the local coastline, even after detailed design in locations of reasonable data availability.

3 MULTI-CRITERIA ASSESSMENT APPROACH

Successful risk management and adaptation planning requires identification and diligent assessment of suitable options to ensure selection of the best strategy. The chosen option should mitigate risk to an acceptable level whilst maximising the values important to the stakeholders. For the Shire of Shark Bay's CHRMAP the key assessment criteria are:

- Effectiveness
  - Ability for the option to mitigate the coastal hazard risk
- Environmental
  - Impact on existing native vegetation / dunes / coastal processes
  - Includes consideration of:
    - Any construction / clearing impacts
    - Impact of maintenance on the environment
- Social: this considers stakeholder and community impacts
- Aesthetic impacts
  - The visual appeal of the option
  - Consideration of option aesthetics tying into the wider town vision
- Future adaptability
  - Whether the option is easily adaptable in future
  - If the option limits the availability of other options in future
- Cost
  - Upfront capital costs
  - Ongoing maintenance costs

In general, consideration shall be given to any option that may have detrimental impacts on indigenous or historical values, through a lowering of the social score along with supplementary notes to indicate the negative interaction. For this CHRMAP several aboriginal sites with heritage value were identified through the AHIS (DPLH, 2018), both to the south of Section 1 and clustered around Lagoon Point in Section 4 and 5. These sites were located within the hazard zones but not significantly close to existing development. An historic building was also identified on Knight Terrace. The aboriginal and historical heritage consequences from the MCA are summarised in Section 4. Information provided by stakeholders is included in the assessment of each value as required. Options are assessed using the multi-criteria assessment (MCA) matrix shown in Table 3-1, which indicates the rating given to each criterion for a given option and provides the recommendation for pursuing the option.

Potential options have been identified as part of the Options Identification Chapter Report (Water Technology, 2018a). These were identified by applying the risk management and adaptation hierarchy specified in SPP2.6 and the CHRMAP guidelines (Figure 3-1). This hierarchy mandates that management options are to be considered in the order: avoid, managed retreat, accommodate, protect. For example, if a managed retreat and a protect option score equal in the MCA, the managed retreat option must always be preferred to a protection option that achieves the same outcome. SPP2.6 states that protection may only be considered when "*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*".

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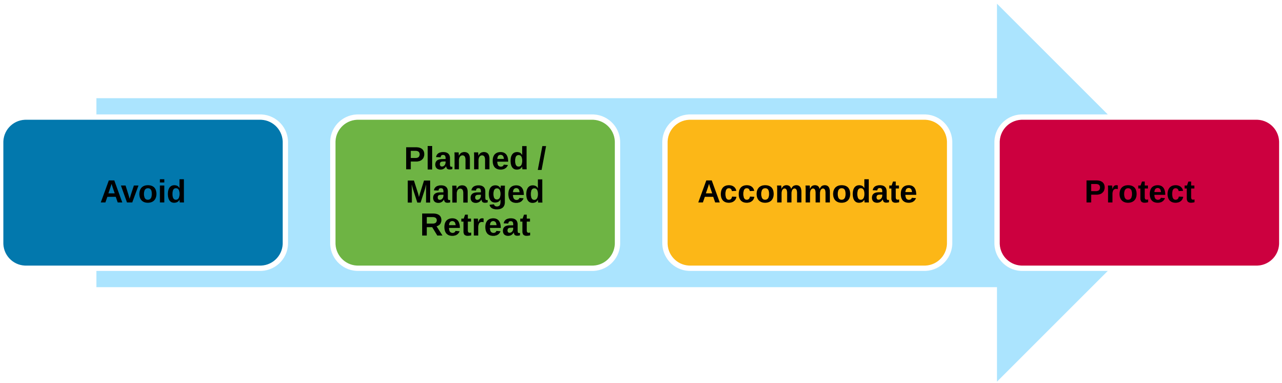

FIGURE 3-1 COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING HIERARCHY (ADAPTED FROM WAPC, 2013)

In most cases it shall be necessary to implement more than one option, and the options selected through the MCA may vary spatially. As a result, a separate MCA has been performed for each of the 5 study area sections (refer Figure 3-2 for section demarcation). The results of the MCA have been summarised in Section 4.

Succeeding the MCA is a cost-benefit analysis (CBA) of options carried forward from the MCA. Separate to the score applied by a coastal expert utilised in the MCA for both present and future costs, the CBA will allocate an estimated cost to all significant values and detractions of a given option, both at present and over the option's intended design life. This work is presented as the net present value (NPV) of an option, allowing direct comparison to aid selection of a final strategy. The report summary is in Section 6, which summaries which options may be suitable where, and what issues they are intended to mitigate.

3.1 Assessment Framework

To perform the MCA, each identified option in Table 2-1 was assessed against each of the criteria shown below in Table 3-1 for each of the five beach sections. The assessment criteria run across the top row whilst the ratings are shown below; each have a possible score from -2 to 2. This methodology is similar to other MCAs undertaken in Western Australia under the same CHRMAP Guidelines (for example: Cardno, 2017). Ratings were assessed by a professional coastal engineer with experience in risk management, adaptation options and their implementation. In this case initial capital and ongoing maintenance costs have been assessed under a single category. The possibility for potential losses is also considered in the cost category. For example, if an option is likely to lead to a drop in land value, that is considered to be a cost to the community, and therefore a lower score. Economic factors have been assessed in more detail within the CBA.

All ratings are somewhat subjective; however, all ratings were discussed with the Steering Committee to ensure the ratings are reflective of stakeholder knowledge. The adaptation options workshop and online survey (discussed in Section 6) allowed for additional feedback from the community. The ratings have been updated to reflect these three engagement activities.

FIGURE 3-2 STUDY AREA SECTIONS

TABLE 3-1 MULTI-CRITERIA ASSESSMENT FRAMEWORK FOR DENHAM

Rating; Score	Effectiveness	Environmental Impact	Social Impact	Aesthetic Impact	Cost (Capital & Ongoing)	Future Adaptability	Final Recommendation
Positive; +1 or +2	Expected to be effective	Positive impact; return to more natural coastline	Positive social impact; encourages community development	Positive aesthetics	Low or reasonable costs	Adaptable, not likely to leave legacy issues	Further Investigation Recommended; Score > 0
Neutral; 0	May or may not be effective, possibly unable to predict	No (or unclear) environmental impact	No discernible social impact; indeterminate net impact	Neutral aesthetic	Moderate costs	May leave legacy issues	Suitability unclear; Score = 0
Negative; -1 or -2	Likely to be ineffective in the short or long term	Potential significant negative impacts	Negative social impact. May discourage new or existing people from the area	Negative aesthetic	High initial or ongoing costs	Will create legacy issues	Not recommended; Score < 0

4 MULTI-CRITERIA ASSESSMENT RESULTS

A full MCA was conducted for each of the five beach sections, with the results presented below in Table 4-1 to Table 4-5; discussion points are included below each table. Note that if the Shire elects to choose certain options this may affect the recommendation rating for other options. For example, where previously a managed retreat option was best suited, this may be switched to accommodate for most assets if the Shire elects to implement a protection strategy for that area (e.g.: retreat may not be required if the Shire builds a seawall in front of a house). If two options are recommended that cannot both be selected or are illogical to combine, the CBA and the strength of the MCA recommendation has been used to determine the optimal course of action.

For Accommodation Option 3.3, re-design for hazards, the scoring has been split into re-design for inundation (3.3I) and re-design for erosion (3.3E). This is because the options to mitigate either hazard can vary significantly for all of the assessed categories. For the purpose of this MCA, re-design options to mitigate inundation risk are generally considered small and easy to implement. These include minor electrical works to move services higher, removal of valuables from the ground floor (or placement on shelves prior to flooding events), or installation of an emergency pump in the case of low-lying areas or basements. Erosion mitigation options that can be employed on an individual asset basis are generally very expensive and intrusive. These include construction of a retaining wall adjacent to the structure, buried concrete skirting around the foundation, or other buried structures. For this reason, it is rare to see erosion protection for a specific low-medium value asset (e.g.: one house).

Aboriginal heritage sites within or adjacent to the study area were not expected to be significantly impacted by any of the recommended options as part of this analysis. Only options that significantly impeded sediment transport to the north may impact sites at Lagoon Point and would require some infrequent monitoring. However, this is not expected from the options carried forward to the cost-benefit analysis.

The logic behind some of the scores are presented in the comments section of each table. If the reasoning is consistent with an earlier section no comment has been included. Further details may be provided in the next stakeholder engagement session as required.

TABLE 4-1 MCA FOR SECTION 1

Option Category	Option Nº	Effectiveness	Environment	Social	Aesthetic	Cost	Future Adaptability	Score / Recommendation	Comment
Avoid	1.1	2	2	0	1	2	2	Recommended (9)	Unclear social net score. Benefit to using foreshore land for the community means developing at-risk areas.
Managed Retreat	2.1	-2	0	-2	-1	-1	-2	Not recommended (-8)	Not an effective adaptation option and unlikely to be popular with the community. Cost to be investigated further in CBA.
	2.2	2	1	-1	1	-1	2	Recommended (4)	Effective but costly option. Creates foreshore, may be unpopular depending on implementation strategy. May cost less than protection.
	2.3	1	1	-1	0	2	1	Recommended (4)	Not as effective or forward thinking as relocate, but still positive. Likely to be unpopular with landholders.
Accommodation	3.1	1	0	-1	0	0	2	Recommended (2)	Likely to be effective at encouraging development outside of hazard zones. Cost shifted from Shire to small number of landholders, likely to be unpopular with those landholders.
	3.2	-1	0	1	0	2	0	Recommended (2)	Not effective or future facing in terms of asset adaptation, but good to have as a town and design is low in cost.
	3.3I	1	0	1	0	2	0	Recommended (4)	Low cost and could be effective at reducing damage costs.
	3.3E	1	-1	0	-1	-2	-1	Not recommended (-4)	Expensive and intrusive to construct. Private asset protection may have detrimental impacts on adjacent assets.
Protect	4.1	1	1	1	1	-2	-1	Recommended (1)	Expensive with lower confidence in effectiveness. Creates legacy issues for future. Cost may be reduced through use of maintenance dredge spoil.
	4.2	1	-1	-1	-2	-2	-1	Not recommended (-6)	Effective but often with unexpected detrimental effects nearby. Expensive and usually not beneficial for the environment or aesthetics. Net social impact unclear, may protect assets, may interrupt highly valued natural beach profile.
	4.3	2	-2	-2	-2	-2	-1	Not recommended (-7)	Expensive option, and not preferred from the stakeholder engagement

1.1: Avoid
2.1: Do Nothing
2.2: Relocate
2.3: Prevent further development
3.1: Notification on land titles
3.2:Emergency Plans
3.3I: Re-design for hazards (Inundation)
3.3E: Re-design for hazards (Erosion)
4.1: Dune renourishment
4.2: Groyne(s)
4.3: Seawall

4.1 Section 1

For Section 1, six different implementable options scored positively in the MCA and shall be assessed in the CBA. Hard protection options (groynes, seawall) scored poorly due to its inherent utility value, and the high value placed by the stakeholders on the natural appearance of the beach in this section.

Erosion is a significant risk to houses on Knight Terrace within this section. Other case studies have shown that accommodating residential property to resist erosion can quickly become expensive, may incur unforeseen damage up or downdrift, and ultimately may fail.

Doing nothing in such an important area of the town could be expected to negatively impact residents and tourism businesses and may ultimately place more pressure on an adaptive decision in the future. If protection options were implemented in the adjacent Section 2, this may trigger reassessment of the future adaptation options for this area.

TABLE 4-2 MCA FOR SECTION 2

Option Category	Option Nº	Effectiveness	Environment	Social	Aesthetic	Cost	Future Adaptability	Score / Recommendation	Comment
Avoid	**1.1**	2	2	0	1	2	2	Recommended (9)	Same as Section 1
Managed Retreat	**2.1**	-2	-1	-2	-2	-1	-2	Not recommended (-10)	Damage to commercial assets may place environment at risk (e.g.: fuel). Erosion of main street (Knight Terrace) not conducive to attracting visitors to the town.
	2.2	1	1	-1	-1	-1	2	Recommended (1)	Staged relocation back through main street with commercial access may be difficult, unpopular, and visually unappealing.
	2.3	1	1	-1	0	2	1	Recommended (4)	Same as Section 1
Accommodation	**3.1**	1	0	-1	0	0	2	Recommended (2)	Same as Section 1
	3.2	-1	0	1	0	2	0	Recommended (2)	Same as Section 1
	3.3I	1	0	1	0	2	0	Recommended (4)	Same as Section 1
	3.3E	1	-1	0	-1	-2	-1	Not recommended (-4)	Same as Section 1
Protect	**4.1**	-2	1	1	1	-2	-1	Not recommended (-2)	Sediment likely to be removed quickly by coastal processes, no beach to renourish.
	4.2	1	0	0	0	-2	-1	Not recommended (-2)	Increased in most scores compared to Section 1 as area is already developed and beach condition is comparatively poor.
	4.3	2	-1	2	0	-2	-1	Neutral (0)	Increased in most scores compared to Section 1 as area is already developed, beach condition is comparatively poor and a temporary structure already in place.

1.1: Avoid
2.1: Do Nothing
2.2: Relocate
2.3: Prevent further development
3.1: Notification on land titles
3.2: Emergency Plans
3.3I: Re-design for hazards (Inundation)
3.3E: Re-design for hazards (Erosion)
4.1: Dune renourishment
4.2: Groyne(s)
4.3: Seawall

4.2 Section 2

Section 2 has five recommended options and one split option, where accommodation by redesign is recommended for inundation but not for erosion. In this section the only significant protection work that appears logical is to formalise the ad-hoc seawall already in place. However, this option is not necessarily preferable to other options higher up the adaptation hierarchy and further investigation is required.

Minor accommodation to existing structures landward of Knight Terrace to accommodate coastal inundation could extend the usable life of these structures. If protection is not adopted, retreat of the commercial properties should be triggered by removal of Knight Terrace if and when required.

If a protection option is selected many of the analyses for this section would look more like Section 3, with development not restrained for erosion impacts, and consideration of relocation delayed. This section contains a building with historic heritage value, the current location of the restaurant "The Pearler". More specific determination of its value with regards to coastal hazard protection will be discussed at the second stakeholder engagement meeting.

TABLE 4-3 MCA FOR SECTION 3

Option Category	Option Nº	Effectiveness	Environment	Social	Aesthetic	Cost	Future Adaptability	Score / Recommendation	Comment
Avoid	1.1	0	0	-2	0	-1	1	Not recommended (-2)	Foreshore is already fully developed. Seawall will protect this area from erosion for at least a few decades, therefore avoid generally neutral. Hindrance to community values and negative impact on town productivity to avoid this area now.
Managed Retreat	2.1	0	0	1	0	0	-2	Not recommended (-1)	Assume seawall is maintained for safety, therefore net impact of doing nothing (else) is generally neutral. Palatable community option, poor future consideration.
	2.2	0	0	0	0	-1	2	Recommended (1)	Not prudent to implement presently due to seawall protection but should be considered in future here so that relocation can be planned to coincide with seawall end of life.
	2.3	0	0	-1	-1	-1	1	Not recommended (-2)	Area is already protected; restricted development should continue until protection strategy is abandoned / designed appropriately. Negative community impacts to restrict development here at this time.
Accommodation	3.1	1	0	-1	0	0	2	Recommended (2)	Erosion risk is reduced due to seawall protection; inundation is still a risk here so still effective.
	3.2	-1	0	1	0	2	0	Recommended (2)	Same as Section 1
	3.3I	1	0	1	0	2	0	Recommended (4)	Same as Section 1
	3.3E	1	-1	0	-1	-2	-1	Not recommended (-4)	Same as Section 1
Protect	4.1	NA	NA	NA	NA	NA	NA	NA	Not applicable due to existing seawall (no dune)
	4.2	0	0	0	-2	-2	-2	Not recommended (-6)	Not recommended in conjunction with existing structures
	4.3	2	0	2	0	0	-1	Recommended (3)	I.e.: maintenance of the existing seawall recommended

1.1: Avoid
2.1: Do Nothing
2.2: Relocate
2.3: Prevent further development
3.1: Notification on land titles
3.2: Emergency Plans
3.3I: Re-design for hazards (Inundation)
3.3E: Re-design for hazards (Erosion)
4.1: Dune renourishment
4.2: Groyne(s)
4.3: Seawall

4.3 Section 3

Section 3 is already protected by a rock armour seawall along its entirety. In this case the economic and effectiveness criteria score highly for maintaining this structure over the short to medium term. Given this, an avoid or development prevention option is unnecessary for erosion impacts and would likely inhibit economic benefits gained by development within this zone. With notification on titles and community awareness of the risks of inundation (and potentially erosion in the future if the seawall is abandoned) it makes sense to allow for well-considered and approved development, incorporating recommended finished floor levels.

Assets already located in this area are not predicted to be at risk of erosion until 2030. Inundation risk is low in the present day, increasing to medium by 2030 and high by 2050. Minor accommodation of these structures to mitigate some inundation risk would be relatively simple (moving at risk services, raising portable electronics prior to cyclone impact) and residual risk could be accepted, as per a do nothing and repair damage approach.

TABLE 4-4 MCA FOR SECTION 4

Option Category	Option Nº	Effectiveness	Environment	Social	Aesthetic	Cost	Future Adaptability	Score / Recommendation	Comment
Avoid	**1.1**	2	2	1	2	2	2	Recommended (11)	Undeveloped area, most assets relocatable. Avoiding placing permanent assets in the hazard zone considered positive all around.
Managed Retreat	**2.1**	0	0	0	0	2	-1	Recommended (1)	Minimal assets mean minimal net change if do nothing is implemented. Always less future facing than a planned manage retreat.
	2.2	2	2	2	2	1	1	Recommended (10)	Planned relocation of minimal assets within the hazard zone should be effective and broadly positive.
	2.3	2	2	-1	2	2	2	Recommended (9)	Minimal assets mean relocation relatively simple
Accommodation	**3.1**	1	0	-1	0	0	2	Recommended (3)	Less social impact in less developed area.
	3.2	-1	0	1	0	2	0	Recommended (2)	Same as Section 1
	3.3I	1	0	1	0	2	0	Recommended (4)	Same as Section 1
	3.3E	1	-1	0	-1	-2	-1	Not recommended (-4)	Same as Section 1
Protect	**4.1**	1	0	1	1	-2	-1	Neutral (0)	No significant gain expected, low value of assets to protect.
	4.2	1	-1	-1	-2	-2	-1	Not recommended (-6)	Low scores due to natural beach interruption (environment, social, aesthetic) and high costs and creation of legacy issues.
	4.3	1	-2	-2	-2	-2	-2	Not recommended (-10)	Same as 4.2 but more intrusive.

1.1: Avoid
2.1: Do Nothing
2.2: Relocate
2.3: Prevent further development
3.1: Notification on land titles
3.2: Emergency Plans
3.3I: Re-design for hazards (Inundation)
3.3E: Re-design for hazards (Erosion)
4.1: Dune renourishment
4.2: Groyne(s)
4.3: Seawall

4.4 Section 4

Given the natural, undeveloped profile of the existing shoreline and foreshore reserve in this section, the selection of adaptation options was simpler. Avoidance and restriction of further development are logical solutions to avoid legacy issues in the future. Current development is limited to beach access and portions of the Denham Seaside Caravan Park at the southern end of the section. Relocation prior to erosion damage should be relatively simple compared to other areas of the town. Inundation is not a significant risk in this section.

Protection options score poorly with few assets to consider and a high value held by stakeholders on areas of natural coastline close to town. Renourishment of the southern section could be a suitable protection item if required, based on the availability of sediment from maintenance dredging. However, without abundant low-cost sediment the cost benefit would come into question, given the low value of assets inland.

TABLE 4-5 MCA FOR SECTION 5

Option Category	Option No	Effectiveness	Environment	Social	Aesthetic	Cost	Future Adaptability	Score / Recommendation	Comment
Avoid	**1.1**	2	2	2	2	2	2	Recommended (12)	Same as Section 4. No caravan park to relocate.
Managed Retreat	**2.1**	0	0	0	0	2	-1	Recommended (1)	Same as Section 4.
	2.2	2	2	2	2	1	1	Recommended (10)	Relocation favourable due to low number of assets
	2.3	2	2	-1	2	2	2	Recommended (9)	Simple to restrict further development
Accommodation	**3.1**	1	0	-1	0	0	2	Recommended (3)	Same as Section 1
	3.2	-1	0	1	0	2	0	Recommended (2)	Same as Section 1
	3.3I	1	0	1	0	2	0	Recommended (4)	Not applicable to any existing assets in practice.
	3.3E	1	-1	0	-1	-2	-1	Not recommended (-4)	Same as Section 1
Protect	**4.1**	1	0	1	1	-2	-1	Neutral (0)	No significant gain expected, low value of assets to protect.
	4.2	0	-2	-2	-2	-2	-2	Not recommended (-10)	Same as Section 4 but less necessary.
	4.3	0	-2	-2	-2	-2	-2	Not recommended (-10)	Same as Section 4.

1.1: Avoid
2.1: Do Nothing
2.2: Relocate
2.3: Prevent further development
3.1: Notification on land titles
3.2: Emergency Plans
3.3I: Re-design for hazards (Inundation)
3.3E: Re-design for hazards (Erosion)
4.1: Dune renourishment
4.2: Groyne(s)
4.3: Seawall

4.5 Section 5

The only assets in Section 5 that fall within the hazard zone are vehicle access paths with a small car park, and a small section of Stella Rowley Drive. Protective options are not recommended for these assets of relatively lower importance. Trigger based relocation of access paths is preferred over waiting until paths are damaged.

The consequence of inundation to the road is minimal and simple emergency plans such as a flood gauge should mitigate risks to vehicles in the unlikely event of flooding.

5 COST BENEFIT ANALYSIS

5.1 Analysis Approach

The purpose of the Cost-Benefit Analysis (CBA) as part of this CHRMAP is to elucidate the selection of adaptation options through economic analysis. In the previous section, potential adaptation options have been assessed against a range of criteria, including expected lifetime cost (score only). Options with significant investment that scored positively in the MCA have been included in this CBA. The idea is that a more rigorous assessment of costs and benefits for an option will assist with preferential selection and potentially uncover any inaccurate costing assumptions previously made in the MCA. This analysis also ensures that selected adaptation options are economically defendable.

The cost-benefit of each option is presented in net present value (NPV) terms. NPV is a standard economic analysis for options with costs and benefits that vary across a given timeframe and allows for discounting of all future economic considerations to present day dollars for a more direct comparison. This relates to the time-value of money as planned expenses in the future are, in a sense, cheaper than equivalent costs today, because the money required for that future expense could be invested elsewhere today to provide value to the community over time. Whereas if that expense occurred today the money could not be invested and would be spent.

The discount rate chosen for this project was 7% based on similar assessments (Baird, 2018). The discount rate essentially converts all future costs and benefits back to today's dollar value for comparison (in the NPV). For example, a project with a cost of $1 million per year for 10 years would discount to an NPV of roughly $7.5 million, whereas a project that only has a single outlay of $10 million in 10 years' time would have an NPV of roughly $5.4 million, both discounted at 7%. A project that cost $10 million today would have an NPV of $10 million. This example shows the importance of when a cost is realised.

The CBA has been performed over a 50-year period, designed to match the expected lifespan of the proposed adaptation options. This means that the costs and benefits are only applied up to 2070, i.e.: assets not affected by this point are not included. Beyond this timeframe, any consideration of costs contains significant uncertainty and therefore has minimal bearing on analysis. Also, errors in data and errors arising from assumptions would likely be significant and multiple rounds of adaptation would have to be considered. Long-term adaptation pathways should always be monitored and updated over time. Whilst this analysis considers only the next 50 years, the overall CHRMAP considers planning over a 100-year timeframe and will include recommendations to re-assess adaptation strategies in the future.

5.2 Adaptation Options Assessed

The options considered here were determined in the MCA. The 'avoid' strategy was not assessed here as its implementation is logical and recommended for any case where non-infill development would be considered within the hazard zone. **Other low-cost options such as planning instruments (prevent / restrict further development, notification on land title), emergency plans and accommodation for inundation at existing structures only require assessment at the MCA level. Options scoring positively in the MCA are recommended for implementation in the CHRMAP**.

Despite its poor score in the MCA, the construction of groynes in Section 1 was considered as well as Section 2 due to the large amount of residential assets in the area. Note that a viable economic assessment does not address issues raised in other categories of the MCA.

The 'managed retreat' option does not distinguish who shall bear the cost of retreat. This will depend on the adaptation strategy chosen as well as the policies of the local and state government. For this portion of the analysis there is no cost distinction between a 'do nothing' managed retreat and a 'relocate' managed retreat, so both are presented under ‘managed retreat’. However, for future planning a proactive ‘planned retreat’ is considered preferable to a reactive ‘do nothing’ retreat.

Whilst typically a range of different options are assessed, in reality it may be a combination of options that is required to be effective in addressing coastal hazards and accommodating stakeholder values. For this reason, we have included some combination options in the cost benefit assessment to provide an indication of economic feasibility, although scores for other criteria in the MCA should still be given due regard. In this case, the small groynes costed were not considered to be effective erosion mitigation strategies on their own, whilst larger groynes were not considered appropriate for the setting. As a result, two additional groyne combination options were costed that would improve overall effectiveness and also increase beach amenity value. These are groynes with regular renourishment and the same with a small, potentially buried revetment in case groynes were outflanked or erosion was severe.

TABLE 5-1 OUTLINE OF OPTIONS ASSESSED IN THE CBA

Option No.	Option Name	Section 1	Section 2	Section 3	Section 4	Section 5
2.1	Managed retreat	✓	✓	✓	✓	✓
4.1	Renourishment	✓			✓	
4.2	Groynes		✓			
4.3	Seawall		✓	✓		
4.2+	Groynes + renourishment	✓	✓			
4.2+s	Groynes + renourishment + small seawall		✓			

5.3 Erosion and Inundation

The primary focus of this CBA is the predicted progression of erosion inland and its significant impact on assets when realised. None of the options assessed in this analysis are expected to significantly reduce the risk or consequence of inundation. Short of building a levee around the entire lower section of town, inundation is unlikely to be arrested. As a result, **the recommendations for inundation adaptation are managed retreat, restricted development and accommodation**.

For private assets, inundation accommodation should be considered on a case by case basis by landholders. The combined risk of inundation and erosion should be considered by landholders before implementing significant upgrades, with private works implemented as a ’user pays’ scenario (noting development approval may be restricted by the Shire has part of the adaptation process). Public assets should also be considered on a case by case basis by the Shire, with those assets at risk implementing low cost adaptation options as required. Retreat or significant accommodation works should be considered after a trigger event.

In summary, the consequences and risk of inundation:

- Is not reduced by the protection options assessed in the CBA
- Should be considered on an asset by asset basis by the landholder
- Could result in significantly variable damage, based on asset floor level, asset type, and preparedness

As a result, it has not been further considered as part of this CBA. Adaptation implementation pathways will outline the main strategies for inundation mitigation and are discussed in more detail in the Implementation Chapter of the final CHRMAP report.

5.4 Asset Valuation

Economic data on public assets within the hazard zone were provided by the Shire and other relevant government departments. For residential assets, valuations were collected from online real estate valuation resources. Commercial and tourism assets were valued based on the rates paid to the Shire, as supplied by the Shire. All values collected for the analysis were in 2018 dollars.

Growth in certain asset classes is encompassed in the analysis' chosen discount rate. These classes include residential, commercial, and tourism, meaning that the analysis assumes these classes will increase by inflation only over the 50-year assessment period. It is true that assets in these classes may generally be expected to outpace this assumed growth, for example, the long-term return on Australian houses is around 7.25% (RBA, past 30 years), whereas inflation targets are 2-3% (RBA, 2018). However, given the proximity to coastal hazards and the high likelihood of Section 70A title notifications, slower growth of 2-3% is assumed to be applicable to assets considered here. This is in line with inflation rates.

Public assets come under four categories of valuation for the CBA:

1. Easily relocatable: assets like picnic tables that can be moved to a new suitable location at low cost are not considered in this analysis.
2. Maintainable: assets such as roads that require maintenance to a high standard are assumed to not depreciate, essentially assuming that routine maintenance preserves the asset at its 2018 value, without requiring the addition of such maintenance costs in the CBA. This category mainly applies to roads and services.
3. Depreciable: assets such as the BBQ structures can be expected to linearly depreciate to zero over their design life. As such, the value of these assets has been calculated as the depreciated value at time of loss. Some significant assets such as the Shire's offices come under this category.
4. Intrinsic values: assets that have inherent value to the community such as parks and beaches have been valued using relevant literature and some assumptions. Most assets that are generally difficult to value have been assessed this way.

It is important to note that no usage values have been included in the CBA. Each visitor places a certain value on their visit which is essentially an additional value of that place (e.g.: a beach has high intrinsic and usage values), but without further data this amount is difficult to calculate with any confidence. As a result, this has not been included and decision makers should keep in mind that the loss of such assets incurs an extra uncalculated cost. These kinds of assets include beaches, parks, the Discovery Centre, or anywhere people enjoy visiting (except commercial and residential assets).

Data was considered appropriate for comparative quantitative analysis only and should not be applied to any future detailed design. A full table of the value assets considered in this analysis is presented in 8Appendix A.

5.5 Options Costing

Each adaptation option was priced based on the cost of similar projects or project estimates from recent years. Renourishment of Section 1 was estimated to require 7 m^3/m per year along the beach at a cost of \$20/m^3. Appropriate sediment sources both offshore and onshore are expected to be available to keep costs reasonable, although offshore sources may require environmental approval. Renourishment for Section 4 was estimated similarly, but only for a short section where assets are already in place. Annual renourishment is not actually required and can be installed in larger discrete placements.

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The cost of groynes used was $400,000 per groyne, with two included per section. This is in line with the cost of the FRP sheet pile groyne ($430,000) and a recent estimate for geotextile sand bag groynes at Geraldton ($360,000 per groyne). Significant rock armour structures that are designed to not be outflanked or overtopped in any conditions are not considered to be the most appropriate structures here, due to the limited setback and requirement of rising much higher than the surrounding land. Where groynes and renourishment have been recommended, the renourishment requirement has been reduced (compared to renourish only). This cost was the same for both Section 1 and 2; two groynes with an initial renourishment of 8,000 m^3 and 1,000 m^3 total per year.

Seawalls were based on the cost of constructing a significant rock armour structure similar to the revetment in Section 3. The cost of this was estimated at $7,000 per m with a 2% annual maintenance cost. For the final option that includes a smaller revetment for the groynes to tieback to the estimated cost was $3,500 per m with the same renourishment as the groyne plus renourishment option and the same maintenance estimate (2%).

5.6 Assumptions

The assumptions required to perform this analysis are listed below:

- Assume linear depreciation of public assets over effective lifespan. E.g.: a seawall designed for 50 years will at the end of its life have no value.
- Assume commercial and tourism assets increase in value in-line with long-term inflation. This assumption is based on the fact that these properties could be expected to be kept fit-for-purpose over the analysis through minor improvements. Business trademark value does not require inclusion.
- An asset is considered lost when the first structure on the structure footprint is estimated to be impacted by erosion.
- 171 and 179 Knight Terrace (undeveloped land parcels to the south-east of the end of Knight Terrace) have been excluded from the CBA. These are stipulated as ‘unrateable’ in the Shire’s provided cost information.
- ‘Easily’ relocatable assets are moved before erosion damage; applies to assets such as picnic tables, art, reclaimed wood displays, historic / tourism displays. Relocation costs are not included in the CBA.
- DoT seafront assets (jetty, ramp) are included as a benefit to maintaining the seawall that already exists, as not doing so may jeopardize these assets’ integrity.

5.7 Results

The results of the complete cost benefit analysis are presented in Table 5-2 below. All costs are compared against the ‘managed retreat’ approach. Options that are significantly cheaper than retreat are highlighted green, while options that are significantly more expensive are highlighted red. Options that fall within ±25% of the expected cost of retreat are highlighted in orange and may be suitable. However, careful consideration of the other potential costs and benefits not included in this analysis come into play (such as those considered in the MCA). The primary costs not considered in this analysis are the costs of inundation and the usage benefits of the foreshore and beach amenities.

TABLE 5-2 CBA RESULTS

Option No.	Option Name	Costs (thousands of dollars)				
		Section 1	Section 2	Section 3	Section 4	Section 5
2.1	Managed retreat	2,960	4,020	6,090	550	120
4.1	Renourishment	1,320			840	
4.2	Groynes		1,060			
4.3	Seawall		3,700	4,870		
4.2+	Groynes + renourishment	2,440	1,300			
4.2+s	Groynes + renourishment + small seawall	4,000	3,090			

Section 1 recommends renourishment or groynes with renourishment as viable adaptation options. However, given the uncertainty regarding the effectiveness of only groynes to fully arrest erosion it may not be the most suitable option. Furthermore, installation of groynes may signal to landholders and developers not to adopt a retreat policy when possible, leaving the area exposed to greater risk of inundation in the future. Given the option is only recommended marginally here and scored poorly in the MCA, it is not recommended at this time.

Section 2 contains significant assets within the hazard zone and as a result some significant protection options may be viable. Results from Section 3 indicate the existing seawall infrastructure should be maintained and in Section 4 renourishment was considered a potentially viable option.

Whilst the economic viability of some of the adaptation options assessed here appears positive, there are many more factors that need to be taken into account to implement a successful long-term CHRMAP. The summary in the following section considers the results of the MCA and the CBA together with the potential impacts of inundation, and the potential issues of actually implementing each of options.

6 ADAPTATION PLANNING – COMMUNITY ENGAGEMENT

6.1 Engagement Process

The Stakeholder and Community Engagement Plan (Water Technology, 2018e) aimed to engage all relevant stakeholders to provide them with ownership of the CHRMAP and acceptance of its outcomes. The objectives of the strategy are as follows:

- Consult with stakeholders and the community on climate change and its impacts in the coastal zone within the Denham Townsite:
  - What does this mean for the community?
  - How can we adapt?
- Generate the success criteria for the risk assessment component of the CHRMAP. Success criteria represent stakeholders' tolerance and acceptability of the impact to assets from the identified coastal hazards.
- Aid in the selection of site-specific adaptation measures. Stakeholders on the ground are likely to have a knowledge of the site developed over years of interaction. This provides invaluable information that can be applied to generate innovative adaptation measures.

As part of the Adaptation Options Assessment, the engagement strategy (Water Technology, 2018e) identified a workshop and an online survey to collate the stakeholder and community's views on different adaptation options.

6.2 Stakeholders

As defined in Water Technology (2018e), stakeholders for the project can be split into two categories:

- Internal Stakeholders:
  - Part of the decision-making team. Predominantly, these will be Shire of Shark Bay Councillors and staff, although state government will also play a role. A Steering Committee was established to oversee preparation and completion of the CHRMAP, including review of project deliverables. This includes representatives from state government.
- External Stakeholders:
  - Not decision-makers but are affected by the project outcomes. They might live near the coast, use an asset or resource located in the coastal zone, or simply have an interest in the coastal foreshore reserve.

The aim of the Adaptation Options Assessment engagement was to engage both internal and external stakeholders. To this end, a Community Information Sheet was developed to advertise the workshop and its purpose (refer Appendix B).

6.3 Adaptation Options Workshop Summary

The workshop was held on 11th December 2018. There were around 10 attendees and information was presented by Water Technology representatives interactively with attendees. Brief post workshop surveys indicated that the sessions were beneficial and generally well received.

A primary goal of the second workshop was to inform attendees about the adaptation planning phase of the CHRMAP process and to receive feedback on the recently undertaken assessment of adaptation options. Short (up to 2050) and long-term (up to 2119) options identified as part of the project were presented and discussed. This was followed by an outline of the assessment process and a more detailed discussion of the results. Attendees were encouraged to suggest alternative scores for the MCA, where appropriate, and several minor alterations were discussed. Overall the adaptation options assessment was well received. Some of the most important discussion points from the meeting were as follows:

- Consensus on upgrading of the protection to Section 2, similar to Section 3 and Section 4;
- No desire to begin seriously considering relocation of Knight Terrace assets and town 'hub' in the short-term while risk of inundation is still relatively low;
  - Shire staff and Councillors already thinking about redevelopment of Shire's offices due to particularly low-lying FFL;
- Limited money available for private asset protection or relocation;
- Seawalls in Section 2, Section 3, and Section 4, along with irregular renourishment of Section 1 as required considered to be the best short-term strategies;
- Funding options such as tourist levies or increased council rates for coastal adaptation considered a difficult subject, unlikely to get majority support from council or residents;
- User pays principle generally well received but implementation considered difficult as well;
- Uncertainties in long-term predictions and real-world implications generally result in a 'wait and see' consensus for long-term planning.

6.4 Adaptation Options Survey

The online adaptation options survey aimed to enhance the results of the adaptation options workshop results, as well as generate information for implementation of the CHRMAP. The survey was posted online for a period of approximately 2 months: from 21st December 2018 to 1st March 2019. This extended period was selected to allow for the Christmas break and January school holiday period. A total of 35 responses were received; all had a 100% completion rate.

The survey questions are displayed in Appendix A. The full results are presented in Appendix B. A summary and discussion of the results is as follows:

- Most of the responses were residents of Denham;
  - The majority of those were landowners.
- Only 1 respondent also attended a workshop.
- Just over half of the respondents viewed the online hazard mapping database prior to completing the survey. Of these, 7 respondents would benefit from additional explanation on the CHRMAP process.
- Most people were at least somewhat concerned about the permanent impacts of sea level rise.
- There is a need for further information to be provided in order to improve understanding of coastal erosion and coastal inundation.
- Only 5 respondents knew they owned an asset that may be at risk of inundation or erosion.
- A large majority of respondents supported some form of coastal hazard warning on land (e.g.: notification on title).
- Managed retreat was preferred to protection structures.
- A persistent minority were willing to pay higher rates for coastal adaptation and/or foreshore improvement works.

- An overwhelming majority did not believe that those who benefit more from an adaptation option should be required to pay more to fund that option (**NOTE this is in direct opposition to the State Coastal Strategy and SPP2.6**).
  - It is likely that more work is needed to educate the community on the 'user pays' principle.
- The majority of respondents agreed with the workshop consensus that plans to move the town hub could be discussed in future. About a third preferred to remain in place and increase protection as required.
- Most respondents believed the owner should pay for the loss of their private property due to coastal hazards. There was no clear consensus on when a property should be removed.
- In terms of future foreshore developments, leaving the coast as it is now or increasing recreational and community facilities were strongly preferred options for all areas of coastline.

6.5 Engagement Summary

To date the community engagement strategy has included two workshops, two online surveys, and the publishing of the online coastal hazards database. Earlier engagement focused on the community's success criteria for the project while later engagement focused on optimising the selection of possible adaptation options.

Overall the community engagement was helpful in guiding the project and the work was generally well received. However, more education on the CHRMAP process and on coastal management in general may result in higher local participation in the engagement process. Survey results indicate that more awareness of the online database and its contents may also improve community awareness, with a significant number of survey respondents not having viewed the CHRMAP hazard lines.

The community placed a high value on the recreational and environmental value of the coastline which guided the options assessment processes.

7 SUMMARY

The adaptation options assessment has further defined the hazard mitigation options identified in the options identification report (Water Technology, 2018a) and applied them to the coastal hazards faced within the Denham townsite and surrounds. As discussed in the Water Technology (2018a), WAPC (2014) strongly recommend a tiered preference system geared towards managed retreat for existing assets, then accommodation and finally protection when no other strategy is plausible.

This report adheres to those guidelines, recommending avoid, managed retreat and some accommodation options in all areas. Through a multi-criteria assessment and a cost-benefit analysis, various adaptation options were scored and compared to the alternative of retreat. A summary of the final recommended options from this report are presented in Table 7-1.

From this table some recommendations for the Shire are as follows:

- All new ***non-infill permanent*** development within the identified hazard zones should be avoided
- A special control area (SCA) should be created including, but not limited to the following:
  - All proposed development within the SCA requires approval. (This would include development that would not ordinarily require development approval under the scheme).
    - Referral of applications (any planning application should be referred to the Department of Transport, the Western Australian Planning Commission and any other relevant authority for advice and comment on the coastal risk).
  - Placement of Section 70A notification on appropriate land titles (notifying of coastal hazard risk)
  - Prevention of further development for lots within the erosion hazard zone of the next epoch (i.e.: staged prevention of development, initially for lots at risk by 2030, then later for lots at risk by 2050 if hazard triggers are reached). This criterion may be relaxed for lots inland of protection structures.
  - Requirement of houses damaged or otherwise triggered (see Section 2.2) by coastal hazards to be relocated or rebuilt out of the hazard zone.
  - Minimum finished floor levels and/or other development standards (4.2 metres AHD has been identified as the appropriate minimum FFL).
- Land developers should also be made aware of the risks from inundation at present and in the future and be educated of the steps they can take to minimise damage from such events.

TABLE 7-1 SUMMARY OF ADAPTATION OPTIONS ASSESSMENT (*POINTS BELOW)

Option Nº.	Option Name	Section 1	Section 2	Section 3	Section 4	Section 5
1.1	Avoid (where possible)		NA	NA		
2.2	Relocate					
2.3	Prevent further development		*2	*1		
3.1	Notification on land titles					
3.3I	Minor re-design to help accommodate inundation (where possible)					
4.1	Renourishment	*3				
4.2/3	Hard structure protection		*4			

1. Potential to continue development behind seawall protection as long as the finished floor level requirements are met, and developers are made aware of the potential for long-term retreat when marina facilities are retired (could be implemented with a timeframe limit to the development).
2. Restriction of further development dependent on the final adaptation pathway chosen for this area. If protection is chosen, then a similar strategy to Point 1 could be implemented.
3. Renourishment to limit erosion may be viable for Section 1 and could be based on a monitoring and trigger-based strategy.
4. Potential to install some form of coastal protection structure in Section 2 to allow more time for assets inland to be relocated over time. Potential options to be discussed with stakeholders

If Section 70A notifications were to be implemented for all residential and commercial lots within the 2118 hazards zone, a total of 51 residential and 14 commercial properties would be impacted. If a policy of managed retreat were adopted, Table 7-2 (adapted from the Water Technology, 2018c) shows the number of assets that would be affected. Assets vulnerable between the present day and 2030 are considered at extreme risk and relocation should be considered. Assets vulnerable by 2050 are considered high risk and monitoring and consideration of long-term options should occur. Assets at risk by 2118 should also monitor the progress of erosion and sea level rise and consider their options as the risk of hazards increases. Note that most of these assets are already exposed to inundation risks.

TABLE 7-2 ASSETS EXPOSED TO EROSION UNDER MANAGED RETREAT PREDICTIONS

Asset Classification	Present day to 2030 (extreme risk)	By 2050 (high risk)	By 2118 (moderate risk)
Commercial	1	5	14
Public	64	70	74
Residential	0	18	51
Tourism Related	1	4	10

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The Denham townsite is situated close to or within the active coastal zone, especially high value areas such as the hub of Knight Terrace and the marina facilities. This makes some interaction with coastal processes unavoidable. This has already been observed through the placement of various coastal protection structures over time, ranging from the new marina rock revetment to old ad-hoc erosion guards near vulnerable assets. The upgrade of marina facilities has somewhat cemented a section of the town's coastline in place for the next few decades. Both the MCA and the CBA recommended this protection be maintained for the time being.

Given the results of the assessment, three primary adaptation pathways for the next 50-years are presented below. These options were discussed with stakeholders with feedback implemented into the final recommended adaptation pathways. Stakeholders should note that while the assessment indicated that certain protection options may be viable, they do not include all the potential costs. Implementation of a protection strategy may encourage developers to commit to areas at risk of inundation and may increase difficulty of a successful managed retreat in the future.

1. **Managed retreat for all areas except Section 3**
2. **Construction of more formal seawall in Section 2; managed retreat for all other areas except Section 3.**
3. **Renourishment for protection of Section 1; independent of whether Option 1 or 2 is selected, managed retreat for all other areas except Section 3**.

Whilst erosion may be locally restricted in the near future if a protection strategy is pursued, it is clear from inundation hazard mapping that as sea level rise progresses, the feasibility of development in low lying areas will decline. The Shire should begin to prepare for long-term adaptation pathways that potentially involve managed retreat of significant parts of the town, mainly Knight Terrace and associated lots. While the above options under the managed retreat and accommodation groupings aim to make this process easier in the long run, such a significant shift will require a clear and collaborative vision for Denham's future. It is recommended that the Shire investigate potential town structure plans that can achieve this goal over the next decade. Staged infill to raise low lying parts of the town between new and old developments may be expensive and require coastal protection indefinitely, which will be very difficult to justify.

The next stage of the project considers implementation of the selected options. An implementation plan will be prepared for each vulnerable group of assets, identifying long-term pathways, considering trigger points and all components of the CHRMAP to date. A short-term implementation plan to produce a clear action plan to 2030 will be developed, as well as a monitoring plan, detailing any monitoring or review that may be required over the full 100-year planning timeframe.

8 REFERENCES

Baird (2018). *Geraldton Coastal Hazard Risk Management and Adaption Planning Project*, Report Nº 12693.101.R2.RevB, prepared for the City of Greater Geraldton.

Cardno (2017). *Coastal Hazard Risk Management and Adaption Plan: CHRMAP For the Onslow Coast,* Report Nº 59916801 R06 Rev0, prepared for the Shire of Ashburton.

Department of Planning, Lands and Heritage (2018). *Aboriginal Heritage Inquiry System*, viewed 13th November, 2018, <https://maps.daa.wa.gov.au/AHIS/>.

Intergovernmental Panel on Climate Change (IPCC, 2014). *Climate Change 2014: Synthesis Report*, Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland, Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)], IPCC, Geneva, Switzerland, 151 pp.

Kohler, M., and van der Merwe, M. (2015). *Long-run Trends in Housing Price Growth*, prepared for Reserve Bank of Australia Bulletin September Quarter 2015.

Pascoe, S., Doshi, A., Kovac, M., Austin, A., (2017). *What's my beach worth? Economic values of NSW coastal assets*, prepared by CSIRO and NSW Office of Environment and Heritage.

Reserve Bank of Australia 2018, *Inflation Target*, viewed 1st October 2018, <https://www.rba.gov.au/inflation/inflation-target.html>.

Water Technology (2018a). *Denham Townsite CHRMAP Chapter Report: Adaptation Options Identification*, Report Nº 5652-01 R06v01, prepared for Shire of Shark Bay.

Water Technology (2018b). *Denham Townsite CHRMAP Chapter Report: Risk Assessment*, Report Nº 5652-01 R05v01, prepared for Shire of Shark Bay.

Water Technology (2018c). *Denham Townsite CHRMAP Chapter Report: Coastal Hazard & Vulnerability Assessment*, Report Nº 5652-01 R04v01, prepared for Shire of Shark Bay.

Water Technology (2018d). *Denham Townsite CHRMAP Chapter Report: Establish the Context*, Report Nº 5652-01 R03v02, prepared for Shire of Shark Bay.

Water Technology (2018e). *Denham Townsite CHRMAP: Stakeholder and Community Engagement Plan*, Report Nº 5562-01 R01v01, prepared for Shire of Shark Bay.

Western Australian Planning Commission (WAPC, 2013). State Planning Policy No. 2.6 – State Coastal Planning Policy, prepared under the Planning and Development Act 2005.

Western Australian Planning Commission (WAPC, 2014). Coastal Hazard Risk Management and Adaptation Planning Guidelines.

Western Australian Planning Commission (WAPC, 2017). Draft Planned or Managed Retreat Guidelines, published by WAPC, Department of Planning, Lands and Heritage.

WorleyParsons (WP, 2016). *Denham Foreshore Revitalisation Stage 1A: Design Report*, Report No 301012-02233 – GE-REP-002, prepared for Department of Transport

Appendix A
ASSET VALUES

TABLE A-1 CBA ASSET VALUATIONS

Asset	Class	Value	Source
13 Knight Terrace	Residential	$500,000	CoreLogic
15 Knight Terrace	Residential	$310,000	CoreLogic
17 Knight Terrace	Residential	$600,000	CoreLogic
19A Knight Terrace	Residential	$185,000	CoreLogic
19B Knight Terrace	Residential	$320,000	CoreLogic
21 Knight Terrace	Residential	$180,000	CoreLogic
23 Knight Terrace	Residential	$91,000	Gross Rates Valuation
25 Knight Terrace	Residential	$390,000	Last sale
27 Knight Terrace	Residential	$590,000	CoreLogic
29 Knight Terrace	Residential	$530,000	CoreLogic
31 Knight Terrace	Residential	$330,000	CoreLogic
35 Knight Terrace	Residential	$94,000	CoreLogic
37 Knight Terrace	Residential	$94,000	CoreLogic
39 Knight Terrace	Residential	$650,000	Last sale
111 Knight Terrace	Residential	$305,000	CoreLogic
121 Knight Terrace	Residential	$630,000	Last sale
123 Knight Terrace	Residential	$1,175,000	Last sale
127 Knight Terrace	Residential	$435,000	CoreLogic
129 Knight Terrace	Residential	$570,000	CoreLogic
131 Knight Terrace	Residential	$250,000	Current listing
133 Knight Terrace	Residential	$670,000	CoreLogic
135 Knight Terrace	Residential	$420,000	CoreLogic
137 Knight Terrace	Residential	$560,000	CoreLogic
139 Knight Terrace	Residential	$335,000	CoreLogic
141 Knight Terrace	Residential	$615,00	CoreLogic
143 Knight Terrace	Residential	$84,000	Gross Rates Valuation
145 Knight Terrace	Residential	$265,000	CoreLogic
147 Knight Terrace	Residential	$450,000	CoreLogic
149 Knight Terrace	Residential	$145,000	CoreLogic
151 Knight Terrace	Residential	$1,030,000	Last sale
153 Knight Terrace	Residential	$690,000	CoreLogic
155 Knight Terrace	Residential	$645,000	CoreLogic
161 Knight Terrace	Residential	$705,000	CoreLogic
Road to beach drains	Public	$5,000 per drain	Shire of Shark Bay

Asset	Class	Value	Source
BBQ w/ structure	Public	$150,000	Shire of Shark Bay
Fish cleaning station	Public	$45,000	Shire of Shark Bay
Children’s playground	Public	$750,000	Shire of Shark Bay
BBQ w/ structure	Public	$130,000	Shire of Shark Bay
Limestone retaining wall	Public	$46,000	Shire of Shark Bay
Toilet block	Public	$80,000	Shire of Shark Bay
Community Resource Centre	Public	$850,000	Shire of Shark Bay
Shire's Office	Public	$1,600,000	Shire of Shark Bay
Charlie Sappie Park	Public	$75,000	Shire of Shark Bay
Shark Bay Discovery Centre	Public	$7,500,000	Shire of Shark Bay
Commercial Boat Ramp	Public	$750,000	Department of Transport
Rock armour revetment	Public	$400,000	Department of Transport
FRP Groyne	Public	$430,000	Department of Transport
Boat ramp car park	Public	$1,000,000	Department of Transport
Service Jetty	Public	$3,000,000	Department of Transport
Recreational Jetty	Public	$2,000,000	Department of Transport
Toilet block at jetty	Public	$150,000	Department of Transport
Jinker Jetty	Public	$200,000	Department of Transport
Fuel Facility	Public	$650,000	Department of Transport

CoreLogic provides real estate valuations for www.realestate.com.au. Any assets that could not be valued were either reasonably estimated from similar assets or not included in the CBA.

APPENDIX B
COMMUNITY INFORMATION SHEET

Coastal Hazard Planning for the Denham Townsite
Workshop 2

The Shire of Shark Bay has engaged Water Technology to prepare a **Coastal Hazard Risk Management and Adaptation Plan (CHRMAP)** for the Denham Townsite. Undertaking a CHRMAP is a recommendation of the Western Australian Planning Commission (WAPC).

Information regarding this plan and its objectives, as well as details for the corresponding community consultation program are outlined in this information sheet.

Community Involvement

Community and stakeholder involvement is a critical component of the CHRMAP process, as it defines the inherent value of the built and natural assets within the study area. This will inform the adaptation planning process and ensure all needs are considered.

How can I be involved?

- Community Workshop 1: **Completed May 2018**
- Community Survey 1: **Completed July 2018**
- Community Workshop 2: **5:30pm, Tuesday December 11th 2018**
  - **Recreation Centre, Francis Street, Denham**
- Community Survey 2: Posted to Shire website after Workshop 2

Contact Details

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Progress to Date

At the first public workshop, stakeholders from Denham discussed the values and concerns regarding the town's interaction with the coastal environment. High value assets and locations within the coastal zone were discussed, as were previous iterations of coastal management and historic coastal hazard events.

Following the WAPC's coastal hazard calculation guidelines, hazard maps were created using coastal inundation and erosion modelling. These identified assets at risk in the present day, by 2030 (extreme risk), by 2050 (high risk) and by 2118 (moderate risk). Assets identified as being at risk:

- **Present day to 2030 – 66 assets (0 residential lots)**
- **By 2050 – 97 (18 residential lots)**
- **By 2118 – 149 (51 residential lots)**

From this data Water Technology assessed a range of potential adaptation options using the WAPC's assessment hierarchy. Options recommended include the relocation of assets to outside of the hazard zone at the end of their useful lifetime, restriction of development within certain risk zones and minor re-design and floodproofing of assets below a certain floor level. Options to be discussed include a renourishment program for the area southeast of Knight Terrace and potential to build a formal protection structure along Knight Terrace between Denham Road and Durlacher Street. Also to be discussed are the long term adaptation pathways that will allow the town to effectively accommodate predicted sea level rise over the next 100 years.

CHRMAP Process

Workshop Objectives

- **To discuss the coastal hazard adaptation options identified that are expected to have an overall positive impact on local values and are economically feasible.**
- **Identify the community's preferences for adaptation and discuss the pros and cons of each option, and how it fits in with the WAPC's planning guidelines for coastal hazards.**
- **Begin to develop an adaptation pathway for the town that reduces coastal risks and encompasses the community values without hampering local community development.**

What is a CHRMAP?

A CHRMAP is a strategic plan that provides a framework for decision makers to meet the challenges associated with coastal hazards, including erosion, inundation and sea level rise.

Why Does Denham need a CHRMAP?

Residents of and visitors to Denham place a high value on the surrounding coastline. In addition, the town site has significant assets within 50 metres of the present day coastline. The processes that affect this area are multiple and complex.

Status

Water Technology has conducted the first three stages as per the CHRMAP process to the left. The Shire is now ready to conduct the second public workshop to discuss the adaptation planning options for the future.

APPENDIX C
ADAPTATION OPTIONS SURVEY QUESTIONS

Thank you for taking the time to complete the Shire of Shark Bay's adaptation options survey. This survey is part of the Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) for the town of Denham to address the risks of coastal hazards both now and over the next 100 years. Undertaking a CHRMAP is a recommendation of the Western Australian Planning Commission's (WAPC) State Planning Policy 2.6 (SPP2.6).

As part of this project the Shire of Shark Bay (Shire) has identified all assets within the town that may be subject to coastal inundation or erosion over the next 100 years. WAPC provides guidelines for the calculation of these hazard zones and mandates the inclusion of 0.9 m sea level rise (SLR) over the coming century as predicted by studies from the Intergovernmental Panel on Climate Change (IPCC).

The results of the asset survey and coastal hazard study can be found on the online database here:

It is recommended that you read the database notice and view the calculated erosion and inundation hazard lines before taking the survey. Please keep in mind that these allowances **are not** a prediction of the future shoreline but rather a planning tool for decision makers.

Using the information from the asset database the Shire is developing a risk management and adaptation plan to help the town of Denham adapt to hazards over both the short and long term. When developing an adaptation plan the WAPC requires that planners follow the **adaptation hierarchy**:

Avoid > Planned / Managed Retreat > Accommodate > Protect

This hierarchy shows, for example, that it is preferred to move assets away from coastal hazard zones rather than protect them. The WAPC's planning policy and guidelines also state that the **user pays** principle should be adopted. This principle simply states that those who benefit most from coastal adaptation works should contribute the most towards the project. It should also be noted that **the State and Local Government are not legally obliged to protect private assets or fund coastal adaptation works or strategies**. These core points: the adaptation hierarchy, the user pays principle, and the Government's obligations, are not considered well known amongst communities, but should be noted by anyone thinking about coastal planning and adaptation.

On the 11th of December 2018, the Shire held a community workshop to discuss the recommendations from the CHRMAP and the potential adaptation options identified for the future. This survey is to provide further insight into the community's preferences for the future of Denham and also into the community's understanding and satisfaction with the project process so far.

This survey can be completed by any member of the community regardless of whether they have attended any of the CHRMAP workshops or not. It should only take you 5-10 minutes to complete the survey.

If you would like to share observations or thoughts on coastal adaptation, or if you have any questions regarding the CHRMAP process, please email us at:

ceo@sharkbay.wa.gov.au

OR

joanna.garcia-webb@watertech.com.au

TABLE C-1 PROPOSED ADAPTATION OPTIONS SURVEY QUESTIONS

Question	Response Prompts
1. How would you describe your connection to the Denham Townsite?	▪ Resident – landowner ▪ Resident - tenant ▪ Rate payer (non-resident) ▪ Work in the town ▪ Holiday in the town ▪ Other / special interest (please specify)
2. What is your age?	▪ <20 ▪ 20-39 ▪ 40-59 ▪ >60
3. What is your residential address? (optional)	
4. Did you attend either of the Denham CHRMAP community workshops?	▪ Workshop 1 (3rd May 2018) ▪ Workshop 2 (11th December 2018) ▪ Both ▪ Neither
5. Have you viewed the online hazard mapping database for the Town of Denham? If so, how would you describe your understanding of the hazard mapping?	▪ Yes… very easy to understand ▪ Yes… easy to understand ▪ Yes… difficult to understand ▪ Yes… very difficult to understand ▪ I have not viewed it
6. How would you describe your understanding of coastal erosion and coastal flooding due to storm surge inundation?	▪ Very good understanding ▪ Good understanding ▪ General awareness ▪ Uncertain ▪ Not aware
7. How would you describe your concern about the permanent impacts of sea level rise? For example, permanent coastal erosion and frequent coastal inundation.	▪ Very concerned ▪ Somewhat concerned ▪ Unconcerned ▪ No opinion
8. To your knowledge, do you own any vulnerable assets (residential or otherwise) that may be at risk to coastal erosion and/or coastal inundation due to storm surge?	▪ Yes ▪ No ▪ Not sure
9. Landholders should be informed about the risks of coastal erosion and inundation before purchasing or developing in hazardous areas	▪ Strongly agree ▪ Somewhat agree ▪ Neutral ▪ Strongly disagree ▪ Somewhat disagree ▪ Not sure

Question	Response Prompts
10. Do you think we should progressively move assets out of hazard zones and let natural processes take their course, e.g. let shorelines retreat as predicted?	▪ Yes, move assets when they are damaged (e.g. house is flooded) ▪ Yes, move assets before they are damaged ▪ No, assets should be protected by structures such as seawalls ▪ I am not sure or do not have an opinion.
11. How much extra would you be willing to pay on your rates / rent / local accommodation each year to maintain the **current** amount of **sandy beach** along the town shoreline?	▪ 0 / nothing ▪ $20 ▪ $50 ▪ $100 ▪ $200 ▪ $400 or more
12. How much extra would you be willing to pay on your rates / rent / local accommodation each year to maintain the **current** amount of **natural foreshore reserve** along the town shoreline?	▪ 0 / nothing ▪ $20 ▪ $50 ▪ $100 ▪ $200 ▪ $400 or more
13. How much extra would you be willing to pay on your rates / rent / local accommodation each year to maintain the **current** amount of **recreational foreshore** along the town shoreline? (e.g. coastal walkways, grassed areas, BBQ and gathering areas)	▪ 0 / nothing ▪ $20 ▪ $50 ▪ $100 ▪ $200 ▪ $400 or more
14. How much extra would you be willing to pay on your rates / rent / local accommodation each year to **extend coastal protection** along the town shoreline? (e.g. construct more rock revetment/seawall structures along areas with assets at risk)	▪ 0 / nothing ▪ $20 ▪ $50 ▪ $100 ▪ $200 ▪ $400 or more
15. For the previous few questions, please select an answer that best sums up your choices	▪ I selected my answers based on how much I value the foreshore and did not consider whether I could afford a rate increase or not ▪ My answers were mainly based on not being able to afford a rate increase ▪ I do not believe I should fund coastal management out of my own pocket ▪ I do not trust the funds would be used to best manage coastal hazards ▪ I do not think the funds would go towards directly benefiting me and my assets ▪ I'd rather not say / I'm not sure ▪ Other…

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Question	Response Prompts
16. Do you think that ratepayers who benefit more from a coastal protection structure such as a seawall should pay more than other ratepayers in Denham?	▪ Yes ▪ No ▪ Not sure
17. Do you think Denham should think about long term plans to relocate the primary hub of tourism and commerce (e.g.: Knight Terrace at present) further inland out of coastal hazard risks?	▪ Yes, we should start moving ASAP ▪ Yes, we should start thinking about a plan for the future but not move just yet ▪ No, we should only start thinking about retreat when things get bad (e.g.: storm damage, frequent flooding) ▪ No, we should just increase our protection structures and build the foreshore up out of reach of severe storm activity ▪ Not sure yet
18. If no protection is built in some areas and the shoreline retreats, when do you think a property should be removed?	▪ When the property is damaged and no longer safe to use ▪ When the shoreline is within a certain distance of the property, e.g.: 40 m ▪ When the risk to the property reaches a high enough level, but before damage ▪ When services can no longer be supplied by the Shire e.g. water, sewerage or electricity ▪ Any of the above ▪ Whenever the owner decides
19. If a property must be removed due to a certain trigger (such as the options in the previous question), who do you think should pay for the loss of the property?	▪ The owner (i.e.: they lose all their investment in the property) ▪ A government body, noting policy indicates government is not responsible for private property ▪ A coastal protection fee on tourists visiting the Shire ▪ An increase in rates for all ratepayers in the Shire ▪ An increase in rates for all ratepayers within the hazard zone ▪ A combination of the methods listed above ▪ Another option (blank space)…
20. For the section of coast from the south-east end of Knight Terrace to the Denham Rd intersection, what is your preference for the coast over the next 20-years?	▪ Do Nothing / Leave as is ▪ Conservation Activities ▪ Recreational Facilities / Community Activities ▪ Amenity/ Access Facilities ▪ Private Development ▪ Coastal Protection Engineering ▪ Planning Amendments, e.g. development regulations and limitations / relocate

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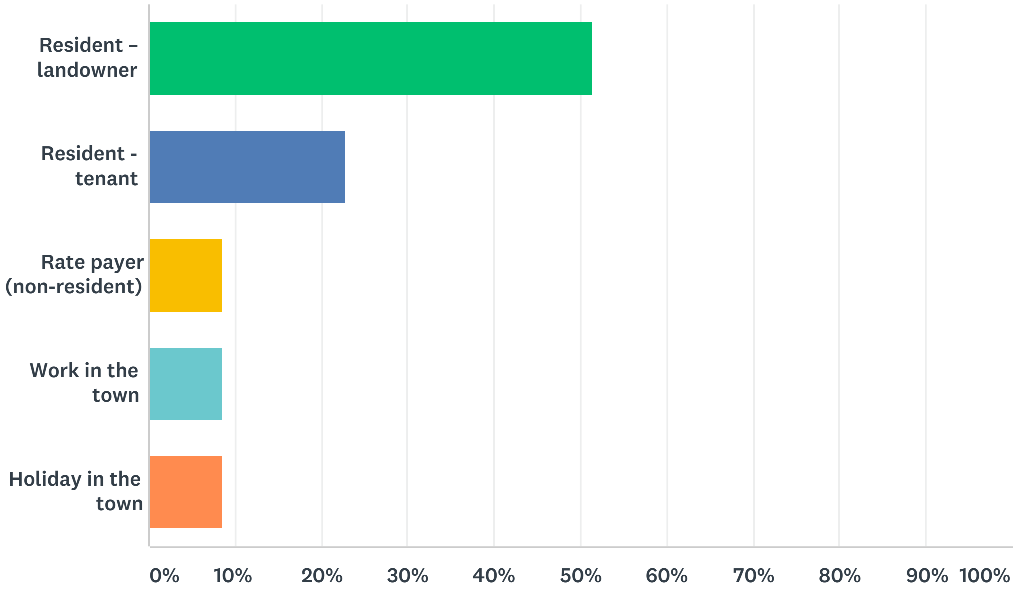
Question	Response Prompts
21. For the section of coast along Knight Terrace from Denham Rd intersection to the FRP Groyne / Marina, what is your preference for the coast over the next 20-years?	▪ Do Nothing / Leave as is ▪ Conservation Activities ▪ Recreational Facilities / Community Activities ▪ Amenity/ Access Facilities ▪ Private Development ▪ Coastal Protection Engineering ▪ Planning Amendments, e.g. development regulations and limitations / relocate
22. For the section of coast along Knight Terrace from the FRP Groyne / Marina to the Stella Rowley Drive intersection, what is your preference for the coast over the next 20-years?	▪ Do Nothing / Leave as is ▪ Conservation Activities ▪ Recreational Facilities / Community Activities ▪ Amenity/ Access Facilities ▪ Private Development ▪ Coastal Protection Engineering ▪ Planning Amendments, e.g. development regulations and limitations / relocate
23. Did you find the questions confusing or difficult to answer?	▪ Very difficult / confusing ▪ Somewhat difficult / confusing ▪ A little difficult / confusing ▪ Not difficult / confusing
24. Please provide any comments or feedback on this survey	▪ Space for text

APPENDIX D
ADAPTATION OPTIONS SURVEY RESULTS

Q1 How would you describe your connection to the Denham Townsite?

Answered: 35 Skipped: 0

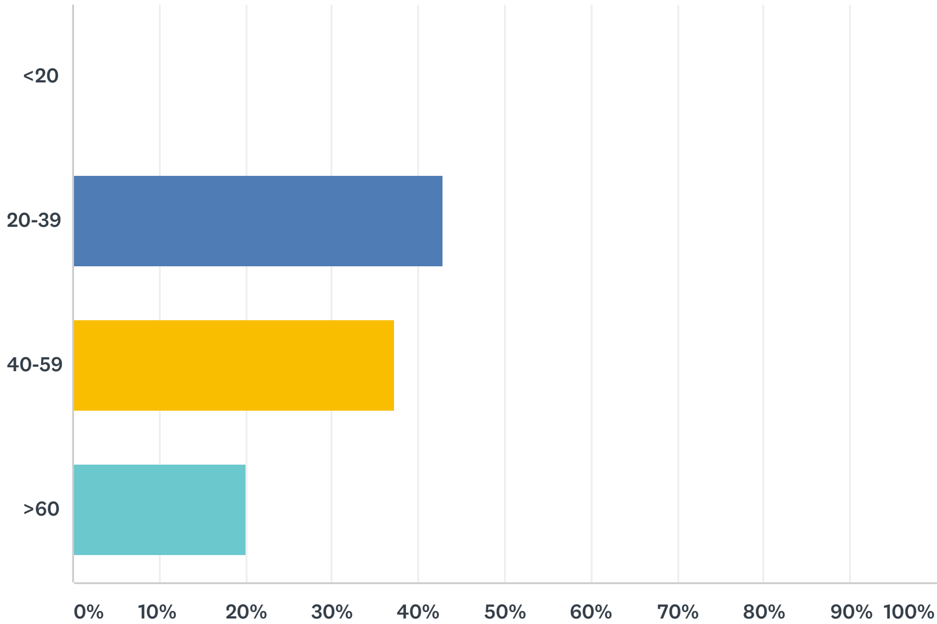


ANSWER CHOICES	RESPONSES	
Resident – landowner	51.43%	18
Resident - tenant	22.86%	8
Rate payer (non-resident)	8.57%	3
Work in the town	8.57%	3
Holiday in the town	8.57%	3
TOTAL		35

#	OTHER / SPECIAL INTEREST (PLEASE SPECIFY)	DATE
1	Denham Seaside Caravan Park Owner	1/2/2019 3:43 PM
2	Denham is my hometown	12/21/2018 9:17 PM
3	I have worked and holiday every year there	12/21/2018 6:35 PM
4	Pensioner	12/21/2018 2:38 PM
5	Business Owner	12/21/2018 10:23 AM

Q2 What is your age?

Answered: 35 Skipped: 0



ANSWER CHOICES	RESPONSES	
<20	0.00%	0
20-39	42.86%	15
40-59	37.14%	13
>60	20.00%	7
TOTAL		35

Q3 What is your residential address? (Optional)

Answered: 14 Skipped: 21

ANSWER CHOICES	RESPONSES	
Name	0.00%	0
Company	0.00%	0
Address	92.86%	13
Address 2	7.14%	1
City/Town	92.86%	13
State/Province	78.57%	11
ZIP/Postal Code	71.43%	10
Country	64.29%	9
Email Address	0.00%	0
Phone Number	0.00%	0

#	NAME	DATE
	There are no responses.	

#	COMPANY	DATE
	There are no responses.	

#	ADDRESS	DATE
1	17 Percival Pl	1/2/2019 3:43 PM
2	lot 4 nanga bay rd	12/22/2018 10:05 AM
3	153 Knight Terrace	12/22/2018 9:10 AM
4	74 Winnetta Rdge	12/21/2018 9:17 PM
5	104 jones st	12/21/2018 6:35 PM
6	60 Brockman st	12/21/2018 5:11 PM
7	1/18 Hartog crescent	12/21/2018 2:38 PM
8	22 Capewell St.	12/21/2018 1:10 PM
9	5 Richardson street	12/21/2018 10:41 AM
10	46 BROCKMAN ST	12/21/2018 10:22 AM
11	656 south river red carnarvon	12/21/2018 10:19 AM
12	17 Fry Court	12/21/2018 10:18 AM
13	39 durlacher st	12/21/2018 9:19 AM

#	ADDRESS 2	DATE
1	5eaton pl geraltdon	12/21/2018 10:19 AM

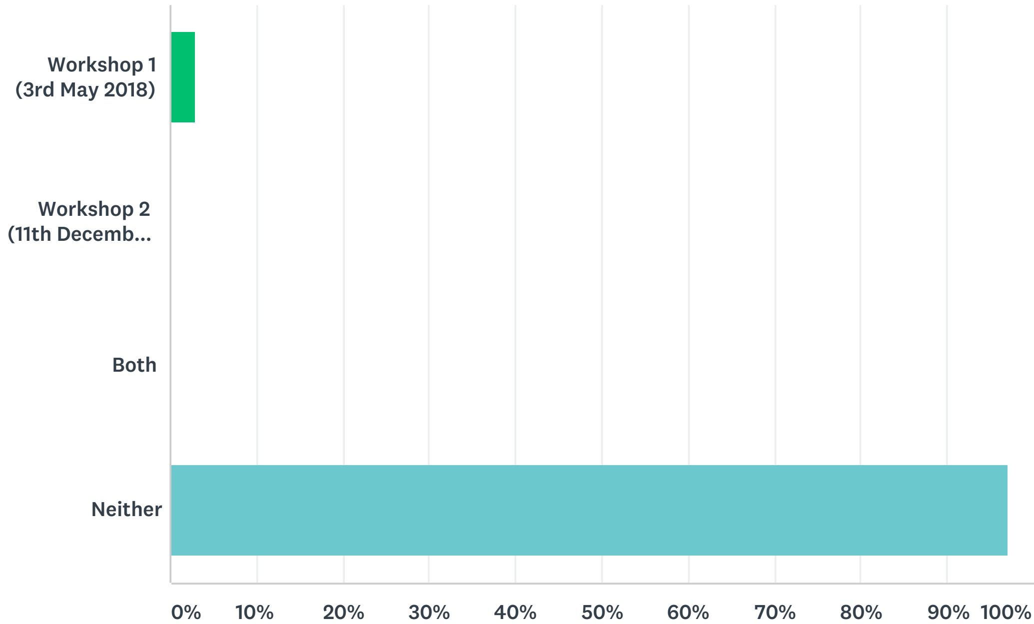
#	CITY/TOWN	DATE
1	BROADWATER	1/2/2019 3:43 PM
2	6233	12/23/2018 12:16 AM
3	nanga bay	12/22/2018 10:05 AM
4	Denham	12/22/2018 9:10 AM
5	WANDINA	12/21/2018 9:17 PM

6	Coliie	12/21/2018 6:35 PM
7	Denham	12/21/2018 5:11 PM
8	Denham	12/21/2018 2:38 PM
9	Denham	12/21/2018 1:10 PM
10	South Carnarvon	12/21/2018 10:41 AM
11	DENHAM	12/21/2018 10:22 AM
12	6530	12/21/2018 10:19 AM
13	Denham	12/21/2018 10:18 AM
#	**STATE/PROVINCE**	**DATE**
1	WA	1/2/2019 3:43 PM
2	WA	12/22/2018 10:05 AM
3	WA	12/22/2018 9:10 AM
4	WA	12/21/2018 9:17 PM
5	Wa	12/21/2018 6:35 PM
6	WA	12/21/2018 5:11 PM
7	WA	12/21/2018 2:38 PM
8	Wa	12/21/2018 10:41 AM
9	9	12/21/2018 10:22 AM
10	Wa	12/21/2018 10:19 AM
11	WA	12/21/2018 10:18 AM
#	**ZIP/POSTAL CODE**	**DATE**
1	6280	1/2/2019 3:43 PM
2	6537	12/22/2018 10:05 AM
3	6537	12/22/2018 9:10 AM
4	6530	12/21/2018 9:17 PM
5	6225	12/21/2018 6:35 PM
6	6537	12/21/2018 5:11 PM
7	6537	12/21/2018 2:38 PM
8	6701	12/21/2018 10:41 AM
9	6537	12/21/2018 10:22 AM
10	6710	12/21/2018 10:18 AM
#	**COUNTRY**	**DATE**
1	Australia	1/2/2019 3:43 PM
2	Australia	12/22/2018 10:05 AM
3	Australia	12/22/2018 9:10 AM
4	Australia	12/21/2018 9:17 PM
5	Australia	12/21/2018 6:35 PM
6	Australia	12/21/2018 5:11 PM
7	Australia	12/21/2018 2:38 PM
8	Australia	12/21/2018 10:22 AM
9	Australia	12/21/2018 10:18 AM
#	**EMAIL ADDRESS**	**DATE**
	There are no responses.	
#	**PHONE NUMBER**	**DATE**

There are no responses.

Q4 Did you attend either of the Denham CHRMAP community workshops?

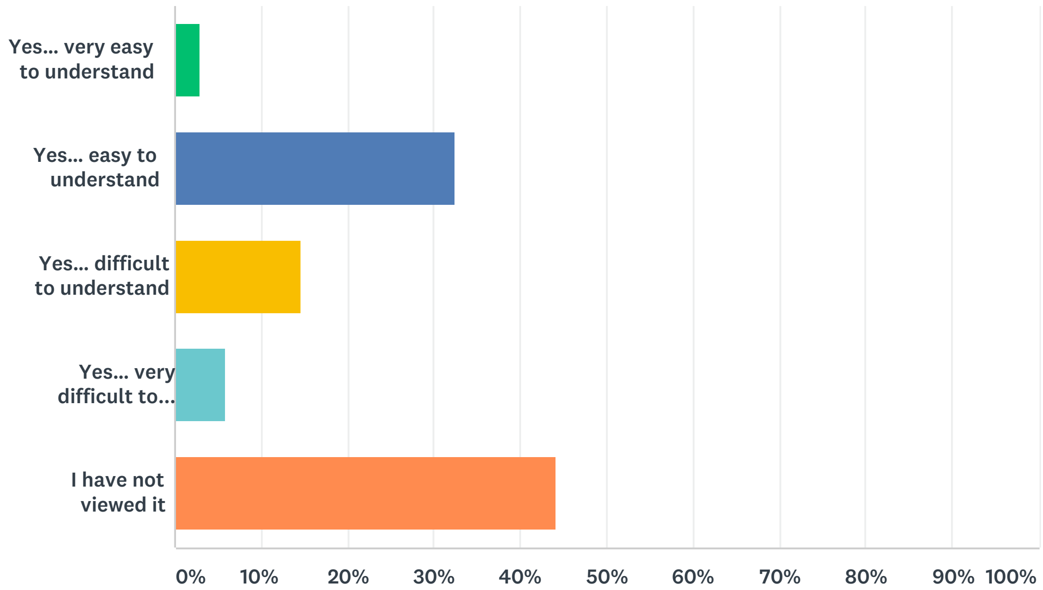
Answered: 34 Skipped: 1



ANSWER CHOICES	RESPONSES	
Workshop 1 (3rd May 2018)	2.94%	1
Workshop 2 (11th December 2018)	0.00%	0
Both	0.00%	0
Neither	97.06%	33
TOTAL		34

Q5 Have you viewed the online hazard mapping database for the Town of Denham? If so, how would you describe your understanding of the hazard mapping?

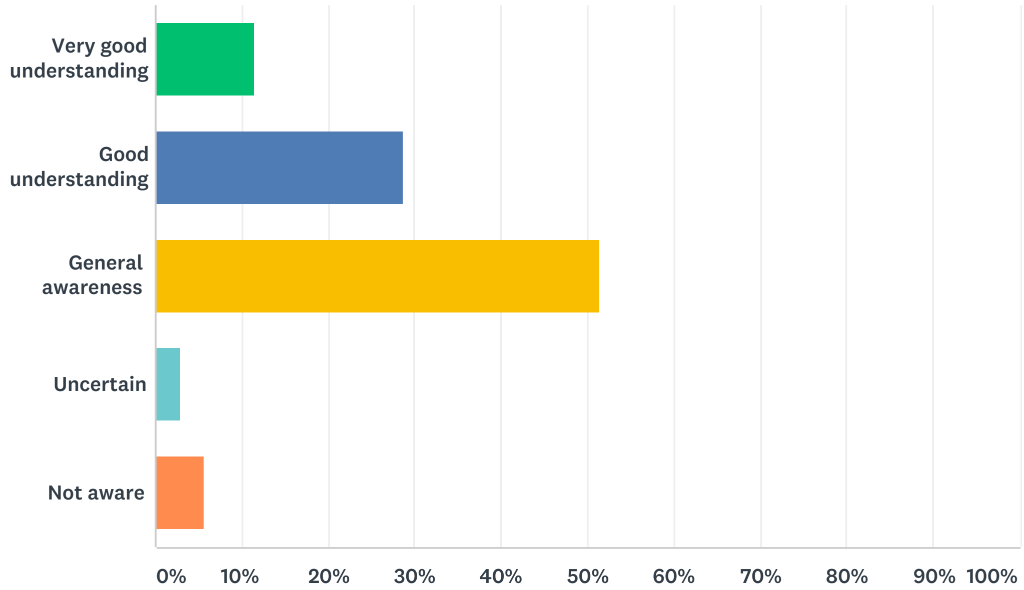
Answered: 34   Skipped: 1



ANSWER CHOICES	RESPONSES	
Yes… very easy to understand	2.94%	1
Yes… easy to understand	32.35%	11
Yes… difficult to understand	14.71%	5
Yes… very difficult to understand	5.88%	2
I have not viewed it	44.12%	15
TOTAL		34

Q6 How would you describe your understanding of coastal erosion and coastal flooding due to storm surge inundation?

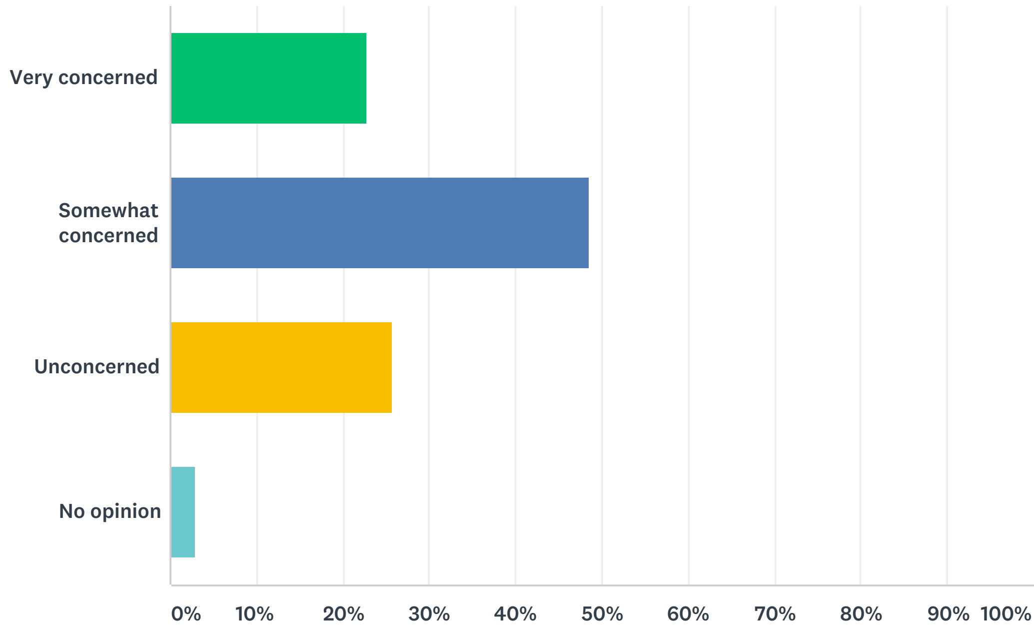
Answered: 35 Skipped: 0



ANSWER CHOICES	RESPONSES	
Very good understanding	11.43%	4
Good understanding	28.57%	10
General awareness	51.43%	18
Uncertain	2.86%	1
Not aware	5.71%	2
TOTAL		35

Q7 How would you describe your concern about the permanent impacts of sea level rise? For example, permanent coastal erosion and frequent coastal inundation

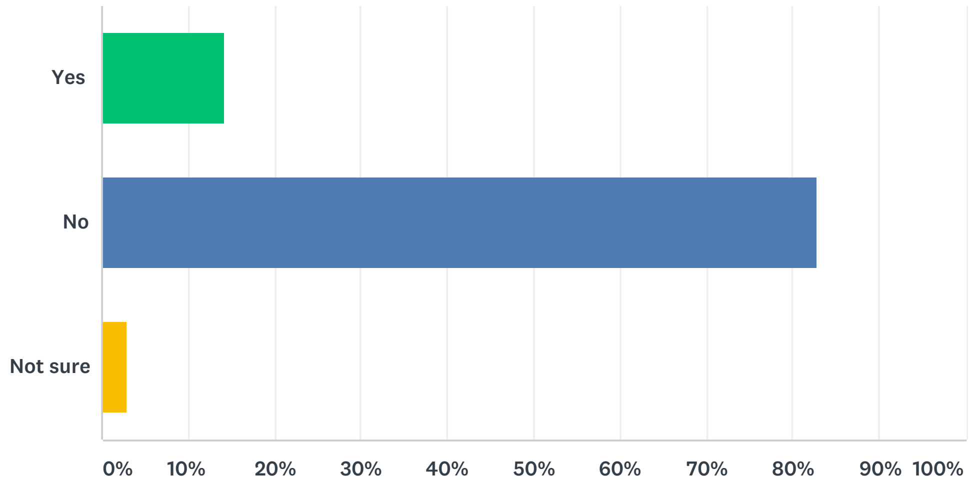
Answered: 35 Skipped: 0



ANSWER CHOICES	RESPONSES	
Very concerned	22.86%	8
Somewhat concerned	48.57%	17
Unconcerned	25.71%	9
No opinion	2.86%	1
TOTAL		35

Q8 To your knowledge, do you own any vulnerable assets (residential or otherwise) that may be at risk to coastal erosion and/or coastal inundation due to storm surge?

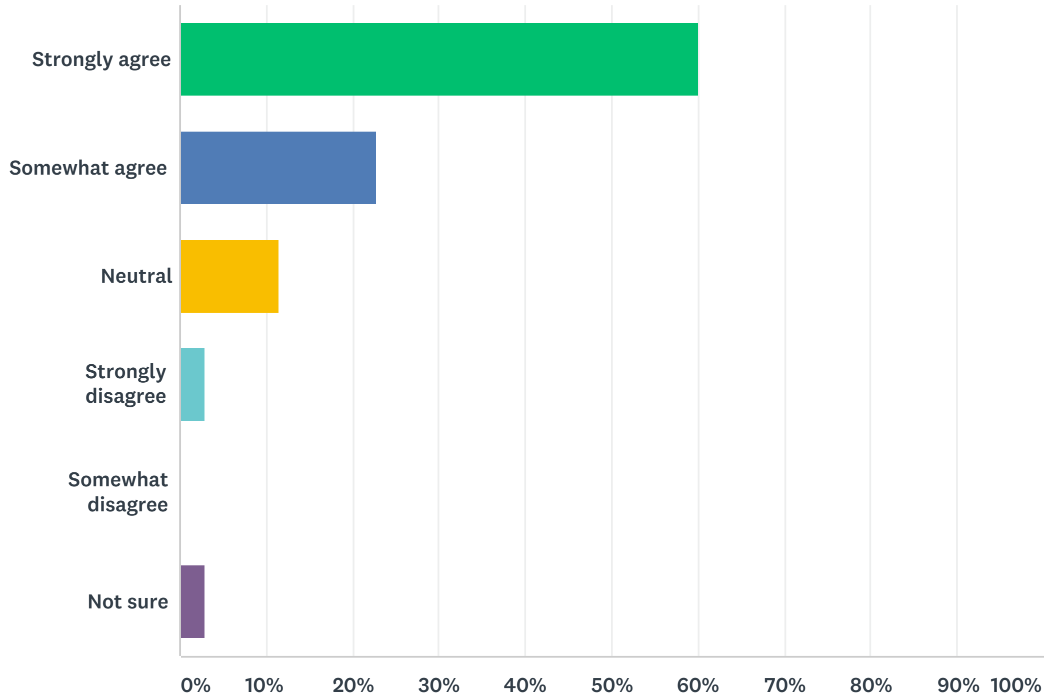
Answered: 35 Skipped: 0



ANSWER CHOICES	RESPONSES	
Yes	14.29%	5
No	82.86%	29
Not sure	2.86%	1
TOTAL		35

Q9 Landholders should be informed about the risks of coastal erosion and inundation before purchasing or developing in hazardous areas

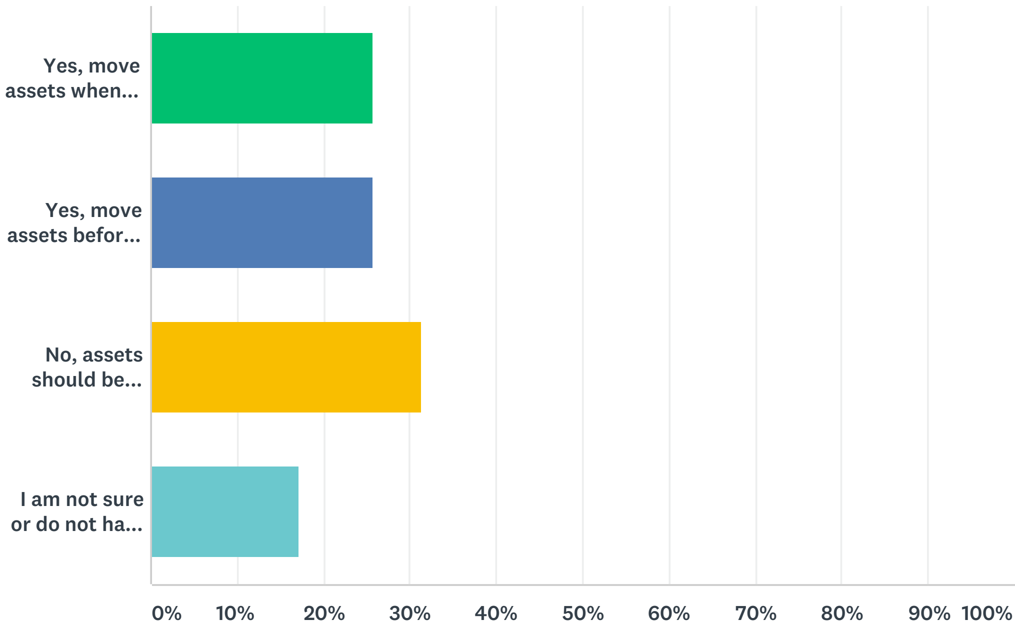
Answered: 35   Skipped: 0



ANSWER CHOICES	RESPONSES	
Strongly agree	60.00%	21
Somewhat agree	22.86%	8
Neutral	11.43%	4
Strongly disagree	2.86%	1
Somewhat disagree	0.00%	0
Not sure	2.86%	1
TOTAL		35

Q10 Do you think we should progressively move assets out of hazard zones and let natural processes take their course, e.g. let shorelines retreat as predicted?

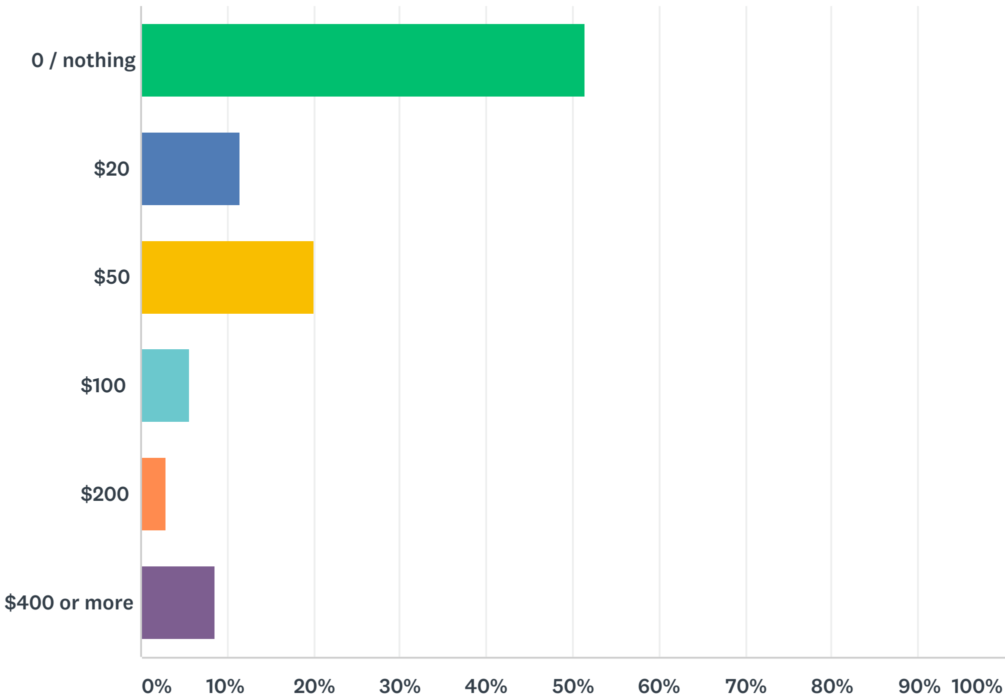
Answered: 35 Skipped: 0



ANSWER CHOICES	RESPONSES	
Yes, move assets when they are damaged (e.g. house is flooded)	25.71%	9
Yes, move assets before they are damaged	25.71%	9
No, assets should be protected by structures such as seawalls	31.43%	11
I am not sure or do not have an opinion	17.14%	6
TOTAL		35

Q11 How much extra would you be willing to pay on your rates / rent / local accommodation each year to maintain the current amount of sandy beach along the town shoreline?

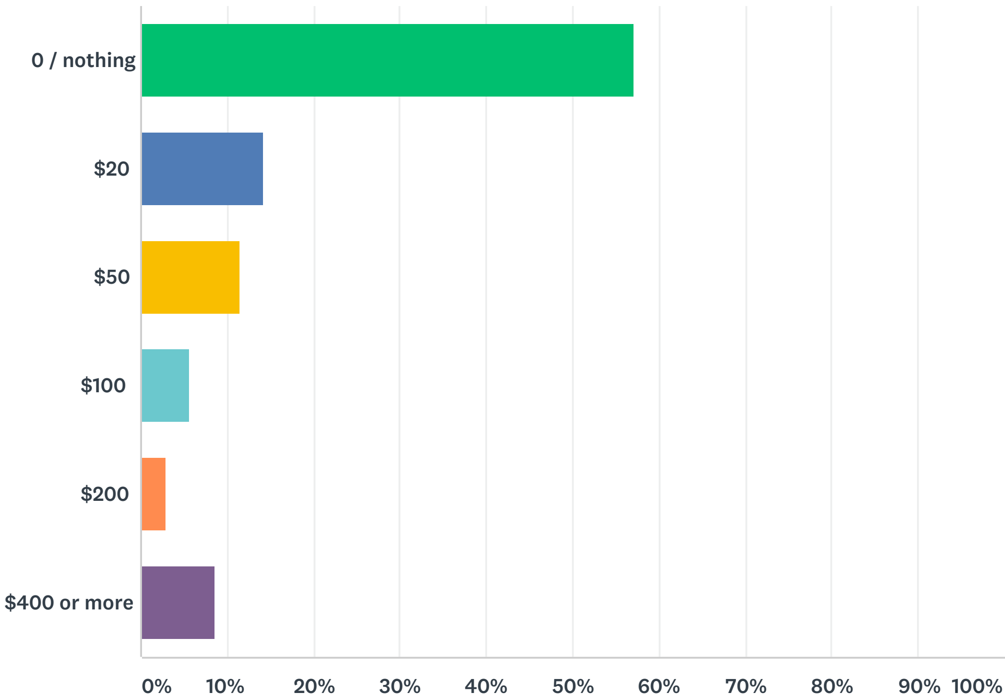
Answered: 35 Skipped: 0



ANSWER CHOICES	RESPONSES	
0 / nothing	51.43%	18
$20	11.43%	4
$50	20.00%	7
$100	5.71%	2
$200	2.86%	1
$400 or more	8.57%	3
TOTAL		35

Q12 How much extra would you be willing to pay on your rates / rent / local accommodation each year to maintain the current amount of natural foreshore reserve along the town shoreline?

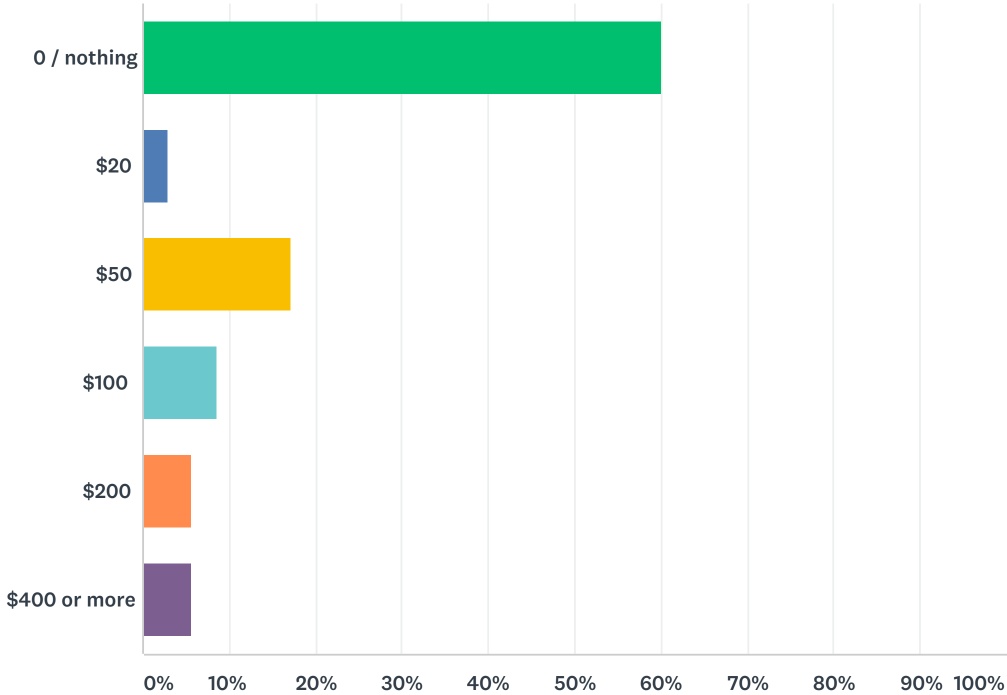
Answered: 35 Skipped: 0



ANSWER CHOICES	RESPONSES	
0 / nothing	57.14%	20
$20	14.29%	5
$50	11.43%	4
$100	5.71%	2
$200	2.86%	1
$400 or more	8.57%	3
TOTAL		35

Q13 How much extra would you be willing to pay on your rates / rent / local accommodation each year to maintain the current amount of recreational foreshore along the town shoreline? (e.g. coastal walkways, grassed areas, BBQ and gathering areas)

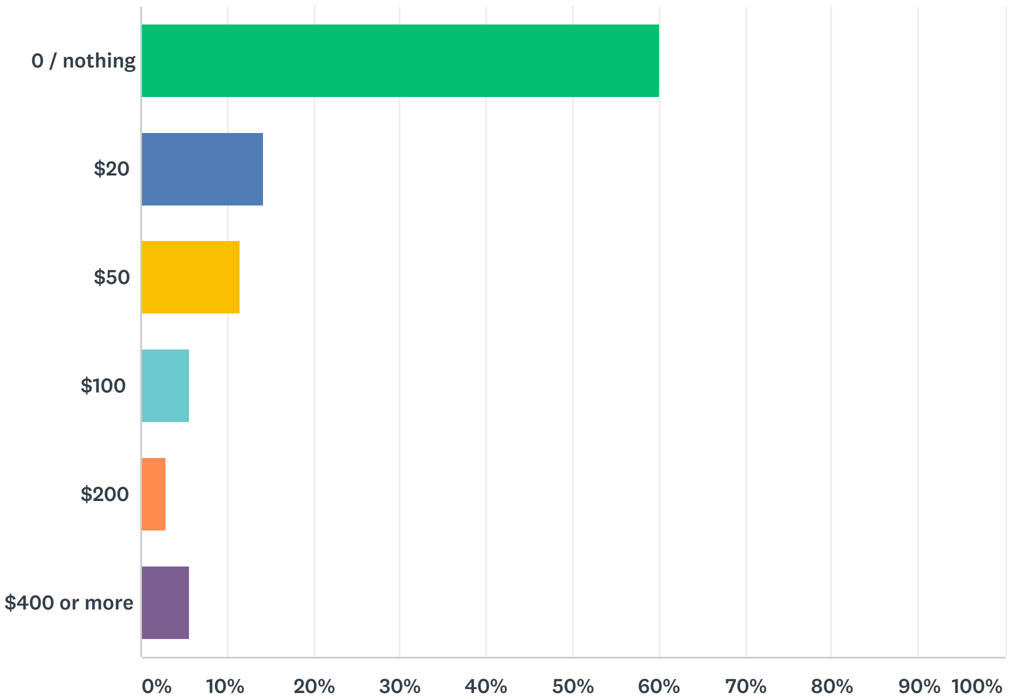
Answered: 35 Skipped: 0



ANSWER CHOICES	RESPONSES	
0 / nothing	60.00%	21
$20	2.86%	1
$50	17.14%	6
$100	8.57%	3
$200	5.71%	2
$400 or more	5.71%	2
TOTAL		35

Q14 How much extra would you be willing to pay on your rates / rent / local accommodation each year to extend coastal protection along the town shoreline? (e.g. construct more rock revetment/seawall structures along areas with assets at risk)

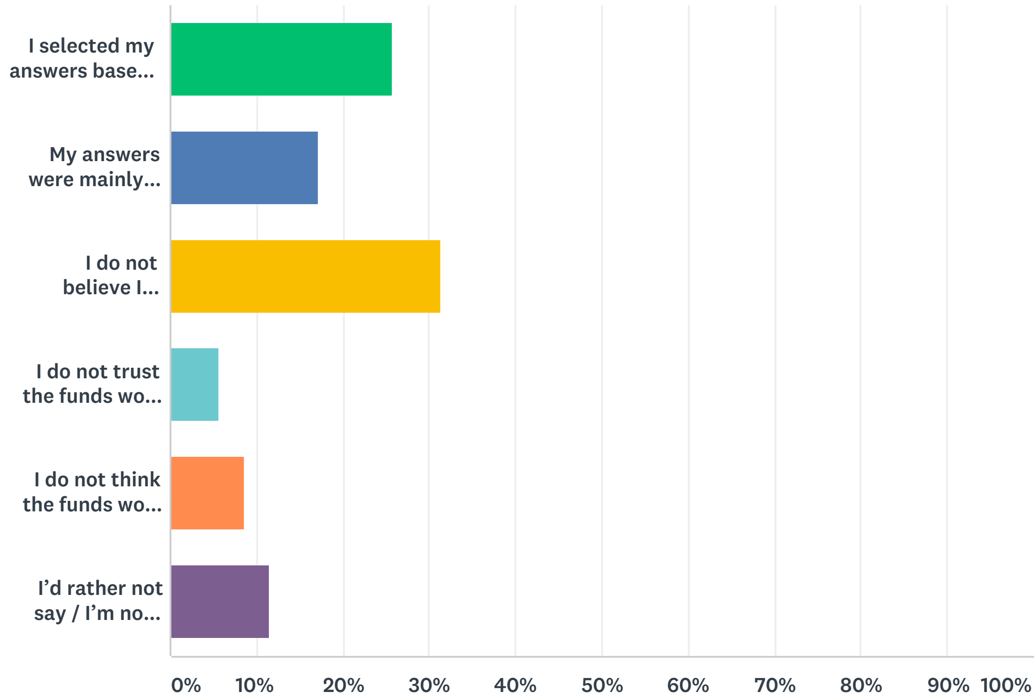
Answered: 35 Skipped: 0



ANSWER CHOICES	RESPONSES	
0 / nothing	60.00%	21
$20	14.29%	5
$50	11.43%	4
$100	5.71%	2
$200	2.86%	1
$400 or more	5.71%	2
TOTAL		35

Q15 For the previous few questions, please select an answer that best sums up your choices

Answered: 35 Skipped: 0



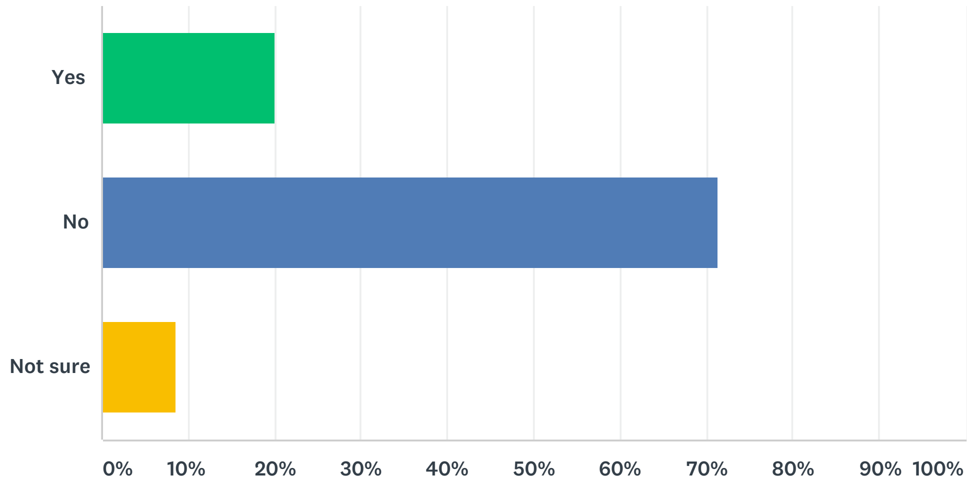
ANSWER CHOICES	RESPONSES	
I selected my answers based on how much I value the foreshore and did not consider whether I could afford a rate increase or not	25.71%	9
My answers were mainly based on not being able to afford a rate increase	17.14%	6
I do not believe I should fund coastal management out of my own pocket	31.43%	11
I do not trust the funds would be used to best manage coastal hazards	5.71%	2
I do not think the funds would go towards directly benefiting me and my assets	8.57%	3
I'd rather not say / I'm not sure	11.43%	4
TOTAL		35

#	OTHER (PLEASE SPECIFY):	DATE
1	Provided the rates are used to protect the assets of the town, its residents and businesses then we will do what is required, when it is required.	1/2/2019 3:43 PM
2	I am if I willing to fund these activities, which is fine. But I would rather be asked if I would want my government to invest in coal or fossil fuel, or waging war overseas in the slip stream of the power hungry yanks. I don't agree with numerous spendings of the government. If they would stop borrowing money from private banks against interest and stop investing in wars and war tools, we would have all the money available to us for education, coastal protection, the homeless, poor refugees, etc etc. We should also spend some money on finding out if global warming actually is real. My 2cents.	12/24/2018 5:56 PM
3	I think it should be up to the individual asset owner to foot any costs of climate change sea level changes. If that is a shire owned asset, I would happily chip in. Privately owned assets should be solely funded by the owner. We deliberately purchased property well above tbe current high tide mark because we like to think ahead a bit. If other investors can't do the same, why should I pay for their stupidity? I can't wait to see how much the value of my asset will increase when it's a waterfront property...	12/21/2018 11:58 PM

4	I could find the extra money in a rates increase	12/21/2018 5:40 PM
5	Would need to look into more coastal erosion management plans to make informed choices. Happy to support coastal conservation if it was human influenced damage/changes and less support to people use/recreational areas.	12/21/2018 5:11 PM
6	Stop people grinding shell in their back yard. Especially on Sunday.	12/21/2018 2:38 PM
7	Sea rise is inevitable, use the funds to relocate assets to higher ground. No amount of short term infrastructure development will accommodate the predicted rises.	12/21/2018 9:19 AM

Q16 Do you think that ratepayers who benefit more from a coastal protection structure such as a seawall should pay more than other ratepayers in Denham?

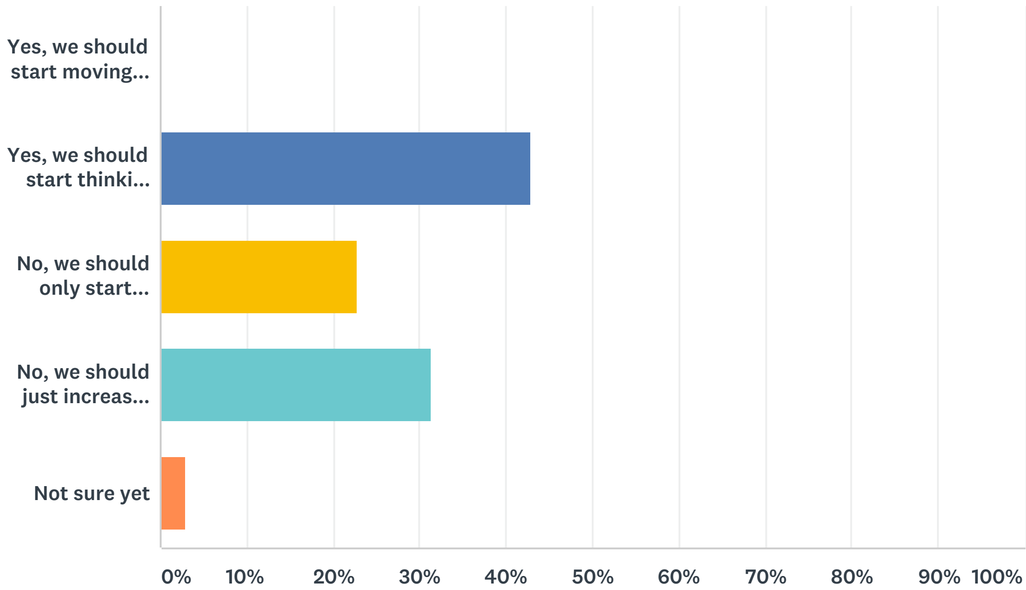
Answered: 35 Skipped: 0



ANSWER CHOICES	RESPONSES	
Yes	20.00%	7
No	71.43%	25
Not sure	8.57%	3
TOTAL		35

Q17 Do you think Denham should think about long term plans to relocate the primary hub of tourism and commerce (e.g.: Knight Terrace at present) further inland out of coastal hazard risks?

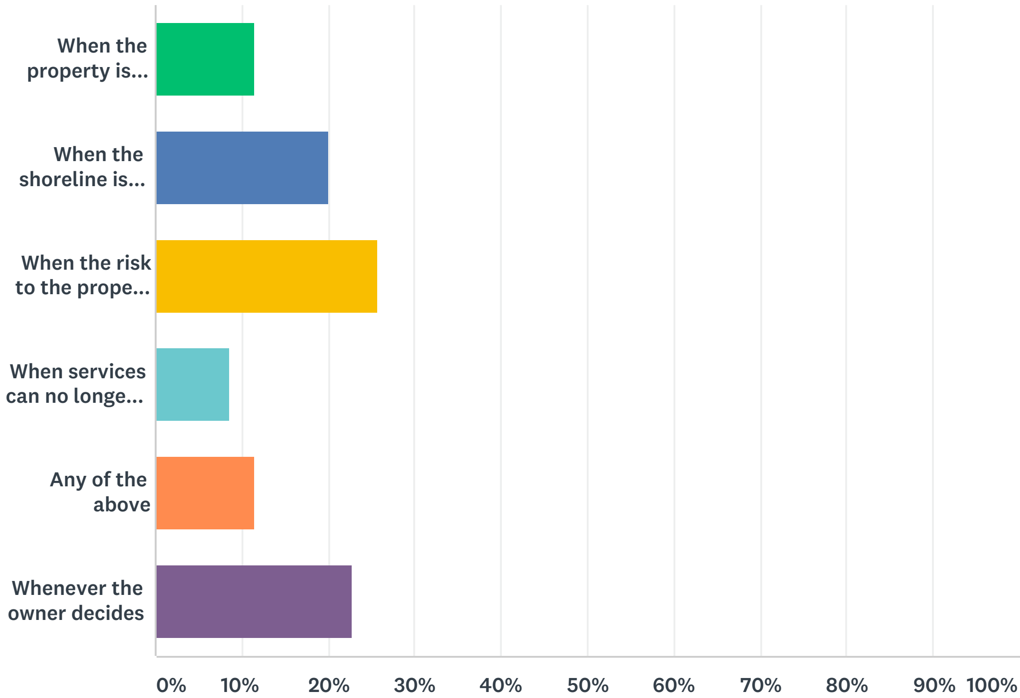
Answered: 35 Skipped: 0



ANSWER CHOICES	RESPONSES	
Yes, we should start moving ASAP	0.00%	0
Yes, we should start thinking about a plan for the future but not move just yet	42.86%	15
No, we should only start thinking about retreat when things get bad (e.g.: storm damage, frequent flooding)	22.86%	8
No, we should just increase our protection structures and build the foreshore up out of reach of severe storm activity	31.43%	11
Not sure yet	2.86%	1
TOTAL		35

Q18 If no protection is built in some areas and the shoreline retreats, when do you think a property should be removed?

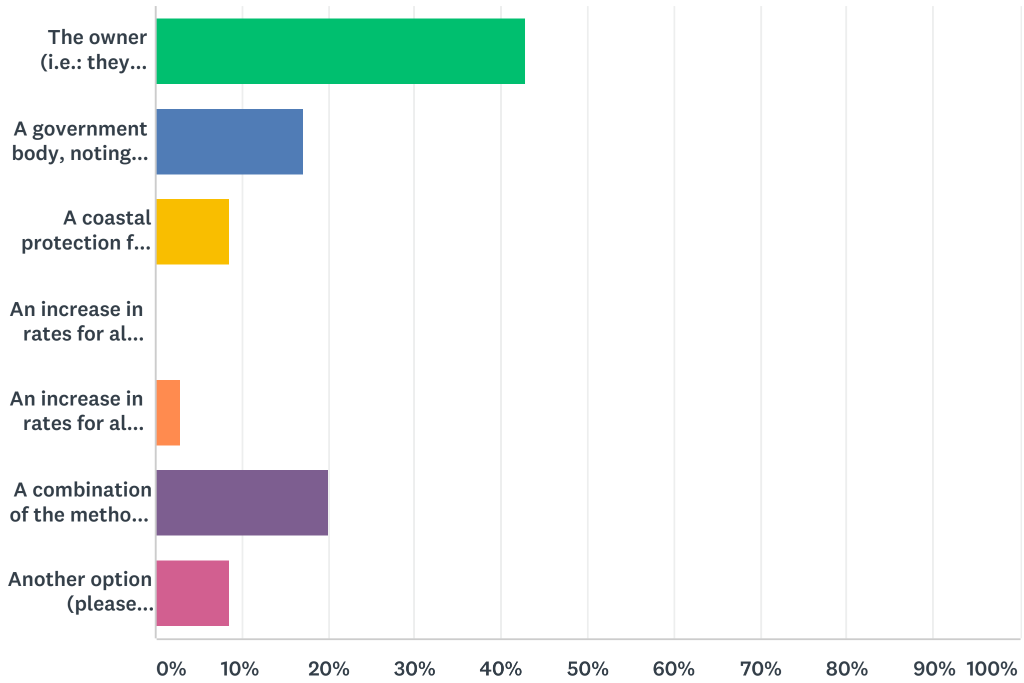
Answered: 35 Skipped: 0



ANSWER CHOICES	RESPONSES	
When the property is damaged and no longer safe to use	11.43%	4
When the shoreline is within a certain distance of the property, e.g.: 40 m	20.00%	7
When the risk to the property reaches a high enough level, but before damage	25.71%	9
When services can no longer be supplied by the Shire e.g. water, sewerage or electricity	8.57%	3
Any of the above	11.43%	4
Whenever the owner decides	22.86%	8
TOTAL		35

Q19 If a property must be removed due to a certain trigger (such as the options in the previous question), who do you think should pay for the loss of the property?

Answered: 35   Skipped: 0

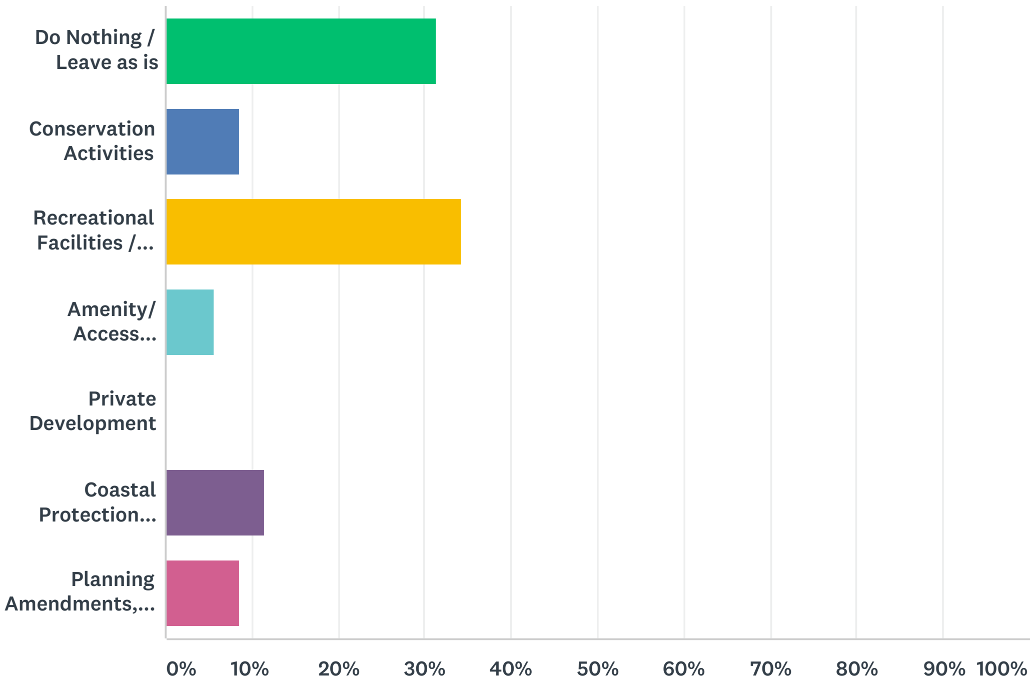


ANSWER CHOICES	RESPONSES	
The owner (i.e.: they lose all their investment in the property)	42.86%	15
A government body, noting policy indicates government is not responsible for private property	17.14%	6
A coastal protection fee on tourists visiting the Shire	8.57%	3
An increase in rates for all ratepayers in the Shire	0.00%	0
An increase in rates for all ratepayers within the hazard zone	2.86%	1
A combination of the methods listed above	20.00%	7
Another option (please specify):	8.57%	3
TOTAL		35

#	ANOTHER OPTION (PLEASE SPECIFY):	DATE
1	Is there some type of insurance at risk property owners can take out?	12/21/2018 5:48 PM
2	Owners insurance if covered	12/21/2018 10:22 AM
3	Allow shire to buy the properties along the foreshore, give landowners access through land Corp to equivalent block size on high ground. Move services and the tourism hub to Sellenger heights area.	12/21/2018 9:19 AM

Q20 For the section of coast from the south-east end of Knight Terrace to the Denham Rd intersection, what is your preference for the coast over the next 20-years?

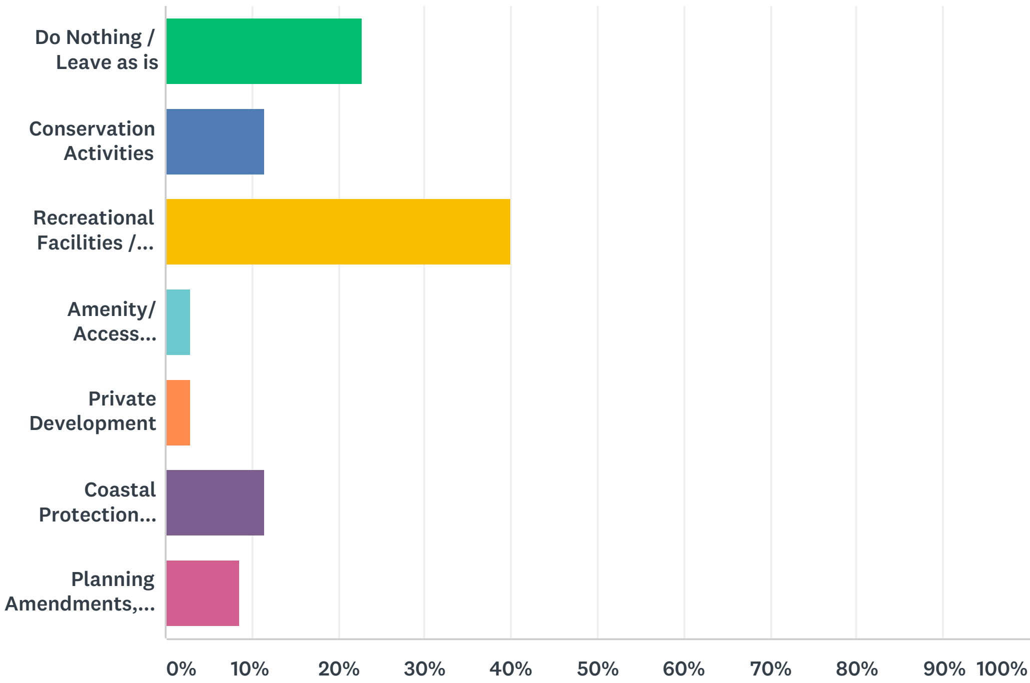
Answered: 35   Skipped: 0



ANSWER CHOICES	RESPONSES	
Do Nothing / Leave as is	31.43%	11
Conservation Activities	8.57%	3
Recreational Facilities / Community Activities	34.29%	12
Amenity/ Access Facilities	5.71%	2
Private Development	0.00%	0
Coastal Protection Engineering	11.43%	4
Planning Amendments, e.g. development regulations and limitations / relocate	8.57%	3
TOTAL		35

Q21 For the section of coast along Knight Terrace from Denham Rd intersection to the FRP Groyne / Marina, what is your preference for the coast over the next 20-years?

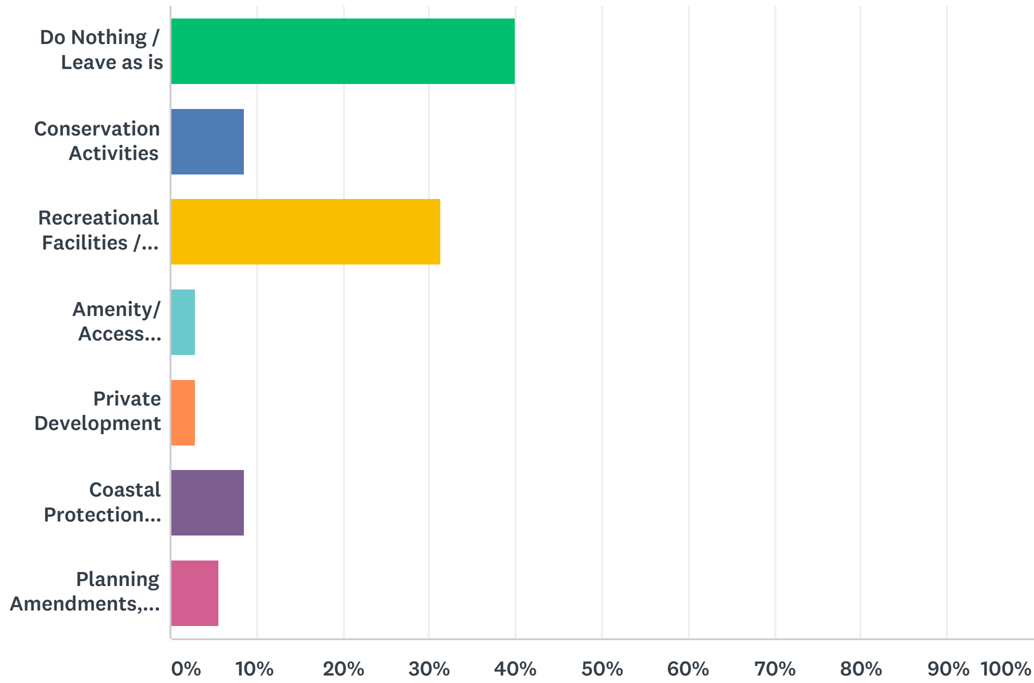
Answered: 35 Skipped: 0



ANSWER CHOICES	RESPONSES	
Do Nothing / Leave as is	22.86%	8
Conservation Activities	11.43%	4
Recreational Facilities / Community Activities	40.00%	14
Amenity/ Access Facilities	2.86%	1
Private Development	2.86%	1
Coastal Protection Engineering	11.43%	4
Planning Amendments, e.g. development regulations and limitations / relocate	8.57%	3
TOTAL		35

Q22 For the section of coast along Knight Terrace from the FRP Groyne / Marina to the Stella Rowley Drive intersection, what is your preference for the coast over the next 20-years?

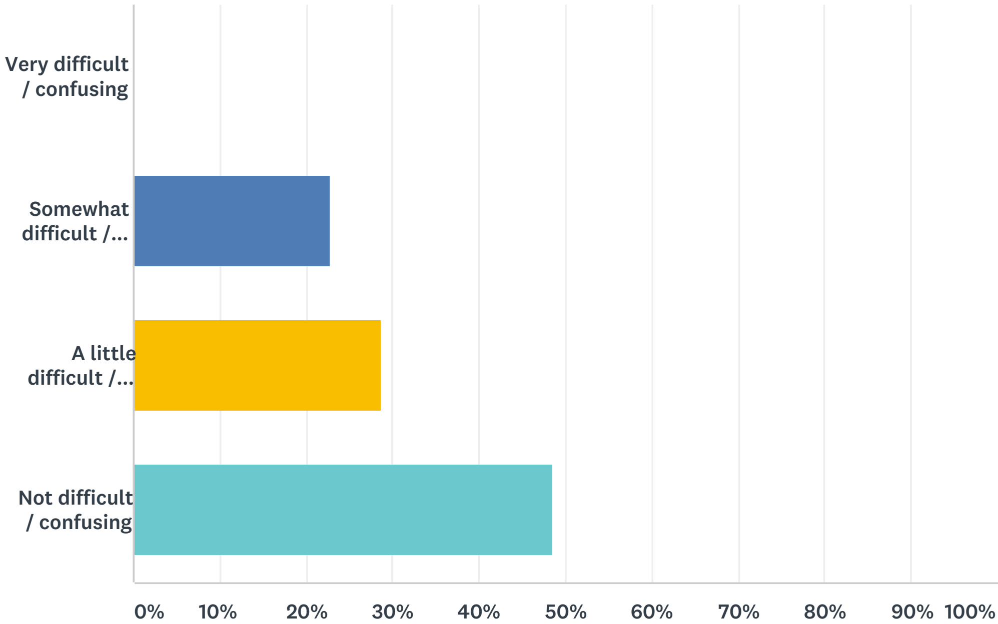
Answered: 35 Skipped: 0



ANSWER CHOICES	RESPONSES	
Do Nothing / Leave as is	40.00%	14
Conservation Activities	8.57%	3
Recreational Facilities / Community Activities	31.43%	11
Amenity/ Access Facilities	2.86%	1
Private Development	2.86%	1
Coastal Protection Engineering	8.57%	3
Planning Amendments, e.g. development regulations and limitations / relocate	5.71%	2
TOTAL		35

Q23 Did you find the questions confusing or difficult to answer?

Answered: 35 Skipped: 0



ANSWER CHOICES	RESPONSES	
Very difficult / confusing	0.00%	0
Somewhat difficult / confusing	22.86%	8
A little difficult / confusing	28.57%	10
Not difficult / confusing	48.57%	17
TOTAL		35

Q24 Please provide any comments or feedback on this survey

Answered: 8 Skipped: 27

#	RESPONSES	DATE
1	Lets wait and see if the predictions of sea level rises due to global warming ever actually occur.	1/4/2019 7:34 AM
2	Great forward thinking. I'd be happy to contribute to future discussions.	1/2/2019 3:43 PM
3	This town would do well to offer more for tourists as tourism will do wonders for this town. It will be the foundation for more people wanting to live and work here. More job opportunities for the youth, more infrastructural improvements and services. Up until now, the shire council seems to be focused on keeping it all as it is, making it harder for local businesses and start ups to be successful. This town doesn't have a proper coffee shop when Shark Bay Cafe is closed for whatever reason.The attitude of the former cops (Sgt South!) didn't help things either. There are many examples on the planet of towns that got their planning and marketing right and are thriving now. This town? Not so much. And it appears that the powers that be have a strong reason to keep it all as it is. I do like this survey initiative and salute you.	12/24/2018 5:56 PM
4	If the shire/state government were to build a marina on the foreshore, not only would it protect tbe current assets along the foreshore, it would attract huge tourism $$$. All the old dinosaurs who have the time to attend shire meetings and have voted it down in the past, need to be ignored or nullified. The future of this town relies solely on tourism. A marina would not only protect our foreshore, it would attract tourism dollars. And if rising sea levels cause a problem for private land owners, tough titties. Thats their problem and the rest of us shouldn't be made to suffer (financially) because of their shortsightedness. Their insurance should cover it and if they're not insured, again, why shouldthe rest of us suffer for their idiocy? Shire owned assets are all insured (?) So there should be little to no cost involved in upgrading/ replacing the jetties, boatramps, bbqs and other ammenities which also draw tourists to our town.	12/21/2018 11:58 PM
5	leading questions	12/21/2018 8:15 PM
6	Great town i love it i will be moving there soon	12/21/2018 6:35 PM
7	What about planning something like a marina that todays present population can use rather than planning and wasting money on something that MIGHT happen over the next 100 years.	12/21/2018 1:10 PM
8	Just leave it alone	12/21/2018 10:19 AM

APPENDIX G
PUBLIC CONSULTATION SUMMARY

Two submissions were received during the public consultation period. These two submissions are attached to this appendix and discussed below.

G-1 Submission 1

The full submission is presented in Table G-1.

TABLE G-1 SUBMISSION 1

Re Coastal Management of potential rising sea water. I strongly recommend that the council not take any more action with regards to the threat. Reason being that we have always had an in-inundation threat from extreme events like cyclones and always will have. The community will pull together in time of need and repair itself as it has done after previous events. While acknowledging climate change is taking place and has always been, there is little if any historical data to support the current predictions. These events are only one in 30-50 years.

There is a wealth of research and data providing evidence of climate change. Some of this can be found at the Intergovernmental Panel for Climate Change (IPCC) website:

https://www.ipcc.ch/reports/

A summary is also contained within IPCC (2014), the document referenced in this report.

The data indicates the frequency and intensity of extreme events will increase. This means the inundation events the town has experienced historically have a higher chance of happening going forward, with a greater impact. In addition, the average mean sea level is predicted to rise by approximately 0.3m over the next 30 years, which would lead to the impact of storms reaching up to 30m further inland than they presently do.

This CHRMAP aims to develop a plan to enable the community to reduce the impact during these events.

G-2 Submission 2

This is a detailed submission, and as such is responded to by the three main statements that are made at the end of the submission. Other components of the submission are referred to and responded to in the context of these three statements. The full submission is attached to the back of this appendix.

G-2-1 Concern 1: Coastal Process Allowance

TABLE G-2 EXTRACT OF CONCERN 1 FROM SUBMISSION 2

On the basis that Denham is not a "sandy coast", the Coastal Process Allowances for 2030, 2050 and 2118 should be adjusted by Water Technology with consideration given to the variation in local coastal processes and driving forces within sheltered inland waters as per SPP No. 2.6 State Coastal Planning Policy - Section 4.8.

Classification of Coastline & Application of SPP2.6

Water Technology agree with the statement that Shark Bay has sheltered shorelines, with low energy beaches protected somewhat by seagrass banks, but more so by the shallow intertidal flats. This protection has been accounted for in the coastal processes allowance as further outlined below.

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The bay, whilst sheltered, can still receive wave energy propagating through the gaps between Dirk Hartog and Dorre Island (approximately 25km wide), and, to a lesser extent, Bernier Island and the mainland coast (approximately 40km for the purpose of wave penetration). To the south of Denham, local, wind generated waves can form with a fetch of 35-40km; the dominant wind direction at Denham is from the south. The 100-year ARI synthetic cyclone used in the SBEACH modelling to calculate S1 (the response due to storm erosion) generated waves approximately 2.5-3 m in height in 5m of water offshore from Denham. This was then brought into shore over the tidal flats using the SBEACH model.

It should be noted that significant wave height (H_s) represents the mean wave height (trough to crest) of the highest third of the waves during a given time period. The maximum wave height (H_{max}) experienced during a storm would be higher. The ratio of H_{max}/H_s is typically in the range 1.6 to 2.2.

As such, it isn't appropriate to classify the Denham coast as "tidally affected inland waters". Tidally affected inland waters are considerably more sheltered. For example, the Swan River Estuary, the Princess Royal Harbour (Albany) and the Peel-Harvey Estuary where wave energy is substantially restricted.

The model created for this study does take the unique properties of Shark Bay into account. The full bay is included in the model, as is the entire northwest shelf (Figure 4-1 of Coastal Hazard & Vulnerability Assessment (Appendix C of this document). This includes the shoals and tidal flats in the nearshore at Denham. As such, the protection afforded to Denham from wave energy is represented by the significantly lower 100-year ARI wave height compared with typical open ocean conditions on the west coast of Australia.

Seagrass does have a wave mitigation effect, however with sea level rise this will reduce. Deeper water means the waves "feel" the seabed less and therefor the energy reduction is also less. For the purpose of assessing the coastal erosion hazard, DoT recommends modelling the storm response assuming marine vegetation such as seagrass beds and mangroves aren't present, as there is no guarantee it will remain between storms or under future conditions, thus removing the wave attenuation properties.

The submission references papers by Nahas et al. (2005) and Hetzel et al. (2015) that discuss the mixing phenomena in Shark Bay due to tides, wind and evaporation. They contain no mention of extreme water level or coastal geomorphology processes. Whilst Shark Bay exhibits some highly unusual mixing characteristics, these processes are not inherently related to extreme inundation or erosion events.

In summary, Denham should still be classified as 'sandy coast' rather than 'tidally affected inland waters' due to the potential for wave energy exposure in a cyclone.

Geological Setting & Susceptibility

The coastline at Denham does appear to have underlying rock. However, the horizontal and vertical spatial extent is not currently known. According to the definitions provided in SPP2.6, the Denham coastline could be characterised as "Mixed sandy and rocky coasts", most likely "discontinuous rocky coast". However, SPP2.6 also states:

"The allowance for the current and future risk of erosion should be based on a geotechnical assessment of the shoreline stability. The geotechnical assessment should include consideration of: slope elevation, slope angle, durability of material, consistency of material, angle of bedding layers and thickness of bedding layers."

For this reason, Water Technology have recommended that a geotechnical assessment be carried out to determine the extent of the rock layers, and their likelihood to contribute to protection at Denham. This is noted in both our Establish the Context Chapter Report (Appendix B), our Coastal Hazard & Vulnerability Assessment Chapter Report (Appendix C), and our Knowledge Gaps and Recommendations section of this report, Section 8.6.

For steep slopes, SPP2.6 notes that *"coasts may also be subject to coastal recession as a result of slope failure."* Given the unknown geological setting of this area, no reduction in the erosion allowance was included in this assessment. However, it is acknowledged that the presence of bedrock may have an impact on the level of erosion in the vicinity of and to the west of the Seaside Denham Seaside Caravan Park. It is for this reason that we recommended the geotechnical assessment.

For the low-lying areas along Knight Terrace, the presence of bedrock will not have the limiting impact on erosion, as during a storm these areas will be inundated.

Eliot et al. (2012) prepared a report for the Department of Planning (now Department of Planning, Lands and Heritage) and the Department of Transport to determine the vulnerability of landforms on the Gascoyne coast to changing environmental conditions, including predicted sea level rise. This document was referenced in the submission. Careful review of this report highlights the risk of applying broadscale geological and geomorphological classifications to highly localised studies. Whilst the area including Denham was rated low susceptibility, their assessment of the Denham townsite area is shown below:

The cell has low susceptibility and low instability. Across the cell, there is a low vulnerability with risks including inundation and foredune plain retreat caused by alteration to sediment supply likely to provide low constraints to coastal management.

However, there are landforms within the cell that are more unstable and hence are likely to provide greater coastal planning constraint, such as the storm ridge and tidal flat on which the original townsite was constructed, including the reclaimed foreshore of Knight Terrace. This low-lying area will be prone to increased inundation and consequently shore retreat due to projected sea level rise. Without adequate adaptation, a rise in sea level and associated rise in groundwater levels may progress the landforms to a tidal flat similar to the coast north of the Oceanarium (Figure G-4; Figure 6-7).

In the absence of adequate engineered structures the storm ridge would migrate landwards during inundation events, with increased frequency due to higher sea levels. The rate of retreat is affected by the underlying rock structures, with low elevation or discontinuous rock features potentially enhancing rates of erosion. The subtidal terrace is also likely to rise and narrow in response to rising sea level with potentially altered rates of sand and shell supply from the adjacent seagrass beds and nett northerly sediment transport rates along the terrace and beachface (bar migration).

In summary, the following knowledge gap recommendation was made in our CHRMAP, in line with the request of the submission: Collection of geotechnical data to confirm the risk of erosion in coastline Section 4. This is in line with our initial recommendations. It is noted that the presence of bedrock in coastline Sections 1 to 3 will not significantly alter the risk profile. These low-lying areas will still be inundated under extreme events, and the coastline will recede correspondingly.

The classifications and current assessments are in line with the local coastal processes, SPP2.6, and state government requirements.

Calculation of S3 – Erosion due to Sea Level Rise (Use of the Bruun Rule)

The referenced paper by Cooper and Pilkey (2004) presents an analysis on the shortcomings of the Bruun Rule and its application to shoreline evolution. Following this paper, further research has been done to investigate potential shoreline evolution, summarised in review papers by Fitzgerald et al. (2008) and McInnes et al. (2016). Localised physical models (e.g.: Woodroffe et al., 2012) and probabilistic models (e.g.: Gutierrez et al., 2011, Ranasinghe et al., 2012) have been put forward as alternative methods to the Bruun rule, with results suggesting the Bruun rule may be conservative in those instances. However, the use of such methods was not suggested by Water Technology in the present study for two main reasons:

1. Deriving defensible results from such methods with reasonable levels of uncertainty would require more site-specific data then available at present.

2. The WAPC's SPP2.6 specifies the use of the Bruun rule for sandy coasts; "*The allowance for erosion caused by future sea level rise on sandy coasts should be calculated as 100 times the adopted sea level rise value of 0.9m over a 100-year timeframe or 90 metres. Consideration should be given to* ***increasing*** *the allowance where the impact of obstacles (natural or manmade) may influence future trends by reducing updrift longshore sediment transport".* This same allowance would also be required for Denham if given a classification of discontinuous rocky coast or tidal reaches of inland waters; "*The allowance for erosion on tidal reaches of inland waters should generally be determined using the methods specified for sandy, rocky, and mixed sandy and rocky coasts".* With the data available at present, reclassification of the coastline to mixed sandy or rocky coasts, or inland waters would result in **no change to the final erosion assessment**. In this case, no sufficient evidence could be found to not use the SPP2.6 recommendation for sandy coastline under SPP2.6.

In summary, the Bruun rule has been used here due to the requirements of the SPP2.6 and the paucity of local field observations (a primary limitation of this study). Water Technology acknowledges that the Bruun rule is an empirical formula used to indicate potential areas of risk (and not future coastline position) and has been found to be conservative in recent scientific studies. The CHRMAP could be considered the first step towards a more rigorous study that could be implemented to provide sufficient evidence to the WAPC and DoT to override the use of SPP2.6 for the case of Denham. The Shire should consider the impact of the present recommendations and the cost of future work before proceeding with future studies.

G-2-2 Concern 2: Calculation of S4

TABLE G-3 EXTRACT OF CONCERN 2 FROM SUBMISSION 2

The 500-year inundation storm surge model should be recalibrated by Water Technology to include the only TC cyclone (TC Hazel) that impacted Denham and is also recorded in the Carnarvon water levels.

Cyclone Hazel was one of the events used in the model calibration by MRA (2014). This applied the anecdotal water levels observed in Denham during the event, that is, a peak level of 1.9m AHD. If data at Carnarvon was obtained for this cyclone, the model could be re-simulated and compared to this dataset. However, the focus of the study is at Denham and therefore it is most important that the water levels are replicated there – as they were in the MRA (2014) model calibration.

Calibrating a model to a dataset some 115km away is not best practice. The only instance this would be carried out is if there was no data locally, as it does provide an indication of general model performance.

The modelling undertaken by Water Technology utilised the cyclone tracks generated by MRA (2014), and hence the model applied in the CHRMAP has already been calibrated including the effects of TC Hazel.

A more valuable exercise would be to recalibrate the model upon collection of local data at Denham under future cyclones. This is the aim of the recommendation made in the CHRMAP to collect local wave and water level data at Denham. During the recalibration process, the other pertinent recommendations made by Bruce Harper in his Peer Review can also be applied.

SPP2.6 states: *The values given for each factor should be based upon the best available data and be a conservative estimate of that factor and include allowance for uncertainty*.

The present uncertainties cannot be resolved without additional data recorded at Denham – as per our recommendation. The existing level of 4.2m AHD represents the level based upon the best available data, and is a conservative estimate that includes an allowance for uncertainty.

G-2-3 Concern 3: Calculation of S2 (Historical Shoreline Movement)

TABLE G-4 EXTRACT OF CONCERN 3 FROM SUBMISSION 2

The Historic Shoreline movement trends need to be adjusted to take historic sediment pulses into account.

For this assessment, we examined long-term changes to the vegetation line using the supplied aerial images from DoT and Landgate, as described in Section 5.2 of the Coastal Hazard & Vulnerability Assessment Chapter Report (Appendix C of this document). This does take into account natural, large scale sediment pulses that have a duration long enough for vegetation to form (and thus are considered stable). A detailed description of the methodology can be found in Section 5.2.2 "Historical Shoreline Change Calculations".

This analysis was undertaken in consultation with Department of Transport coastal engineers. The advice provided was to remove the influence of the dredge spoil placement in Coastline Section 4 as this cannot be guaranteed to continue in the future. As per SPP2.6, planning for a CHRMAP should not lead to legacy issues. Assuming that the dredge spoil renourishment will continue for the next 100-years is an inappropriate assumption, especially as there is presently no formal arrangement for this to occur.

G-2-4 General: Implementation of Special Control Area & Notification on Title

Implementation of Special Control Area (SCA)

Please refer to Section 6.2 of this document for a description of the planning adaptation options. The Adaptation Option Identification Chapter Report provides a further description of the purpose of the SCA (Section 3.3.2 of Appendix E). An extract is provided below:

The purpose of the SCA is to provide guidance as to the appropriate scope of land use and development to be permitted within a coastal erosion and inundation hazard risk area. Its objectives would be:

a. To ensure land in the coastal zone is continuously provided for coastal foreshore management, public access, recreation and conservation.

b. To ensure public safety and reduce risk associated with coastal erosion and inundation.

c. To avoid inappropriate land use and development of land at risk from coastal erosion and inundation.

d. To ensure land use and development does not accelerate coastal erosion or inundation risks; or have a detrimental impact on the functions of public reserves.

e. To ensure that development addresses the Denham Townsite CHRMAP prepared in accordance with SPP2.6 and prepared in accordance with the Denham Townsite CHRMAP.

The SCA would include additional provisions (over and above or overriding provisions for development not within the SCA), such as:

a. All proposed development within the SCA requires approval. (This would include development that would not ordinarily require development approval under the scheme).

b. Approval to be issued on a temporary or time limited basis. (The applicant could later apply for a further approval, which could be granted if the risk from coastal processes was still considered acceptable).

c. Referral of applications. (Any planning application should be referred to the Department of Transport, the Western Australian Planning Commission and any other relevant authority for advice and comment on the coastal risk.)

d. Minimum finished floor levels (FFLs) and/or other development standards. (4.2 metres AHD has been identified as the appropriate minimum FFL).

The Draft CHRMAP put out for public comment defined the extent of the SCA as "delimited by the position of either the 2118 coastal processes setback line or the inundation extent of the 500-year ARI event in the year 2118, whichever is the more landward". To better acknowledge the limitations of the erosion hazard line, this should be defined by simply the 500-year ARI inundation event in the year 2118. The erosion hazard can then be separately assigned to properties at risk within the next planning epoch, as per the recommendations in Section 7 of this document:

- Prevention of further development for lots within the erosion hazard zone of the next epoch (i.e.: staged prevention of development, initially for lots at risk by 2030, then later for lots at risk by 2050 if hazard triggers are reached). This criterion may be relaxed for lots inland of protection structures as long as the new development and protection structure design lives are taken into account.
- Requirement of houses damaged or otherwise triggered (see Section 6.4.1) by coastal hazards to be relocated or rebuilt out of the hazard zone.

In this way, the erosion risk adaptation is staged so that only assets located within the hazard line of the next epoch are affected, and adaptation actions are based on triggers. Currently, there are no residential assets located in the predicted 2030 hazard zone. Any uncertainties associated with the definition of the hazard zone are allowed for, as long as the hazard zones are redefined regularly, as new data and climate science information comes to hand.

The requirements under the SCA for inundation are the same as that already defined in the current Shire Planning Scheme, i.e.: no change to the FFL has been recommended in this study.

Notifications on Title

Please refer to Section 6.2 of this document for a description of the planning adaptation options. The Adaptation Option Identification Chapter Report provides a further description of Notifications on Title (Section 3.3.4 of Appendix E). An extract is provided below:

"Section 70A of the Transfer of Land Act 1893 and Section 165 of the Planning and Development Act 2005 enables a local government or public authority to cause a notification to be placed on the certificate of title of land to make landholders and future landholders aware of a factor that may affect the use and enjoyment of the land. The process requires the written consent of the landholder and payment of a fee, so it is usual for the requirement for placement of a notification to be a condition of development or subdivision approval. However, placement of a notification on the title does not have to be tied to an application and could take place at any time with owner consent."

This indicates that there is no immediate impact on the majority of current landholders with respect to this action.

G-2-5 State Government Response

As part of the review process of this document, both the Department of Transport (DoT) and Department of Planning, Lands and Heritage (DPLH) were provided the public submission and Water Technology's draft response. DPLH comments were included in this final report version across the relevant sections of the document; DoT's response is included below:

Thank you for forwarding DoT the Denham CHRMAP's public submissions and sharing Water Technology response.

The Coastal Hazard Assessment component of this CHRMAP project was funded through DoT's Coastal Adaptation and Protection (CAP) Grant scheme 2017/2018 round. We have been working closely with Water

Technology and the Shire of Shark Bay on this component of the CHRMAP since DoT co-funded this project with the Shire. We have also been involved with the subsequent components of the CHRMAP project as we were requested to be a part of the Steering Committee for the project.

We note that there have been some concerns on the methodology, the hazard maps and what it means for the Denham community in terms of implementation. This is understandable. This is the reason why public consultation is a key component of any CHRMAP project so that issues can be identified and hopefully by working together, sustainable and workable solutions can be planned for and the Shire and the community are prepared for future changes.

We would like to point out that the methodology prescribed by SPP2.6 is used to come up with a conservative allowance for coastal hazards so it can be used to identify risks and plan for them. This method is not intended to come up with the best estimate of shoreline position at a given timeframe. SPP2.6 (Section 4) states that "The values given for each factor should be based upon the best available data and be a conservative estimate of that factor and include allowance for uncertainty. As knowledge improves, the WAPC in consultation with and agreement of the Department of Planning will update the values and methods". In order to refine the allowances for coastal hazard, the CHRMAP data collection recommendations can be implemented and after sufficient period of data collection, the data can be reviewed and potentially used to update the CHRMAP.

On the specific concerns:

- *The study area doesn't seem to have visible rock outcrop/platform. Without further geotechnical investigation as evidence, the assessment of the project site should be treated as sandy coast as per SPP2.6. Further details are outlined in Water Technology's response.*
- *As discussed in Water Technology's response, this area is not considered as tidal reaches of inland waters under SPP2.6.*
- *S3 allowance methodology. Water Technology's response have detailed the reasons behind the methodology used for S3 allowance. It is acknowledged the methodology has limitations. However due to lack of alternative defensible methodology presented by the scientific community, the conservative factor of 100 was specified by SPP2.6.*
- *S2 allowance. As per Water Technology's response, DoT's dredging operation in the area is very infrequent and should not be relied upon for future planning. Since the facility was built, there were only four significant (dredging volume more than 30,000 m^3) dredging campaigns completed at the site.*
- *Inundation level. As discussed in Water Technology's response there are limitations in using available datasets, which led to the CHRMAP recommendation to collect local data. The Shire and DoT is currently discussing installation of water level measurement at Denham, which may assist with refining this in the future.*

In summary, we are satisfied that the CHRMAP has been completed using best currently available information. The purpose of the project is to identify a conservative allowance for coastal hazards to allow risk identification and future planning/risk management to happen. The intent of the assessment was not to give a best estimate of shoreline position at a given timeframe. The CHRMAP recommendations regarding data collection/monitoring hopefully can be implemented as soon as possible, pending the Shire's decision and resource availability. Other implementation actions seem to be trigger based, which the recently commenced coastal monitoring can assist with.

G-2-6 Summary

The adaptation options recommended within this CHRMAP aim to minimise the impact of coastal hazards to the community as a whole, as well as retaining the coastal values of the town. As per SPP2.6: Successful coastal zone planning today will ensure that current and future generations of Western Australians can benefit from the opportunities presented by the values and resources of the Western Australian coast.

As noted earlier, if the Shire chooses not to adopt the recommended adaptation measures, the impact on the community could be significantly greater than that if a planned approach is taken. Inaction in planning for long-term coastal hazards are likely to result in far greater economic losses, community discontent, safety issues and potential legal action.

The study presented for Denham represents a best practice approach that adheres to the relevant policies, and takes into account the site-specific conditions at Denham using the available data. It has been peer reviewed by Department of Planning, Lands & Heritage, and the coastal engineers at Department of Transport.

Key points for this submission are as follows:

- It is noted that the Finished Floor Level (FFL) in the Shire's Planning Scheme is not recommended to be changed. This was put in place before the outcomes of the study were determined. Without any additional water level data with which to calibrate the models, this cannot be reduced or changed.
- Use of the Bruun rule is specified by SPP2.6.
- Denham should still be classified as 'sandy coast' rather than 'tidally affected inland waters' due to the potential for wave energy exposure in a cyclone. In fact, at present, reclassification of the coast type would result in no change to the erosion assessment methodology and results.
- Previous assessments agree that the low-lying areas of Denham are vulnerable to inundation and erosion at present which will be exacerbated by sea level rise.
- Unknown geological features may enhance local rates of erosion.
- An SCA is recommended immediately to allow for additional consideration of any proposed development. This is recommended to remain in place while a long-term adaptation strategy is selected by the Shire. Selection of a long-term adaptation strategy should not be rushed and should involve the community.
- Trigger-based adaptation strategies have been developed to determine when to implement certain strategies (e.g.: when to retreat/protect). In addition, the SCA allows for better development control within the hazard zone.

We note your concerns regarding emotional and financial burden. These are valid concerns that have been directed to the Shire. The final decision, including consideration of potential impacts to members of the community, lies with the Shire.

In adapting to the impacts of climate change, it would be impossible to avoid any impact, financial or otherwise, to the community. The main aim of planning for the future now is to reduce the burden through long term adaptation that allows for community values to be upheld throughout the planning timeframe. This is the goal of SPP2.6.

References are included in Section 10 – main references section for this document.

05/02/2020

Shire of Shark Bay
Paul Anderson
Chief Executive Officer
Via Email: ceo@sharkbay.wa.gov.au

Dear Mr Anderson,

RE: Denham Town Site CHRMAP

Thank you for the opportunity to comment on the Denham Town Site CHRMAP. We support 11 of the 13 recommendations of the CHRMAP "Short & Long - term Implementation Plans" (Table 8.4 page 43 Denham Town Site CHRMAP Final Report, 2019).

However, we are concerned that the potential implementation of a Special Control Area, as currently designated by Water Technology, is based on incorrect assumptions, that are not scientifically defendable. These limitations could place many assets incorrectly into a hazard area resulting in the inappropriate determination of notifications on titles (under Section 70A of the *Transfer of Land Act 1893*) since the definition "*all land located seaward of the 100-year hazard line*" (Section 6.4.2, p 34; CHRMAP Final report, 2019), depends on the veracity of the assumptions that underlie the mapping and modelling. Consequently this will likely place unreasonable financial, and emotional burdens on the owners of these assets under the 'user pays' system.

The approach taken by Water Technology (CHRMAP Final Report, 2019) does not take into account the site specific conditions in Denham. Specifically the coastal classification used by the consultants to determine the S3 erosion factor component as required by the *SPP2.6 Schedule One Calculation of coastal processes* is not justified in the Denham setting. The consultants based these erosion factors on the coastline being classified as a 'sandy coast'. Significantly the Denham beaches, designated as WA 1339 to 1341 by Short (2005), are recognized as "rock + sand flat" (p 302; Short, 2005) beaches as part of the Western Australian sheltered beach system, and are allocated to a tide-dominated beach setting (Short, 2005). Shark Bay is widely documented to have very sheltered shorelines, with extremely low energy beaches protected by fronting seagrass banks (Short, 2019). Studies of the hydrodynamics within Shark Bay have long stated that the embayment structure is that of an inverse estuary with the metahaline state in the waters around Denham (Logan and Cebulski, 1970; Nahas, 2005; Hetzel, 2015) providing clear evidence of the dominance of inland water processes at this location and as such it should be allocated to the *SPP2.6 Schedule One Calculation of coastal processes* coastal classification of 'tidally effected inland waters'. The consequence of ignoring these well documented and readily available studies of the conditions around Denham (both circulation and beach state) is that the 'sandy coast' classification is an open marine model with potential for significantly higher and likely unrealistic, erosion rates than will be seen at the Denham Town Site.

The use of an open coast 'sandy coast' framework in this setting goes against the SPP2.6 guidelines which state that the 'sandy coast' erosion rate, " *methods are principally derived for open ocean coasts and case by case consideration should be given to variation in underlying coastal processes and diverse forces within sheltered inland waters*" (p16 SPP2.6). No case by case consideration is evident in the work done by Water Technology.

Indeed the consultants have ubiquitously applied the Bruun rule (see discussion in Cooper and Pilkey 2004) to determine the position of the "2118 Coastal Processes Allowance" line on the map on the basis that SPP2.6 recommended its application. However, this recommendation is suggested only in the case of open "sandy coasts" with Schedule 1 of the policy placing a caveat on the case of estuaries such as Denham Sound " *The allowance for erosion on tidal reaches of inland water should generally be determined using the methods specified for sandy, rocky, and mixed sandy and rocky coasts. It is however, acknowledged that these methods are principally derived for open ocean coast and case-by-case consideration should be given to the variation in underlying coastal processes and driving forces within sheltered inland waters*." (Section 4.8 p17, SPP2.6)

The use of the Bruun rule has allowed the "2118 Coastal Process Allowance" line to reach an approximate elevation of at least 24 m AHD to the west of the caravan park, well above any likely extent of coastal processes based on the modelled future projections under IPCC 2014 given the geology of the setting. What's more despite recognizing that a rocky scarp extends steeply upwards from around the 4m AHD contour that "may limit the level of erosion" and that it is "*particularly the case seaward of the Denham Seaside Caravan Park, and to the west around to the public lookout, where the scarp line is quite close to the existing shoreline*." (p 18, Appendix C; CHRMAP Final report, 2019) no sensible adjustments to the position of the "2118 Coastal Process Allowance" line have been made.

Schedule 1 of the policy states that "C*onsideration should be given to the cause of shoreline movement trends*" (Section 4.4.1 p 15 SPP 2.6) when determining the S2 erosion component. It is clear that there has been no credible allowance given for the processes that locally operate to make this setting unique. For example the inclusion of shoreline movement by erosion /accretion waves that may be instigated by storm or dredge spoil alterations at the beach face were not factored in to erosion estimates, and were omitted from a list of coastal processes for the site. The lack of understanding of these local processes, will result in inaccurate application of erosion rates across the different segments.

With regard to assessment of the *'Allowance for the current risk of storm surge inundation (S4 Inundation)'* required under SPP2.6, it is of concern that Water Technology continues to use the MP Rogers and Associates report (MRA 2014) as a basis for their inundation modelling despite the limitations identified by the Systems Engineering Australia (SEA 2019) peer review. "*Whilst every effort was made by MRA to calibrate their hydrodynamic model with TC's measured at other locations (Carnarvon, Useless Loop), uncertainties resulting from a lack of measured data are present in MRA's final report which have been carried through to this project*" (page 39 Appendix C CHRMAP Final report, 2019) PSWL (Peak Steady Water Level).

Three cyclones were used to calibrate the MRA cyclone model, including a single anecdotal report of maximum water elevation at Denham during the passage of TC Hazel (Tropical Cyclone), the other two cyclones (TC Elaine, and TC Narelle) did not result in a measured storm surge in Denham. More detailed data for TC Hazel was recorded at the Carnarvon Tide Gauge during 1979 and could have been incorporated in the model calibration and validation, however, the MRA report failed to recognize it, stating that water level data from Carnarvon is only available from April 1984 to present day. This was despite their report noting that "*As the focus of this study is on the storm surge levels at Denham, further investigation was completed to try and find details of inundation levels within and around the Denham townsite. Information from the BoM provides details regarding TC Hazel which occurred in March 1979. BoM (2014b) notes the passage of TC Hazel resulted in a storm surge at Denham and along the coast south of Carnarvon which lead to building being inundated and people being evacuated within the Denham Townsite. SoSB (2009) states that the peak water level observed at Denham during the passage of TC Hazel was 2.7 mCD (around 1.9 mAHD)"* (p 5 – Denham Inundation Levels MRA 2015). Water Technology also did not recognise that the water level data at Carnarvon had recorded the 1979 TC Hazel storm surge, stating that the available water level data from DoT was from the period 1996 to 2018 (Table 3.1 Available data – Appendix B; CHRMAP Final report, 2019). It is unclear as to why both MRA and Water Technology were unable to locate the full water level data from Carnarvon as these data are readily available at the WADoT from 1965 to present day and are reported on in Fandry et al (1984), Hubbert et al (1991) and Eliot (2012). While there are some gaps in the data set prior to July 1989, key to note is that the maximum recorded water level ever recorded was observed on 13 March 1979 during the passage of TC Hazel, and that this cyclone directly passed over Denham Sound and so its full bay wide, and significant, record of impact should have been used to generate storm surge information.

While Water Technology acknowledges the issues with the MRA report they suggest that *"the project scope and budgetary constraints may have restricted the detail of the study*" (p 16 -Appendix B, CHRMAP Final report, 2019). Water Technology states that they "*believe the most effective approach is to use the modelling to identify triggers, and their corresponding coastal management action.*" (p 16, Appendix B; CHRMAP Final report, 2019). However, the final product of their modelling approach is used to generate the 500-year ARI Inundation Assessment 2118, and this is used conjunction with the " 2118 Coastal Process Allowance" to determine the boundary of the Special Control Area's (SCA). "*Cover all land identified as being at risk of coastal erosion and / or inundation. The SCA would be delimited by the position of either the 2118 coastal erosion setback line or the inundation extent of the 500-year ARI event in the year 2118, whichever is the more landward.*" (p 31, CHRMAP Final report 2019). Thus the use of their modelling clearly goes beyond simply trigger based decision making (see Section 6.2 *"Amend the local planning scheme to introduce a Special Control Area (SCA)"* p 31, CHRMAP Final report, 2019) and inaccuracies within it have financial and social consequences similar to those generated by the inappropriate application of open water coastal classifications within an embayed setting.

Water Technology recommends an Implementation Timeline of 'ASAP' to introduce a Special Control Area with the funding and legal responsibility to borne by the Shire (page 43 Table 8.4 - CHRMAP Final Report). However, we believe that before the Shire amends the local planning scheme to introduce a Special Control Area that the coastal erosion setback lines need to be recalculated with the inundation extents determined by a scientific valid evidence based approach rather than the simplistic approach that Water Technology have inappropriately applied in this unique setting.

The Special Control Area as designated by Water Technology has likely incorrectly identified assets not at risk due to coastal erosion and should not be used until the following issues are rectified;

1. On the basis that Denham is not a "sandy coast", the Coastal Process Allowances for 2030, 2050 and 2118 should be adjusted by Water Technology with consideration given to the variation in local coastal processes and driving forces within sheltered inland waters as per SPP No. 2.6 State Coastal Planning Policy - Section 4.8
2. The 500-year inundation storm surge model should be recalibrated by Water Technology to include the only TC cyclone (TC Hazel) that impacted Denham and is also recorded in the Carnarvon water levels.
3. The Historic Shoreline movement trends need to be adjusted to take historic sediment pulses into account

While it is important to ensure that the Shire is compliant with state government obligations, rushing amendments through without a scientifically defendable study will result in both an unreasonable financial and emotional burden on those people effected. Moreover, in order to prevent legal action and low community confidence in the Shire's planning decisions future amendments must be based on robust assessments.

Yours Sincerely

References

Cooper, J. A. G., and O. H. Pilkey. 2004. *'Sea-level rise and shoreline retreat: Time to abandon the Bruun Rule'*, Global and Planetary Change, 43: 157-71

Eliot I., Gozzard J.R., Eliot M., Stul T. and McCormack G. (2012). *The Coast of the Shires of Shark Bay to Exmouth, Gascoyne, Western Australia: Geology, Geomorphology & Vulnerability*, Prepared by Damara WA Pty Ltd and Geological Survey of Western Australia for the Department of Planning and the Department of Transport

Fandry, C.B, Leslie L.M., and Steedman R.K., 1984. *Kelvin-type coastal surges generated by tropical cyclone*', Journal of physical oceanography, 14: 582-93.

Hetzel, Y., Pattiaratchi, C., Lowe, R., Hofmeister, R., 2015. *Wind and tidal mixing controls on stratification and dense water outflows in a large hypersaline bay*. J. Geophys. Res. Oceans 120 (9), 6034–6056.

Hubbert, G.D., Holland, G.J. Leslie, L.M. Manton, M.J., 1991 *A Real-Time System for Forecasting Tropical Cyclone Storm Surges*. Weather and Forecasting 6, 86-97

Logan, B.W. and Cebulski, D.E., 1970. *Sedimentary environments of Shark Bay, Western Australia*.

MRA (2014). *Denham Inundation Levels Storm Surge Modelling Report*, report to the Shire of Shark Bay

Nahas, E.L., Pattiaratchi, C.B., Ivey, G.N., 2005. *Processes controlling the position of frontal systems in Shark Bay, Western Australia*. Estuarine, Coastal and Shelf Science Estuar. Coast. Shelf Sci. 65 (3), 463–474.

Short, A. D. 2005. *Beaches of the Western Australian Coast: Eucla to Roebuck Bay: A guide to their nature, characteristics, surf and safety* (Sydney University Press).

Short, A. D. 2019. *Australian Coastal Systems: Beaches, Barriers and Sediment Compartments* (Springer Nature).

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