Coastal Hazard Risk Management & Adaption Plan

CHRMAP For the Onslow Coast

59916801

Prepared for
Shire of Ashburton

19 November 2017

Cardno
Shaping the Future

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Executive Summary

Like a number of coastal communities in the north west, the town of Onslow is preparing for the threats of climate change and sea level rise to property, infrastructure, the environment and ultimately the viability of the town itself. Historically Onslow was established to service agricultural activities, primarily sheep and cattle grazing within the hinterland, then supported fishing and salt production and more recently mining and oil and gas activities. The town was originally sited in 1885 near the mouth of the Ashburton River, about 20 km southwest of its current location. Following cyclone damage to the critical jetty infrastructure in the early 1920's it was decided to relocate the town to its current location near the mouth of Beadon Creek. This Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) has been prepared to provide a long term view of the possible strategies to adapt to the changing future conditions that will impact the current town.

A key aspect for the future of the town is the threat of steadily rising sea levels, combined with storm events - ocean storm surge, local rainfall-induced flooding and rising water tables – that will affect the viability of low lying areas of the town. In addition, coastal erosion is likely to threaten some infrastructure in the lee of the present Town Beach, including the Bindi Bindi community area. Strategies that might be adopted to respond to these threats at significant future turning points are articulated in this plan.

Development of the Onslow CHRMAP has followed the requirements of WA State Planning Policy 2.6: Coastal Policy (SPP2.6) and supporting guideline documents. A series of 37 recommendations for implementation is tabulated in Chapter 7 Conclusions and Recommendations of this Plan. The key strategies and actions to plan for future adaptation in the immediate (< 5 years) and short term (5-10 years) may be summarised as:

Avoid

Implement changes to the land zonings that are currently covering undeveloped land within the designated 2110 coastal erosion hazard zones.

Update Special Control Area (SCA)

Retreat

Immediate action - Develop an integrated coastal and water management plan to guide stormwater management strategies and planned retreat from the town's flood-prone areas.

Short term - Monitor sea level, coastal vegetation boundaries and storm erosion movements and review the hazard line estimates and strategies for retreat of public and private assets (including the Onslow Salt infrastructure) in the current foreshore zone. Review the foreshore land zone boundaries and adjust, where appropriate, to facilitate retreat of assets within the future foreshore zones.

Accommodate

Immediate action – Establish database of assets in the 2110 flood-prone area including present day value and projected end of life cycle. Identify options for mitigating the impacts of increased flooding, undertake a detailed cost benefit analysis and communicate with the community and stakeholders to agree on preferred options and communicate the significance of residual risks.

Review and adjust local government Planning Controls to ensure proposed developments in the flood prone areas accommodate the future threats and minimise liabilities.

Incorporate coastal erosion and flooding risks into emergency response plans.

Short term – monitor flood levels and extents and review boundaries and water level implications for the Hazard Control Area and planning controls

Protect

Immediate action – Collect data on the geology of the Front Beach hinterland (including the possible sea wall extension to the northeast of the existing seawall) to assess whether the current hazard line estimates can be revised. Liaise with the stakeholders to assess future protect or retreat options at the end of life of houses in the housing estate.

Short term – monitor beach profiles at Front Beach to assist considerations of future beach nourishment options.

Abbreviations and Acronyms

Abbreviation	Description
AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
ANSIA	Ashburton North Strategic Industrial Area
AS	Australian Standard
CHRMAP	Coastal Hazard Risk Mitigation and Adaption Plan
FFL	Finished Floor Level
HSD	Horizontal Shoreline Datum
MCA	Multi-criteria analysis
GIS	Geographical information Systems
MS	Microsoft
SCA	Special Control Area
SPP2.6	State Planning Policy No 2.6
the Shire	Shire of Ashburton
WAPC	Western Australian Planning Commission

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1 INTRODUCTION

1.1 Purpose/ Objectives

Climate change, including sea-level rise, is expected to bring changes to the West Australian coastline over coming decades. To plan for this, all levels of government are putting in place planning processes to ensure that communities understand the risks to values and assets on the coast, and plan to adapt over time.

To demonstrate the change in mean sea level at Onslow water level data collected at Beadon Point tide gauge is shown in **Figure 1-1** along with the projected sea level rise for WA as adopted by the State (DoT, 2010).

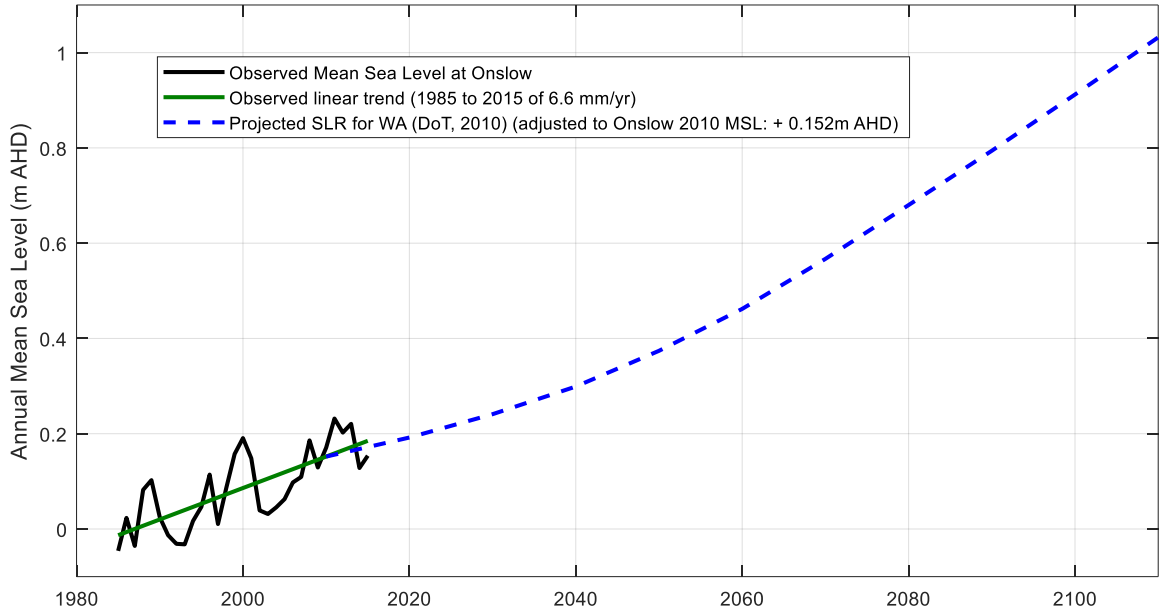

Figure 1-1 Graph showing annual mean sea level at Onslow over the past 3 decades (1985 to 2015), its annual trend and projected sea level increase to 2110 (DoT 2010)

This Coastal Hazard Risk Management and Adaption Plan (CHRMAP) has been undertaken by Cardno on behalf of the Shire of Ashburton (hereafter called 'the Shire') to identify risks and plan responses to climate change impacts for the Onslow coastline.

The purpose of the CHRMAP is to:

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

An example of the possible scenario of future maximum annual still water levels is provided below in **Figure 1-2.** Rising sea levels at Onslow will affect:

- the town stormwater drainage efficiency;
- increase the frequency of flooding of current low lying flood-prone areas;
- rate of erosion of the shoreline;
- overtopping of sea defence structures; and
- increase the groundwater table leading to longer ponding times in the town drainage basins and low lying swales.

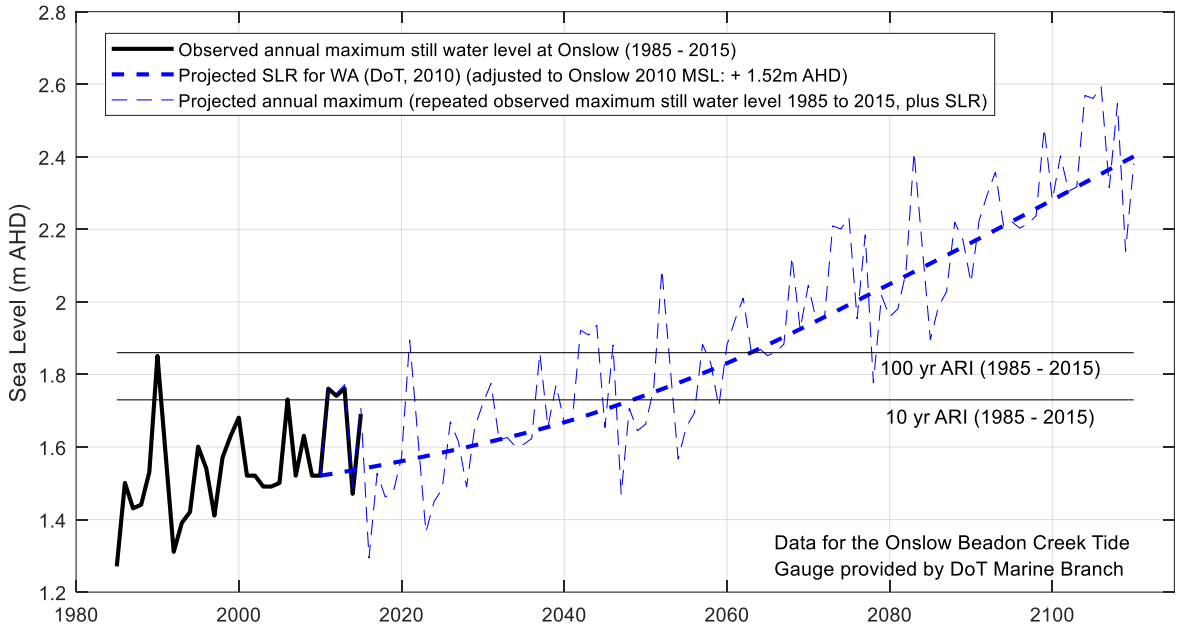

Figure 1-2 Observed maximum annual water level from 1985 to 2015. The observed sequence (1985-2015) has been projected into the future to highlight a possible scenario of future events.

1.2 Overview of CHRMAP Process

The key policy governing coastal planning in Western Australia is the State Planning Policy 2.6: Coastal Planning (2006, herein referred to as 'SPP2.6'), which recommends that management authorities develop a CHRMAP using a risk mitigation approach to planning that identifies the hazards associated with existing and future development in the coastal zone. SPP2.6 (WAPC 2013a) and the SPP2.6 Guidelines (WAPC 2013b) contain prescriptive details, for example in relation to scales of assessment, storm event types and sea-level rise allowances.

The Western Australian Planning Commission (WAPC) has also developed CHRMAP Guidelines which are less prescriptive, but are aimed to ensure that planning is carried out using a risk based approach with due regard for stakeholder engagement, community consultation and education, and that a full range of adaptation options is considered. An overview of the CHRMAP process is shown in **Figure 1-3.**

Coastal planning in accordance with SPP2.6 also needs to take into consideration the requirements of other planning policies, including State Planning Policy No. 2 Environment and Natural Resources Policy and State Planning Policy No. 3 Urban Growth and Settlement. State Planning Policy 2.9 Water Resources also require consideration in relation to the implementation of total water cycle management planning for urban growth and settlement.

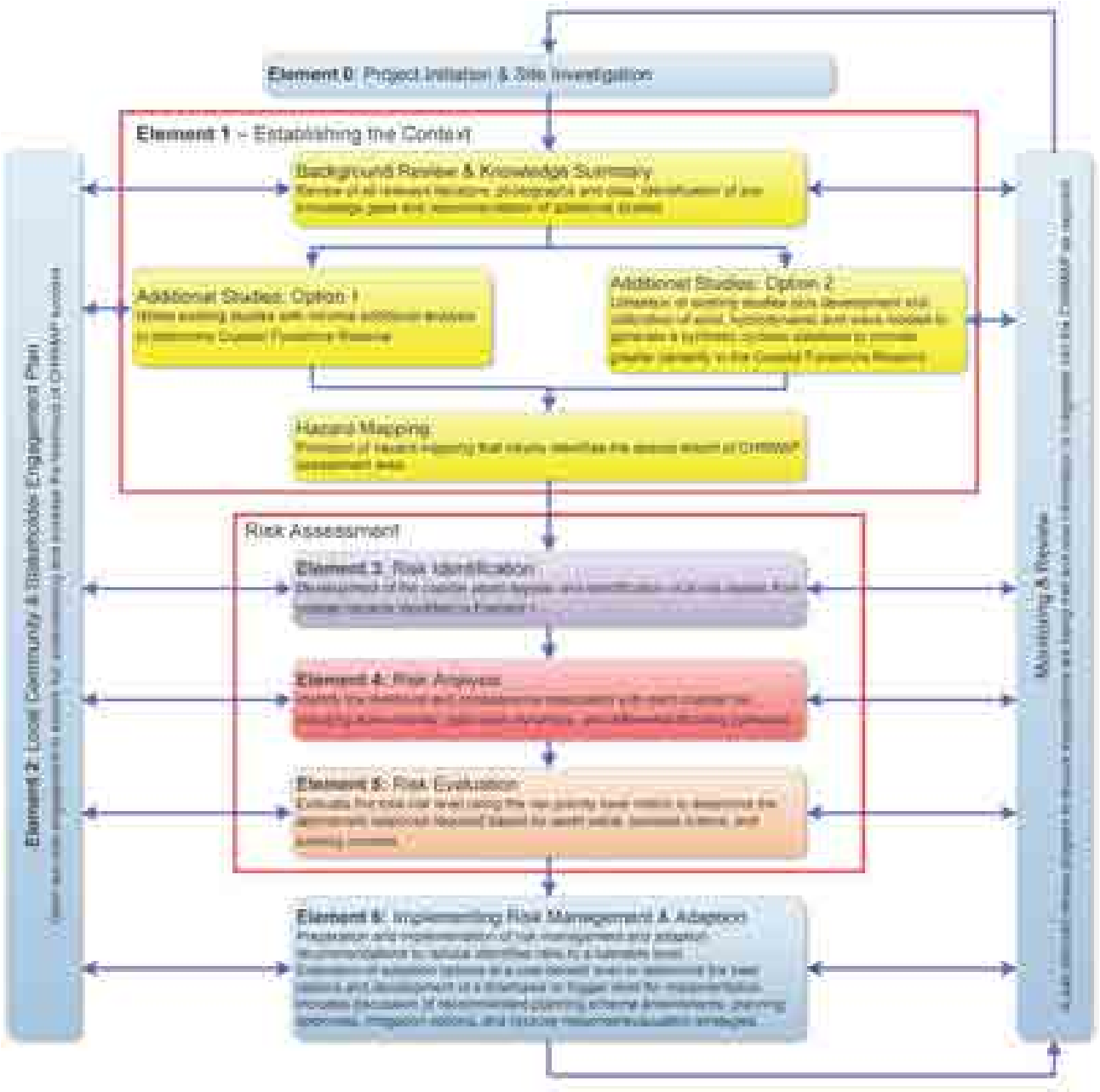

Figure 1-3 CHRMAP methodology flow chart (adapted from WAPC CHRMAP Guidelines)

1.3 Guiding Principles and Concepts

Underlying the CHRMAP process are a number of guiding principles and concepts which are fundamental to understanding the purpose and outcomes of the process.

1.3.1 Equity

Equity is a concept that is central to the purpose of the CHRMAP process. Australia's coastline is highly valued by the community as a public asset, and stakeholders range from individual property owners adjacent to the coast, to all levels of government, and users both within and outside jurisdictional boundaries.

Responsibility for coastal planning lies with both State and Local Government, and in making decisions these authorities need to consider equity of access, equity of enjoyment and equity of public good in terms of budget allocation for coastal protection over and above other community needs.

Equity is also relevant to considerations about how a protection structure (for example a Groyne) might impact on coastal processes. Protection structures may exacerbate erosion immediately adjacent to the structure,

and limit sediment availability for maintaining beaches and community values some distance from the protected area. Coastal protection creates beneficiaries (those who are protected from hazards) and potentially creates disadvantage to others who may be considered to be injured parties. In this regard coastal management has similarities to the management of water rights, if one user takes all the water upstream and leaves none for downstream users then this is clearly not fair and equitable. In a future of eroding coastlines due to sea-level rise, sand for maintaining beaches and former protection buffers for coastal assets is likely to become a valuable commodity. Under the user pays principle it is expected that the beneficiaries of coastal works will bare the costs of such works, both capital and ongoing maintenance. Determining the key beneficiaries and apportioning costs in an equitable and appropriate manner will require further investigation. The challenge is to ensure that planning and management is as transparent and equitable as possible.

1.3.2 Coastal Foreshore Reserve

The coastal foreshore provides beach access, recreation and conservation, is a tourist attraction and provides habitat for native flora and fauna. Importantly, it also provides a buffer to mitigate risks to high value assets such as buildings and infrastructure.

SPP2.6 provides guidance for calculating the component of the coastal foreshore reserve required to allow for coastal processes, based on the 100-year hazard line determined in accordance with SPP2.6, to be contained in an appropriate coastal foreshore reserve (determined in accordance with clause 5.9 of SPP2.6) of greater width to ensure that at the end of the planning timeframe a coastal foreshore reserve is provided which is not exposed to the adverse impacts of coastal erosion and inundation. Development is able to be considered behind this point. In addition to the allowance for physical processes such as erosion, the coastal foreshore reserve includes land allocation for maintaining the values, functions and equitable use of the coast over the 100 year planning horizon (WAPC 2013b). SPP2.6 (clause 7), however, outlines specific instances where certain types of developments may be considered appropriate to locate within a coastal foreshore reserve regardless of the allowance for coastal physical processes.

Permanent and easy public access to the beach and coastal recreation (foreshore) reserves is a fundamental coastal planning objective. The coast and coastal recreation reserves are a public asset which should not, now or in the future, become the de facto exclusive domain of private landowners by virtue of the erosion of coastal reserves or other coastal processes. Coastal reserves should be wide enough that they can still perform recreation and/or conservation functions (according to the reasons for their initial designation) even if they are affected by coastal erosion or diminution due to sea level rise.

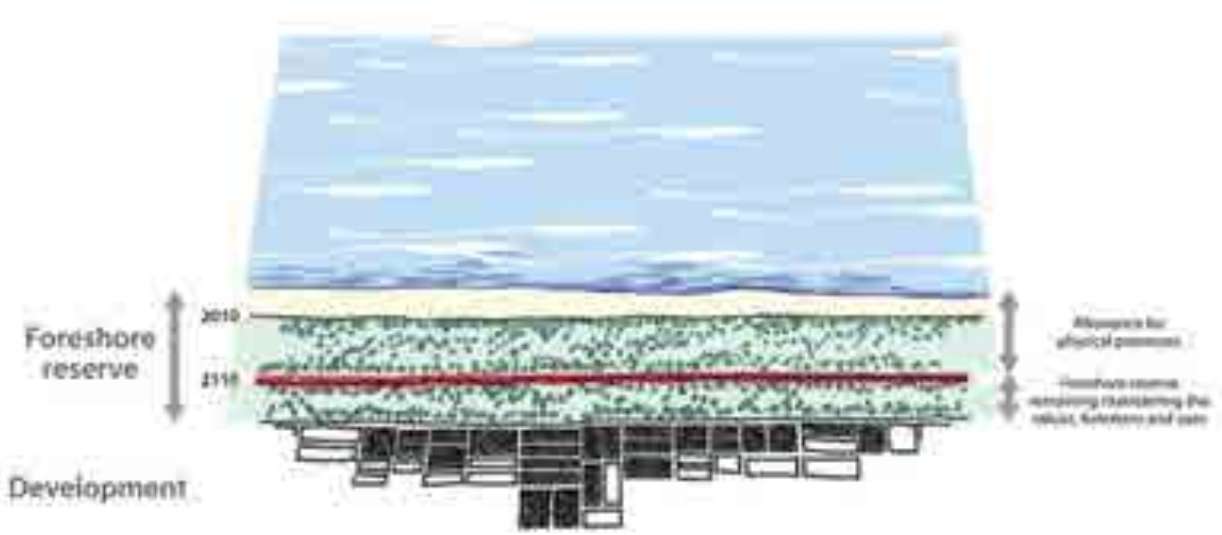

Figure 1-4 Coastal foreshore reserve – sandy coast example (WAPC 2013b)

1.3.3 Rights and Responsibilities

There is no law requiring the government (at any level) to provide protection of private property from natural hazards nor compensation when land is lost to the sea. There are, however, several laws which allow the intervention of governments to enforce eviction if private property becomes uninhabitable or removal of

property if it constitutes a public risk. In the event of coastal erosion causing a property to "fall into the sea", and the land to disappear below the high water mark, the loss is to be borne by the property owner.

Nonetheless, it is the aim of all levels of government to protect the interests of all Australians, and the CHRMAP process ultimately intends to minimise risks and maximize beneficial use of the coast from an economic, social and environmental perspective. In reality, mechanisms for managed retreat are likely to be aided by public monies, and in some instances where public good can also be demonstrated, protection may also be funded. Where the benefits of a particular coastal protection measure is limited to private beneficiaries, there is an expectation that the cost will be borne by those beneficiaries under the "user pays" principle. Again, identifying the key beneficiaries of any coastal works required for future hazard mitigation and apportioning costs in an equitable manner will require further investigation.

1.3.4 Hazards

Sea-level rise is predicted to result in both erosion and inundation of the Onslow area due to seawater encroaching on the land. In this report inundation due to seawater ingress is called "coastal inundation". Erosion and coastal inundation hazards are modelled using oceanographic models.

In Onslow, a secondary hazard exists from freshwater inundation during high rainfall events (such as cyclones). This is related to the issue of sea-level rise due to constraints on drainage at high tide and higher groundwater table levels due to increased sea-level. In this report, inundation from rainfall has been modelled in addition to the modelling of coastal processes, and is called "pluvial inundation".

Details of the hazard assessment are provided in the Coastal Hazard Assessment Report (Cardno 2016a), and key outcomes are summarised in **Section 2.7.1**.

1.3.5 Assets

An asset is defined a useful or valuable thing. As defined by AS 5334-2013, value can be tangible or intangible, financial or non-financial; examples of assets include financial assets, human resource assets, physical assets, and organization reputation. Value includes consideration of risks and liabilities, and can be positive or negative at different stages of the asset's life.

In the current CHRMAP, assets include:

- Natural features such as beaches and native vegetation;
- Buildings and other structures (sheds, shade structures);
- Infrastructure such as fences, lighting, water and sewerage;
- Roads, paths and walkways; and
- Existing protection structures, such as the seawall.

1.3.6 Risk

Risk is defined as a hazardous event or circumstance and the consequences that may flow from it. Risk is measured in terms of a combination of the likelihood of a hazard occurring and the consequence of that hazard occurring. (likelihood and consequence).

1.3.7 Adaptive Capacity

Adaptation is defined by SPP2.6 as:

> "*an adjustment in natural or human systems in response to actual or expected stimuli or their effects, which moderates harm or exploits beneficial opportunities. Adaptation is the means for maximising the gains and minimising the losses associated with coastal hazards over the planning timeframe."*

WAPC (2014) further defines adaptive capacity as reflecting the ability of an asset to change in a way that makes it better equipped to deal with external influences (e.g. coastal climate change impacts).

In this report, adaptive capacity has been assessed in relation to the ability of an asset to be modified to reduce risk (for example raising the height of the seawall) or relocated (for example moving a wooden walkway inland).

1.3.8 Vulnerability

Vulnerability has a specific meaning in the context of risk based approaches to climate change adaptations, in accordance with Australian Standards (AS 5334-2013) and SPP2.6, which defines vulnerability as:

> *"the means the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity. Systems that are highly exposed, sensitive and less able to adapt are vulnerable"*

This report uses vulnerability as the final outcome of the risk assessment process, combining likelihood and consequence of hazards with the adaptive capacity of assets in a stepwise process as summarised in **Section 3.1** and fully described in the risk assessment report (Cardno 2016b).

1.3.9 Temporal scales

Coastal hazard assessment and planning needs consider a number of different timeframes (**Figure 1-5**). SPP2.6 specifies the need for identifying risks and extending planning considerations out to a one hundred year planning horizon, whereas practical planning from the Shire's point of view needs to consider the current planning period (5 year horizon), short (5 - 10 years) and medium term (10 - 25 years). Planning for more than 25 years into the future is considered to be long term.

The need for identifying potential long term risks is important for ensuring these risks are taken into consideration in Onslow's asset management strategy and statutory planning framework. The long term perspective is also important for management of community expectations and gives potentially impacted stakeholders ample time to appropriately manage assets potentially at risk.

This CHRMAP includes predictions of current to long-term risks associated with climate change and predicted "planning pathways" to guide management approaches for vulnerable assets. The planning pathways result from the risk and adaptation options assessment, taking into account the timing of likely impacts, the lifecycle of the asset and any other relevant timing constraints and opportunities.

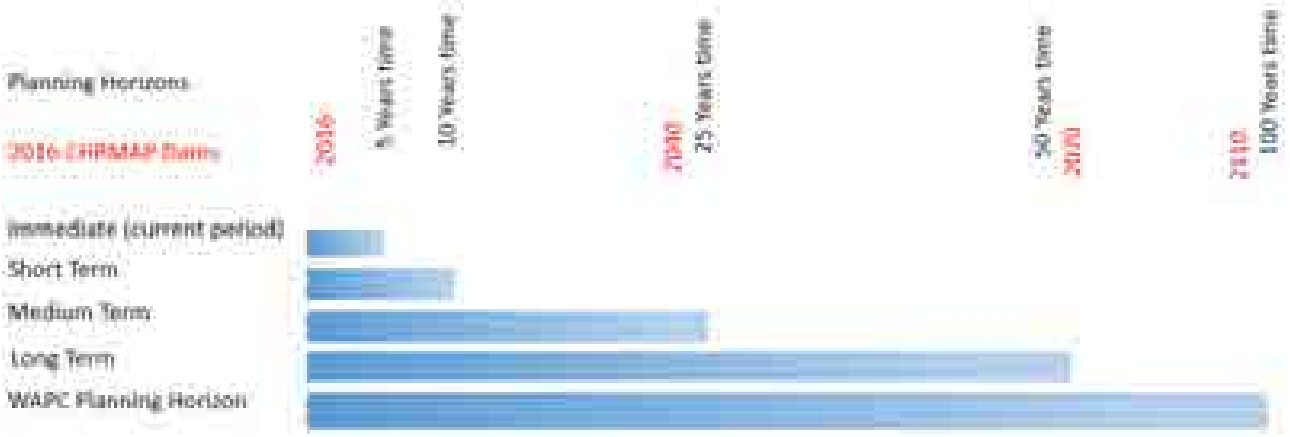

Figure 1-5 Coastal planning timeframes used in this report

1.3.10 Spatial scales

The CHRMAP process also considers a range of spatial scales, from the individual asset scale to groups of assets that belong to the same functional coastal management unit. SPP2.6 requires that hazard assessment is carried out at the "coastal compartment" scale, to reflect the reality that modifying one part of a coastline will have impacts beyond the immediate area of the works.

The prescribed methods for predicting future shoreline position (or hazard lines) incorporate a number of assumptions that need to be tested in time to review the predicted hazard lines. Interpretation of hazard lines needs to be approached carefully, since the underlying assumptions used to predict erosion allowances (see **Section 2.7.1.1**), leads to hazard line estimates with considerable variability in scale.

1.3.11 Reactive Management

Reactive (or adaptive) management is the term given to a structured, iterative process of robust decision making in the face of uncertainty (Allan & Stankey 2009). In the CHRMAP context it allows for predictions of

potential impacts and long term planning pathways to mitigate against risks, while at the same time acknowledging that things will change over time. It is certain there will be changes in context (for example population pressures), risk profile (for example occurrence of storm events) and implementation of controls (for example extension of the seawall) that will require adjustments to the type and timing of management response.

The CHRMAP therefore also includes directions for the monitoring and review process and defines triggers for implementation of management actions to manage risk and achieve adaptation objectives in the event of "things not going according to plan".

1.4 CHRMAP Format

This document has been designed to inform the community and provide direction to the Shire for planning for climate change risks facing the Town of Onslow. The structure of the document also allow for the planning context of individual assets or groups of assets to be separated from the main document with Appendices formatted as separate sheets provided for each of the coastal assets.

2 ESTABLISHING THE CONTEXT

2.1 Overview of CHRMAP Area

Onslow is located on the Shire's coastline in the Pilbara Region of northwest WA, approximately 100 km east-northeast of Exmouth and 200 km southwest of Karratha. The Ashburton North Strategic Industrial Area (ANSIA) is located around 13 km to the west of the town; together these areas are two of the Shire's important coastal developments (refer inset in Figure 2-1 for study area and locality plan). The tertiary coastal cell boundaries indicate areas of similar coastal geomorphology. The focus of this study is the town and foreshore defined by the four coastal units (sections 1 to 4 in Figure 2-1) that delineate particular shoreline characteristics.

2.2 Relevant Socio-economic Aspects

Onslow has traditionally been a small town supporting fishing, pastoral and tourism industries as well as a significant salt production facility. Due to the development of the ANSIA and Chevron's Wheatstone Project, the town is expecting significant population growth; LandCorp have recently developed and released a 220 lot subdivision as a first step towards accommodating this growth.

Primarily a service town, the prosperity of Onslow is highly dependent on the commodities market, and the population has a large proportion of transient residents.

It is significant in the context of coastal planning that the Onslow town site was moved in 1923. Old Onslow was situated 18 kilometres to the south-west of the current site. The decision to move the town was made due to repeated cyclone damage and the silting up of the river caused increasing problems with the loading and unloading of visiting ships. The new town-site was gazetted on 10 January 1924, and the residents of Old Onslow moved across in 1925. The new location for Onslow's jetty was better protected from storm damage with the townsite more conveniently located on the coast (http://www.ashburton.wa.gov.au/visit-ashburton/onslow/history).

To adequately plan for the future, and accommodate the increased pressure on the coastal zone from increased development, the Shire has investigated and redefined the 'Onslow Coastal Hazard Area – Special Control Area' which covers a significant portion of the town site, including low-lying coastal areas deemed at risk by previous studies. A key outcome of this CHRMAP is to investigate the extent of this coastal hazard area so that sustainable development of the coastline can occur for the long term and the Shire can maximise its use of the coastal foreshore area.

The area has a long and rich aboriginal heritage of the Thalanyji people and the coastal area was accessed by a number of tribes who inhabited the hinterland areas of the West Pilbara. Native title of lands surrounding the town site is vested in the Buurabalayji Thalanyji Aboriginal Corporation who administer a number of services and local businesses in Onslow. A number of culturally significant sites are located around the Beadon Bay foreshores.

2.3 Relevant Environmental Aspects

The study area coastline is a diverse and, at times, challenging environment that experiences seasonal cyclones with potentially dangerous storm surges. The tidal range at Onslow is approximately 3 m but the extreme meteorological and oceanographic conditions generated in a cyclone have the potential to raise the sea level several metres higher than normal, as was the case during Tropical Cyclone Vance in 1999 (BoM, 2000), and a number of other cyclones (**Figure 2-2**). Flooding is relatively common and the coastal zone can be hazardous, and extreme events such as TC Vance can result in significant ocean inundation and coastal erosion. In addition to ocean storm surge cyclones also dump torrential rains leading to local catchment flooding of the local drainage infrastructure, also known as pluvial inundation.

Figure 2-1 The CHRMAP study area extents shown in yellow (detailed model extent) and red (regional assessment extent); tertiary sediment cell boundaries indicated by the red crosses.

a)

b)

Figure 2-2 Photographs of historical of Onslow town site flooding in a) 1963 and b) 2015

The Shire of Ashburton have been undertaking modifications to roads and stormwater drainage infrastructure to mitigate flooding impacts associated with the threats of the 1 in 10 year Average Recurrence Interval rainfall events. These works are also attempting to keep pace with the effects of rising sea level that is gradually increasing the frequency of flooding in low lying areas. For example, the 1 in 10 year flood event in 2010 is likely to occur more frequently, say 1 in 5 years, in 2030 due to the increase in the sea level that inhibits stormwater drainage. Rising sea level is also gradually increasing the annual mean level of the water table that can influence flooding characteristics and the type of vegetation.

Surface levels at the northwest end of Onslow derived from LIDAR data collected in 2012 and a land surface cross section adjacent Simpson St are shown in **Figure 2-3**. The cross section highlights the low lying area at Third Ave that forms the main drainage conduit for the northwest end of the town.

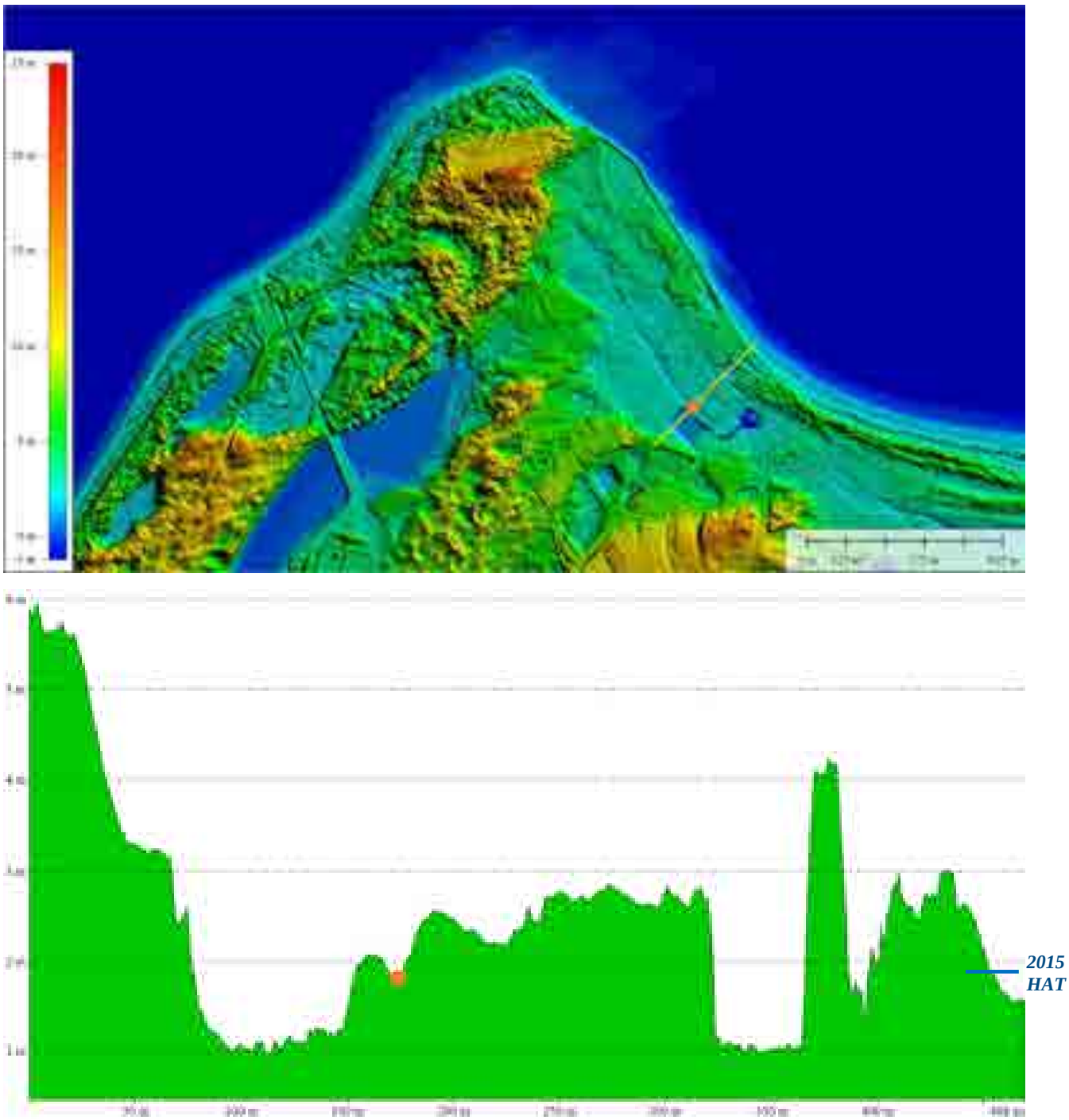

Figure 2-3 LIDAR Surface levels in north west Onslow and a land surface cross section along the section A-B adjacent Simpson St (Vertical Datum is AHD)

Erosion of the beaches and damage to coastal infrastructure is also driven by extreme ocean water levels and wave events that typically occur under tropical low pressure and cyclone weather systems. Examples of the impact of coastal erosion are presented in **Figure 2-4** that shows the loss of beach sands and the erosion escarpment produced by the combined effects of storm surge inundation and large waves associated with Tropical Cyclone Vance in March 1999. With rising sea levels these effects will effectively move the coastline landward threatening coastal habitats and infrastructure.

Figure 2-4 Image showing the erosion escarpment at beach west of Onslow after TC Vance in March, 1999.

2.4 Planning Context and Existing Controls

The key statutory planning document is the Shire of Ashburton Town Planning Scheme No. 7 (TPS 7). This applies zones and reserves to land within the Shire, and outlines the permissibility of land uses, the requirements for development, and the processes for seeking approval for proposed development. Of particular significance to the CHRMAP is the delineation on the Scheme Map of a Special Control Area (SCA); the Onslow Coastal Hazard Area SCA (Onslow SCA). TPS 7 was gazetted in 2004. Amendment 24 to TPS 7 was gazetted on 1 August 2014 with relevant text around the SCA reprinted here:

Under the Shire of Ashburton Local Planning Scheme No. 7 ('Scheme'), much of the land within the Onslow townsite is included with the *Onslow Coastal Hazard Area – Scheme Control Area (SCA)*.

The SCA applies to all land up to 4m Australian Height Datum (AHD) in the coastal zone and 5m AHD in the frontal dune areas of the townsite, between Four Mile Creek in the south-west and Beadon Creek in the north-east.

The Shire is aware that some modification to the minimum AHD is likely due to a review undertaken by LandCorp and other State Agencies. This review is still to be finalised however the Shire is becoming increasingly aware of numerous proposals looming with the SCA.

In areas outside this SCA (Figure 2-5**)**, if the Shire considers that a proposed development could potentially be incompatible with TPS 7 and prone to flood and storm surge events it may still have regard to information about these events when determining applications for planning approval. A considerable part of the Onslow townsite is affected by the Onslow SCA, including all of the town centre, Bindi Bindi Aboriginal Community, much of the older residential part of town on both sides of Third Avenue, both caravan parks, the primary school, hospital site, and most of the oval.

These existing statutory planning and physical controls (discussed below) form the key tools available to mitigate the risks of the identified future hazards. The potential social and economic consequences associated with implementing such changes will require additional analyses to optimise proposed options. The risk analysis considers these tools when assigning risk levels, vulnerability scales and the subsequent mitigation options. For the development of the future strategy options (Appendix B and C) the proposed introduction of planning controls that can minimise exposure to future liability are deemed preferred to physical or structural controls that may currently exist. The future pathway options identified and discussed in Appendix C are then subject to reanalysis of the risk assuming that the option is implemented in the future. This process then leads to an estimate of the residual risk that may remain after implementation of the particular option. Note that each option aims to reduce the risk to some degree that then needs to be assessed in terms of the acceptability of the residual risk. This process includes a number of steps that all include a level of uncertainty that will require refinement in future reviews and investigations. This CHRMAP (2017) documents the first attempt to articulate each component of the risk assessment and proposed mitigation options process to assist Council and the community understand the potential costs of the threat of rising sea level and the complexities of managing these future risks in a viable and equitable manner.

The adaptation process involves an integrated plan to monitor, investigate, implement and review the consequences of particular options as the threat intensifies in the future. The ongoing process then repeats these steps nominally each 5 years to revise the plan and optimise future responses. This approach is therefore a continuous process of adapting to the changing conditions in a measured and proactive way that ultimately aims to reduce the liability of today's decisions.

2.5 Existing Structural Controls

The key existing structural controls protecting the Onslow coastline are the seawall and the Beadon Creek Groyne. In addition to being an existing structural control for protection of the town site against coastal hazards, the seawall is also considered in this assessment as an asset.

The seawall extends from the western end of the town beach to the main drain discharge point near the end of Cameron Ave. The main flood storage basins in the town ultimately discharge through this drain. During extreme rainfall and potentially storm surge events in future, the drain is critical to the stormwater drainage from the western end of the town. Most of the time it is used as a beach access route across the beach berm. To the east of the drain it is appears there is some rock buried beneath the beach berm. It is not clear how far this material extends and its integrity as a protection structure could not be confirmed. Hence, hazard line estimates east of the seawall assumed this area is sand and subject to future erosion. The seawall is a rubble mound structure and as sea level rises may be subject to larger wave attack and failure modes such as slumping of the wall due to undercutting by extreme waves. As these events occur in the future it is likely the seawall will require more frequent repairs and maintenance.

The actual design specifications for the seawall (presumably reported prior to the commencement of the seawall construction in 2002, completed in 2003) were not available at the time of preparing this report. The following typical specifications have been assumed. The seawall design life is assumed to be 50 years and hence the future adaptation pathway will need to address the end of life of the asset in 2053. In addition, the design crest level (assumed to be 3.5 m) was based on wave conditions most likely derived from pre-2000 data sets. The rising sea level will effectively mean that the present day seawall is under-designed for the future conditions and hence more frequent maintenance and refurbishment is likely to be required. This is also likely to require consideration of beach amenity and mechanisms to facilitate retention of beaches for future community such as sand nourishment to maintain an accessible beach.

Figure 2-5 Onslow Coastal Hazard Area Special Control Area

2.6 Existing Hydrology and Stormwater Management

The township of Onslow is situated on a peninsula, with a ridge running north-south on the western edge of the town. The town does not have any significant creek or river systems running through it. Drainage in the township is through a stormwater network consisting of drainage pits and pipes, some open channels and a number of detention basins (**Figure 2-6**). The western end of the town drains through 3 detention basins and ultimately to the town beach through the drain at the end of Cameron Ave.

The release of water from the retarding basins via the drainage network to the ocean is impacted once tide levels rise above approximately 1 m Australian Height Datum (AHD). Typical one-way flap valves (**Figure 2-7**) are installed on pipes discharging to the ocean to prevent ocean waters flowing into the town during times of storm surge sea level.

Figure 2-6 Key drainage catchments and drainage paths in Onslow. The existing 10 year ARI pluvial flood extent is shown

a)

b)

c)

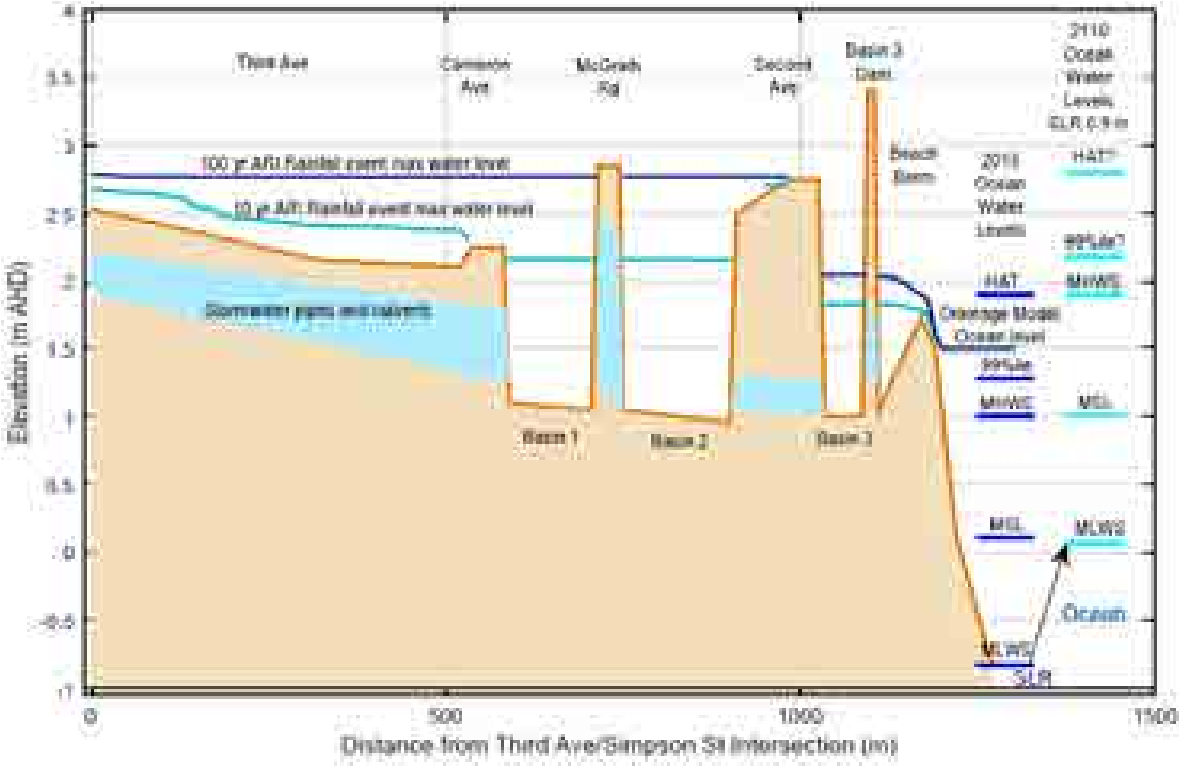

Figure 2-7 Key stormwater management features a) map of detention basin system and ocean discharge, b) photograph of stormwater discharge pipe on Front Beach and c) schematic representation of drainage network

2.7 Key CHRMAP Inputs

To effectively assess the risks and plan for the future management of the coastal zone, information is needed on:

- present and future erosion and inundation hazards;
- current assets, current worth and lifecycles; and
- community and stakeholder values.

As illustrated in **Figure 2-8,** over time it is the interrelationship between these which defines the priorities for adaptation planning.

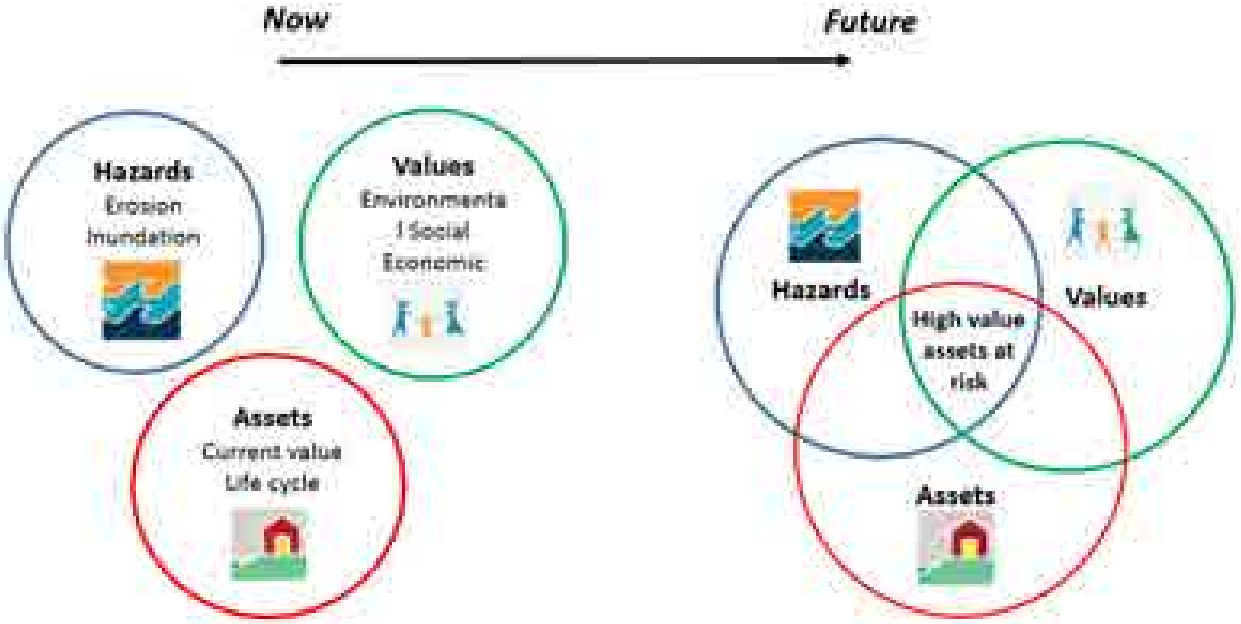

Figure 2-8 Conceptual relationship between key inputs to the coastal risk assessment process

2.7.1 Hazards

2.7.1.1 Erosion and Coastal Inundation

The study area was grouped into four sections by location and morphology as part of the shoreline stability assessment discussed in Cardno (2016a) (**Figure 2-9**). A horizontal shoreline datum (HSD) was defined on the basis of the type of coastline being assessed to define the active limit of the shoreline under storm activity. Based on the levels calculated in the Storm Surge Inundation Assessment (Cardno 2016a), the HSD corresponds to 2.71 m AHD. This value represents the 100-year Average Recurrence Interval (ARI) water level plus an allowance for wave setup.

The hazard maps for the storm surge inundation assessment and the shoreline stability assessment are presented in the Coastal Hazard Assessment Report (Cardno 2016a). They provide the predicted extents for inundation and erosion under present day conditions, as well as the 2040, 2070 and 2110 planning horizons. The erosion allowances are presented in **Table 2-1** for each section of the coastline.

Figure 2-9 Shoreline stability assessment study sections (1 to 4) (aerial image source: NearMap)

Table 2-1 Coastal processes erosion allowance for present day and predicted conditions

Section	Total Erosion Allowance (m)			
	Present-day (2016)	2040	2070	2110
1	19	49	79	119
2	7	41	75	120
3	10	13	16	20
4	25	55	85	125

2.7.1.2 Pluvial Inundation

Pluvial assessment has adopted a direct rainfall approach for assessing the catchment inflows. This approach was selected due to the contained nature of the catchments that drain through Onslow and that the pluvial inundation assessment is for the township areas only as discussed in Cardno (2016a). The results of storm surge inundation assessment indicate that for the township of Onslow:

> Township flooding is primarily from pluvial sources up to 2110. The increasing sea levels and rainfall intensity as a result of climate change will exacerbate the existing flooding that occurs in low-lying areas of the township.

> In the 2110 0.2% Annual Exceedance Probability (AEP) event, the township is significantly impacted by coastal inundation. Dunes and protection structures are overtopped and the township area floods to a level equivalent to the tidal level (approximately 4.55 m AHD).

> In the 2110 1% AEP event, although some overtopping of the dune occurs, it does not significantly impact the township, although access along Onslow Road is cut as a result of the storm surge water level.

For a full suite of inundation maps at a range of scales, see Cardno (2016a).

2.7.2 Assets

Key assets were identified using a variety of methods, including community and stakeholder consultation, examination of the Shire's asset register and a detailed asset survey. For details of the community consultation and asset survey methods and outcomes see the Key Issues Paper (Cardno 2016c).

Assets at risk from inundation were categorised as commercial, public, tourism related and residential to assist in the assessment of values and consequences, and further categorised for management planning purposes as:

> Houses, buildings and property;

> Parks and recreation grounds;

> Public Infrastructure;

> Car parks;

> Roads and footpaths; and

> Sheds.

Table 2-2 presents the property and infrastructure that are predicted to be affected within the coastal foreshore reserve allowance for coastal processes, and **Table 2-3** presents the total count of assets affected by inundation hazards under 100 and 500 year ARI scenarios.

Additional information for each asset or asset type is provided in **Appendix A**.

Table 2-2 Assets at risk from coastal process hazards

Timeframe	Assets At Risk
Present Day	▪ On-ground infrastructure at Onslow Salt Jetty ▪ Onslow Back Beach picnic area (low risk) ▪ Front Beach / Sunrise Beach ▪ Town Seawall will need to be maintained for full planning timeframe to limit the risks to assets. Coastal erosion hazard extents allowed for in this section mainly consist of the uncertainty factor required as per SPP2.6. Present day: 1 bench is at risk
2040	▪ Seaview Drive near 12 Mile Creek / 4 Mile Beach ▪ Assets adjacent to crest of seawall (bins, shade structures, benches) ▪ Shire of Ashburton Offices (Business House) at the intersection of Second Ave and McGrath Rd (still Shire-owned) ▪ Aboriginal community on Second Ave ▪ Second Ave
2070	▪ Western half of Ian Donald Blair Memorial Walkway
2110	▪ Intersection of Seaview Drive and Back Beach Road ▪ Eastern end of Ian Donald Blair Memorial Walkway ▪ Lot 381 (top of hill at Beadon Point). Noting presence of underlying rock within Beadon Point hill may limit this erosion. In addition, elevation is not considered when applying methodology of SPP2.6. Hill crest is 10 to 15 m AHD. This additional volume of sediment means the 2110 hazard line is conservative

Table 2-3 Assets at risk from pluvial inundation hazards

ARI Event	Affected Assets	Assets Not Affected	Total Assets	Percentage Affected
Present Day 100 Year	259	277	536	48%
Present Day 500 Year	327	208	536	61%
2040 100 Year	282	254	536	53%
2040 500 Year	352	182	536	66%
2070 100 Year	286	250	536	53%
2070 500 Year	395	117	536	74%
2110 100 Year	373	163	536	70%
2110 500 Year	447	84	536	83%

2.7.3 Values

Community and stakeholder engagement was undertaken to establish the spatial, social, and economic context of the CHRMAP, and develop the success criteria for the CHRMAP. Details of consultation methods and outcomes are provided in the Key Issues Paper (Cardno 2016c).

The stakeholder values were mapped according to the following categories:

> Recreational;

> Commercial;

> Environmental;

> Historic / heritage;

> Physical infrastructure;

> Aboriginal.

An example of recreational values identified is provided in **Figure 2-10**.

Success criteria were developed with the stakeholders and prioritised according to importance:

> Maintenance of the foreshore;

> Protection and enhancement of the local economy;

> Well maintained community structures;

> Year round accessibility to Onslow via Onslow Ring Road;

> Realistic and sustainable strategies;

> Sustaining and enhancing natural environmental values;

> Strategy not reliant on building heights;

> Not prohibitive of future development; and

> Year round accessibility of the foreshore (as was historically the case).

Whilst all of these success criteria will be considered during the CHRMAP process, it should be noted that not all may be realistically achievable.

Figure 2-100 Example of values mapping showing recreational values for the study area

3 RISK ASSESSMENT

3.1 Risk Assessment Framework

To provide a transparent and logical basis for determining adaptation planning priorities, a risk assessment was undertaken based on AS5334-2013, and the CHRMAP guidelines (WAPC 2014). As illustrated by **Figure 3-1**, risk was assessed in relation to likelihood, consequence and adaptive capacity. Likelihood was assigned using the results of the hazard assessment and consequence ratings were informed by public consultation. Risk is considered to be the combination of likelihood and consequence with consideration of adaptive capacity determining an assets overall vulnerability to climate change (as defined in **Section 1.3.6**).

The Risk Assessment Report (Cardno 2016b) provides a full description of the risk assessment process. A summary of the assigned likelihood, consequence and adaptive capacity for each asset is provided in **Appendix A**, and the resultant risk and vulnerability profile over time for each asset is provided in **Appendix B**.

Figure 3-1 Conceptual relationship between risk assessment elements

3.2 Assets at Risk from Erosion and Coastal Inundation

Assets identified as being at risk of erosion and coastal inundation are shown in **Figure 3-2**. A brief description of the assessed risk and vulnerability profile for each of the assets is summarised below.

3.2.1 On-ground Infrastructure at Onslow Salt Jetty

The current hazard line is immediately adjacent to the seaward edge of on ground infrastructure at Onslow Salt jetty. These assets are therefore at risk of erosion before 2040, with likelihood increasing over time, and impacts considered to be almost certain by 2070 (**Appendix A**).

The current economic value of the assets and role of Onslow Salt as a significant local employer lead to a consequence rating of major being assigned to this group of assets. (**Appendix A**) However, since the assets include a number of relatively adaptable and relocatable elements, the adaptive capacity was deemed moderate and overall vulnerability was assessed as being high in 2070 and very high from 2110 (**Appendix B**).

Figure 3-2 Map of assets at risk from coastal hazards

3.2.2 On-ground Infrastructure at Onslow Salt Jetty

The current hazard line is immediately adjacent to the seaward edge of on ground infrastructure at Onslow Back Beach Picnic Area

The picnic area assets are predicted to be at risk of erosion between 2070 and 2110. While having considerable value in terms of public recreational amenity, the economic value was estimated to be between $100 - $1M and therefore only a moderate consequence of loss (**Appendix A**). Furthermore the assets are considered to be relocatable so the adaptive capacity was deemed high and overall vulnerability was assessed as being low up to 2110 after which time it rises to medium vulnerability (**Appendix B**).

3.2.3 Front / Sunrise Beach

The front beach is highly valued by the community for recreation purposes, it has environmental value (including turtle nesting) aboriginal significance as a fishing area and commercial value in relation to tourism. The hazard assessment indicates that the beach will erode over time, intersecting with the Bindi Bindi community by 2040 and Second Avenue by 2070. Despite having being of high value, due to the inherently mobile nature of beaches - the consequences of the erosion are considered to be low initially, increasing over time as the space available reduces and there is conflict with other assets (**Appendix A**).

The results of the risk assessment show that the beach has a high vulnerability rating from 2070 and is considered very highly vulnerable from 2110 (**Appendix B**).

3.2.4 Existing Seawall

The risk assessment for the seawall is confounded by the fact that the seawall itself is a previously installed risk mitigation optoin. Firstly, the hazard lines show erosion landward of the wall, which is an artefact of the method prescribed in SPP2.6 that requires an allowance for sea-level rise even behind physical infrastructure. Secondly, the risk assessment was based on the assumption that the wall was not maintained and thirdly, in the CHRMAP context, its primary role is as a structural control influencing coastal processes. Nonetheless, in terms of public infrastructure and the Shire's operations it is a key asset and was assessed as such. The risk assessment was completed as if there were no mitigating factors (the seawall) and the likelihood, consequence and existing risk were assessed on this basis. The adaptive capacity and existing controls are then factored in to determine the vulnerability. The design life and future presence and functionality of the seawall need to be considered in long-term planning around both the seawall itself and adjacent assets which it presently protects.

It was considered possible that erosion will occur in the present day timeframe, consequences were considered to be moderate (assuming that the portion of wall that may be damaged has a value of $0.1M - $2M), but it is considered to have a high adaptive capacity (**Appendix A**).

The results of the risk assessment show that the seawall has a medium vulnerability at present up to 2070 at which time it has a high vulnerability rating through to the end of the planning horizon (**Appendix B**).

3.2.5 Assets adjacent to Seawall

As for the assets adjacent to the seawall, the erosion hazard lines landward of the seawall are an artefact of the way in which SPP2.6 requires that allowances are made for sea-level rise, and in reality if the seawall is maintained appropriately then these should not be at risk of erosion. Nonetheless the hazard assessment shows the assets adjacent to the seawall as possibly being impacted by 2070, with minor consequences increasing to moderate in 2110 (**Appendix A**). These assets are considered to have a moderate adaptive capacity because, although they are relocatable, the options for where to put them become limited if the reserve is eroded. Therefore the assets are considered to have a medium level of vulnerability by 2070 (**Appendix B**).

3.2.6 Shire of Ashburton Offices (Business House)

The Shire offices (Business House) are predicted to be impacted by erosion between 2040 and 2070, with major consequences (based on the assumed economic value of the property) (**Appendix A**). This assigned consequence rating along with a low adaptive capacity, results in the asset being assessed as having medium vulnerability by 2040 and increasing to high throughout the rest of the planning horizon.

The results of the risk assessment show that the Shire of Ashburton Offices (Business House) have a low vulnerability at present up to 2040, at which time it has a high vulnerability rating which increases again to very high in 2070 (**Appendix B**).

3.2.7 Bindi Bindi Community

The Bindi Bindi community has high cultural value and has the same risk and vulnerability profile as the shire offices (Business House) located approximately 300 m northwest (**Appendix A, Appendix B**). These two assets are ranked as having the highest priority for adaptation planning.

3.2.8 Western half of Ian Donald Blair Memorial Walkway

A portion of the Ian Donald Blair Memorial Walkway is predicted to be possibly impacted by erosion between 2040 and 2070, with a larger area becoming likely to be impacted between 2070 and 2110 (**Appendix A**). Although impact is almost certain by 2110, the consequence of this is thought to be minor due to the limited extent of the potential impact, and the highly adaptable nature of this asset results in a medium vulnerability rating by 2070 (**Appendix B**).

3.2.9 Intersection of Seaview Dr & Back Beach Rd

The road intersection is predicted to be at risk of erosion between 2070 and 2110 (**Appendix A**). Although it has considerable value providing beach access, consequence of erosion is thought to be minor. Furthermore, the asset is considered to be resilient so the adaptive capacity was deemed as high. The vulnerability was assessed as being low throughout the planning horizon (**Appendix B**).

3.2.10 Eastern half of Ian Donald Blair Memorial Walkway

The eastern portion of the Ian Donald Blair Memorial Walkway is located closer to the coast and therefore predicted to be at risk of erosion by 2040 (**Appendix A**). Similar to the western portion, impact is almost certain by 2110. However, due to minor consequences and the high adaptability of the walkway, the vulnerability rating is low until 2070 when it increases to medium (**Appendix B**).

3.2.11 Seaview Drive near 12 Mile Creek

The portion of Seaview Drive located near 12 Mile Creek is predicted to be at risk of erosion between 2040 and 2070 (**Appendix A**). Consequence of erosion to the road was considered to be minor. Due to its high adaptive capacity, vulnerability of the asset was assessed as being low until 2110 when it rises to medium (**Appendix B**).

3.2.12 Second Avenue

Second Avenue is considered to be a highly valuable asset, being one of the main roads in the Onslow Township. The road is considered to be at risk of erosion between 2070 and 2110 (**Appendix A**). Being of high value, any damages caused by erosion is thought to have moderate consequences. Combined with its moderate adaptive capacity, the road was assessed as having low vulnerability until 2070, when it increases to a medium level of vulnerability (**Appendix B**).

3.3 Assets at Risk from Pluvial Inundation

3.3.1 Housing, Buildings and Property

The asset survey identified approximately 530 houses and buildings. These included both privately and publically owned buildings and ranged considerably in economic value and ability to withstand flooding impacts (**Figure 3-3**). Additional information on this asset group is provided in **Appendix A**.

During the 100 year storm event, these assets are currently at risk of inundation, with likelihood increasing over time and impacts considered almost certain by 2110. Despite the variability in the state of each asset, all assets in this category were assessed as having moderate consequences to inundation, increasing to major in 2070. Due to the low adaptive capacity of these assets, overall vulnerability was assessed as being medium at present, increasing to high in 2070 and to very high in 2110 (**Appendix B**).

Figure 3-3 Examples of houses and buildings of varying value and existing ability to accommodate inundation risk

3.3.2 Parks & Recreation Grounds

Parks and recreation grounds include assets such as public open spaces and the public pool.

The risk of inundation for this set of assets was found to be low until 2070, where it increases to medium through to the end of the planning horizon. Consequence of erosion was considered as insignificant to minor by 2070. Due to the high adaptive capacity of assets in this category, vulnerability was only deemed to be medium from 2070 (**Appendix B**).

3.3.3 Public Infrastructure

Public infrastructure refers to amenities, such as gazebos, bins, light poles, water tanks. Overall, there are approximately 530 public assets identified by the asset survey. A more comprehensive list of items included in this category is provided in **Appendix A**.

The likelihood profiles for the public infrastructure follow that of the previous two categories. Many of the assets within this category do not have high economic value and are considered to be easily replaceable or relocatable. Hence, they were considered to have a moderate adaptive capacity throughout the planning horizon (**Appendix B**). These assets were determined to have minor consequences until 2070, where it increases to moderate.

The results of the assessment show that assets in the public infrastructure category have low vulnerability to pluvial inundation, increasing to medium by 2040, then again to high by 2110.

3.3.4 Car parks

Car parks were identified as privately owned and public parking. Any garages that are not connected to the house or are not buildings with utility services connected are categorised as car parks (**Appendix A**).

Car parks were found to be at risk of inundation before 2040, with likelihood increasing over time, and impacts considered to be almost certain by 2070 (**Appendix A**). The combination of having minor consequences and moderate adaptive capacity resulted in the assets having medium vulnerability from 2070 (**Appendix B**).

3.3.5 Roads and Footpaths

Roads and footpaths were found to have medium risk by 2040, with likelihood increasing over time, and impacts considered to be almost certain by 2070 (**Appendix A**). These assets were considered to have moderate adaptive capacity, considered to be resilient to flooding. The assessment found the assets as having medium vulnerability from 2040 and increasing to high in 2110 (**Appendix B**)

3.3.6 Sheds

Sheds include privately and commercially owned storage facilities. Any sea containers used for storage purposes were categorised as a shed. Sheds were found to have the same risk and vulnerability profile as public infrastructure (**Appendix B**).

3.4 Prioritisation of Assets based on Risk Assessment

Base on the outcomes of the risk assessment, the assets were given the priority rankings shown in **Table 3-1** and **Table 3-2**.

Table 3-1 Prioritisation Rankings for Onslow Assets at Risk of Coastal Erosion

Asset Code	Asset	Prioritisation Ranking
1	On-ground infrastructure at Onslow Salt Jetty	2
2	Onslow Back Beach picnic area	3
3	Front Beach / Sunrise Beach	2
4	Seawall	1
5	Assets adjacent to crest of seawall (bins, shade structures, benches)	3
6	Shire of Ashburton Offices (Business House) at the intersection of Second Ave and McGrath Rd	1
7	Aboriginal community on Second Ave	1
8	Western half of Ian Donald Blair Memorial Walkway	3
9	Intersection of Seaview Drive and Back Beach Road	4
10	Eastern end of Ian Donald Blair Memorial Walkway	3
11	Seaview Drive near 12 Mile Creek / 4 Mile Beach	3
12	Second Ave	3

Table 3-2 Prioritisation Rankings for Onslow Assets at Risk of Pluvial Inundation

Asset Code	Asset	Prioritisation Ranking
1	Housing, Buildings & Property	1
2	Parks & Recreation Grounds	3
3	Public Infrastructure (fencing, light poles, playgrounds etc)	2
4	Car parks	3
5	Roads/footpaths	2
6	Sheds	2

4 ADAPTATION OPTION ASSESSMENT

4.1 Overview

Planning for risk adaptation or risk treatment involves the identification and evaluation of several suitable adaption options to mitigate, reduce or eliminate risk and potentially change the consequences or at least the severity of the consequences.

Potential options were identified under the risk management categories of avoid, managed retreat, accommodate and protect in accordance with SPP2.6 and the CHRMAP guidelines (WAPC 2014). These guidelines stipulate a coastal hazard risk management and adaptation planning hierarchy on a sequential and preferential basis (**Figure 4-1**) in which protection is only to be considered where:

> *"sufficient justification can be provided for not avoiding the use or development of land that is at risk from coastal hazards and accommodation measures alone cannot adequately address the risks from coastal hazards, then coastal Protection works may be proposed for areas where there is a need to preserve the foreshore reserve, public access and public safety, property and infrastructure that is not expendable."*

Information gained from the stakeholder and community engagement was also considered in the development of the options.

Figure 4-1 Conceptual representation of adaptation option categories from Coastal Adapt (2016) modified to reflect the WAPC preferred planning hierarchy (WAPC 2014)

4.2 Option Assessment Framework

4.2.1 Potential Adaption Options

The suite of adaptation options considered were as per the CHRMAP guidelines. Adaption Options – Coastal Erosion Mitigation (**Table 4-1**).

Table 4-1 Adaptation options (WAPC 2014)

Option Category	Option Name		Description
Avoid	Avoid	AV1	Locating assets outside of hazard zone
	Re-zoning	AV2	Adjust town zoning/planning where hazard zone overlaps undeveloped parts of current zones/boundaries
Managed Retreat	Accept and repair losses	MR1	Assets are left unprotected and loss is accepted following hazard event. Repairs may be implemented for public safety, and asset is retreated outside hazard zone, or in the case of beaches/vegetation, as natural recession occurs.
	Relocate outside of hazard zone	MR2	Assets located in the hazard zone are relocated or destroyed. Applied to assets of low value where it is impractical to re-design to withstand hazard impacts.
	Prohibit further development	MR3	Allows continued use of the current infrastructure until such time that impacts arise, but prohibits the development of further infrastructure as the area/asset is known to be vulnerable
Accommodate	Notification on title	AC1	Indicates to current and future landholders that an asset is likely to be affected by coastal hazards over the planning timeframe. Helps owners to make informed decisions about level of risk they are/may be willing to accept and that risk management and adaptation is likely to be required at some stage.
	Emergency plans and controls	AC2	Implement plans for asset that are at risk of coastal erosion due to severe weather. Have procedures in place for before, during and after the events for safety. E.g. signage barrier to prevent access.
	Re-design to withstand impact	AC3	Where avoiding or relocating are not an option, re-design to withstand impacts.
Protect	Dune care program	PR1	Development of a long term program for revegetation and rehabilitation of the dune system.
	Beach Nourishment or Replenishment	PR2	Replacement of sand on upper beach face and dunes to re-establish the sandy beach and provide a sediment supply. Generally utilised in conjunction with other methods for sand retention.
	Seawall	PR3	Construct small seawall in front of asset or along length of coastline to protect it from coastal hazards. This may need to be accompanied by beach replenishment/renourishment.
	Groyne	PR4	Construct shore normal groynes along the beach to capture sediment and protect the shoreline and assets behind.
Do Nothing	No prohibitions or development regulations	DN	No limitations on development or controls on adaptation planning. Assumes all risks are accepted at their present level.

4.2.2 Stakeholder Preferred Options

A stakeholder workshop was held on the 15th August 2016 to present and seek feedback on possible adaptation options to the attendees. Maps were presented to the stakeholders to locate the assets at risk and the table of Adaptation Options presented for reference. Stakeholders then nominated their preferred option for each assets using a worksheet (see Umwelt Outcomes Report, 2016 for details). The majority preferred option for each asset is presented in **Table 4-2**. This information is incorporated in the Multi-Criteria Analysis through 'Community Acceptability' (**Table 4-3**).

Table 4-2 Stakeholder Preferred Adaptation Option (from Umwelt, 2016)

Asset Code	Asset at Risk	First Preferred Adaptation Option	Second Preferred Adaptation Option
1	On-ground infrastructure at Onslow Salt Jetty	MR3 (Prohibit Further Development)	AC2 (Emergency Plans & Controls)
2	Onslow Back Beach picnic area	MR1 (Accept Losses & Repair)	PR1 (Dune Care Program)
3	Front Beach / Sunrise Beach	MR1 (Accept Losses & Repair)	PR2 (Beach Renourishment etc)
4	Seawall (if not maintained)	AC3 (Redesign to Withstand Impact)	-
5	Assets adjacent to crest of seawall (bins, shade structures, benches)	PR1 (Dune Care Program)	PR2 (Beach Renourishment etc)
6	Shire of Ashburton Offices (Business House) at the intersection of Second Ave and McGrath Rd	AC1 (Notification on Title)	MR3 (Prohibit Further Development)
7	Bindi Bindi Aboriginal Community on Second Ave	AC1 (Notification on Title)	MR3 (Prohibit Further Development)
8	Western half of Ian Donald Blair Memorial Walkway	PR1 (Dune Care Program)	MR2 (Relocate Outside of Hazard Zone)
9	Intersection of Seaview Drive and Back Beach Road	MR3 (Prohibit Further Development)	AC2 (Emergency Plans & Controls)
10	Eastern end of Ian Donald Blair Memorial Walkway	MR1 (Accept Losses & Repair)	PR1 (Dune Care Program)
11	Seaview Drive near 12 Mile Creek / 4 Mile Beach	PR1 (Dune Care Program)	MR2 (Relocate Outside of Hazard Zone)
12	Second Ave	AC3 (Redesign to Withstand Impact)	PR1 (Dune Care Program)

4.2.3 Multi-criteria and Cost Benefit Analysis

The CHRMAP employed an overview evaluation system to identify practical adaption options for each identified risk. This evaluation method incorporates a qualitative multi-criteria analysis and a preliminary cost benefit analysis. It is designed to provide an overall indication of an option's suitability. Options are colour coded according to a traffic light method, displayed in **Table 4-3**. Red lights are not always intended to completely disregard the option, but more to provide an indication of when reassessment may be required.

4.3 Assessment Results

The results of the options assessment for each asset are provided in **Appendix B**. This presentation summarises the risk and vulnerability profile for each asset and provides a preliminary assessment of the acceptability of the options in accordance with the MCA criteria (**Table 4-3**).

A summary of recommendations arising from the assessment is provided in **Table 4-4 and 4-5**. Options are either recommended, not recommended or it is suggested that they be investigated further. Where options are rated as "recommended" or "further investigation, these are discussed in greater detail in **Section 6**.

Table 4-3 Multi-criteria assessment and qualitative cost benefit input ratings and assessment outcome categories

	Preliminary Feasibility			Preliminary Acceptability		Preliminary Financial Implication			Outcome
	Effectiveness	Legal / Approval Risk	Reversibility / Adaptability	Environmental / Social Impact	Community Acceptability	Financial Gain / Avoidance of Cost	Capital Cost	Ongoing Cost	Recommendation
Unlikely to be acceptable	Likely to be Ineffective	Not likely to be approved / likely to result in legal risk	Not likely to be reversible. Limits future options once implemented	Likely to have unacceptable negative impacts	Unlikely to meet most success criteria	No financial gain or avoidance of loss	Very expensive	Very expensive	Not Recommended
May be acceptable	May be effective	May not be approved / may present legal risk	Likely to be reversible / adaptable at high costs	Some impacts that can be managed to an acceptable level	Mixed response, may meet some success criteria but not others	Some financial gain / small number of benefactors	Moderately expensive	Moderately expensive	Investigate / detailed option assessment
"No regrets"	Likely to be effective	Likely to be approved / minimal legal risk	Easily reversible or adaptable for the future, no negative impacts in the future	Not likely to have negative impact, may have positive impacts	Likely to meet most acceptability criteria	Large financial gain / public benefit	Low cost	Low cost	Recommended
Not Applicable									

Table 4-4 Summary of outcomes from the preliminary MCA/CBA of adaptation options for coastal erosion . Recommended (R) options are in green, not recommended (NR) options in red and adaptation planning options which are further investigated (I) in yellow. Option descriptions are provided in Table 4-1.

Description	Avoid		Managed Retreat			Accommodate			Protect				Do Nothing	Preliminary long term pathway
	AV1	AV2	MR1	MR2	MR3	AC1	AC2	AC3	PR1	PR2	PR3	PR4	DN	
1: On-ground Infrastructure at Onslow Jetty	R	R	NR	R	R	R	R	R	R	NR	NR	NR	NR	Avoidence of additional development. Managed retreat with low-level protection (dune care program).
2: Onslow Back Beach Picnic Area	R	N/A	NR	R	R	N/A	R	I	NR	NR	NR	NR	NR	Avoidence of additional development.
3: Front Beach / Sunrise Beach	R	N/A	NR	N/A	R	N/A	R	N/A	I	I	I	I	NR	Avoidence of additional development. Managed retreat with possible protection.
4: Seawall (if not maintained)	N/A	N/A	NR	N/A	N/A	N/A	R	R	N/A	I	N/A	I	NR	Protection of asset.
5: Assets adjacent to crest of seawall (bins, shade structures, benches)	R	N/A	NR	N/A	R	N/A	R	R	N/A	I	I	I	NR	Avoidence of additional development. Managed retreat with possible protection.
6: Shire of Ashburton Offices at the intersection of Second Ave and McGrath Rd	R	R	NR	I	R	R	R	I	R	I	I	I	NR	Avoidence of additional development. Managed retreat with low-level protection (dune care program); possible construction of protection structures.
7: Bindi Bindi Aboriginal Community on Second Ave	R	R	NR	I	R	R	R	I	I	I	I	I	NR	Avoidence of additional development. Managed retreat with possible protection.
8: Western half of Ian Donald Blair Memorial Walkway	R	N/A	I	R	R	N/A	R	I	R	NR	NR	NR	I	Avoidence of additional development. Managed retreat with low-level protection (dune care program).
9: Intersection of Seaview Drive and Back Beach Road	R	N/A	R	R	R	N/A	R	I	R	NR	NR	NR	NR	Avoidence of additional development. Managed retreat with low-level protection (dune care program).
10: Eastern end of Ian Donald Blair Memorial Walkway	R	N/A	I	R	R	N/A	R	I	R	I	I	I	I	Avoidence of additional development. Managed retreat with low-level protection (dune care program); possible construction of protection structures.
11: Seaview Drive near 12 Mile Creek / 4 Mile Beach	R	N/A	R	R	R	N/A	R	I	R	I	I	I	NR	Avoidence of additional development. Managed retreat with low-level protection (dune care program); possible construction of protection structures.
12: Second Ave	R	N/A	NR	I	R	N/A	R	NR	R	I	I	I	NR	Avoidence of additional development. Managed retreat with low-level protection (dune care program); possible construction of protection structures.

AV1: Avoid
AV2: Re-zoning
MR1: Accept and repair losses
MR2: Relocate outside of hazard zone
MR3: Prohibit further development / redevelopment
AC1: Notification on title
AC2: Emergency plans ad controls
AC3: Re-design to withstand impact

PR1: Dune care program
PR2: Beach nourishment or replenishment
PR3: Seawall
PR4: Groyne
DN: No prohibitions or development regulations

Table 4-5 Summary of outcomes from the preliminary MCA/CBA of adaptation options for inundation. Recommended (R) options are in green, not recommended (NR) options in red and adaptation planning options which are further investigated (I) in yellow. Option descriptions are provided in Table 4-1.

Description	Avoid		Managed Retreat			Accommodate			Protect		Do Nothing	Preliminary long term pathway
	AV1	AV2	MR1	MR2	MR3	AC1	AC2	AC3	PR1	PR2	DN	
Housing, Buildings, Property	R	R	R	I	R	R	R	I	NR	NR	NR	Avoidence of additional development. Managed retreat.
Parks and Recreation Grounds	I	N/A	R	I	R	N/A	R	R	NR	NR	NR	Avoidence of additional development.
Public Infrastructure	R	N/A	R	R	R	N/A	R	R	NR	NR	I	Avoidence of additional development. Managed retreat.
Car Parks	R	R	R	I	R	R	R	I	NR	NR	NR	Avoidence of additional development. Managed retreat.
Roads / Footpaths	R	R	R	R	R	R	R	R	I	I	NR	Avoidence of additional development. Managed retreat with possible protection.
Sheds	R	R	R	R	R	R	R	I	NR	NR	NR	Avoidence of additional development. Managed retreat.

AV1: Avoid
AV2: Re-zoning
MR1: Accept and repair losses
MR2: Relocate outside of hazard zone
MR3: Prohibit further development / redevelopment
AC1: Notification on title
AC2: Emergency plans ad controls
AC3: Re-design to withstand impact
PR1: Levee
PR2: Levees and pump systems
DN: No prohibitions or development regulations

5 ADAPTATION MANAGEMENT PLAN

5.1 Predicted Planning Pathways

For each asset a predicted planning pathway has been developed based on the risk and vulnerability profile over time and the results of the options assessment (**Appendix C**). In general the pathway follows the hierarchy of avoid and accommodate where possible, with managed retreat and protect only being presented as alternative options in the planning pathway for some assets.

The planning time frames used incorporate the Shire's immediate and short term planning horizons as well as the longer term planning horizons required by the WAPC. The predicted planning pathway is the culmination best estimates of climate change (in particular sea level rise), community and stakeholder consultation, risk assessment results and the adaptation options assessment. The predicted pathway provides the current thinking in regard to how individual assets will be managed, thereby allowing stakeholders and community to prepare for these future threats.

One of the mechanisms assumed to be available to is prohibit further development within designated hazard areas. The actual planning or development control mechanism implemented to achieve a prohibition requires careful consideration of the legal status of the Planning instruments to ensure no unintended consequences, such as a triggering of injurious affection under the Act are to be dealt with. The recommendations below are framed around options for reducing the risks of coastal erosion and pluvial inundation. It will be imperative to successful and realistic implementation of such recommendations for not only the risk, but possible cost and sources of funds to pay such costs being investigated prior to being implemented. For the purpose of the discussion in the following chapters it is assumed that development can be prohibited but the actual mechanism by which this is achieved will require further investigation.

5.2 Reactive Management Framework

As introduced in **Section 1.3.11**, planning also needs to be responsive to changes in the risk profile over time. The predicted planning pathway will need to be updated following regular monitoring (for example monitoring of erosion or inundation levels) and review of other factors as per existing planning review requirements. If risks are increasing faster than expected, then management response needs to also be moved forwards, and conversely if risks are less than anticipated, then risks may remain tolerable for longer and management actions may be delayed. This approach is called a reactive management framework and is illustrated in **Figure 5-1**.

In addition to triggers associated with risks, other triggers may include the life cycle of an asset, and altered circumstances (for instance social pressures or economic climate).

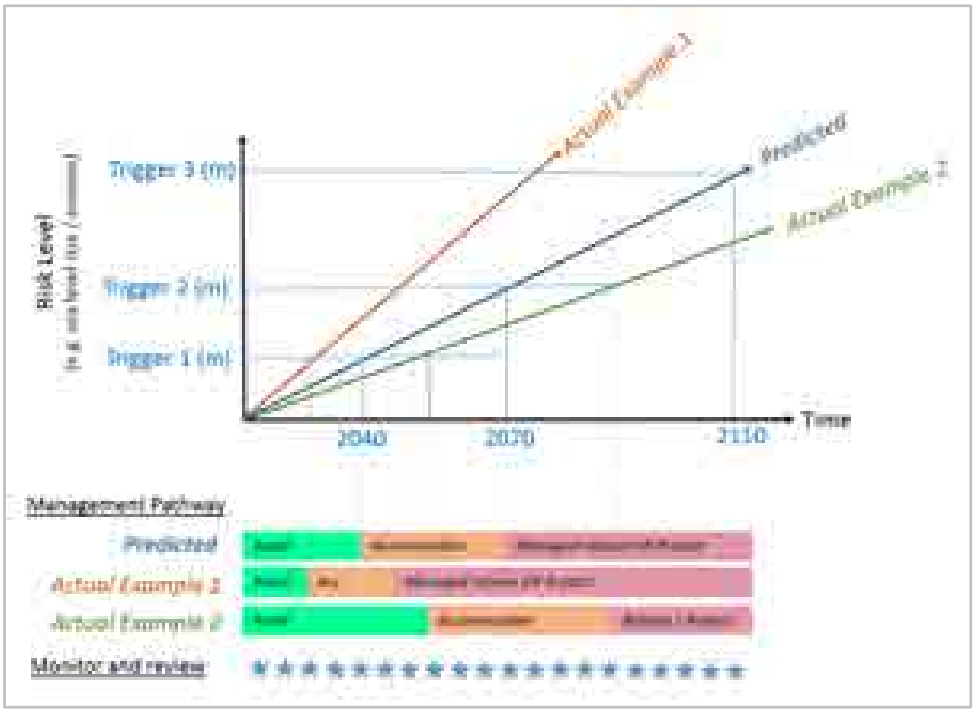

Figure 5-1 Representation of reactive management framework showing example of how triggers relate to the predicted and actual asset management pathways.

5.2.1 Existing Controls and Future Residual Risk Management

The residual risk identified in Appendix C is a direct outcome of inclusion of existing controls and the impact this has on the risk scale. The use of the existing controls and mechanisms that can be used to reduce the risk and the sequence of introducing controls or implementing strategies effectively means that future Adaptation options will be managed according to the residual risk levels. This is the assumption used Appendix C following the assumed implementation of a control at future time horizon. Note, however, that the CHRMAP review at each nominal 5 years will lead to a reassessment of the risk levels as new and more robust options are identified and assessed. For this 2017 CHRMAP the existing controls are assumed to continue into the future and hence have been incorporated into the risk levels for each asset as discussed the following sections 5.3 and 5.5. This approach flows on to the management and adaptation actions and recommendations.

5.3 Adaptation Management of Assets at Risk from Erosion

5.3.1 On-ground Infrastructure at Onslow Jetty

The vulnerability of the on-ground infrastructure at Onslow Jetty was assessed as being low until 2040, after which time it continually increases from medium to very high in 2110 (**Appendix B**). For the immediate term (5 years), adaptation management planning focuses on avoiding further development; and implementation of the "no regret" options: Emergency Plans and Dune Care Program (**Appendix C**).

In the short term (5-10 years), management aims to continue the existing management options, while at the same time commencing to plan for managed retreat or protection actions. During this period it is anticipated that some assets may be designed to withstand impacts and if damages do occur then short term repairs may enable continued functioning of the assets in their current location.

In the medium term (10-25 years) it is predicted that substantial re-design would be required to maintain functionality and relocation of assets is likely to be required. If the decision had been made to protect the assets in their current location, then this would need to be implemented.

Triggers for reactive management are based on the rate of erosion, occurrence of events causing damage to assets, asset lifecycle and potential for cessation of industry (**Appendix C**). Responsibility for management

of the salt export assets lies with Onslow Salt. If protection options are considered appropriate then as beneficiaries of the protection works, it is expected the company would contribute to the costs of protection and also show that any potential shifts in erosion hazards will not disadvantage other neighbouring stakeholders.

5.3.2 Back Beach Picnic Area

The picnic area assets were assessed as having low vulnerability until 2110 at which time they a medium vulnerability (**Appendix B**). For the immediate to short term (5-10 years), adaptation management planning focuses on avoiding and prohibiting further development; and implementation of Dune Care Program and Emergency Plans (**Appendix C**).

In the medium term (10-25 years), existing management options will remain, whilst commencing to plan for managed retreat actions. During this period it is anticipated that re-design of assets and potential protection options be investigated. Any damage to assets are to be repaired so that continued function in their current location can occur. Consideration should be given to any changes in zoning that may be required for creation of an alternative picnic area in the vicinity of Back Beach.

In the long term (50 -100 years) relocation of assets may be required. If the decision is made to protect the assets in their current location, then this would need to be implemented.

Triggers for reactive management are based on the rate of erosion, occurrence of events causing damage to assets and asset lifecycle. Responsibility for management of the assets lies with the Shire of Ashburton.

5.3.3 Front / Sunrise Beach

The results of the risk assessment show that the beach has a high level of vulnerability in 2070, increasing to very high by 2110 (**Appendix B**). For the immediate term (5 years), implementation of Emergency Plans and a Dune Care Program is recommended, as well as investigations into protection options (**Appendix C**).

In the short term (5-10 years), existing management options and investigations into protection options would continue. By the medium term (10-25 years) any protection options selected would need to be implemented.

The beach itself is not treated as an economic asset in this analysis, and it is deemed to have reasonable adaptive capacity in the medium term. However, if the decision is made to implement protective measures such as the extension of the seawall (**Section 6.4.2**), then earlier intervention will maintain more of the functionality of the beach and retain the natural dune buffers.

The main trigger for reactive management is based on the rate of erosion of the beach (**Appendix C**). Responsibility for management of the assets lies with the Shire of Ashburton.

5.3.4 Existing Seawall

The seawall has a medium vulnerability at present up to 2070 at which time it has a high vulnerability rating through to the end of the planning horizon (**Appendix B**). For the immediate to short term (5-10 years), implementation of Emergency Plans is necessary, while investigation into protection options should commence (**Appendix C**). Any damages to the seawall in any event are to be repaired to withstand future impacts.

In the medium term (10-25 years) continual improvements to the seawall would be required to maintain the integrity of the structure. During this time, any protection options selected would need to be implemented.

Triggers for reactive management (**Appendix C**) are based on the rate of erosion, occurrence of events causing damage to the seawall and adjacent properties. Responsibility for management of the assets lies with the Shire of Ashburton.

5.3.5 Assets adjacent to seawall

The assets adjacent to the crest of the seawall are considered to have low vulnerability to coastal erosion until 2110, when it increase to medium (**Appendix B**). For the immediate to short term (5-10 years), implementation of Emergency Plans is necessary and any further development in the area is to be prohibited (**Appendix C**).

In the medium term (10-25 years), management aims to continue the existing management options, while at the same time commencing to plan for managed retreat or protection actions in association with protection of the seawall described above. During this period it is anticipated that some assets may be designed to

withstand impacts and if they do occur then short term repairs may enable continued functioning of the assets in their current location.

In the long term (50-100 years) it is predicted relocation of assets is likely to be required unless maintenance of the seawall is sufficient to mitigate the erosion risk. If the decision is made to protect the assets in their current location, then this would need to be implemented.

Triggers for reactive management (**Appendix C**) are based on the occurrence of overtopping, erosion impacts to the seawall and events causing damage to property. Responsibility for management of the assets lies with the Shire of Ashburton.

5.3.6 Shire of Ashburton Offices

The Shire offices (Business House) become highly vulnerable in 2040 (**Appendix B**) and require immediate (5 years) implementation of "No regret" options: Emergency Plans and Dune Care Program (**Appendix C**). Further development is to be avoided until plans to implement managed retreat options are to be developed and agreed.

In the short term (5-10 years), re-design would be required to maintain functionality. If the decision had been made to protect the assets in their current location, then this would need to be implemented. In the medium term (10-25 years), relocation of assets is likely to be required and further development in the area be prohibited.

The risk profile of this asset is linked to other assets including the Front Beach, Bindi-Bindi Community and Second Avenue. Any protection measures implemented in this area will alter the hazard lines and therefore likelihood and consequences of erosion. If protection options are considered, investigations would need to commence in the immediate term.

Triggers for reactive management (**Appendix C**) are based on the rate of erosion, occurrence of events causing damage to property and asset lifecycle. Responsibility for management of the assets lies with the Shire of Ashburton.

5.3.7 Bindi Bindi Community

Similar to the adjacent Shire of Ashburton Offices (Business House), the results of the risk assessment show that the Bindi Bindi Community becomes highly vulnerable in 2040 (**Appendix B**) and require immediate (5 years) implementation of "No regret" options: Emergency Plans and Dune Care Program (**Appendix C**). Future development in its current location is to be avoided.

In the short term (5-10 years), re-design would be required to maintain functionality of assets. If the decision had been made to protect the assets in their current location, then this would need to be implemented. In the medium term (10-25 years), relocation of assets is likely to be required and further development in the area be prohibited.

The risk profile of this asset is linked to other assets including the Front Beach, Shire of Ashburton Offices (Business House) and Second Avenue. Any protection measures implemented in this area will alter the hazard lines and therefore likelihood and consequences of erosion. If protection options are considered for the collection of assets then investigations would need to commence in the immediate term.

Triggers for reactive management are based on the rate of erosion, occurrence of events causing damage to property and asset lifecycle (**Appendix C**). Responsibility for management of the assets lies with the community itself and the relevant state government authorities.

5.3.8 Western half of Ian Donald Blair Memorial Walkway

The western portion of the Ian Donald Blair Memorial Walkway was assessed as having medium vulnerability from 2070 (**Appendix B**). For the immediate to short term (5-10 years), implementation of Emergency Plans and Dune Care Program is recommended and any further development is to be prohibited (**Appendix C**).

In the medium term (10-25 years) it is anticipated that the walkway may be designed to withstand impacts and if damages do occur then short term repairs may enable continued functioning of the walkway in its current location.

In the long term (25-50 years) it is predicted that substantial re-design would be required to maintain functionality and relocation of the walkway is likely to be required.

Triggers for reactive management are based on the rate of erosion, occurrence of events causing damage to assets and asset lifecycle (**Appendix C**). Responsibility for management of the assets lies with the Shire of Ashburton.

5.3.9 Intersection of Seaview Dr & Back Beach Rd

The results of the risk assessment show that the intersection of Seaview Drive and Back Beach Road has a low level of vulnerability to coastal erosion throughout the planning horizon (**Appendix B**). Emergency Plans and Dune Care programs would be required in the immediate term (5 years) and further development is to be prohibited.

In the long term (25-50 years), any damages to the asset are to be repaired so that functionality is maintained. It is anticipated that re-design may be required withstand future impacts.

In the long term (50-100 years), relocation of the asset is likely to be required

Triggers for reactive management are based on the rate of erosion, occurrence of events causing damage to assets and asset lifecycle (**Appendix C**). Responsibility for management of the assets lies with the Shire of Ashburton.

5.3.10 Eastern half of Ian Donald Blair Memorial Walkway

The eastern portion of the Ian Donald Blair Memorial Walkway was assessed as having medium vulnerability from 2070 (**Appendix B**). For the immediate to short term (5-10 years), implementation of Emergency Plans and Dune Care Program is necessary and any further development is to be prohibited (**Appendix C**).

In the medium term (10-25 years), if damages occur then short term repairs may enable continued functioning of the walkway in its current location. However, investigation into re-design options would be required.

In the long term (25-50 years) it is predicted that re-design would be required to maintain functionality and relocation of the walkway is likely to be required.

Triggers for reactive management are based on the rate of erosion, occurrence of events causing damage to assets and asset lifecycle. Responsibility for management of the assets lies with the Shire of Ashburton.

5.3.11 Seaview Drive near 12 Mile Creek

The section of Seaview Drive near 12 Mile Creek was considered as having medium vulnerability by 2110 (**Appendix B**). Emergency Plans and Dune Care programs would be required in the immediate term (5 years) and further development is to be prohibited.

In the medium term (10-25 years), the road is anticipated to require a re-design to withstand impact. Any damages sustained could be repaired in the short term which will enable continued function in its current location.

In the long term (50-100 years) to maintain the road's function, substantial re-design and/or relocation may be required.

Triggers for reactive management are based on the rate of erosion and occurrence of events causing damage to assets (**Appendix C)**. Responsibility for management of the assets lies with the Shire of Ashburton.

5.3.12 Second Avenue

The vulnerability of Second Avenue was assessed as having low vulnerability until 2070 when it increases to medium for the rest of the planning horizon (**Appendix B**). For the immediate term (5 years), implementation of Emergency Plans and Dune Care Program is necessary (**Appendix C**). Further developments in the area would need to be prohibited.

In the short term (5-10 years), existing management options will continually be implemented, while at the same time commencing to investigate protection actions. During this period it is anticipated that the road may be designed to withstand impacts and if damages do occur then short term repairs may enable continued functioning of the road in its current location.

In the long term (25-50 years) it is predicted that substantial re-design would be required to maintain functionality and relocation is likely to be required. If the decision had been made to protect the road in its current location, then this would need to be implemented.

Triggers for reactive management are based on the rate of erosion and occurrence of events causing damage to property. Responsibility for management of Second Avenue lies with the Shire of Ashburton.

The risk profile of this asset is linked to other assets including the Front Beach, Shire of Ashburton Offices (Business House) and the Bindi Bindi Community. Any protection measures implemented in this area will alter the hazard lines and therefore likelihood and consequences of erosion. Potential protection options for this group of assets is discussed in **Section 6.4.2**.

5.4 Adaptation Management Plan of Assets at Risk from Inundation

5.4.1 Housing, Buildings and Property

The vulnerability of housing, buildings and properties to inundation was assessed was assessed as being high in the present day, increasing to extreme from 2040 for the rest of the planning horizon (**Appendix B**). For the immediate term (5 years), a range of adaptation options are indicated, including avoid, accommodate and protect actions (**Appendix C**). Adaptive management focuses on prohibiting of further development, zoning of land for acceptable use, design to withstand flooding, putting emergency plans in place, and undertaking further investigations to better understand and develop strategies to address drainage/ water management issues. Protective actions including maintenance (and possible extension of the seawall) and upgrade of drainage controls are recommended. Investigation of a levee system may be required as an alternative to managed retreat in the medium (10 years) to long term (25 – 50 years).

Due to the high level of current vulnerability of housing, buildings and property, the implementation plan focuses largely on the issue of risk of inundation to these assets and recommends a number of mitigation measures (Section 6).

Triggers for reactive management are based on the rate of occurrence of flood events causing damage to property. Responsibility for management of this asset group lies with asset owners and the Shire of Ashburton.

5.4.2 Parks & Recreation Grounds

Despite having a similar likelihood, consequences of inundation are considered to be lower and adaptive capacity higher for this asset group than for housing, buildings and properties (**Appendix A**). Therefore risk vulnerability are also considered to be lower (**Appendix B**). However, by 2070 vulnerability was assessed as having increased to a rating of medium, and recommended adaptation options are recommended which focus on accommodation (design to withstand impact) for the immediate to long term (<5 to 50 years) and managed retreat in the long term (50 – 100 years). Prohibiting further development is recommended. Protective actions and recommended investigations discussed above and detailed in **Section 6** will also result in mitigation of risks to this asset group.

Triggers for reactive management are based on the rate of occurrence of flood events causing damage to property. Responsibility for management of drainage lies with the Shire of Ashburton and adaptation planning aims to minimise risk, however ultimately responsibility for housing, buildings and property ultimately rests with asset owners.

5.4.3 Public Infrastructure

Vulnerability of public infrastructure to inundation is considered to be higher than for parks and recreation grounds but lower than for housing, buildings and properties (**Appendix B**). Present day vulnerability is considered medium and by 2070 these assets are predicted to be highly vulnerable. In the immediate to short term (<10 years) adaptation focuses on avoidance actions and accommodation by way of design to withstand inundation where possible. From 10 years on, managed retreat is recommended.

Protective actions and recommended investigations discussed above and detailed in **Section 6** will also result in mitigation of risks to this asset group.

Triggers for reactive management are based on the rate of occurrence of flood events causing damage to the assets. Responsibility for management of public infrastructure lies with the Shire of Ashburton and relevant State Government departments.

5.4.4 Car parks

The risk and vulnerability profile for carparks was assessed as being the same as for parks and recreation grounds (**Appendix B**). Functionality can largely be maintained despite inundation and this form f asset is considered to have a high adaptive capacity. However, by 2070 vulnerability was assessed as having increased to a rating of medium, and recommended adaptation options are recommended which focus on accommodation (design to withstand impact) for the immediate to long term (<5 to 50 years) and managed retreat in the long term (50 – 100 years). Prohibiting further development is recommended. Protective actions and recommended investigations discussed above and detailed in **Section 6** will also result in mitigation of risks to this asset group.

Triggers for reactive management are based on the rate of occurrence of flood events causing damage to property. Responsibility for management of this asset group lies with both the asset owners and the Shire of Ashburton.

5.4.5 Roads and footpaths

Vulnerability of roads and footpaths to inundation is considered similar to that of other types of public infrastructure (**Appendix B**). Present day vulnerability is considered medium and by 2070 these assets are predicted to be highly vulnerable. In the immediate to short term (<10 years) adaptation focuses on avoidance actions and accommodation by way of design to withstand inundation where possible. From 10 years on, managed retreat is recommended.

Protective actions and recommended investigations discussed above and detailed in **Section 6** will also result in mitigation of risks to this asset group.

Triggers for reactive management are based on the rate of occurrence of flood events causing damage to the assets. Responsibility for management of public infrastructure lies with the Shire of Ashburton and relevant State Government departments.

5.4.6 Sheds

Sheds are a type of property, but due to the nature of their construction and use they are considered to be less vulnerable to inundation (**Appendix B**). Present day vulnerability is considered medium and by 2070 these assets are predicted to be highly vulnerable. In the immediate to short term (<10 years) adaptation focuses on avoidance actions and accommodation by way of design to withstand inundation where possible. From 10 years on, managed retreat is recommended.

Protective actions and recommended investigations discussed above and detailed in **Section 6** will also result in mitigation of risks to this asset group.

Triggers for reactive management are based on the rate of occurrence of flood events causing damage to the assets. Responsibility for management of this asset group lies with both the asset owners and the Shire of Ashburton.

5.5 Residual Risk

A residual risk assessment for each asset group and time frame was undertaken based on the following assumptions:

- No protection measures are undertaken for coastal assets other than those behind front beach that may be implemented in the short term;
- The seawall is maintained and extended eastwards to at least beyond the Bindi Bindi community, and that the risk of erosion in this area becomes similar to that of the land currently behind the seawall;
- Houses and properties are protected by the presence and extension of the seawall;
- Accommodation actions reduce the consequences of inundation for all asset types;

> Managed retreat reduces the risk from both coastal erosion and inundation as it is assumed that the asset is no longer located in a hazard zone.

The results of the residual risk assessment are presented in **Appendix C** for each asset along with the assumed adaptation pathway.

6 IMPLEMENTATION PLAN

6.1 Overview

The information collated through the various stages of the CHRMAP process including outcomes of the risk assessment and subsequent analyses summarised in the preceding sections have been used to define priority actions for implementation by the Shire and other stakeholders. The proposed implementation actions are intended to reduce the risk posed by coastal hazards in the immediate to short term, with consideration of the 100 year planning horizon.

The implementation plan has been structured to group actions in accordance with the WAPC (2014) adaptation hierarchy. In addition, adaptation responses can be defined as being related to either, planning and development or to engineering as discussed by the Planning Institute of Australia's (PIA) National Land Use Planning Guidelines for Disaster Resilient Communities (2015) and show schematically in the **Table 6-1**.

Table 6-1 Effectiveness of land use planning and building responses in treating specific natural hazard risks relevant to coastal planning

Hazard	Detailed Action		
	Land use (spatial, zoning)	Built form (building form, lot layout)	Building (design, structural)
Flood	Strong	Strong	Strong
Storm Tide	Strong	Strong	Strong
Coastal Erosion	Strong	Strong	Strong
Sea Level Rise	Strong	Strong	Strong
Cyclonic Wind	Limited	Moderate	Strong
Storm (incl. hail)	Limited	Limited	Moderate

Table source: National Land Use Planning Guidelines for Disaster Resilient Communities (PIA 2015) p.31

6.1.1 Planning and Development Responses

Land use planning and development control responses may not always be appropriate to treat the risk borne by a particular hazard. Effective management for coastal hazards does not necessarily mean there can be no development in designated high risk areas. Part of the purpose of this CHRMAP is to help articulate the possible consequences of development in these areas so that the Onslow community may consider what risk it is prepared to accept in those areas – now, and in the future.

Land use planning and building regulations apply only to new properties and developments or significant modification to existing properties. They may have little or no influence in the short-term but a very significant long-term effect. It is, therefore, extremely important to make good decisions now, as the consequences of poor decisions may last for decades.

Spatial controls, like zoning, set limits on the type and extent of development that can happen in particular areas (or zones). The SCA is a form of spatial control, but the zones underlying the SCA are also important as these may still permit land uses that would be vulnerable to hazard impacts within the overall planning timeframe (100 years).

It is important to identify land uses that are strategically compatible with the risk, and to zone the land accordingly. Therefore, a review of current zoning and land use permissibility within these zones should be undertaken in light of the outcomes of the risk identification and assessment. Appropriate zoning is important to provide clarity for both the community and developers. Any ambiguity due to potential coastal hazards may stifle development and consideration of such hazards should not be left until the development assessment stage.

Once appropriate development has been confirmed, building controls may be helpful to address risks for that type of development. The links between planning and building processes must be clearly articulated, so that

building controls are appropriately applied in the right areas – planning and building are covered by different legislation and are (usually) managed by different personnel.

Responsive building design requirements may be introduced in planning controls – as is the case already in Appendix 12 of TPS 7, that don't exist in the building regulation. For example, planning provisions and policies may relate to the form and density of buildings, including lot size and layout, or to the design of buildings such as prescribed minimum FFL, elevation above anticipated flood levels, etc.

'Overlays' such as special control areas or precincts can articulate specific building siting requirements, densities, or other requirements that address and seek to reduce the impact of coastal hazards.

As a general rule, privatisation of coastal land at risk of erosion or long term inundation through freehold or long term leasehold subdivision should be avoided. Permanent structures including buildings should not be permitted on land at risk of erosion or long term inundation. Redevelopment of land at risk of erosion or long term inundation with permanent structures should not be permitted within the at-risk parts of the site.

R1. A detailed review of current zoning and land use permissibility within zones should be undertaken in light of the results of the risk assessment outcomes.

R2. Appendix 12 SCA in LPS 7 should be reviewed to reflect the outcomes of the CHRMAP process and, where relevant, include specific clauses to, for example, ensure that actions are enforceable

6.1.2 Engineering Responses

Engineering responses included in the implementation plan focus on:

- generalised adaptation engineering responses and design standards,
- specific concept designs for protective structures mitigating the risk of coastal erosion; and
- identifying drainage engineering issues and investigations required to reduce risks from pluvial inundation now and in the future.

6.1.3 Beneficiary pays principle and Equity Considerations

The beneficiary pays principle has been adopted policy of Australian governments for some time although its implementation and the identification of project beneficiaries and apportionment of costs has been a vexing issue in the coastal zone. SPP 2.6 aims to reduce the liability for future protection of privately owned coastal assets at risk of erosion or inundation by changing climate and sea level rise. Coastal projects (eg. protection and sand nourishment works) requiring significant capital and ongoing maintenance funding will be subject to an assessment of the beneficiary pays principle and a mechanism for equitable apportionment of costs to identified beneficiaries will be required. This mechanism will require further investigation to determine a fair and equitable process to mitigate the future threats to the coastal zone.

6.2 Avoid / Retreat Actions

6.2.1 Zoning

It is recommended that the existing Conservation, Recreation & Nature zoning is maintained / extended along coastline, seaward of 2110 hazard line. Where current zoning permits development that is incompatible with identified risk, rezoning may be required to prevent further inappropriate development. Two examples identified in this assessment are:

- Bring Strategic Industry zone near jetty inland of 2110 hazard line
- Prior to development of Lot 381 consider adjusting north east boundary to be inland of 2110 hazard line (or move the whole block to the south-west).

R3. The existing Conservation, Recreation & Nature zoning should be maintained / extended along the coastline, seaward of 2110 hazard line

R4. Move the Strategic Industry zone near jetty inland of 2110 hazard line

R5. Prior to development of Lot 381 consider adjusting north east boundary to be inland of 2110 hazard line.

6.2.2 Coastal Reserve Planning

The coastal foreshore reserve serves a number of functions and, as identified during preparation of this CHRMAP, it holds value in a variety of aspects. The coastal foreshore provides beach access, recreation and conservation, is a tourist attraction and provides habitat for native flora and fauna. Importantly, it also provides a buffer to mitigate risks to high value assets such as buildings and infrastructure.

An assessment has been made of the current function(s), use and assets present within the coastal foreshore reserve. The hazard mapping indicates that in some locations the existing coastal foreshore reserve could completely disappear, including in front of the existing sea wall **(Figure 6-1)**. If the loss of the foreshore reserve in any particular location would be unacceptable, consideration should be given to amending the scheme to extend the local scheme reserve for the foreshore area beyond the coastal hazard line a sufficient distance to accommodate relocation of foreshore assets. The exact distance would have to be calculated according the amount of land likely to be required to accommodate those assets (eg: beach access paths, public toilets, picnic facilities, car parking, boat ramps, ecosystem conservation, etc).

Extending the reservation in the scheme may only be necessary in the longer term to accommodate loss of the existing foreshore past an acceptable limit, however no new high value or permanent assets should be permitted inside the forecast 100 year hazard line.

Where extending the reserve or preventing new development or significant redevelopment would impact zoned private land there could be implications such as claims for injurious affection. However, this will have to be balanced with the potential public costs of funding asset protection measures for future development on private land, and the loss of public access to the foreshore.

R6. Consideration should be given to amending the scheme to extend the local scheme reserve for the foreshore area beyond the 2110 coastal hazard line a sufficient distance to accommodate relocation of foreshore assets. Where this may impact on private land, consideration should include risk of claims arising.

Figure 6-1 Coastal hazard lines in relation to town planning scheme zones

6.2.3 Special Control Area

The SCA currently applies to all land up to the 4m AHD contour in the coastal zone, and 5m AHD contour in frontal dune areas (Shire of Ashburton 2016) (see also **Section 2.4** of this report). The SCA also extends some way along the coast adjacent to Sunset Beach.

On the basis of the coastal hazard assessment, it is recommended that the SCA be extended inland to the 2110 coastal hazard line along the length of coastline, from the southern extent of the study area to Four Mile Creek.

In addition to coastal hazard allowances due to coastal erosion, SPP 2.6 could be interpreted such that it is appropriate for the extent of the SCA to reflect the modelling undertaken by the current study for the 1:500 year coastal inundation event. As described in **Section 2.7.2**, flooding in Onslow is dominated by pluvial (rainfall) inundation for all events except for the 1:500 year event in the year 2110. In this scenario, sea-level rise coupled with storm event metocean conditions results in the overtopping of the seawall, and extensive breaching of coastal dunes to the north and land to the east of the township towards Beadon Creek.

As presented in **Section 2.7.2**, the peak sea level for the 1:500 year event is approximately 4.55 m. Flood modelling is not as simple as assuming this level across the entire area as there are variations in peak water levels across the flooded footprint boundary, however, for the purposes of this study it is suggested that a level of 4.5 m AHD better represents the requirements of SPP2.6, and that this level is justified as the SCA for the current 100 year planning horizon. The coastal hazard assessment report (Cardno 2016a) provides additional technical detail about how the modelling was carried out and the results obtained. Figure 6-2shows the 4.5 m contour in relation to the SCA extent (as provided to Cardno – See **Figure 2-5**).

Every five years, when the local planning scheme is reviewed (as required by the *Local Government (Local Planning Schemes) Regulations*), the appropriateness of the SCA extent in the light of any studies undertaken by proponents in compliance with the provisions of Appendix 12 of the scheme can also be considered, and further adjustments made if appropriate. To aid this review, data relating to localised and general flooding in Onslow (not just the SCA) should be recorded in sufficient detail to identify trends over time, including any changes that may result from development that has taken place.

A Special Control Area is a mechanism that can be specifically used to assist facilitation of planned or managed retreat and is an adaptation option recommended for a number of areas of the Onslow Town site. In this instance the SCA classification can mandate that all development requires approval where ordinarily, development (e.g. single residential development) may otherwise be exempt from development control. The goal is to ensure any further development can only occur if the Shire considers it acceptable in light of the policy of planned or managed retreat. The existing Appendix 12 wording should be reviewed to ensure that it requires ALL development to obtain approval. This is not clear in the current wording as it only states that application for approval need to comply. Other issues should also be investigated for potential in facilitating planned or managed retreat through the SCA. Approval can be granted on a temporary basis (e.g. for 10 years) to permit the use for a limited time. This does not preclude a person from seeking further approval at the end of that timeframe. This permits or facilitates land to continue to be used in the immediate future whilst taking into account foreshadowed risks associated with rapid environmental changes in the medium to long term. This should be investigated further and included in the management and adaptation and implementation where relevant with regard to the planned or managed retreat recommendations.

CHRMAP guidelines also stipulate regular review of the CHRMAP. When this is done, the extent and level of the SCA should be reviewed in the light of monitoring results and updated hazard and risk assessments.

Updated survey data may be required if site works are carried out which change the ground level (for example the Berrada Estate) the fact that the SCA boundary will change over time, in response to changes in the risk profile due to uncertainty surrounding the prediction of future hazards, implementation of protective actions and adaptive responses such as raising the land level, as has been done at Berrada.

It would be appropriate to identify areas within the SCA and study area where avoidance of development altogether is the most advisable strategy. In these areas changes to zoning should be considered in order to prevent any inappropriate development. To assist in the Shire's planning in this regard, it is recommended that in addition to the updated SCA boundary, the 4.5 m contour, 1:10, 1:100 and 1:500 (for current, 2040, 2070 and 2110) flooding data layers be added to the Shires GIS to allow for cross referencing with other spatial data and enabling provision of advice and response to applications.

In accordance with existing policy, in areas not within the SCA, if the Shire considers that a proposed development could potentially be incompatible with and prone to flood and storm surge events, it may still have regard to information about these events when determining applications for planning approval.

It is recommended that intensification of development at the Bindi Bindi community should not be permitted. Renewal of existing infrastructure might be considered with flood-resistant building, such as houses raised on stilts (discussed in **Section 6.3.4**).

R7. The SCA should be extended inland to the 2110 coastal hazard line along the length of coastline, from the southern extent of the study area to 4 Mile Creek.

R8. For the current 100 year planning horizon the SCA extent should be defined by the 4.5 m AHD contour

R9. The SCA extent and provisions of Appendix 12 of the local planning scheme should be included in the five yearly local planning scheme review

R10. Review of the CHRMAP every five years is to include a review of the SCA extent and relevant provisions including Appendix 12 of TPS 7

R11. Data relating to localised and general flooding in Onslow (not just the SCA) should be recorded in sufficient detail to identify trends over time, including any changes that may result from development that has taken place

R12. Identify areas within the SCA and study area where avoidance of development altogether is the most advisable strategy

R13. Update of Shires GIS to include contours and flooding data from this study

R14. Intensification of development at the Bindi Bindi community should not be permitted. Renewal of existing infrastructure should only be considered with appropriate flood-resistant design

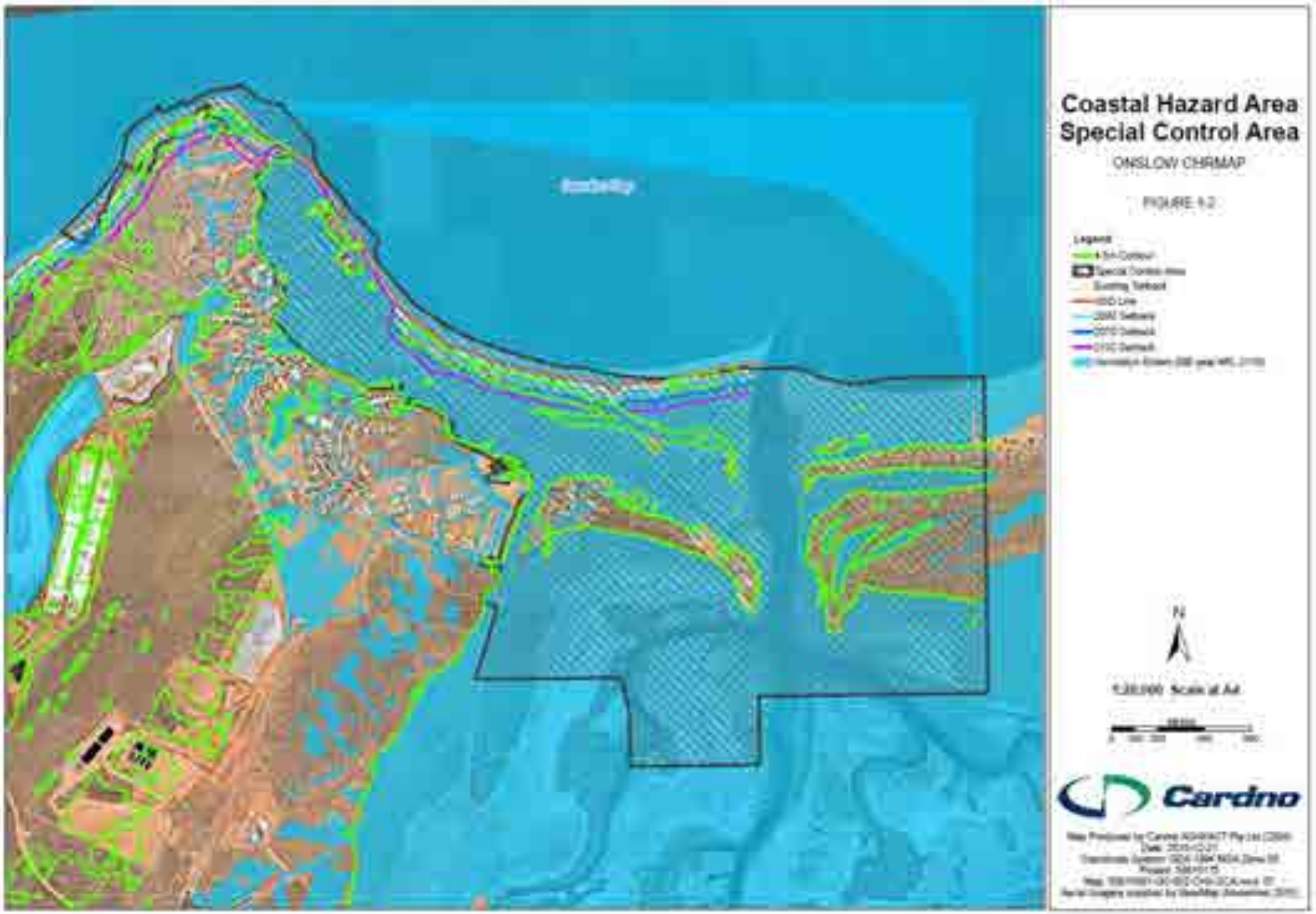

Figure 6-2 2004 Gazetted SCA overlaying current Onslow township zoning

6.2.4 Site Selection for Future Assets

Avoiding new development in hazard-prone areas and managed retreat requires the identification of alternative suitable sites for development. Where the risks of erosion or frequent inundation are high, new development should be avoided and strategies for retreat put in place as hazard event triggers that impact existing land uses are reached.

The predicted lifespan of the proposed development and its potential impact on other land during that lifetime, should be considerations for any application in areas identified as being at risk from coastal processes. Temporary land uses that can be removed before or when a nominated trigger is reached might be considered (for example, if the recurrence of flooding becomes unacceptably frequent and repair costs begin to exceed the retreat option costs). Appendix 12 to TPS 7 already contains provisions relating to temporary or transient development, requiring its removal by 31 December 2040.

No new development should be contemplated within the defined 2110 hazard line other than low impact, (relatively) low value and/or removable structures (such as beach shelters, access paths, fences, caravans, etc). No further subdivision of land within the 2110 hazard line should be contemplated, nor further intensification of existing development.

It has already been noted that the town of Onslow was completely relocated in the 1920's from its original location at the mouth of the Ashburton River, some 18 kilometres south-west of the current location. Whilst such a dramatic move is unlikely to be necessary again, it is nevertheless advisable to plan for the evolution of the town to achieve a gradual retreat of development in vulnerable areas to 'higher ground' (**Figure 6-3**). This recommendation should not cause alarm – dramatic and sudden changes should not be required if planning takes place early enough. All settlements evolve; this recommendation simply requires that improving the resilience of Onslow and its community to coastal erosion and inundation over time is a conscious inclusion in plan making.

A structure planning approach may be the best way of testing scenarios and producing a strategy that articulates a community vision for adapting Onslow iteratively over the long term to achieve an urban form that responds to storm tide and sea level rise risks. It would allow the establishment of a schedule or (more likely) milestones against which planning and development activity can be measured.

The endorsed structure plan for the expansion of the Onslow townsite already provides a direction for future development. Much of the plan is intended to cater for residential development. Structure plans are not statutory and some flexibility remains to identify sites suitable for the long term relocation of some land uses into the structure plan area if necessary. Thought could be given to keeping development on some sites relatively temporary to retain flexibility for the long term.

This CHRMAP looks 100 years ahead but also requires regular review to take into account new information and changing circumstances. A local planning strategy generally has a planning horizon of around 15 to 20 years, whereas a local planning scheme is reviewed every five years. Changes to planning controls, including the extent of the SCA and the development requirements that apply, are likely to be modest and incremental. As discussed in the previous section, 6.2.3, a SCA provides a mechanism to facilitate the implementation goal but a more detailed review needs to be undertaken to reduce the risks of unintended consequences of any proposed amendments.

R15. No new development should be contemplated within the defined 2110 hazard line other than low impact, (relatively) low value and/or removable structures

R16. Applications in areas identified as being at risk from coastal processes should consider the predicted lifespan of the proposed development and its potential impact on other land during that lifetime. Temporary land uses that can be removed before or when a nominated trigger is reached might be considered.

R17. No further subdivision of land within the 2110 hazard line should be contemplated, nor further intensification of existing development

R18. *Planning should guide the evolution of the town to less hazardous areas, from a flooding and coastal erosion perspective*

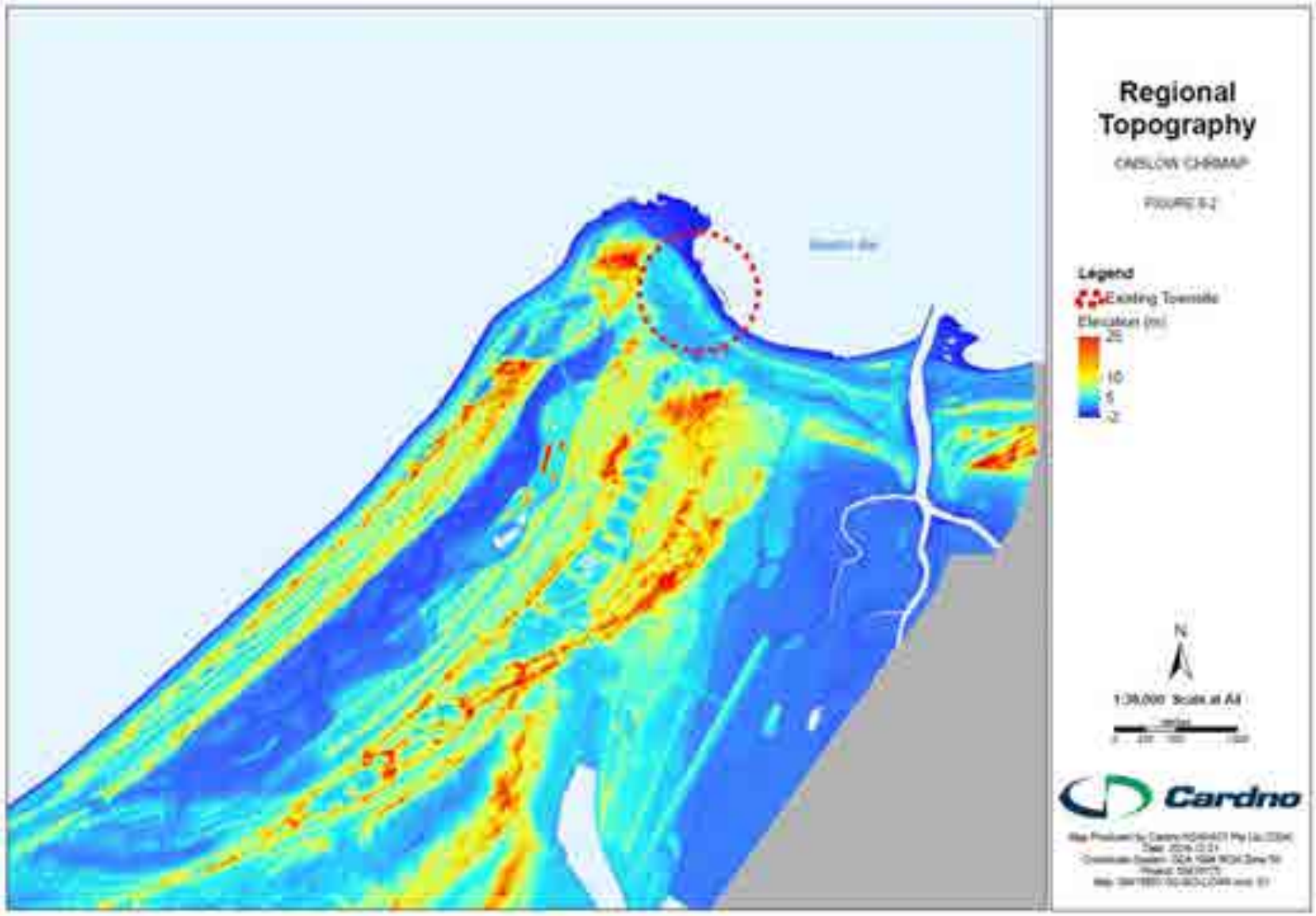

Figure 6-3 Topography of Onslow Region

6.2.5 Asset Relocation

This study has identified a number of public assets vulnerable to erosion for which the medium to long term pathway for adaptation is "managed retreat" (**Section 5.3**), including:

- Onslow salt infrastructure;
- Onslow Back Beach picnic area;
- Portions of the Ian Donald Blair Memorial Walkway; and
- Portions of Seaview Drive, Back Beach Road and Second Ave.

Ideally, the long-term preferred pathway for all assets in the SCA (i.e. at risk of inundation) is managed retreat, with some potential for accommodation in the form of changed land use and design to withstand impacts.

It is recommended that the Shire adopt a policy for relocation of public and Shire-owned assets from within the SCA at end of their lifecycle wherever possible. For some assets such as parks and recreations grounds and car parks these may be considered to be acceptable land uses and infrastructure should be designed to accommodate the risk as described in **Section 1.3**. It is recommended that the Shire's Asset Management Plan be updated to reflect the relocation policy.

Relocation of privately owned residential and commercial assets is a complex issue. As introduced in **Section 6.1**, it is important to identify land uses that are strategically compatible with the risk and zone the land accordingly, and a review of current zoning and land use permissibility with zones is recommended. Informing potential buyers of the long term risk is an important component as discussed in the following Section. Additional proactive strategies could include land buy back and land swap schemes (**Figure 6-4**).

Onslow salt infrastructure is vulnerable prior to 2040, and although there is scope for accommodation in the short term, the medium term adaptation pathway is for managed retreat (**Section 5.3.1**). It is recommended that the Shire convey the outcomes of this CHRMAP report and the expectation for long-term managed retreat to Onslow Salt management.

Consideration should also be given to the long term possibility of relocating the Bindi Bindi community to higher ground. This would obviously be something to be canvassed with the Bindi Bindi community given the tenure of the land and the cultural connections with the site, which was established as a 'native reserve' to house the many tribes forced off their country by the encroaching spread of pastoralism.

Alternative locations for all relocated assets would need to be identified as recommended in **Section 6.2.4** above.

R19. It is recommended that the Shire adopt a policy for relocation of public and Shire-owned assets from within the SCA at the end of their lifecycle wherever possible, and that the Shire's Asset Management Plan be updated to reflect the relocation policy

R20. The outcomes of this CHRMAP report and the expectation for long term management retreat should be conveyed to Onslow Salt management.

R21. Consideration should also be given to the long term possibility of relocating the Bindi Bindi community to higher ground.

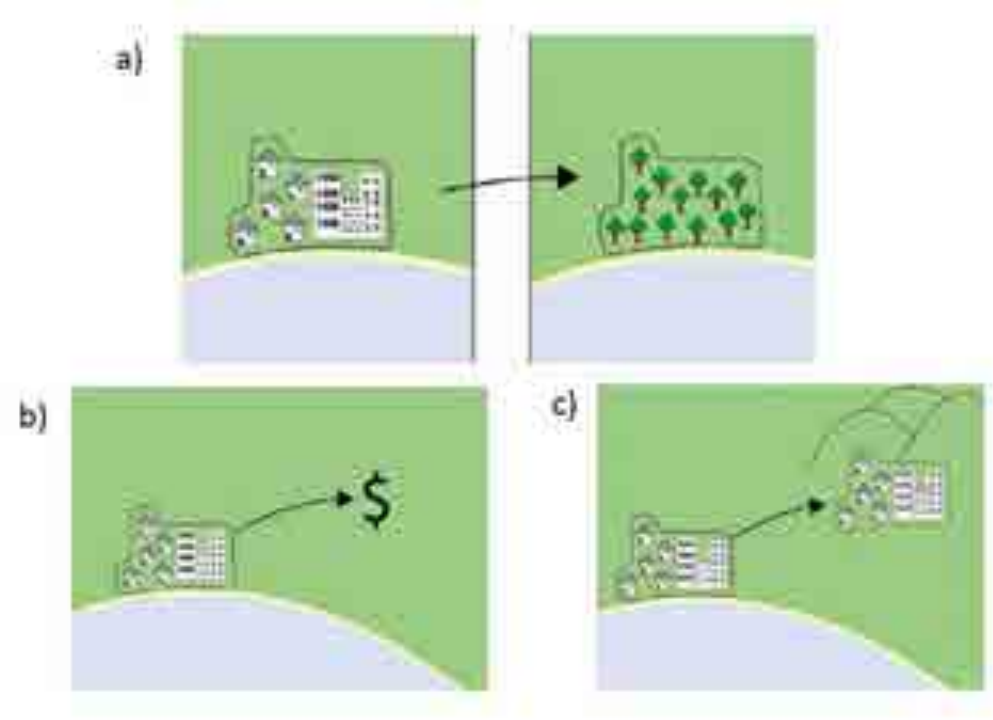

Figure 6-4 Relocation concepts a) changed land use within high risk coastal areas and strategies of b) land buy back and c) land swap (adapted from Griffith University Centre for Coastal Management, 2012)

6.2.6 Flood-prone Areas - Information for land buyers

Informing potential purchasers of land within the SCA and other flood prone land of the risk of flooding is important to allow people to make informed decisions about land they may look to purchase and develop. The Shire already has one mechanism for doing this, in some circumstances.

The provisions of Appendix 12 of TPS 7 include the requirement that any planning approval issued for development within the Onslow SCA shall include a condition requiring that a notification be placed on the certificate of title stating: "*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."* This provision should remain.

Such a notification would take the form of a Notification under section 70A of the *Transfer of Land Act 1893*. A Section 70A Notice, as it is commonly known, advises prospective purchasers of a potential hazard or factor that might impact the enjoyment of the property. Typically it is only acceptable to place such a notice on a certificate of title if the factor is relatively permanent and would not be evident at all or would not necessarily be obvious on inspection of the land. Potential flooding is one such factor.

Except when the notification is required as a condition of development or subdivision approval, the land owner's acceptance is required before application to place a notice on a title can be lodged with the Registrar of Titles. Therefore whilst it is possible to apply to have a section 70A notice placed on the Title in other circumstances, it can only be with the agreement of the owner. Also, a fee is payable which might make the task cost prohibitive depending on the number of titles involved. Nevertheless it is something to consider and possibly negotiate with the State Government to remove the associated fees, in the public interest.

Information should also be given to prospective purchasers of flood-prone premises about the potential for inundation. This advice should be provided by the Shire in conjunction with the issue of zoning certificates and/or property enquiries. If it doesn't already, the information should be stored in the Shire's property data base where it can be accessed by Shire personnel responsible for responding to such enquiries. A GIS data base could also record incidences of flooding as they occur (along with a range of other site specific information), helping to build up a comprehensive picture that will aid future planning and investment decisions.

R22. Provision 6 of Appendix 12 of TPS 7 (requiring a notification be placed on the certificate of title) should remain

R23. Information on inundation risk should also be given to prospective purchasers of flood-prone premises by the Shire in conjunction with the issue of zoning certificates and/or property enquiries

6.3 Accommodate Actions

6.3.1 Sea Wall Maintenance

The seawall forms a protective structure not only in relation to coastal erosion, but also in the protection of the township from inundation. The maintenance of the seawall is assumed in the predicted risk profile of the assets protected by it (for example buildings in the township). For the assumed protective capacity of the seawall to be realised into the future, it must be adequately maintained. It is thus highly recommended that the seawall be maintained and current and future maintenance specifications should be developed. It is also recommended that consideration is given to extending the seawall as presented below (**Section 6.4.2**).

R24. It is highly recommended that the seawall be maintained, that detailed current and future maintenance specifications be developed and that beneficiaries and equitable apportionment of costs be investigated.

R25. Consideration should be given to extending the seawall to the east. This consideration should be informed by a Benefit Cost Analysis including options to equitably apportion costs to beneficiaries.

6.3.2 Land Use within the SCA

As introduced in **Section 6.1**, management for coastal hazards does not necessarily mean there can be no development in high risk areas. The SCA is a form of spatial control, but the zones underlying the SCA are also important as these may still permit land uses that would be vulnerable to hazard impacts within the planning timeframe (100 years). Zoning sets limits on the type and extent of development that can happen in particular areas. It is important to identify land uses that are strategically compatible with the risk and to zone the land accordingly. A review of current zoning and land use permissibility with zones is recommended.

Landuse within the SCA is considered in Appendix 12 of TPS 7 with specific reference to land use types: Health and Welfare and Community Services (Strategic and Non-strategic), Commercial (Strategic and Non-strategic), Residential, Temporary and or Transient; and Entertainment, Recreation and Culture (Appendix D).

In the context of adaptation planning, however it is recommended that land uses within the SCA be examined in greater details and consideration given to the formulation of guidelines on the preferred landuse within the SCA. In general, preference should be given to land uses which are by nature temporary or transient (for example caravan parks), and are readily relocatable in response to changes in the risk profile, or otherwise make the risk of erosion and inundation more tolerable. Extension of the conservation reserve may also be appropriate in some areas

R26. A detailed review of current zoning within the SCA and land use permissibility within zones is recommended.

R27. Consideration should be given to the formulation of guidelines on preferred landuses within the SCA. These guidelines may be incorporated into the update to the TPS.

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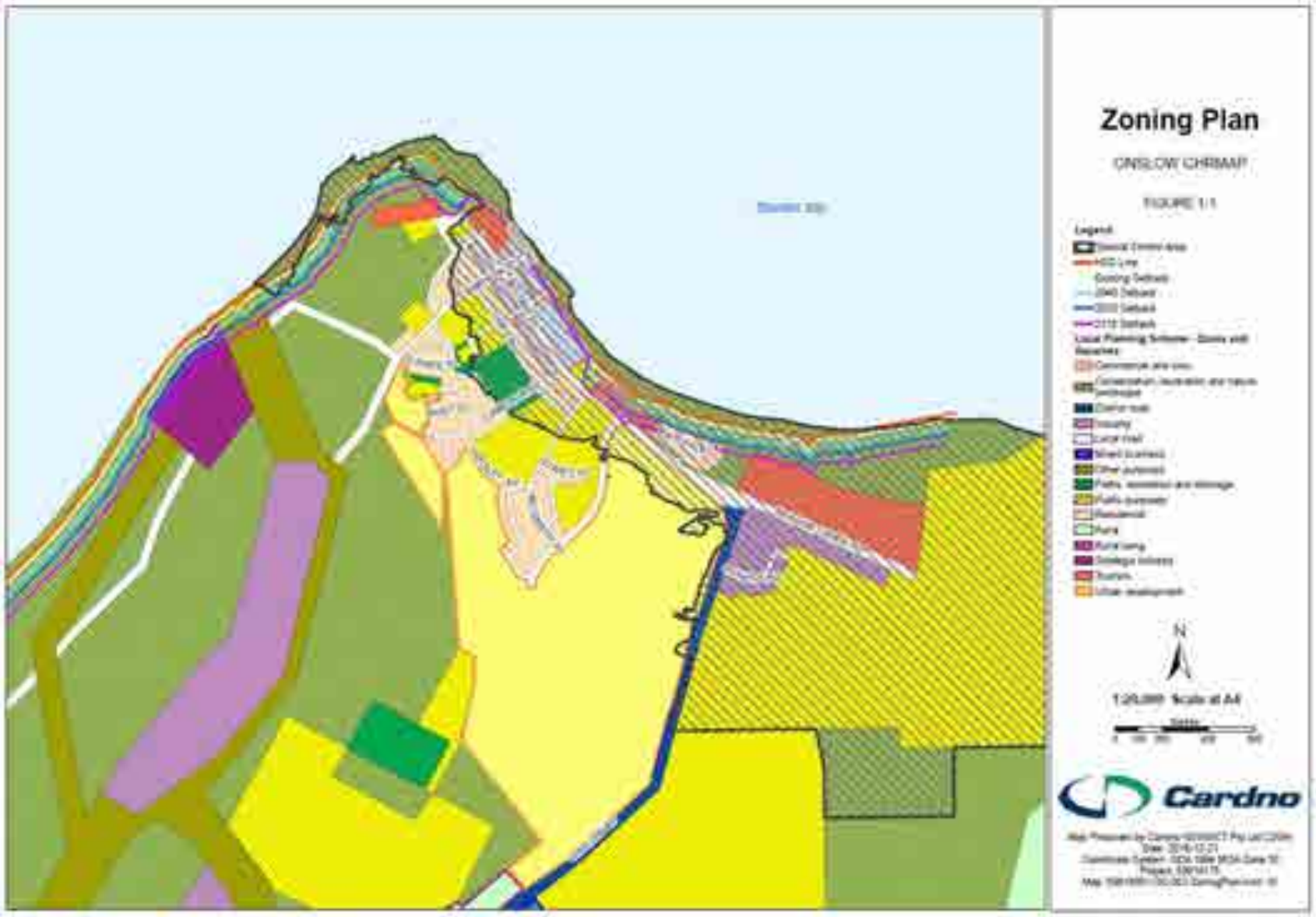


Figure 6-5 2004 Gazetted SCA overlaying current Onslow township zoning

6.3.3 Ground and Floor Levels

Inundation risks can also be managed through the application of planning and building controls, requiring elevated floor levels to reduce the impact of the expected flooding, especially under future conditions. This is usually implemented as a requirement to have a certain freeboard above a design flood level.

It is necessary to differentiate between finished ground level and finished floor level. All land that is the subject of a planning approval within the Onslow Coastal Hazard Area shall have minimum finished ground level of 2.5m AHD. However, fill to achieve a finished ground level of higher than 2.5m AHD is generally not supported, because increasing ground levels in one area can impact on other areas.

TPS 7 Appendix 12 currently specifies the minimum FFL for any building within the SCA as 2.5m AHD, with entertainment, cultural and recreation uses being permitted at this level. This minimum is specified to ensure that roads are less vulnerable to flooding. Other types of uses must have minimum floor levels of between 4m AHD and 6.4m AHD (Table 6-2), depending on their perceived vulnerability (refer to **Appendix D** of this document for the full text of Appendix 12 including a break-down of specific land uses included within each category).

On the basis of the results from coastal hazard assessment (Cardno 2016a), an appropriate level might be the 500-year ARI 2110 flood level of 4.5 m AHD with a 300mm or 600mm freeboard (i.e 4.8 -5.1 m AHD). This is in general agreement with the current FFLs (except for Temporary and/or Transient use and development). However, it is recommended that the Shire undertake a full review of FFL provided in Appendix 12 in relation to the flood levels provided in this document and existing precedents for land-use dependent freeboard allowances.

It is further recommended that this is reviewed again following review of the town drainage system as discussed in **Section 0.**

Table 6-2 TPS 7 Appendix 12 minimum Finished Floor Levels (FFL)

Land Use and Development	Minimum FFL (M AHD)
Health, Welfare and Community Services—Strategic use and development	6.4
Commercial—Strategic use and development	5.9
Residential use and development	5.9
Industry use and development shall be at a minimum finished floor level of	4.9
Commercial—non Strategic use and development	4.9
Health, Welfare and Community Services—non Strategic use and development	4.9
Temporary and/or Transient use and development*	4.0
Entertainment, Recreation and Culture use and development	2.5

* Where planning approval is issued, the use and development shall not remain beyond 31 December 2040.

R28. It is recommended that the Shire undertake a full review of FFL provided in TPS Appendix 12 in relation to the flood levels provided in this document

R29. FFL provided in TPS Appendix 12 should be reviewed again following review of the town drainage system

6.3.4 Design Guidelines

There are a range of adaptation approaches to inundation risk for property and building design as illustrated in **Figure 6-6**.

The Landcorp (2012) published document, *Pilbara Vernacular Handbook* already identifies a range of design considerations for building in the Pilbara, and includes a section on Onslow (Part 5). It describes elements of

the design vernacular typical of Onslow. This includes local typologies and use of materials and design elements to accommodate the climate, including heat, cyclones and inundation.

In terms of accommodating inundation, the most appropriate design element may be raising buildings on stumps or stilts so that water can flow beneath them (**Figure 6-6**). The height required in some locations may not make this a feasible response for retail and commercial buildings but it is a technique that has been employed for many years. Design guidelines might address the use of undercrofts, with habitable rooms raised above expected flood levels and other rooms and car parking permitted with lower FFLs.

Design guidelines are typically not statutory as writing specific design requirements into the planning scheme can limit innovative design responses. Only those design elements, such as FFL for habitable rooms, that are considered essential should be in the planning scheme. Beyond that, making design guidelines a local planning policy under the planning will provide them with sufficient status to require them to be given due regard, whilst maintaining flexibility to allow variations in specific circumstances.

It is recommended that design guidelines be developed to compliment those published by Landcorp to more specifically address measures for protection from inundation.

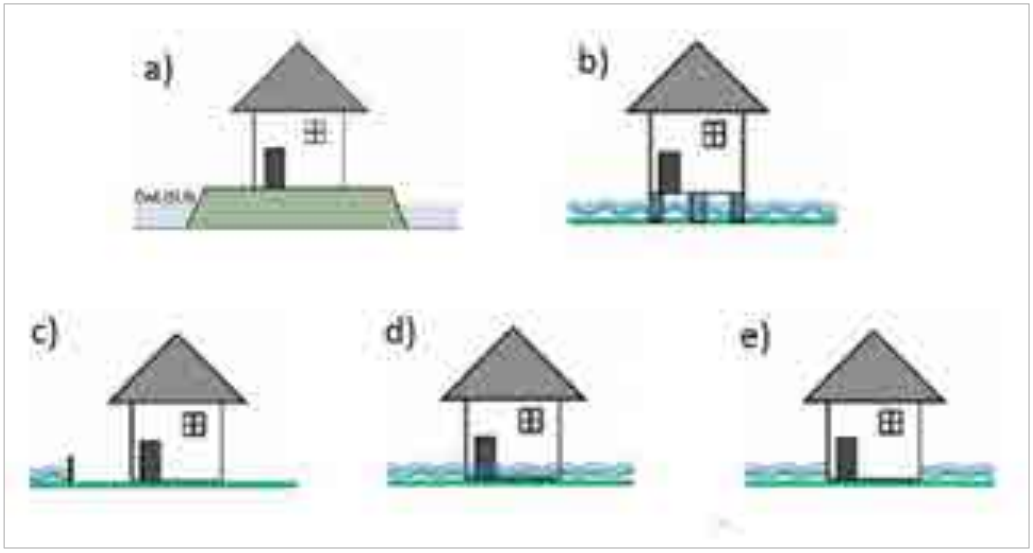


Figure 6-6 Property and building design adaptation responses a) raised ground levels, b) elevated buildings c) localised levees d) "wet" flood proofing and e) "dry" flood proofing (adapted from Griffith University Centre for Coastal Management, 2012)

R30. It is recommended that design guidelines be developed to specifically address measures for protection from inundation.

6.3.5 Drainage Design

Much of the town is relatively low and flat and the town's drainage relies on conveying runoff to stormwater detention basins prior to its discharge to the sea (see **Section 2.6**). This is particularly apparent for the drainage basins at the western end of the town. Over the 100 year planning horizon, the efficiency of the town drainage system is likely to be reduced (due to rising sea levels and the rising water table reducing the flood storage capacity of the drainage basins) leading to more frequent and prolonged flooding of low lying areas. Following significant future flood events the cost of repairs to any damaged infrastructure is likely to continue rising.

R31. It is recommended that prior to the next review of the CHRMAP the town drainage system be investigated and a strategy that meets the requirements of SPP2.6 and the CHRMAP Guidelines, the Water Management Plans, and other related State guidelines be developed.

6.3.6 Emergency Planning

It is recommended that the risks associated with emergency management and planning be considered through the implementation of cyclone and flood emergency response plans or similar. These plans map out the response to flood and coastal erosion emergencies prior to their occurrence and include the consideration of warnings, evacuation routes, trigger levels for response actions and the community recovery, post disaster.

R32. It is recommended that during the next phase of review Emergency Management plans incorporate the risks identified in this CHRMAP.

6.4 Protect Actions

6.4.1 Dune Care

On sandy shorelines, coastal dunes represent the last line of defence against erosion by providing a reservoir of sand for waves to utilise during storms (NSW Department of Land and Water Conservation 2001). In Onslow the dune system is low lying and generally sparsely vegetated (**Figure 6-7**). The current threats include uncontrolled vehicle and pedestrian access. These human impacts can also lead to excessive wind-blown erosion, above that expected naturally.

Figure 6-7 Track through the dunes near the Onslow Jetty

It is recommended that the Shire initiate a dune care program that considers the following elements:

- Analysis of historical aerial photography to understand the impacts of 4WD on vegetation loss and the development of mobile substrate to guide an effective dune care program;
- Restriction of vehicle and pedestrian access;
- Dune stabilisation works where required; and
- Planting of native species.

NSW Department of Land and Water Conservation (2001), Coastal Dune Management: A Manual of Coastal Dune Management and Rehabilitation Techniques is a recommended resource for developing this program.

R33. It is recommended that the Shire initiate a dune care program.

6.4.2 Seawall Extension

An option that may be considered to protect the town from coastal erosion and inundation if the dunes to the eastern end of the town beach are eroded would be to extend the existing seawall towards the east. This option would provide a number of benefits to protect assets into the future but ultimately in the long-term the seawall is likely to be outflanked and/or overtopped.

The seawall could be extended to various distances and it may be appropriate to use a staged approach. These distances/stages might include:

1. Approximately 300 m extension, consistent with the span of the remnant seawall to protect infrastructure directly behind;
2. Approximately 700 m total extension (additional 400 m) to the eastern end of the Bindi Bindi community;
3. Approximately 1700 m total extension (additional 1 km) to the Beadon Creek groyne.

The cost for construction of such an extension is difficult to estimate due the variable nature of availability of construction plant and equipment, its mobilisation to Onslow, the source of appropriately sized rocks for the armour units and range of other factors. For comparison, a recent similar height and width seawall in the South west of WA, with a reasonably close source of amour rock, was estimated to cost about $500k per 100m length of seawall. Allowing an additional 50% for mobilising to Onslow and assuming a similar source of rock is reasonably close then the extension is likely to cost around $750k per 100 m length or approximately $5M for the 700m extension and approximately $7.5M for the 1000m extension. The total length of seawall is estimated to cost around $12.5M.

R34. It is recommended that the Shire initiate investigations into the availability of rock materials and undertake a more detailed costing of carrying out seawall extension using a staged approach. This consideration should be informed by a Benefit Cost Analysis including options to equitably apportion costs to beneficiaries.

6.4.3 Drainage Infrastructure

As discussed in **Section 0** the design of the stormwater drainage system will require consideration of a number of issues to remain effective into the future. Stormwater drainage infrastructure is critical to the functions of the town. In the absence of any changes to the system the flooding of low lying areas will continue to worsen into the medium term. The present program of maintaining the system to mitigate flood impacts at the 10 year ARI rainfall event and undertaking reactive works to improve elements of the system. The drainage maintenance and development strategy needs to be reviewed in the short term in the context of the medium to longer term sea level rise effects. Investigations of options to assist develop a more detailed Benefit Cost Analysis of the whole system asset base may be considered in the immediate term.

R35. It is recommended that the Shire initiate investigations of the drainage system and its performance/requirements in the longer term. The review to incorporate more detailed Benefit Cost Analyses to inform future decisions on adaptation of the stormwater drainage system.

6.5 Economic Aspects

6.5.1 Coastal Erosion

A strategic economic assessment was undertaken to assess the economic implications of the risk of coastal erosion and pluvial inundation (**Appendix E**). The costs over the 100 yr planning timeframe was assessed to be $0.6 to $3.7 million (present value, $2016) associated with coastal erosion. The assessment concluded that, based on the existing information, there are not enough costs associated with inaction to justify immediate

relocation of assets to reduce risk. It is recommended to wait as long as possible before incurring replacement costs. A more detailed evaluation of costs and benefits of erosion specific management options is recommended.

In the medium term the costs associated with the seawall extension option (see **Section 6.4.2**) is likely to be less than the value of the assets that would be afforded protection from coastal erosion and inundation up to the 100 yr ARI ocean storm surge event. Ultimately in the long term the seawall would be outflanked and therefore a retreat strategy is recommended. These confounding factors require more detailed assessment and consideration of the longer term benefits to inform decisions on the future of these assets and at what time protect or retreat strategy may be implemented.

R36. A more detailed evaluation of costs, benefits and equitable apportionment of costs for erosion specific management options is recommended.

6.5.2 Pluvial Inundation

The strategic economic assessment also considered the damage repair costs of the 10 and 100 year ARI pluvial flooding events occurring at the present time and at the 2110 horizon. The method and assumptions used to produce relative costs are outlined in the Appendix E. Based on the number of buildings impacted and the damage cost per asset, the damage cost estimates for any one event is presented **Table 6-3**.

Table 6-3 Pluvial inundation damage cost per single event in 2016

Scenario	Damage Cost per Event
10 Year ARI (current)	$6.7M
100 Year ARI (current)	$9.9M
10 Year ARI (2110)	$9.9M
100 Year ARI (2110)	$14.5M

Table 6-4 presents the expected present value costs (expected value = probability x cost of damage / repair) of each scenario given their likelihood of occurrence over the 100 year period. The 10 Year ARI event is less intense but more frequent and as such is more costly than the 100 Year ARI event. The current value of the assets impacted by a 100 year event (should it occur today) is estimated at $110M.

Table 6-4 Pluvial inundation damage cost over 100 years

Scenario	Expected value of damage cost over 100 years	Present expected value of damage cost over 100 year assessment period
10 Year ARI	$78.6M	$10.8M
100 Year ARI	$11.6M	$1.6M

As for erosion, the inundation economic assessment concluded that, based on the existing information, there are not enough costs associated with inaction to justify immediate relocation of assets to reduce risk. It is recommended to wait as long as possible before incurring replacement costs. A more detailed evaluation of costs and benefits of inundation specific management options is recommended.

R37. A more detailed evaluation of costs, benefits and equitable apportionment of costs for inundation specific management options is recommended.

6.6 Performance, monitoring and reporting

A well planned monitoring and review program is essential to the success of the CHRMAP process. The guidelines suggest that the CHRMAP be reviewed and updated each 5 years to reflect the improved knowledge base and contribute to more effective planning. Regular monitoring, evaluation, review, and where necessary, amendment of adaption plans are part of the continual improvement process. Triggers for actions and review may include time frames, new site specific information, new general coastal process information, updated climate change predictions, damage assessment and improved asset condition and life cycle information.

As part of the CHRMAP, Cardno will develop a basic monitoring and review program that identifies specific triggers and helps the Shire identify other events that may be a trigger. Adaption itself can induce secondary risks and the monitoring plan will assist in the early identification of unexpected consequences, so that the triggering of a review process can occur prior to intolerable risk.

Time and cost related parameters assessed in the adaption planning stage will also be re-assessed during the monitoring and review process. This is important as these factors may change over time, such as when risks increase in likelihood and become more frequent. The priority of risks will change over time, and so will the cost/benefits and other factors, including the Shire's budget.

6.6.1 Coastal Monitoring

Wave information – Council to seek access to NWS wave monitoring data information and wave transformation modelling to assess wave characteristics at the Onslow coast during significant storms/cyclones. This information may be updated or seek advice from the BoM on incorporating annual event reports into Councils reporting system.

- S1 opportunistic shoreline surveys through aerial survey of the beach and dunes annually and immediately after significant events (10 year ARI wave event)
- S2 Shoreline surveys and sediment surveys
- S3 historic shoreline movement. Obtain aerial photography each 5 years to assess shoreline movement
- Sea Level Rise – Utilise analysis of Beadon Creek water levels to determine the actual sea level rise each 2-5 years.

The effects of broader scale coastal sediment transport processes within the secondary sediment cell (that includes the recently completed Wheatstone harbour development) should be monitored and analysed to assess potential effects on the future hazard line estimates.

If rapid erosion of Sunset Beach and the dunes is observed over next 10 years then undertake geophysical survey of dunes to assess the erodibility of soils and substrate and review of the hazard line estimates.

6.6.2 Inundation monitoring

Supplement BoM weather and rainfall monitoring with water table monitoring near the drainage basins to assess the influence of groundwater on the basin capacity during events.

Undertake flood debris level monitoring immediately after significant floods to assist assess the flood characteristics.

Utilise existing models to further assess the monitoring data and flood characteristics

6.6.3 Assets and Damage Assessment Reports

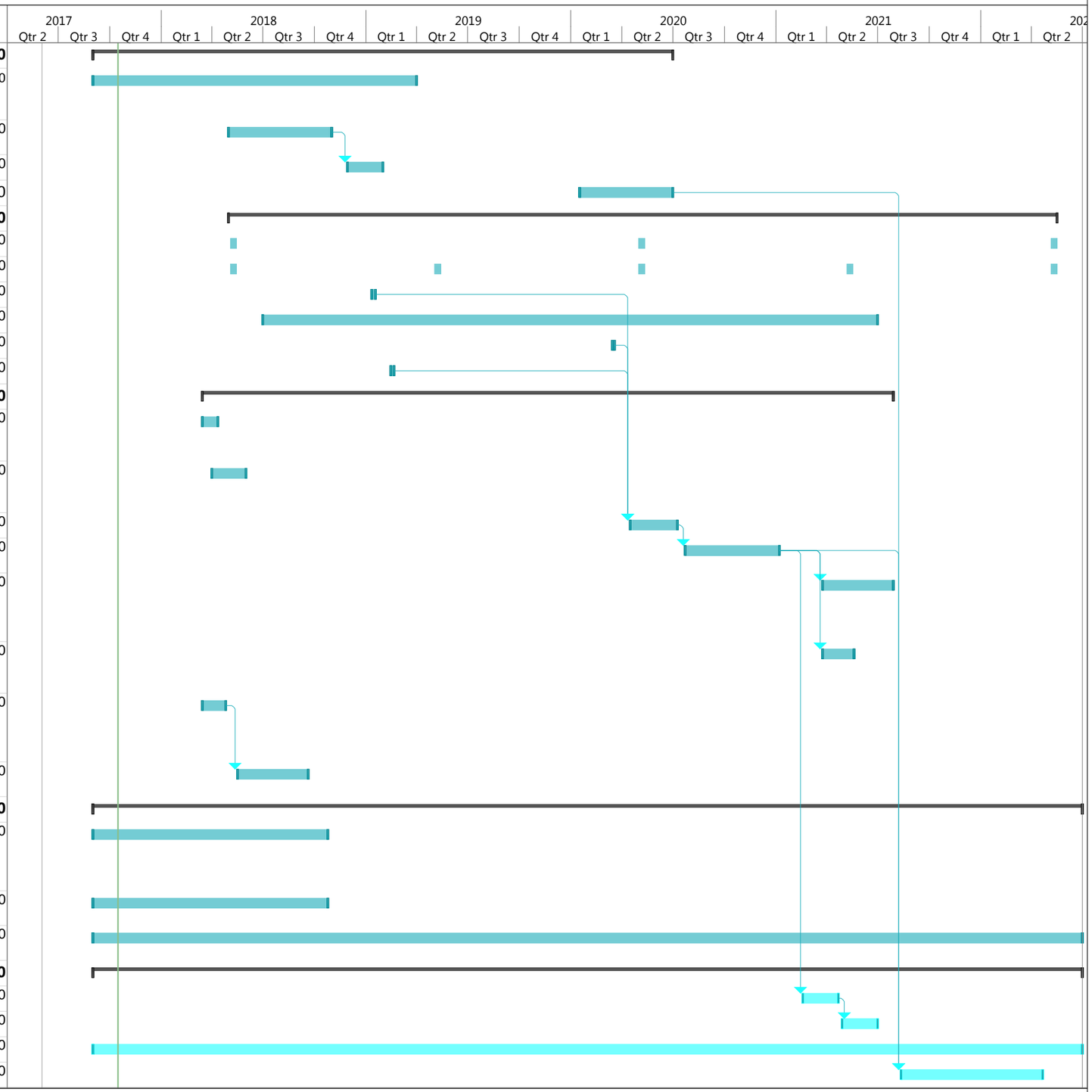
Develop asset database and tracking of post event asset damage to aid economic assessments.

6.7 Immediate Term Program Summary

A program of works for the immediate term 2017-2022, up to the next CHRMAP review is outlined in the Gantt Chart presented in Figure 6-8. The program summarises activities associated with each of the recommendations the monitoring discussed above and also highlights the linkages between the key activities.

Onslow CHRMAP 5 Year Program

ID	Task Name	Start	Finish	Cost Estimate
1	**Planning and Development Controls Review**	**1 Sep '17**	**30 Jun '20**	**$80,000**
2	Review Planning and Development Controls and Recommend Amendments as required: Recommendations R1, R2, R9, R10, R12, R14, R15, R17, R18, R21, R22, R26	1 Sep '17	31 Mar '19	$80,000
3	Amend current zone and SCA boundaries: Recommendations R3, R4, R5, R7	1 May '18	31 Oct '18	$0
4	Update SCA special provisions	29 Nov '18	30 Jan '19	$0
5	TPS 7 Update and Endorsement by WAPC	17 Jan '20	30 Jun '20	$0
6	**Monitoring**	**1 May '18**	**16 May '22**	**$300,000**
7	Horizontal Shoreline Datum (Aerial Photo Analysis)	1 May '18	2 May '22	$40,000
11	Annual Beach Profile Surveys	1 May '18	9 May '22	$125,000
17	Post wave erosion Event (>2 yr ARI wave) Beach Profiles	11 Jan '19	17 Jan '19	$30,000
18	Assess Current and Future Sediment Budget in the Secondary Cell	1 Jul '18	30 Jun '21	$80,000
19	Cyclone storm surge flooding Event	15 Mar '20	18 Mar '20	$10,000
20	Pluvial Flood Event (>2 yr ARI Rainfall)	14 Feb '19	19 Feb '19	$15,000
21	**Specialist Investigations**	**15 Mar '1**	**28 Jul '21**	**$310,000**
22	Investigate sufficient coastal foreshore reserve width allowance to extend the 2110 Hazard line a sufficient distance to accommodate future relocation of foreshore assets: Recommendation: R6	15 Mar '18	11 Apr '18	$15,000
23	Investigate planning mechanisms to allow future changes to be triggered including the ultimate retreat strategy. Recommendations: R16, R19	1 Apr '18	31 May '18	$0
24	Analysis of Flood, Storm Surge and Erosion event monitoring	16 Apr '20	8 Jul '20	$40,000
25	Develop integrated Model - Coastal Inundation, Groundwater levels and Pluvial Flooding Scenarios	23 Jul '20	6 Jan '21	$100,000
26	Investigate Pluvial Drainage and Coastal Processes Interactions to define triggers, set FFL, CHRMAP, Water Management Plans and Emergency Managemenet Plan overlaps. Recommendations: R27, R28, R29, R30, R31, R32	25 Mar '21	28 Jul '21	$50,000
27	Investigate wave runup height component for the future inundated areas. Add to the current 100 yr ARI still water level (4.5m AHD) to define the Peak Water Level and SCA extent. Recommendation: R8	25 Mar '21	19 May '21	$10,000
28	Investigate Seawall concept design, rock availability and potential stage triggers for implementing seawall upgrades, extension to Sunrise Beach and potential renourishment requriements for beach amenity. Recommendations: R24, R25, R33, R34	15 Mar '18	25 Apr '18	$15,000
29	Economic Analysis Undertake economic analysis of options. Recommendations: R35, R36, R37	17 May '18	19 Sep '18	$80,000
30	**Operational**	**1 Sep '17**	**30 Jun '22**	**$50,000**
31	Establish Data Management and GIS system (time series, spot levels and remote sensing) relating to localised and general flooding in Onslow allow identification trends over time, and Trigger assesment. Recommendations: R11, R13	1 Sep '17	24 Oct '18	$50,000
32	Update Asset database to incorporate end of life date to facilitate future management of assets. Recommendation: R19	1 Sep '17	24 Oct '18	$0
33	Notifications - Potentially affected land owners by direct contact and property titles. Recommendations: R20, R22, R23	1 Sep '17	30 Jun '22	$0
34	**CHRMAP Review and Update**	**1 Sep '17**	**30 Jun '22**	**$195,000**
35	Review Hazard line estimates (S1, S2, S3 and S4)	18 Feb '21	21 Apr '21	$25,000
36	Review Risk Assesment and Future Pathway Options	29 Apr '21	30 Jun '21	$40,000
37	Community and Stakeholder Consultation	1 Sep '17	30 Jun '22	$50,000
38	Update CHRMAP	12 Aug '21	20 Apr '22	$80,000



Project: 5 Year Implementation
Date: 16 Oct '17

Task	Project Summary	Manual Task	Start-only	Deadline
Split	Inactive Task	Duration-only	Finish-only	Progress
Milestone	Inactive Milestone	Manual Summary Rollup	External Tasks	Manual Progress
Summary	Inactive Summary	Manual Summary	External Milestone

Figure 6-8 Onslow CHRMAP Immediate term suggested program of work

7 CONCLUSIONS AND RECOMMENDATIONS

Climate change, including sea-level rise, is expected to bring changes to the West Australian coastline over coming decades. As a predominantly services oriented town Onslow has historically gone through periods of changing fortunes having been relocated in the early 1920's and ups and downs of various economic cycles centred around the agriculture, fishing, salt production, mining and oil and gas industries that support the area. The town's continued existence bears testament to its resilience and the impending threats of climate change and sea level rise are likely to present new challenges for the community. The threats of sea level rise and inundation events to property, infrastructure and the environment may ultimately again test the viability of the location of the town itself. This Coastal Hazard Mitigation and Adaption Plan (CHRMAP) has been prepared to provide a long term view of the possible strategies to adapt to the changing future conditions.

Development of the Onslow CHRMAP has followed the requirements of WA State Planning Policy 2.6: Coastal Policy (SPP2.6) and supporting guideline documents. An analysis of the coastal processes and predictions of erosion and inundation at future horizons was carried out in Part 1 of this study. The results informed the identification of vulnerable assets and a subsequent risk assesment. Based on the outcomes of the risk assessment a number of adaptation options and possible future pathways for mitigation has been considered.

A key aspect for the future of the town is the threat of steadily rising sea levels, combined with storm events - ocean storm surge, local rainfall-induced flooding and rising water tables – that will affect the viability of low lying areas of the town. In addition, coastal erosion is likely to threaten some infrastructure in the lee of the present Town Beach, including the Bindi Bindi community area. Strategies that might be adopted to respond to these threats at significant future turning points are articulated in this plan. A series of 37 recommendations for implementation in the immediate, short and long term were derived in Chapter 6 and are listed below.

In conclusion this plan outlines a series strategies that will need to be considered, revised and updated in future with the benefit of new information. Adopting the adaptive management approach will assist the community and Shire of Ashburton identify optimal solutions to the threats of climate change and sea level rise.

R1. A detailed review of current zoning and land use permissibility within zones should be undertaken in light of the results of the risk assessment outcomes.

R2. Appendix 12 SCA in LPS 7 should be reviewed to reflect the outcomes of the CHRMAP process and, where relevant, include specific clauses for example, to ensure that actions are enforceable

R3. The existing Conservation, Recreation & Nature zoning should be maintained / extended along the coastline, seaward of 2110 hazard line

R4. Move the Strategic Industry zone near jetty inland of 2110 hazard line

R5. Prior to development of Lot 381 consider adjusting north east boundary to be inland of 2110 hazard line.

R6. Consideration should be given to amending the scheme to extend the local scheme reserve for the foreshore area beyond the 2110 coastal hazard line a sufficient distance to accommodate relocation of foreshore assets. Where this may impact on private land, consideration should include risk of claims arising.

R7. The SCA should be extended inland to the 2110 coastal hazard line along the length of coastline, from the southern extent of the study area to 4 Mile Creek.

R8. For the current 100 year planning horizon the SCA extent should be defined by the 4.5 m AHD contour

R9. The SCA extent and provisions of Appendix 12 of the local planning scheme should be included in the five yearly local planning scheme review

R10. Review of the CHRMAP every five years is to include a review of the SCA extent and relevant provisions including Appendix 12 of TPS 7

R11. Data relating to localised and general flooding in Onslow (not just the SCA) should be recorded in sufficient detail to identify trends over time, including any changes that may result from development that has taken place

R12. Identify areas within the SCA and study area where avoidance of development altogether is the most advisable strategy

R13. Update of Shires GIS to include contours and flooding data from this study

R14. Intensification of development at the Bindi Bindi community should not be permitted. Renewal of existing infrastructure should only be considered with appropriate flood-resistant design

R15. No new development should be contemplated within the defined 2110 hazard line other than low impact, (relatively) low value and/or removable structures

R16. Applications in areas identified as being at risk from coastal processes should consider the predicted lifespan of the proposed development and its potential impact on other land during that lifetime. Temporary land uses that can be removed before or when a nominated trigger is reached might be considered.

R17. No further subdivision of land within the 2110 hazard line should be contemplated, nor further intensification of existing development

R18. Planning should guide the evolution of the town to less hazardous areas, from a flooding and coastal erosion perspective

R19. It is recommended that the Shire adopt a policy for relocation of public and Shire-owned assets from within the SCA at end of their lifecycle wherever possible, and that the Shire's Asset Management Plan be updated to reflect the relocation policy

R20. The outcomes of this CHRMAP report and the expectation for long term management retreat should be conveyed to Onslow Salt management.

R21. Consideration should also be given to the long term possibility of relocating the Bindi Bindi community to higher ground.

R22. Provision 6 of Appendix 12 of TPS 7 (requiring a notification be placed on the certificate of title) should remain

R23. Information on inundation risk should also be given to prospective purchasers of flood-prone by the Shire in conjunction with the issue of zoning certificates and/or property enquiries

R24. It is highly recommended that the seawall be maintained and detailed current and future maintenance specifications should be developed.

R25. Consideration should be given to extending the seawall to the east.

R26. A detailed review of current zoning within the SCA and land use permissibility within zones is recommended.

R27. Consideration should be given to the formulation of guidelines on preferred landuses within the SCA. These guidelines may be incorporated into the update to the TPS.

R28. It is recommended that the Shire undertake a full review of FFL provided in TPS Appendix 12 in relation to the flood levels provided in this document

R29. FFL provided in TPS Appendix 12 should be reviewed again following review of the town drainage system

R30. It is recommended that design guidelines be developed to specifically address measures for protection from inundation.

R31. It is recommended that prior to the next review of the CHRMAP the town drainage system be investigated and a strategy that meets the requirements of SPP2.6 and the CHRMAP Guidelines, the Water Management Plans, and other related State guidelines be developed.

R32. It is recommended that during the next phase of review Emergency Management plans incorporate the risks identified in this CHRMAP.

R33. It is recommended that the Shire initiate a dune care program.

R34. It is recommended that the Shire initiate investigations into the availability of rock materials and undertake a more detailed costing of carrying out seawall extension using a staged approach.

R35. It is recommended that the Shire initiate investigations of the drainage system and its performance/requirements in the longer term. The review to incorporate more detailed Benefit Cost Analyses to inform future decisions on adaptation of the stormwater drainage system.

R36. A more detailed evaluation of costs and benefits of erosion specific management options is recommended.

R37. A more detailed evaluation of costs and benefits of inundation specific management options is recommended.

8 REFERENCES

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CHRMAP For the Onslow Coast

APPENDIX A

ASSET DESCRIPTION

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COASTAL EROSION

Figure A.1. Location map of assets vulnerable to future coastal erosion in Onslow.

COASTAL EROSION

Table A.1. Summary asset information for on-ground infrastructure at Onslow Jetty.

Asset ID Asset 1 On-ground infrastructure at Onslow Jetty	Asset description	Values
   	Onslow salt infrastructure supporting ship loading operations. Consists of: • Rock abutment • Permanent buildings • Demountable buildings • Plant and equipment • Conveyor infrastructure Tenure: Onslow Salt leased crown land	**Economic** Onslow Salt Asset. Estimated Replacement Value[1]: $10M - $100M Estimated Relocation Cost[1]: $1M - $10M **Social** Beach adjacent to asset is valued by community for 4WD access / fishing and passive recreation, sunset viewing. **Environmental** The asset does not have environmental value. The surrounding native vegetation and beach have natural area values.

Assigned coastal erosion risk ratings

	2015	2040	2070	2110
Likelihood	Possible	Likely	Almost Certain	Almost Certain
Consequences	Insignificant	Moderate	Moderate	Major
Adaptive Capacity	High	Moderate	Moderate	Moderate

[1] Costs provided are preliminary estimates only and will be reviewed.

COASTAL EROSION

Table A.2. Summary asset information for the Back Beach picnic area.

Asset ID Asset 2 Onslow Back Beach picnic area	Asset description	Values
  	Picnic area with cooking facilities. Irrigated grass lawn. Maintained by the Shire of Onslow	**Economic** Onsite infrastructure, i.e. barbecue areas. Estimated Replacement Value[1]: $100,000 - $1M Estimated Relocation Cost[1]: $100,000 - $1M **Social** Public amenity, maintained grassed area used for community events and recreation. Picnic infrastructure used by community. **Environmental** The asset itself does not have natural environmental value. The surrounding native vegetation and beach have natural area values.

Assigned coastal erosion risk ratings

	2015	2040	2070	2110
Likelihood	Rare	Unlikely	Possible	Likely
Consequences	Insignificant	Insignificant	Minor	Moderate
Adaptive Capacity	High	High	High	High

[1] Costs provided are preliminary estimates only and will be reviewed.

COASTAL EROSION

Table A.3. Summary asset information for Front / Sunrise Beach.

Asset ID Asset 3 Front / Sunrise Beach	Asset description	Values
 	Public beach used for recreational activities.	**Economic** Tourist destination. Estimated Replacement Value[1]: $100,000 - $1M Estimated Relocation Cost[1]: $100,000 - $1M **Social** Beach used by the community. **Environmental** Natural area. Buffer against storm events.

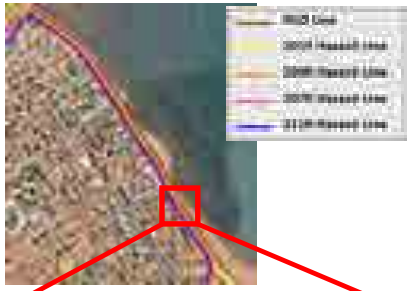
Assigned coastal erosion risk ratings

	2015	2040	2070	2110
Likelihood	Unlikely	Possible	Almost Certain	Almost Certain
Consequences	Insignificant	Minor	Moderate	Major
Adaptive Capacity	Very High	High	High	Moderate

[1] Costs provided are preliminary estimates only and will be reviewed.

COASTAL EROSION

Table A.4. Summary asset information for the seawall.

Asset ID Asset 4 Seawall	Asset description	Values
   	Seawall to protect Onslow from flood damage during cyclones and erosion protection. It was reconstructed in 2002. Seawall built using limestone. Maintained by the Shire of Onslow.	**Economic** Onsite infrastructure. **Social** Provides protection for the township from coastal hazards. **Environmental** Buffer

Assigned coastal erosion risk ratings

	2015	2040	2070	2110
Likelihood	Possible	Likely	Almost Certain	Almost Certain
Consequences	Moderate	Moderate	Major	Major
Adaptive Capacity	High	High	High	High

COASTAL EROSION

Table A.5. Summary information for the assets adjacent to the seawall.

Asset ID Asset 5 Assets adjacent to crest of seawall (bins, shade structures, benches)	Asset description	Values
 	Public grassed area consisting of exercise equipment, benches, shaded structures and bins. Maintained by the Shire of Onslow.	**Economic** Public infrastructure **Social** Public amenity, maintained grassed area used for community recreation. Public infrastructure used by community. **Environmental** Assets do not have environmental value. The surrounding beach has natural area values.

Assigned coastal erosion risk ratings

	2015	2040	2070	2110
Likelihood	Unlikely	Unlikely	Possible	Likely
Consequences	Insignificant	Insignificant	Minor	Moderate
Adaptive Capacity	Moderate	Moderate	Moderate	Moderate

COASTAL EROSION

Table A.6. Summary asset information for the Shire of Ashburton Offices (Business House).

Asset ID Asset 6 Shire of Ashburton Offices (Business House) at the intersection of Second Ave and McGrath Rd	Asset description	Values
  	Office building made of prefab and steel. Asset is situated behind Front/Sunrise Beach.	**Economic** Public infrastructure for Shire services. **Social** Asset has community values as office is used to serve the community. **Environmental** The asset does not have environmental value. The adjacent beach has natural area values.

Assigned coastal erosion risk ratings

	2015	2040	2070	2110
Likelihood	Rare	Unlikely	Possible	Likely
Consequences	Moderate	Major	Major	Major
Adaptive Capacity	Low	Low	Low	Low

COASTAL EROSION

Table A.4. Summary asset information for the Bindi Bindi Aboriginal Community.

Asset ID Asset 7 Bindi Bindi Aboriginal Community on Second Ave	Asset description	Values
 	Community area with high cultural value. Area consists of residential houses, basketball court, gazebo, community office.	**Economic** Public infrastructure. **Social** Housing and public amenity for the Bindi Bindi Indigenous community. **Cultural** Indigenous community. **Environmental** The asset does not have environmental value.

Assigned coastal erosion risk ratings

	2015	2040	2070	2110
Likelihood	Rare	Unlikely	Possible	Likely
Consequences	Moderate	Major	Major	Major
Adaptive Capacity	Low	Low	Low	Low

COASTAL EROSION

Table A.8. Summary asset information for western half of the Ian Donal Blair Memorial Walkway.

Asset ID Asset 8 Western half of Ian Donald Blair Memorial Walkway	Asset description	Values
	Western end of boardwalk near Sunset Beach. Boardwalk is made of wood and recycled plastic. Total length of boardwalk is 1017 m.	**Economic** Boardwalk connecting Beadon Point and Sunset Beach. **Social** Used for community recreation. **Environmental** The asset does not have environmental value. The surrounding native vegetation has natural area values.

Assigned coastal erosion risk ratings

	2015	2040	2070	2110
Likelihood	Rare	Rare	Likely	Almost Certain
Consequences	Minor	Minor	Minor	Minor
Adaptive Capacity	Very High	Very High	Very High	Very High

COASTAL EROSION

Table A.9. Summary asset information for the intersection of Seaview Drive and Back Beach Road.

Asset ID Asset 9 Intersection of Seaview Drive and Back Beach Road	Asset description	Values
	Intersection of two asphalt roads used to access public amenities.	**Economic** Public road. **Social** Provides access to assets used by the community, i.e. barbecue area, beach. **Environmental** Asset does not have environmental value. The surrounding native vegetation and beach have natural values.

Assigned coastal erosion risk ratings

	2015	2040	2070	2110
Likelihood	Rare	Rare	Unlikely	Possible
Consequences	Minor	Minor	Minor	Minor
Adaptive Capacity	High	High	High	High

COASTAL EROSION

Table A.10. Summary asset information for eastern end of the Ian Donald Blair Memorial Walkway.

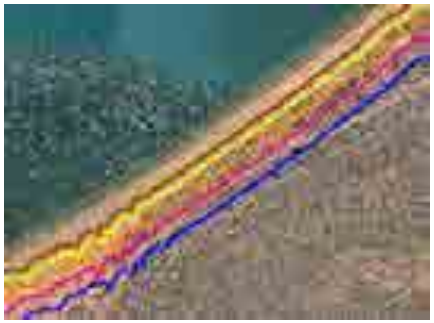
Asset ID Asset 10 Eastern end of Ian Donald Blair Memorial Walkway	Asset description	Values
  	Eastern end of boardwalk at Beadon Point (near the main township). Boardwalk is made of wood and recycled plastic. Total length of boardwalk is 1017 m.	**Economic** Boardwalk connecting Beadon Point and Sunset Beach. **Social** Used for community recreation. **Environmental** The asset does not have environmental value. The surrounding native vegetation has natural area values.

Assigned coastal erosion risk ratings

	2015	2040	2070	2110
Likelihood	Rare	Possible	Likely	Almost Certain
Consequences	Minor	Minor	Minor	Minor
Adaptive Capacity	Very High	Very High	Very High	Very High

COASTAL EROSION

Table A.11. Summary asset information for Seaview Drive near

Asset ID Asset 11 Seaview Drive near Four Mile Creek	Asset description	Values
  	7 km (approximately) asphalt road connecting the township to Four Mile Creek	**Economic** Public infrastructure. **Social** Thoroughfare between assets used by the community. **Environmental** The asset does not have environmental value. The surrounding native vegetation has natural area values.

Assigned coastal erosion risk ratings

	2015	2040	2070	2110
Likelihood	Rare	Unlikely	Possible	Likely
Consequences	Minor	Minor	Minor	Minor
Adaptive Capacity	High	High	High	High

COASTAL EROSION

Table A.12. Summary asset information for Second Avenue.

Asset ID Asset 12 Second Ave	Asset description	Values
 	Highly used main road within the township.	**Economic** Public infrastructure. **Social** Thoroughfare between assets used by the community. **Environmental** The asset does not have environmental value.

Assigned coastal erosion risk ratings

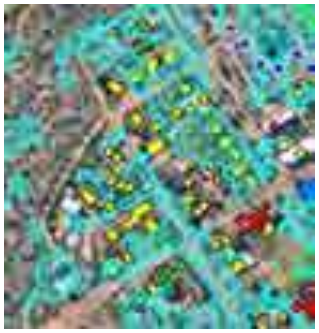
	2015	2040	2070	2110
Likelihood	Rare	Rare	Unlikely	Possible
Consequences	Moderate	Moderate	Moderate	Moderate
Adaptive Capacity	Moderate	Moderate	Moderate	Moderate

INUNDATION

Figure A.2. Location map of assets vulnerable to future inundation in Onslow.

INUNDATION

Table A.13. Summary asset information for houses, buildings and properties.

Housing, Buildings & Property	Asset description	Values
   	Number of assets: 319 Assets in this category include: > Residential homes > Office buildings > Public toilets > Permanent structures > Accommodation buildings > Caravans	Commercial Public Tourism Residential

Assigned 100 yr ARI inundation risk ratings

	2015	2040	2070	2110
Likelihood	Possible	Likely	Likely	Almost Certain
Consequences	Moderate	Moderate	Major	Major
Adaptive Capacity	Low	Low	Low	Low

INUNDATION

Table A.14. Summary asset information for parks and recreation grounds.

Parks & Recreation Grounds	Asset description	Values
  	Number of assets: 4 Assets in this category include: > Public open spaces > Public pools > Sports grounds	Commercial Public

Assigned 100 yr ARI inundation risk ratings

	2015	2040	2070	2110
Likelihood	Possible	Likely	Likely	Almost Certain
Consequences	Insignificant	Insignificant	Minor	Minor
Adaptive Capacity	High	High	High	High

INUNDATION

Table A.15. Summary asset information for public infrastructure.

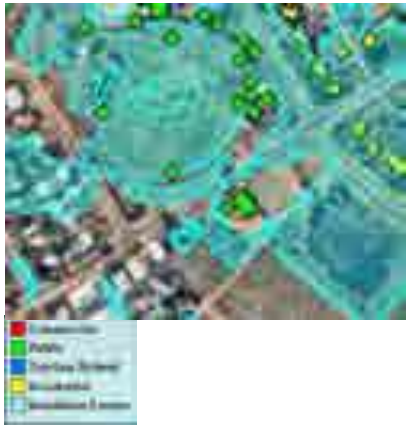
Public Infrastructure	Asset description	Values
  	Number of assets: 118 Assets in this category include: > Gazebos > Water tanks > Light and electrical poles > Benches > Fencing > Playgrounds > Barbecue areas	Commercial Public Tourism Residential

Assigned 100 yr ARI inundation risk ratings

	2015	2040	2070	2110
Likelihood	Possible	Likely	Likely	Almost Certain
Consequences	Minor	Minor	Moderate	Moderate
Adaptive Capacity	Moderate	Moderate	Moderate	Moderate

INUNDATION

Table A.16. Summary asset information for carparks.

Carparks	Asset description	Values
  	Number of assets: 11 Assets in this category include: > Side road parking > Undercover parking > Residential garages not connected to the house or do not have any utility services connected	Commercial Public Residential

Assigned 100 yr ARI inundation risk ratings

	2015	2040	2070	2110
Likelihood	Possible	Likely	Likely	Almost Certain
Consequences	Insignificant	Insignificant	Minor	Minor
Adaptive Capacity	Moderate	Moderate	Moderate	Moderate

INUNDATION

Table A.17. Summary asset information for roads and footpaths.

Roads/footpaths	Asset description	Values
 	Number of assets: Approximately 5 km of roads within the inundation prone area	Public Commercial

Assigned 100 yr ARI inundation risk ratings

	2015	2040	2070	2110
Likelihood	Possible	Likely	Likely	Almost Certain
Consequences	Minor	Minor	Moderate	Moderate
Adaptive Capacity	Moderate	Moderate	Moderate	Moderate

INUNDATION

Table A.18. Summary asset information for sheds.

Sheds	Asset description	Values
   	Number of assets: 112 Assets in this category include: > Private/commercial sheds > Sea containers used for storage purposes	Residential Commercial

Assigned 100 yr ARI inundation risk ratings

	2015	2040	2070	2110
Likelihood	Possible	Likely	Likely	Almost Certain
Consequences	Minor	Minor	Moderate	Moderate
Adaptive Capacity	Moderate	Moderate	Moderate	Moderate

CHRMAP For the Onslow Coast

APPENDIX B

MULTI-CRITERIA ASSESSMENT

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Shaping the Future

COASTAL EROSION

Figure B.1: On-ground Infrastructure at Onslow Jetty

Main asset type Commercial
Long term pathway Managed Retreat / Accomodate
Risk and Vulnerability timeframe

Time	2015	2040	2070	2110
Existing Risk	Low	High	High	Extreme
Vulnerability	Low	High	High	Very High

Option Category	Option Code	Option Name	Preliminary Feasibility			Preliminary Acceptability		Preliminary Financial Implication			Recommendation
			Effectiveness	Legal / Approval Risk	Reversibility / Adaptability	Environmental / Social Impact	Community Acceptability	Economic gain / Avoidance of loss	Capital Cost	Ongoing Cost	
Avoid	AV1	Avoid									Recommended
	AV2	Re-zoning									Recommended
Managed Retreat	MR1	Accept and repair losses									Not recommended
	MR2	Relocate outside of hazard zone									Recommended
	MR3	Prohibit further development / redevelopment									Recommended
Accommodate	AC1	Notification on title									Recommended
	AC2	Emergency plans and controls									Recommended
	AC3	Re-design to withstand impact									Recommended
Protect	PR1	Dune care program									Recommended
	PR2	Beach nourishment or replenishment									Not recommended
	PR3	Seawall									Not recommended
	PR4	Groyne									Not recommended
Do Nothing	DN	No prohibitions or development regulations									Not recommended

Figure B.2: Onslow Back Beach Picnic Area

Main asset type Recreational
Long term pathway Managed Retreat / Accommodate
Risk and Vulnerability timeframe

Time	2015	2040	2070	2110
Existing Risk	Low	Low	Low	Medium
Vulnerability	Low	Low	Low	Medium

Option Category	Option Code	Option Name	Preliminary Feasibility			Preliminary Acceptability		Preliminary Financial Implication			Recommendation
			Effectiveness	Legal / Approval Risk	Reversibility / Adaptability	Environmental / Social Impact	Community Acceptability	Economic gain / Avoidance of loss	Capital Cost	Ongoing Cost	
Avoid	AV1	Avoid									Recommended
	AV2	Re-zoning	N/A								
Managed Retreat	MR1	Accept and repair losses									Not recommended
	MR2	Relocate outside of hazard zone									Recommended
	MR3	Prohibit further development / redevelopment									Recommended
Accommodate	AC1	Notification on title	N/A								
	AC2	Emergency plans and controls									Recommended
	AC3	Re-design to withstand impact									Investigate
Protect	PR1	Dune care program									Not recommended
	PR2	Beach nourishment or replenishment									Not recommended
	PR3	Seawall									Not recommended
	PR4	Groyne									Not recommended
Do Nothing	DN	No prohibitions or development regulations									Not recommended

COASTAL EROSION

Figure B.3: Front Beach / Sunrise Beach

Main asset type Recreational / Environmental

Long term pathway Managed Retreat / Protect

Risk and Vulnerability timeframe

Time	2015	2040	2070	2110
Existing Risk	Low	Low	High	Extreme
Vulnerability	Low	Low	High	Very High

Option Category	Option Code	Option Name	Preliminary Feasibility			Preliminary Acceptability		Preliminary Financial Implication			Recommendation
			Effectiveness	Legal / Approval Risk	Reversibility / Adaptability	Environmental / Social Impact	Community Acceptability	Economic gain / Avoidance of loss	Capital Cost	Ongoing Cost	
Avoid	AV1	Avoid									Recommended
	AV2	Re-zoning	N/A								
Managed Retreat	MR1	Accept and repair losses									Not recommended
	MR2	Relocate outside of hazard zone	N/A								
	MR3	Prohibit further development / redevelopment									Recommended
Accommodate	AC1	Notification on title	N/A								
	AC2	Emergency plans and controls									Recommended
	AC3	Re-design to withstand impact	N/A								
Protect	PR1	Dune care program									Investigate
	PR2	Beach nourishment or replenishment									Investigate
	PR3	Seawall									Investigate
	PR4	Groyne									Investigate
Do Nothing	DN	No prohibitions or development regulations									Not recommended

Figure B.4: Seawall (if not maintained)

Main asset type Commercial

Long term pathway Accommodate / Protect

Risk and Vulnerability timeframe

Time	2015	2040	2070	2110
Existing Risk	Medium	Medium	Extreme	Extreme
Vulnerability	Medium	Medium	High	High

Option Category	Option Code	Option Name	Preliminary Feasibility			Preliminary Acceptability		Preliminary Financial Implication			Recommendation
			Effectiveness	Legal / Approval Risk	Reversibility / Adaptability	Environmental / Social Impact	Community Acceptability	Economic gain / Avoidance of loss	Capital Cost	Ongoing Cost	
Avoid	AV1	Avoid	N/A								
	AV2	Re-zoning	N/A								
Managed Retreat	MR1	Accept and repair losses									Not recommended
	MR2	Relocate outside of hazard zone	N/A								
	MR3	Prohibit further development / redevelopment	N/A								
Accommodate	AC1	Notification on title	N/A								
	AC2	Emergency plans and controls									Recommended
	AC3	Re-design to withstand impact									Recommended
Protect	PR1	Dune care program	N/A								
	PR2	Beach nourishment or replenishment									Investigate
	PR3	Seawall	N/A								
	PR4	Groyne									Investigate
Do Nothing	DN	No prohibitions or development regulations									Not recommended

COASTAL EROSION

Figure B.5: Assets adjacent to crest of seawall (bins, shade structures, benches)

Main asset type Commercial / Public Infrastructure

Long term pathway Accommodate / Protect

Risk and Vulnerability timeframe

Time	2015	2040	2070	2110
Existing Risk	Low	Low	Low	Medium
Vulnerability	Low	Low	Low	Medium

Option Category	Option Code	Option Name	Preliminary Feasibility			Preliminary Acceptability		Preliminary Financial Implication			Recommendation
			Effectiveness	Legal / Approval Risk	Reversibility / Adaptability	Environmental / Social Impact	Community Acceptability	Economic gain / Avoidance of loss	Capital Cost	Ongoing Cost	
Avoid	AV1	Avoid									Recommended
	AV2	Re-zoning	N/A								
Managed Retreat	MR1	Accept and repair losses									Not recommended
	MR2	Relocate outside of hazard zone	N/A								
	MR3	Prohibit further development / redevelopment									Recommended
Accommodate	AC1	Notification on title	N/A								
	AC2	Emergency plans and controls									Recommended
	AC3	Re-design to withstand impact									Recommended
Protect	PR1	Dune care program	N/A								
	PR2	Beach nourishment or replenishment									Investigate
	PR3	Seawall									Investigate
	PR4	Groyne									Investigate
Do Nothing	DN	No prohibitions or development regulations									Not recommended

Figure B.6: Shire of Ashburton Offices (Business House) at the intersection of Second Ave and McGrath Rd

Main asset type Commercial

Long term pathway Managed Retreat

Risk and Vulnerability timeframe

Time	2015	2040	2070	2110
Existing Risk	Low	Medium	High	High
Vulnerability	Low	High	Very High	Very High

Option Category	Option Code	Option Name	Preliminary Feasibility			Preliminary Acceptability		Preliminary Financial Implication			Recommendation
			Effectiveness	Legal / Approval Risk	Reversibility / Adaptability	Environmental / Social Impact	Community Acceptability	Economic gain / Avoidance of loss	Capital Cost	Ongoing Cost	
Avoid	AV1	Avoid									Recommended
	AV2	Re-zoning									Recommended
Managed Retreat	MR1	Accept and repair losses									Not recommended
	MR2	Relocate outside of hazard zone									Investigate
	MR3	Prohibit further development / redevelopment									Recommended
Accommodate	AC1	Notification on title									Recommended
	AC2	Emergency plans and controls									Recommended
	AC3	Re-design to withstand impact									Investigate
Protect	PR1	Dune care program									Recommended
	PR2	Beach nourishment or replenishment									Investigate
	PR3	Seawall									Investigate
	PR4	Groyne									Investigate
Do Nothing	DN	No prohibitions or development regulations									Not recommended

COASTAL EROSION

Figure B.7: Bindi Bindi Aboriginal Community on Second Ave

Main asset type Heritage

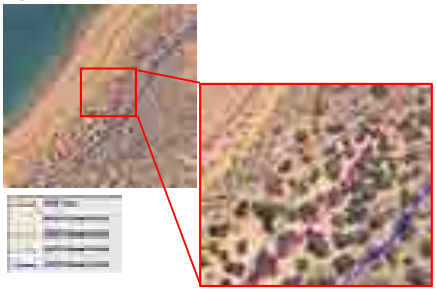
Long term pathway Accommodate / Protect

Risk and Vulnerability timeframe

Time	2015	2040	2070	2110
Existing Risk	Low	Medium	High	High
Vulnerability	Low	High	Very High	Very High

Option Category	Option Code	Option Name	Preliminary Feasibility			Preliminary Acceptability		Preliminary Financial Implication			Recommendation
			Effectiveness	Legal / Approval Risk	Reversibility / Adaptability	Environmental / Social Impact	Community Acceptability	Economic gain / Avoidance of loss	Capital Cost	Ongoing Cost	
Avoid	AV1	Avoid									Recommended
	AV2	Re-zoning									Recommended
Managed Retreat	MR1	Accept and repair losses									Not recommended
	MR2	Relocate outside of hazard zone									Investigate
	MR3	Prohibit further development / redevelopment									Recommended
Accommodate	AC1	Notification on title									Recommended
	AC2	Emergency plans and controls									Recommended
	AC3	Re-design to withstand impact									Investigate
Protect	PR1	Dune care program									Investigate
	PR2	Beach nourishment or replenishment									Investigate
	PR3	Seawall									Investigate
	PR4	Groyne									Investigate
Do Nothing	DN	No prohibitions or development regulations									Not recommended

Figure B.8: Western half of Ian Donald Blair Memorial Walkway



Main asset type Public Infrastructure / Heritage

Long term pathway Managed Retreat / Accommodate

Risk and Vulnerability timeframe

Time	2015	2040	2070	2110
Existing Risk	Low	Low	Medium	Medium
Vulnerability	Low	Low	Medium	Medium

Option Category	Option Code	Option Name	Preliminary Feasibility			Preliminary Acceptability		Preliminary Financial Implication			Recommendation
			Effectiveness	Legal / Approval Risk	Reversibility / Adaptability	Environmental / Social Impact	Community Acceptability	Economic gain / Avoidance of loss	Capital Cost	Ongoing Cost	
Avoid	AV1	Avoid									Recommended
	AV2	Re-zoning	N/A								
Managed Retreat	MR1	Accept and repair losses									Investigate
	MR2	Relocate outside of hazard zone									Recommended
	MR3	Prohibit further development / redevelopment									Recommended
Accommodate	AC1	Notification on title	N/A								
	AC2	Emergency plans and controls									Recommended
	AC3	Re-design to withstand impact									Investigate
Protect	PR1	Dune care program									Recommended
	PR2	Beach nourishment or replenishment									Not recommended
	PR3	Seawall									Not recommended
	PR4	Groyne									Not recommended
Do Nothing	DN	No prohibitions or development regulations									Investigate

COASTAL EROSION

Figure B.9: Intersection of Seaview Drive and Back Beach Road

Main asset type Public Infrastructure / Commercial

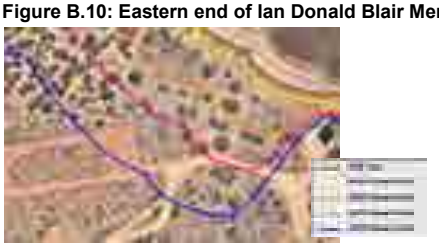
Long term pathway Managed Retreat / Accommodate

Risk and Vulnerability timeframe

Time	2015	2040	2070	2110
Existing Risk	Low	Low	Low	Low
Vulnerability	Low	Low	Low	Low

Option Category	Option Code	Option Name	Preliminary Feasibility			Preliminary Acceptability		Preliminary Financial Implication			Recommendation
			Effectiveness	Legal / Approval Risk	Reversibility / Adaptability	Environmental / Social Impact	Community Acceptability	Economic gain / Avoidance of loss	Capital Cost	Ongoing Cost	
Avoid	AV1	Avoid									Recommended
	AV2	Re-zoning	N/A								
Managed Retreat	MR1	Accept and repair losses									Recommended
	MR2	Relocate outside of hazard zone									Recommended
	MR3	Prohibit further development / redevelopment									Recommended
Accommodate	AC1	Notification on title	N/A								
	AC2	Emergency plans and controls									Recommended
	AC3	Re-design to withstand impact									Investigate
Protect	PR1	Dune care program									Recommended
	PR2	Beach nourishment or replenishment									Not recommended
	PR3	Seawall									Not recommended
	PR4	Groyne									Not recommended
Do Nothing	DN	No prohibitions or development regulations									Not recommended

Figure B.10: Eastern end of Ian Donald Blair Memorial Walkway



Main asset type Public Infrastructure / Heritage

Long term pathway Managed Retreat / Accommodate

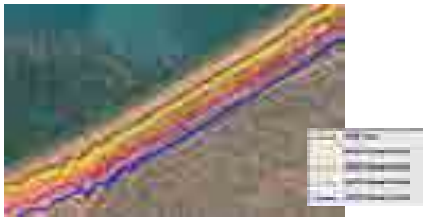
Risk and Vulnerability timeframe

Time	2015	2040	2070	2110
Existing Risk	Low	Low	Medium	Medium
Vulnerability	Low	Low	Medium	Medium

Option Category	Option Code	Option Name	Preliminary Feasibility			Preliminary Acceptability		Preliminary Financial Implication			Recommendation
			Effectiveness	Legal / Approval Risk	Reversibility / Adaptability	Environmental / Social Impact	Community Acceptability	Economic gain / Avoidance of loss	Capital Cost	Ongoing Cost	
Avoid	AV1	Avoid									Recommended
	AV2	Re-zoning	N/A								
Managed Retreat	MR1	Accept and repair losses									Investigate
	MR2	Relocate outside of hazard zone									Recommended
	MR3	Prohibit further development / redevelopment									Recommended
Accommodate	AC1	Notification on title	N/A								
	AC2	Emergency plans and controls									Recommended
	AC3	Re-design to withstand impact									Investigate
Protect	PR1	Dune care program									Recommended
	PR2	Beach nourishment or replenishment									Investigate
	PR3	Seawall									Investigate
	PR4	Groyne									Investigate
Do Nothing	DN	No prohibitions or development regulations									Investigate

COASTAL EROSION

Figure B.11: Seaview Drive near Four Mile Creek



Main asset type Public Infrastructure / Commercial

Long term pathway Managed Retreat / Accommodate

Risk and Vulnerability timeframe

Time	2015	2040	2070	2110
Existing Risk	Low	Low	Low	Medium
Vulnerability	Low	Low	Low	Medium

Option Category	Option Code	Option Name	Preliminary Feasibility			Preliminary Acceptability		Preliminary Financial Implication			Recommendation
			Effectiveness	Legal / Approval Risk	Reversibility / Adaptability	Environmental / Social Impact	Community Acceptability	Economic gain / Avoidance of loss	Capital Cost	Ongoing Cost	
Avoid	AV1	Avoid									Recommended
	AV2	Re-zoning	N/A								
Managed Retreat	MR1	Accept and repair losses									Recommended
	MR2	Relocate outside of hazard zone									Recommended
	MR3	Prohibit further development / redevelopment									Recommended
Accommodate	AC1	Notification on title	N/A								
	AC2	Emergency plans and controls									Recommended
	AC3	Re-design to withstand impact									Investigate
Protect	PR1	Dune care program									Recommended
	PR2	Beach nourishment or replenishment									Investigate
	PR3	Seawall									Investigate
	PR4	Groyne									Investigate
Do Nothing	DN	No prohibitions or development regulations									Not recommended

Figure B.12: Second Ave

Main asset type Public Infrastructure / Commercial

Long term pathway Managed Retreat / Protect

Risk and Vulnerability timeframe

Time	2015	2040	2070	2110
Existing Risk	Low	Low	Medium	Medium
Vulnerability	Low	Low	Medium	Medium

Option Category	Option Code	Option Name	Preliminary Feasibility			Preliminary Acceptability		Preliminary Financial Implication			Recommendation
			Effectiveness	Legal / Approval Risk	Reversibility / Adaptability	Environmental / Social Impact	Community Acceptability	Economic gain / Avoidance of loss	Capital Cost	Ongoing Cost	
Avoid	AV1	Avoid									Recommended
	AV2	Re-zoning	N/A								
Managed Retreat	MR1	Accept and repair losses									Not recommended
	MR2	Relocate outside of hazard zone									Investigate
	MR3	Prohibit further development / redevelopment									Recommended
Accommodate	AC1	Notification on title	N/A								
	AC2	Emergency plans and controls									Recommended
	AC3	Re-design to withstand impact									Not recommended
Protect	PR1	Dune care program									Recommended
	PR2	Beach nourishment or replenishment									Investigate
	PR3	Seawall									Investigate
	PR4	Groyne									Investigate
Do Nothing	DN	No prohibitions or development regulations									Not recommended

Figure B.13: Housing, Buildings and Property (100 yr ARI)

Main asset type Housing, Buildings and Property
Long term pathway Managed Retreat / Accommodate
Risk and Vulnerability timeframe

Time	2015	2040	2070	2110
Existing Risk	Medium	High	Extreme	Extreme
Vulnerability	High	Very High	Very High	Very High

Option Category	Option Code	Option Name	Preliminary Feasibility			Preliminary Acceptability		Preliminary Financial Implication			Recommendation
			Effectiveness	Legal / Approval Risk	Reversibility / Adaptability	Environmental / Social Impact	Community Acceptability	Economic gain / Avoidance of loss	Capital Cost	Ongoing Cost	
Avoid	AV1	Avoid									Recommended
	AV2	Re-zoning									Recommended
Managed Retreat	MR1	Accept and repair losses									Recommended
	MR2	Relocate outside of hazard zone									Investigate
	MR3	Prohibit further development / redevelopment									Recommended
Accommodate	AC1	Notification on title									Recommended
	AC2	Emergency plans and controls									Recommended
	AC3	Re-design to withstand impact									Investigate
Protect	PR1	Levee									Not Recommended
	PR2	Levees and pump systems									Not Recommended
Do Nothing	DN	No prohibitions or development regulations									Not Recommended

Figure B.14: Parks & Recreation Grounds (100 yr ARI)

Main asset type Recreational
Long term pathway Managed Retreat
Risk and Vulnerability timeframe

Time	2015	2040	2070	2110
Existing Risk	Low	Low	Medium	Medium
Vulnerability	Low	Low	Medium	Medium

Option Category	Option Code	Option Name	Preliminary Feasibility			Preliminary Acceptability		Preliminary Financial Implication			Recommendation
			Effectiveness	Legal / Approval Risk	Reversibility / Adaptability	Environmental / Social Impact	Community Acceptability	Economic gain / Avoidance of loss	Capital Cost	Ongoing Cost	
Avoid	AV1	Avoid									Investigate
	AV2	Re-zoning	N/A								
Managed Retreat	MR1	Accept and repair losses									Recommended
	MR2	Relocate outside of hazard zone									Investigate
	MR3	Prohibit further development / redevelopment									Recommended
Accommodate	AC1	Notification on title	N/A								
	AC2	Emergency plans and controls									Recommended
	AC3	Re-design to withstand impact									Recommended
Protect	PR1	Levees									Not Recommended
	PR2	Levees and pump systems									Not Recommended
Do Nothing	DN	No prohibitions or development regulations									Not Recommended

Figure B.15: Public Infrastructure (100 yr ARI)

Main asset type Public Infrastructure
Long term pathway Managed Retreat / Accommodate
Risk and Vulnerability timeframe

Time	2015	2040	2070	2110
Existing Risk	Medium	Medium	High	High
Vulnerability	Medium	Medium	High	High

Option Category	Option Code	Option Name	Preliminary Feasibility			Preliminary Acceptability		Preliminary Financial Implication			Recommendation
			Effectiveness	Legal / Approval Risk	Reversibility / Adaptability	Environmental / Social Impact	Community Acceptability	Economic gain / Avoidance of loss	Capital Cost	Ongoing Cost	
Avoid	AV1	Avoid									Recommended
	AV2	Re-zoning	N/A								
Managed Retreat	MR1	Accept and repair losses									Recommended
	MR2	Relocate outside of hazard zone									Recommended
	MR3	Prohibit further development / redevelopment									Recommended
Accommodate	AC1	Notification on title	N/A								
	AC2	Emergency plans and controls									Recommended
	AC3	Re-design to withstand impact									Recommended
Protect	PR1	Levee									Not Recommended
	PR2	Levees and pump systems									Not Recommended
Do Nothing	DN	No prohibitions or development regulations									Investigate

INUNDATION

Figure B.16: Carparks (100 yr ARI)

Main asset type Carparks

Long term pathway Accommodate

Risk and Vulnerability timeframe

Time	2015	2040	2070	2110
Existing Risk	Low	Low	Medium	Medium
Vulnerability	Low	Low	Medium	Medium

Option Category	Option Code	Option Name	Preliminary Feasibility			Preliminary Acceptability		Preliminary Financial Implication			Recommendation
			Effectiveness	Legal / Approval Risk	Reversibility / Adaptability	Environmental / Social Impact	Community Acceptability	Economic gain / Avoidance of loss	Capital Cost	Ongoing Cost	
Avoid	AV1	Avoid									Recommended
	AV2	Re-zoning									Recommended
Managed Retreat	MR1	Accept and repair losses									Recommended
	MR2	Relocate outside of hazard zone									Investigate
	MR3	Prohibit further development / redevelopment									Recommended
Accommodate	AC1	Notification on title									Recommended
	AC2	Emergency plans and controls									Recommended
	AC3	Re-design to withstand impact									Investigate
Protect	PR1	Levee									Not Recommended
	PR2	Levees and pump systems									Not Recommended
Do Nothing	DN	No prohibitions or development regulations									Not Recommended

Figure B.17: Roads / Footpaths (100 yr ARI)

Main asset type Roads / Footpaths

Long term pathway Accommodate

Risk and Vulnerability timeframe

Time	2015	2040	2070	2110
Existing Risk	Medium	Medium	High	High
Vulnerability	Medium	Medium	High	High

Option Category	Option Code	Option Name	Preliminary Feasibility			Preliminary Acceptability		Preliminary Financial Implication			Recommendation
			Effectiveness	Legal / Approval Risk	Reversibility / Adaptability	Environmental / Social Impact	Community Acceptability	Economic gain / Avoidance of loss	Capital Cost	Ongoing Cost	
Avoid	AV1	Avoid									Recommended
	AV2	Re-zoning									Recommended
Managed Retreat	MR1	Accept and repair losses									Recommended
	MR2	Relocate outside of hazard zone									Recommended
	MR3	Prohibit further development / redevelopment									Recommended
Accommodate	AC1	Notification on title									Recommended
	AC2	Emergency plans and controls									Recommended
	AC3	Re-design to withstand impact									Recommended
Protect	PR1	Levee									Investigate
	PR2	Levees and pump systems									Investigate
Do Nothing	DN	No prohibitions or development regulations									Not recommended

Figure B.18: Sheds (100 yr ARI)

Main asset type Sheds

Long term pathway Accommodate

Risk and Vulnerability timeframe

Time	2015	2040	2070	2110
Existing Risk	Medium	Medium	High	High
Vulnerability	Medium	Medium	High	High

Option Category	Option Code	Option Name	Preliminary Feasibility			Preliminary Acceptability		Preliminary Financial Implication			Recommendation
			Effectiveness	Legal / Approval Risk	Reversibility / Adaptability	Environmental / Social Impact	Community Acceptability	Economic gain / Avoidance of loss	Capital Cost	Ongoing Cost	
Avoid	AV1	Avoid									Recommended
	AV2	Re-zoning									Recommended
Managed Retreat	MR1	Accept and repair losses									Recommended
	MR2	Relocate outside of hazard zone									Recommended
	MR3	Prohibit further development / redevelopment									Recommended
Accommodate	AC1	Notification on title									Recommended
	AC2	Emergency plans and controls									Recommended
	AC3	Re-design to withstand impact									Investigate
Protect	PR1	Levee									Not Recommended
	PR2	Levees and pump systems									Not Recommended
Do Nothing	DN	No prohibitions or development regulations									Not Recommended

CHRMAP For the Onslow Coast

APPENDIX C

ASSET MANAGEMENT PATHWAYS

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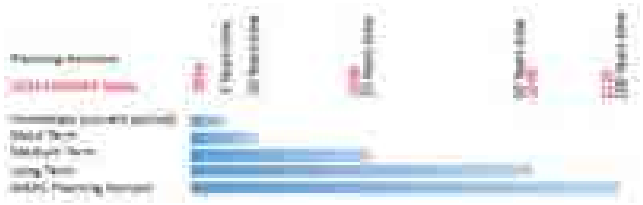
Shaping the Future

COASTAL EROSION

Figure C.1: On-ground Infrastructure at Onslow Jetty

Predicted Pathway	Immediate (<5 yrs)	Short Term (5-10 yrs)	Medium Term (10-25 yrs)	Long Term (25-50 yrs)	WAPC 100 year (50 - 100 yrs)
Risk Rating	Low	Low	High	High	Extreme
Vulnerability Rating	Low	Low	High	High	Very High
Asset life cycle				**Estimated end of lifecycle**	
Pathway	*Avoid / Monitor and review*	*Accommodate*	*Managed Retreat*		
Recommended Actions	Avoid further development Emergency Plans Dune Care Program	Continue to implement avoid and basic protection actions Accept and Repair Redesign to withstand Impact Prohibit further development	Redesign to withstand Impact Relocate outside of hazard zone	Relocate outside of hazard zone	
			Protect		
		Investigate protection options	Initiate protection actions		

Reactive Management Pathway	Trigger 1	Trigger 2	Trigger 3
Trigger	Erosion landward of 2015 hazard line	Distance between HSD line and the asset is less than S1 OR End of asset life cycle	Significant erosion or storm damage resulting in damage to property and risk to worker safety OR Cessation of Industry
Action	Implement accommodate actions	Implement retreat or protect actions	Implement retreat actions or decommission infrastructure
Responsibility	Onslow Salt	Onslow Salt	Onslow Salt



Residual Risk

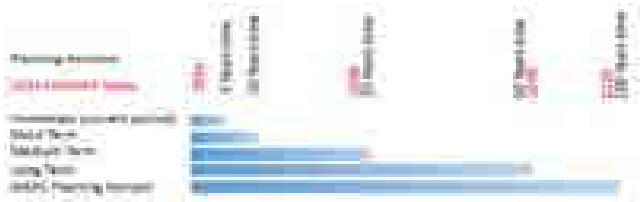
Time	2015	2040	2070	2110
Initial Risk	Low	High	High	Extreme
Adaptation pathway	*Avoid / Monitor and review*	*Managed Retreat*		
Residual Risk	Low	Medium	Medium	Medium

COASTAL EROSION

Figure C.2: Onslow Back Beach picnic area

Predicted Pathway	Immediate (<5 yrs)	Short Term (5-10 yrs)	Medium Term (10-25 yrs)	Long Term (25-50 yrs)	WAPC 100 year (50 - 100 yrs)
Risk Rating **Vulnerability Rating** Asset life cycle	Low Low	Low Low	Low Low	Low Low	Medium Medium Estimated end of lifecycle
Pathway	*Avoid / Monitor and review*		*Accommodate*		*Managed Retreat*
Recommended Actions	Avoid further development Prohibit further development Emergency Plans		Investigate protection options Investigate re-design options to withstand impact Continue to implement avoid and basic protection actions Accept and Repair Plan for managed retreat options, e.g. re-zoning		Relocate outside of hazard zone

Reactive Management Pathway	Trigger 1	Trigger 2	Trigger 3
Trigger	Erosion landward of 2040 hazard line	Distance between HSD line and the asset is less than S1	Significant erosion or storm damage to assets OR End of asset life cycle
Action	Implement accommodate actions	Implement retreat actions	Implement retreat actions
Responsibility	Shire of Ashburton	Shire of Ashburton	Shire of Ashburton



Residual Risk

Time	2015	2040	2070	2110
Initial Risk	Low	Low	Low	Medium
Adaptation pathway	*Avoid / Monitor and review*	*Accommodate*	*Managed Retreat*	
Residual Risk	Low	Low	Low	Low

COASTAL EROSION

Figure C.3: Front Beach / Sunrise Beach

Predicted Pathway	Immediate (<5 yrs)	Short Term (5-10 yrs)	Medium Term (10-25 yrs)	Long Term (25-50 yrs)	WAPC 100 year (50 - 100 yrs)
Risk Rating **Vulnerability Rating**	Low Low	Low Low	Low Low	High High	Extreme Very High
Pathway	*Avoid / Monitor and review*	*Accommodate*			
Recommended Actions	Emergency Plans Dune Care	Continue to implement avoid and basic protection actions Investigate protection options	*Protect* Initiate protection actions		

Reactive Management Pathway	Trigger 1	Trigger 2	Trigger 3
Trigger	Erosion landward of 2016 hazard line	Loss of beach amenity	Unacceptable loss of Beach Amenity
Action	Implement accommodate actions	Investigate protect actions	Implement protect actions
Responsibility	Shire of Ashburton	Shire of Ashburton	Shire of Ashburton

Residual Risk

Time	2015	2040	2070	2110
Initial Risk	Low	Low	High	Extreme
Adaptation pathway	*Avoid / Monitor and review*	*Accommodate*		
Residual Risk	Low	Low	Medium	Medium

COASTAL EROSION

Figure C.4: Seawall (if not maintained)

Predicted Pathway	Immediate (<5 yrs)	Short Term (5-10 yrs)	Medium Term (10-25 yrs)	Long Term (25-50 yrs)	WAPC 100 year (50 - 100 yrs)
Risk Rating	Medium	Medium	Medium	Extreme	Extreme
Vulnerability Rating	Medium	Medium	Medium	High	High
Asset life cycle		**Estimated end of lifecycle**			
Pathway	*Accommodate*				
Recommended Actions	Implement avoid and basic protection actions Emergency Plans Accept and Repair Redesign to withstand Impact Investigate protection options, e.g. beac nourishment, groyne	Continue to implement avoid and basic protection actions Investigate protection options	*Protect* Initiate protection actions		

Reactive Management Pathway	Trigger 1	Trigger 2	Trigger 3
Trigger	Erosion reaching bottom of seawall	Storm damage resulting in significant impact on seawall function OR End of asset life cycle	Significant storm damage resulting in damage to property
Action	Implement accommodate actions	Implement protect actions	Implement protect actions
Responsibility	Shire of Ashburton	Shire of Ashburton	Shire of Ashburton

Residual Risk

Time	2015	2040	2070	2110
Initial Risk	Medium	Medium	Extreme	Extreme
Adaptation pathway	*Protect*			
Residual Risk	Low	Low	Low	Low

COASTAL EROSION

Figure C.5: Assets adjacent to crest of seawall (bins, shade structures, benches)

	Predicted Pathway	Immediate (<5 yrs)	Short Term (5-10 yrs)	Medium Term (10-25 yrs)	Long Term (25-50 yrs)	WAPC 100 year (50 - 100 yrs)
	Risk Rating	Low	Low	Low	Low	Medium
	Vulnerability Rating	Low	Low	Low	Low	Medium
	Asset life cycle			**Estimated end of lifecycle**		
	Pathway	*Avoid / Monitor and review*		*Accommodate*		*Managed Retreat*
	Recommended Actions	Avoid further development Prohibit further development Emergency Plans		Redesign to withstand Impact Relocate outside of hazard zone Continue to implement avoid and basic protection actions Accept and Repair Investigate protection options		Relocate outside of hazard zone
		Protect				
		Seawall is structural protection against erosion impacts to these assets Continue to maintainand raise seawall as required				

Reactive Management Pathway	Trigger 1	Trigger 2	Trigger 3
Trigger	Occasional overtopping or erosion impacts to seawall	Frequent overtopping or erosion impacts landward of seawall	Significant storm damage resulting in damage to property and risk to community safety
Action	Implement accommodate actions	Implement retreat actions	Implement retreat or protect actions
Responsibility	Shire of Ashburton	Shire of Ashburton	Shire of Ashburton

Residual Risk

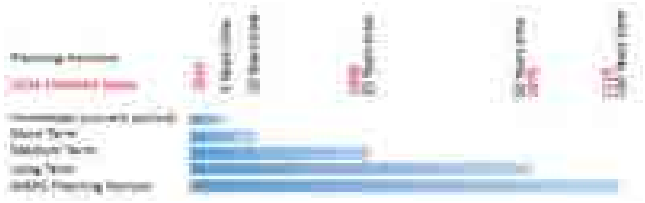
Time	2015	2040	2070	2110
Initial Risk	Low	Low	Low	Medium
Adaptation pathway	*Protect*			
Residual Risk	Low	Low	Low	Medium

COASTAL EROSION

Figure C.6: Shire of Ashburton Offices (Business House) at the intersection of Second Ave and McGrath Rd

	Predicted Pathway	Immediate (<5 yrs)	Short Term (5-10 yrs)	Medium Term (10-25 yrs)	Long Term (25-50 yrs)	WAPC 100 year (50 - 100 yrs)
	Risk Rating	Low	Low	Medium	High	High
	Vulnerability Rating	Low	Low	High	Very High	Very High
	Asset life cycle			**Estimated end of lifecycle**		
	Pathway	*Avoid / Monitor and review*	*Accommodate*	*Managed Retreat*		
	Recommended Actions	Avoid further development	Continue to implement avoid and basic protection actions	Prohibit further development		
		Emergency Plans Dune Care Investigate protection options	Redesign to withstand Impact	Redesign to withstand impact Relocate outside of hazard zone		
			Protect			
		Plan on implementing protect or managed retreat options	Initiate protection actions			

Reactive Management Pathway	Trigger 1	Trigger 2	Trigger 3
Trigger	Erosion landward of 2015 hazard line	Distance between HSD line and the asset is less than S1 OR End of asset life cycle	Significant erosion or storm damage resulting in damage to property and risk to community safety
Action	Implement accommodate actions	Implement retreat or protect actions	Implement retreat actions
Responsibility	Shire of Ashburton	Shire of Ashburton	Shire of Ashburton



Residual Risk

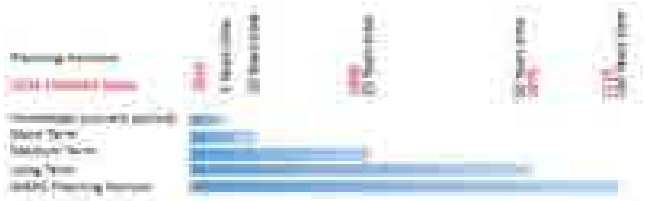
Time	2015	2040	2070	2110
Initial Risk	Low	Medium	High	High
Adaptation pathway	*Avoid / Monitor and review*	*Protect*		
Residual Risk	Low	Medium	Medium	Medium

COASTAL EROSION

Figure C.7: Bindi Bindi Aboriginal Community on Second Ave

	Predicted Pathway	Immediate (<5 yrs)	Short Term (5-10 yrs)	Medium Term (10-25 yrs)	Long Term (25-50 yrs)	WAPC 100 year (50 - 100 yrs)
	Risk Rating	Low	Low	Medium	High	High
	Vulnerability Rating	Low	Low	High	Very High	Very High
	Asset life cycle			**Estimated end of lifecycle**		
	Pathway	*Avoid / Monitor and review*	*Accommodate*	*Managed Retreat*		
	Recommended Actions	Avoid further development	Continue to implement avoid and basic protection actions	Prohibit further development		
			Redesign to withstand Impact	Redesign to withstand impact		
		Emergency Plans Dune Care	Investigate protection options	Relocate outside of hazard zone		
			Protect			
		Investigate protection options	Initiate protection actions			

Reactive Management Pathway	Trigger 1	Trigger 2	Trigger 3
Trigger	Erosion landward of 2015 hazard lIne	Distance between HSD line and the asset is less than S1 OR End of asset life cycle	Significant erosion or storm damage resulting in damage to property and risk to community safety
Action	Implement accommodate actions	Implement retreat or protect actions	Implement retreat actions
Responsibility	Shire of Ashburton	Shire of Ashburton	Shire of Ashburton



Residual Risk

Time	2015	2040	2070	2110
Initial Risk	Low	Medium	High	High
Adaptation pathway	*Avoid / Monitor and review*	*Protect*		
Residual Risk	Low	Medium	Medium	Medium

COASTAL EROSION

Figure C.8: Western half of Ian Donald Blair Memorial Walkway

	Predicted Pathway	Immediate (<5 yrs)	Short Term (5-10 yrs)	Medium Term (10-25 yrs)	Long Term (25-50 yrs)	WAPC 100 year (50 - 100 yrs)
	Risk Rating	Low	Low	Low	Medium	Medium
	Vulnerability Rating	Low	Low	Low	Medium	Medium
	Asset life cycle				**Estimated end of lifecycle**	
	Pathway	*Avoid / Monitor and review*		*Accommodate*	*Managed Retreat*	
	Recommended Actions	Avoid further development Prohibit further development Emergency Plans Dune Care		Continue to implement avoid and basic protection actions Accept and Repair Redesign to withstand Impact	Relocate outside of hazard zone Redesign to withstand impact	

Reactive Management Pathway	Trigger 1	Trigger 2	Trigger 3
Trigger	Erosion landward of 2015 hazard line	Erosion up to 2040 hazard line OR End of assett life cycle	Significant erosion or storm damage to asset
Action	Implement accommodate actions	Implement retreat actions	Implement retreat actions
Responsibility	Shire of Ashburton	Shire of Ashburton	Shire of Ashburton

Residual Risk

Time	2015	2040	2070	2110
Initial Risk	Low	Low	Medium	Medium
Adaptation pathway	*Avoid / Monitor and review*	*Managed Retreat*		
Residual Risk	Low	Low	Low	Low

COASTAL EROSION

Figure C.9: Intersection of Seaview Drive and Back Beach Road

	Predicted Pathway	Immediate (<5 yrs)	Short Term (5-10 yrs)	Medium Term (10-25 yrs)	Long Term (25-50 yrs)	WAPC 100 year (50 - 100 yrs)
	**Risk Rating** **Vulnerability Rating** Asset life cycle	Low Low	Low Low	Low Low	Low Low	Low Low Estimated end of lifecycle
	Pathway	*Avoid / Monitor and review*			*Accommodate*	*Managed Retreat*
	Recommended Actions	Avoid further development Prohibit further development Emergency Plans Dune Care			Redesign to withstand Impact Accept and Repair Continue to implement avoid and basic protection actions	Relocate outside of hazard zone

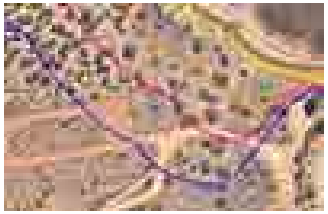
Reactive Management Pathway	Trigger 1	Trigger 2	Trigger 3
Trigger	Erosion landward of 2070 hazard line	Distance between HSD line and the asset is less than S1 OR End of asset life cycle	Significant erosion or storm damage to asset
Action	Implement accommodate actions	Implement retreat actions	Implement retreat actions or decommission asset
Responsibility	Shire of Ashburton	Shire of Ashburton	Shire of Ashburton

Residual Risk

Time	2015	2040	2070	2110
Initial Risk	Low	Low	Low	Low
Adaptation pathway	*Avoid / Monitor and review*	*Accommodate*	*Managed Retreat*	
Residual Risk	Low	Low	Low	Low

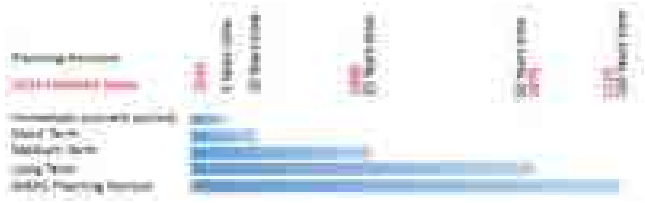
COASTAL EROSION

Figure C.10: Eastern end of Ian Donald Blair Memorial Walkway



Predicted Pathway	Immediate (<5 yrs)	Short Term (5-10 yrs)	Medium Term (10-25 yrs)	Long Term (25-50 yrs)	WAPC 100 year (50 - 100 yrs)
Risk Rating	Low	Low	Low	Medium	Medium
Vulnerability Rating	Low	Low	Low	Medium	Medium
Asset life cycle				Estimated end of lifecycle	
Pathway	*Avoid / Monitor and review*		*Accommodate*	*Managed Retreat*	
Recommended Actions	Avoid further development Prohibit further development Emergency Plans Dune Care		Continue to implement avoid and basic protection actions Accept and Repair Investigate re-design option Investigate protection options	Relocate outside of hazard zone Redesign to withstand impact	

Reactive Management Pathway	Trigger 1	Trigger 2	Trigger 3
Trigger	Erosion landward of 2015 hazard line	Distance between HSD line and the asset is less than S1 OR End of asset life cycle	Significant erosion or storm damage resulting in damage to asset
Action	Implement accommodate actions	Implement retreat or protect actions	Implement retreat actions
Responsibility	Shire of Ashburton	Shire of Ashburton	Shire of Ashburton

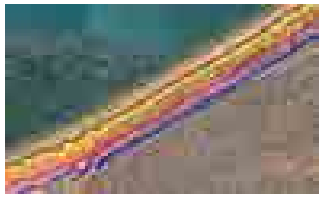


Residual Risk

Time	2015	2040	2070	2110
Initial Risk	Low	Low	Medium	Medium
Adaptation pathway	*Avoid / Monitor and review*	*Managed Retreat*		
Residual Risk	Low	Low	Low	Low

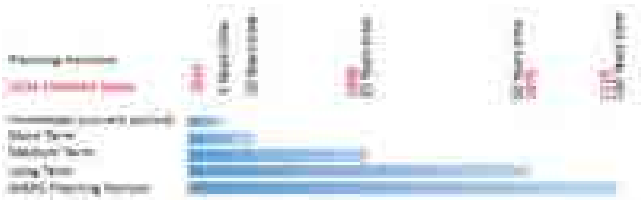
COASTAL EROSION

Figure C.11: Seaview Drive near Four Mile Creek



Predicted Pathway	Immediate (<5 yrs)	Short Term (5-10 yrs)	Medium Term (10-25 yrs)	Long Term (25-50 yrs)	WAPC 100 year (50 - 100 yrs)
Risk Rating **Vulnerability Rating** Asset life cycle	Low Low	Low Low	Low Low	Low Low	Medium Medium Estimated end of lifecycle
Pathway	*Avoid / Monitor and review*		*Accommodate*		*Managed Retreat*
Recommended Actions	Avoid further development Prohibit further development Emergency Plans Dune Care		Continue to implement avoid and basic protection actions Accept and Repair Redesign to withstand Impact		Relocate outside of hazard zone Redesign to withstand Impact

Reactive Management Pathway	Trigger 1	Trigger 2	Trigger 3
Trigger	Erosion landward of 2015 hazard line	Erosion landward of 2040 hazard line	Significant erosion loss or damage to asset
Action	Implement accommodate actions	Implement retreat or protect actions	Implement retreat actions
Responsibility	Shire of Ashburton	Shire of Ashburton	Shire of Ashburton



Residual Risk

Time	2015	2040	2070	2110
Initial Risk	Low	Low	Low	Medium
Adaptation pathway	*Avoid / Monitor and review*	*Accommodate*	*Managed Retreat*	
Residual Risk	Low	Low	Low	Low

COASTAL EROSION

Figure C.12: Second Ave

	Predicted Pathway	Immediate (<5 yrs)	Short Term (5-10 yrs)	Medium Term (10-25 yrs)	Long Term (25-50 yrs)	WAPC 100 year (50 - 100 yrs)
	Risk Rating	Low	Low	Low	Medium	Medium
	Vulnerability Rating	Low	Low	Low	Medium	Medium
	Asset life cycle					**Estimated end of lifecycle**
	Pathway	*Avoid / Monitor and review*	*Accommodate*		*Managed Retreat*	
	Recommended Actions	Avoid further development Prohibit further development Emergency Plans Dune Care	Continue to implement avoid and basic protection actions Accept and Repair Redesign to withstand Impact Investigate protection options		Relocate outside of hazard zone Redesign to withstand Impact *Protect* Initiate protection actions	

Reactive Management Pathway	Trigger 1	Trigger 2	Trigger 3
Trigger	Erosion landward of 2015 hazard lIne	Distance between HSD line and the asset is less than S1	Significant erosion or storm damage resulting in damage to property and risk to community safety
Action	Implement accommodate actions	Implement retreat or protect actions	Implement retreat actions or decommission infrastructure
Responsibility	Shire of Ashburton	Shire of Ashburton	Shire of Ashburton

Residual Risk

Time	2015	2040	2070	2110
Initial Risk	Low	Low	Medium	Medium
Adaptation pathway	*Avoid / Monitor and review*	*Protect*		
Residual Risk	Low	Low	Low	Medium

INUNDATION

Figure C.13: Housing, Buildings and Property (100 yr ARI)

Predicted Pathway	Immediate (<5 yrs)	Short Term (5-10 yrs)	Medium Term (10-25 yrs)	Long Term (25-50 yrs)	WAPC 100 year (50 - 100 yrs)
Risk Rating	Medium	Medium	High	Extreme	Extreme
Vulnerability Rating	High	High	Very High	Very High	Very High
Asset life cycle		Estimated end of lifecycle	Estimated end of lifecycle	Estimated end of lifecycle	Estimated end of lifecycle
Pathway	*Avoid / Monitor and review*		*Managed Retreat*		
Recommended Actions	Prohibit further development Monitor Flood heights, Drainage Outlet Berm height Assess long term drainage needs Integrate Coastal and Water Management Plans		Investigate redesign options Prohibit further development	Redesign to withstand impact Relocate outside of hazard zone	
	Accommodate				
	Design assets to withstand flooding Land use zoning for acceptable use Emergency Plans				
	Protect				
	Maintain / extend seawall Maintain and inmprove drainage controls		Investigate appropriateness of levee systems	Implement levee systems	

Adaptive Management Pathway	Trigger 1	Trigger 2	Trigger 3
Trigger	30% of assets inundated during storm event	60% of assets inundated during storm event with significant damage OR End of life cycle	85% of assets inundated during storm event, significant damage and risk to community safety OR End of life cycle
Action	Implement first set of retreat actions	Implement second set of retreat actions	Implement retreat actions or decommission asset
Responsibility	Asset owners / Shire of Ashburton	Asset owners / Shire of Ashburton	Asset owners / Shire of Ashburton

Residual Risk

Time	2015	2040	2070	2110
Initial Risk	Medium	High	Extreme	Extreme
Adaptation pathway	*Avoid / Accommodate / Protect and Retreat*			
Residual Risk	Medium	Medium	Medium	Medium

INUNDATION

Figure C.14: Parks & Recreation Grounds (100 yr ARI)

Predicted Pathway	Immediate (<5 yrs)	Short Term (5-10 yrs)	Medium Term (10-25 yrs)	Long Term (25-50 yrs)	WAPC 100 year (50 - 100 yrs)
Risk Rating	Low	Low	Low	Medium	Medium
Vulnerability Rating	Low	Low	Low	Medium	Medium
Asset life cycle					**Estimated end of lifecycle**
Pathway	*Avoid / Monitor and review*				*Managed Retreat*
Recommended Actions	Prohibit further development Emergency Plans Monitor Flood heights, Drainage Outlet Berm height Assess long term drainage needs Integrate Coastal and Water Management Plans			Plan for retreat	Relocate outside of hazard zone
	Accommodate				
	Design assets to withstand flooding				

Adaptive Management Pathway	Trigger 1	Trigger 2	Trigger 3
Trigger	50% of assets inundated during storm event	70% of assets inundated during storm event with significant damage OR End of life cycle	90% of assets inundated during storm event, significant damage and risk to community safety OR End of life cycle
Action	Implement accommodate actions	Implement retreat options	Implement retreat options or decomission asset
Responsibility	Shire of Ashburton	Shire of Ashburton	Shire of Ashburton

Residual Risk

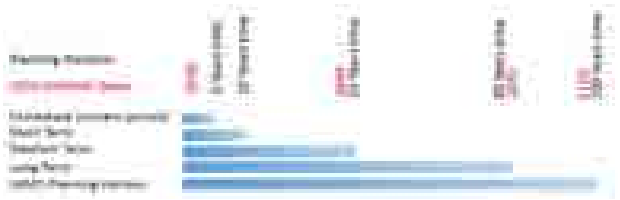
Time	2015	2040	2070	2110
Initial Risk	Low	Low	Medium	Medium
Adaptation pathway	*Accommodate*			
Residual Risk	Low	Low	Low	Medium

INUNDATION

Figure C.15: Public Infrastructure (100 yr ARI)

Predicted Pathway	Immediate (<5 yrs)	Short Term (5-10 yrs)	Medium Term (10-25 yrs)	Long Term (25-50 yrs)	WAPC 100 year (50 - 100 yrs)
Risk Rating	Medium	Medium	Medium	High	High
Vulnerability Rating	Medium	Medium	Medium	High	High
Asset life cycle			**Estimated end of lifecycle**		
Pathway	*Avoid / Monitor and review*		*Managed Retreat*		
Recommended Actions	Prohibit further development Emergency Plans Monitor Flood heights, Drainage Outlet Berm height Assess long term drainage needs Integrate Coastal and Water Management Plans		Continue to implement avoid and basic protection actions Accept and repair Plan for relocation of assets Prohibit further development	Relocate outside of hazard zone	
	Accommodate				
	Design assets to withstand flooding				

Adaptive Management Pathway	Trigger 1	Trigger 2	Trigger 3
Trigger	30% of assets inundated during storm event	50 % assets inundated during storm event with significant damage OR End of life cycle	75% of assets inundated during storm event, significant damage and risk to community safety OR End of life cycle
Action	Implement accommodate actions	Implement retreat options	Implement retreat options or decomission asset
Responsibility	Shire of Ashburton / State agency / service provider	Shire of Ashburton / State agency / service provider	Shire of Ashburton / State agency / service provider



Residual Risk

Time	2015	2040	2070	2110
Initial Risk	Medium	Medium	High	High
Adaptation pathway	*Accommodate*			
Residual Risk	Medium	Medium	Medium	Medium

INUNDATION

Figure C.16: Carparks (100 yr ARI)

Predicted Pathway	Immediate (<5 yrs)	Short Term (5-10 yrs)	Medium Term (10-25 yrs)	Long Term (25-50 yrs)	WAPC 100 year (50 - 100 yrs)
Risk Rating	Low	Low	Low	Medium	Medium
Vulnerability Rating	Low	Low	Low	Medium	Medium
Asset life cycle				**Estimated end of lifecycle**	
Pathway	*Avoid / Monitor and review*				*Managed Retreat*
Recommended Actions	Prohibit further development		Continue to implement avoid and basic protection actions		Relocate outside of hazard zone
	Emergency Plans			Plan for relocation of assets	
	Monitor Flood heights, Drainage Outlet Berm height			Prohibit further development	
	Assess long term drainage needs				
	Integrate Coastal and Water Management Plans				
	Accommodate				
	Design assets to withstand flooding				
	Accept and repair				

Adaptive Management Pathway	Trigger 1	Trigger 2	Trigger 3
Trigger	50% of assets inundated during storm event	70% of assets inundated during storm event with significant damage OR End of life cycle	90% of assets inundated during storm event, significant damage and risk to community safety OR End of life cycle
Action	Implement accommodate actions	Implement retreat options	Implement protect options or decomission asset
Responsibility	Asset owners / Shire of Ashburton	Asset owners / Shire of Ashburton	Asset owners / Shire of Ashburton

Residual Risk

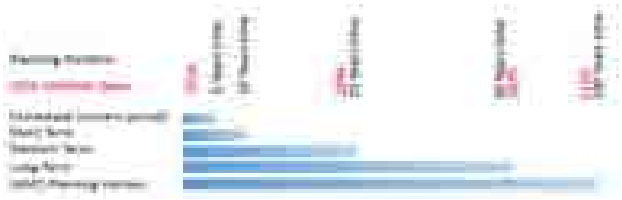
Time	2015	2040	2070	2110
Initial Risk	Low	Low	Medium	Medium
Adaptation pathway	*Accommodate*			
Residual Risk	Low	Low	Medium	Medium

INUNDATION

Figure C.17: Roads / Footpaths (100 yr ARI)

Predicted Pathway	Immediate (<5 yrs)	Short Term (5-10 yrs)	Medium Term (10-25 yrs)	Long Term (25-50 yrs)	WAPC 100 year (50 - 100 yrs)
Risk Rating	Medium	Medium	Medium	High	High
Vulnerability Rating	Medium	Medium	Medium	High	High
Asset life cycle				**Estimated end of lifecycle**	
Pathway	*Avoid / Monitor and review*		*Managed Retreat*		
Recommended Actions	Prohibit further development Emergency Plans Monitor Flood heights, Drainage Outlet Berm height Assess long term drainage needs Integrate Coastal and Water Management Plans		Plan for relocation of assets Prohibit further development	Relocate outside of hazard zone	
	Accommodate				
	Design assets to withstand flooding Accept and repair				

Adaptive Management Pathway	Trigger 1	Trigger 2	Trigger 3
Trigger	30% assets inundated during storm event	50% assets inundated during storm event with significant damage OR End of life cycle	70% assets inundated during storm event, significant damage and risk to community safety OR End of life cycle
Action	Implement accommodate actions	Implement retreat options	Implement retreat options or decomission asset
Responsibility	Shire of Ashburton	Shire of Ashburton	Shire of Ashburton



Residual Risk

Time	2015	2040	2070	2110
Initial Risk	Medium	Medium	High	High
Adaptation pathway	*Accommodate*			
Residual Risk	Medium	Medium	Medium	Medium

INUNDATION

Figure C.18: Sheds (100 yr ARI)

Predicted Pathway	Immediate (<5 yrs)	Short Term (5-10 yrs)	Medium Term (10-25 yrs)	Long Term (25-50 yrs)	WAPC 100 year (50 - 100 yrs)
Risk Rating	Medium	Medium	Medium	High	High
Vulnerability Rating	Medium	Medium	Medium	High	High
Asset life cycle			Estimated end of lifecycle		
Pathway	*Avoid / Monitor and review*		*Managed Retreat*		
Recommended Actions	Prohibit further development Emergency Plans Monitor Flood heights, Drainage Outlet Berm height Assess long term drainage needs Integrate Coastal and Water Management Plans	Continue to implement avoid and basic protection actions Accept and repair	Plan for relocation of assets Prohibit further development	Redesign to withstand impact Relocate outside of hazard zone	
	Accommodate				
	Design assets to withstand flooding Accept and repair				

Adaptive Management Pathway	Trigger 1	Trigger 2	Trigger 3
Trigger	30% of assets inundated during storm event	50% of assets inundated during storm event with significant damage OR End of life cycle	70% of assets inundated during storm event, significant damage and risk to community safety OR End of life cycle
Action	Implement accommodate actions	Implement retreat options	Implement retreat options or decomission asset
Responsibility	Shire of Ashburton	Shire of Ashburton	Shire of Ashburton

Residual Risk

Time	2015	2040	2070	2110
Initial Risk	Medium	Medium	High	High
Adaptation pathway	*Accommodate*			
Residual Risk	Medium	Medium	Medium	Medium

CHRMAP For the Onslow Coast

APPENDIX D

TOWN PLANNING SCHEME NO. 7 – AMENDMENT NO. 24

Cardno
Shaping the Future

PL406*

PLANNING AND DEVELOPMENT ACT 2005

APPROVED LOCAL PLANNING SCHEME AMENDMENT

Shire of Ashburton

Town Planning Scheme No. 7—Amendment No. 24

Ref: TPS/1022

It is hereby notified for public information, in accordance with section 87 of the *Planning and Development Act 2005* that the Minister for Planning approved the Shire of Ashburton local planning scheme amendment on 16 July 2014 for the purpose of—

1. To replace and introduce a revised provision Clause 7.3 as follows—

"7.3 Onslow Coastal Hazard Area

7.3.1 Applications for planning approval within the Special Control Area shall be assessed under Appendix 12 and all development shall conform to the requirements of Appendix 12.

7.3.2 Applications for planning approval not in conformity with Appendix 12 shall not be supported."

2. To replace and introduce a revised provision Clause 6.20.2 and Clause 6.20.3 as follows—

"6.20.2 In areas not subject to Onslow Coastal Hazard Area provisions contained in Clause 7.3 of the Scheme but where the Local Government considers development to be potentially incompatible with land prone to flood and storm surge events, it must be satisfied that approval of such planning applications has regard to flood and storm surge events and may approve, with or without conditions, or refuse proposals at its discretion.

6.20.3 Prior to considering planning applications under Clause 6.20.2 the Local Government shall consult with the relevant agencies regarding the most up-to-date information available about potential flood and storm surge events as relevant to the land subject to the planning application."

3. Introducing a new provision of Appendix 12 as follows—

"APPENDIX 12—Requirements for Onslow Coastal Hazard Area

Purpose—

- To ensure that all development within the Onslow Coastal Hazard Area is designed and developed with finished floor levels to reflect the direction of State Planning Policy 2.6 and State Planning Policy 3.4.

1. To ensure that all development within the Onslow Coastal Hazard Area is designed and developed with finished floor levels to reflect the direction of State Planning Policy 2.6 and State Planning Policy 3.4.
2. For the purpose of Appendix 12, the following land use descriptions apply—
   i. 'Entertainment, recreation and Culture' use means—
      - Clubrooms
      - Equestrian Centre
      - Private Recreation
      - Public Recreation
   ii. 'Commercial-Strategic' use means—
      - Shop (greater than 150m² GLA)
   iii. 'Commercial-non Strategic' use means—
      - Caretaker's Dwelling
      - Display Home Centre
      - Entertainment Venue
      - Exhibition, Display and Outdoor Sales Facilities

viii. 'Temporary and/or Transient' use means use and development that have a limited tenure and operation on land and may include—

- caravan Park;
- transient workforce accommodation that is only required on a temporary basis;
- car Park;
- ablutions;
- any other use and development that is temporary in nature and where the local government resolves that is consistent with the Purposes of Appendix 12.

3. Within the Onslow Coastal Hazard Area the following land use and development shall achieve the following minimum finished floor levels to the satisfaction of the local government—

i. Health, Welfare and Community Services—Strategic use and development shall be at a minimum finished floor level of 6.4m AHD.

ii. Commercial—Strategic use and development shall have a minimum finished floor level of 5.9m AHD.

iii. Commercial—Strategic use and development shall have a minimum finished floor level of 5.9m AHD.

iv. Residential use and development shall have a minimum finished floor level of 5.9m AHD.

v. Industry use and development shall be at a minimum finished floor level of 4.9m AHD.

vi. Commercial—non Strategic use and development shall have a minimum finished floor level of 4.9m AHD.

vii. Health, Welfare and Community Services—non Strategic use and development shall have a minimum finished floor level of 4.9m AHD.

viii. Temporary and/or Transient use and development may be approved at a minimum finished floor level of 4m AHD. Where planning approval is issued, the use and development shall not remain beyond 31 December 2040. All such approved uses shall be removed from the land by 31 December 2040.

ix. Entertainment, Recreation and Culture use and development may have a minimum finished floor level of 2.6m AHD.

4. All land subject of a planning approval within the Onslow Coastal Hazard Area shall have minimum finished ground level of 2.6m AHD.

5. Any filling of land within the Onslow Coastal Hazard Area shall require the approval of the local government. Filling to achieve a finished ground level higher than 2.6m AHD will generally not be supported.

6. A planning approval issued for land located within the Onslow Coastal Hazard Area shall include a condition requiring that a notification be placed on the certificate of title stating: 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.

7. Notwithstanding any provision of Appendix 12, where land is specifically included in an adopted Municipal Inventory of Heritage Places or State Heritage Register, the local government may approve an application for planning approval on land at a finished floor level less than that prescribed in Appendix 12 provided—

i. such approval is in keeping with the historic nature of the existing buildings; and

ii. planning approval includes a notification on title as required in by Part 6.

8. Notwithstanding Part 3 of Appendix 12, any application for use and development of the following kinds—

i. Commercial—non Strategic;

ii. Industry; or

iii. Health, Welfare and Community Services—non Strategic.

may be considered by the local government at the minimum finished floor level prescribed in Part 3 where—

i. the application includes a strategy and management measures to—

(a) ensure that any storage, warehousing, electrical fittings/switchboards (but not including electrical power-points) are provided above 5.9m AHD;

(b) address how an approved use can be removed or adapted as the case may be by the date referred to in ii. below;

ii. an approved use is removed or adapted as the case may be from the land as follows—

(a) where the finished floor level is between 4.0m—4.5m AHD, the development shall be removed by 31 December 2040; and

(b) where the finished floor level is between 4.5m—5.0m AHD, the development shall be removed or adapted by 31 December 2060.

- Holiday Accommodation
- Hotel
- Market
- Motel
- Movable Dwelling
- Motor Vehicle and/or Marine Repair
- Motor Vehicle and/or Marine Sales & Hire
- Motor Vehicle and/or Marine Service Station
- Motor Vehicle and/or Marine Wrecking
- Motor Vehicle Wash
- Office
- Outdoor Display
- Reception Centre
- Restaurant
- Shop (less than 150m² GLFA)
- Showroom
- Commerce continued
- Take-away Food Outlet
- Warehouse
- Tourist Worldwide Accommodation

iv. 'Health, Welfare and Community Services—non Strategic' use means—

- Carpark
- Childcare Service
- Community Use
- Consulting Rooms
- Education Establishment
- Funeral Parlour
- Place of Animal Care
- Place of Public Meeting, Assembly or Worship

v. 'Health, Welfare and Community Services—Strategic' use means—

- Emergency Services
- Hospital
- Medical Centre
- Nursing Home
- Public Utility

vi. 'Industry' use means—

- Abattoir
- Agriculture
- Arts and Crafts Centre
- Harbour and Marina Facilities
- Hire Service (Industrial)
- Home Business
- Home Occupation
- Industry—Extractive
- Industry—General
- Industry—Light
- Industry—Resource Processing
- Industry—Rural
- Industry—Service
- Infrastructure
- Intensive Agriculture
- Research Laboratory
- Stockyard
- Storage facility/depot/yard/area use

vii. 'Residential' use means—

- Aged or Dependent Persons Dwelling
- Grouped Dwelling
- Multiple Dwelling
- Residential Building
- Single House

9. Where a planning approval is issued under Part 7 or Appendix 12 or where a Temporary and/or Transient use and development is approved, the local government shall not support subdivision unless it is an amalgamation of land.

K. WHITE, President.
N. HARTLEY, Chief Executive Officer.

CHRMAP For the Onslow Coast

APPENDIX E

STRATEGIC ECONOMIC ASSESSMENT

Cardno
Shaping the Future

Economic Summary Report

CHRMAP for the Onslow Coast

59916801

Prepared for
The Shire of Ashburton

22 December 2016

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V1	16/12/16	Draft for Cardno Review	Maisie Sargent	Leo Drynan

Table of Contents

1 Introduction

This document outlines Cardno's strategic economic assessment of the impact of pluvial inundation and coastal erosion to the town of Onslow. The purpose of this report is to provide a high level understanding of the costs to the Shire of Ashburton associated with pluvial inundation and coastal erosion under a 'do nothing' scenario (i.e. no adaptation measures undertaken). At this high level stage of analysis, the associated benefits of potential mitigation measures have not been assessed. The aim of this summary is to provide initial, order of magnitude quantification of inundation and erosion risks to aid decision makers in the prioritisation of research, mitigation and management efforts.

It is a recommended that following this initial assessment, a suite of preferred management actions are developed that target prioritised infrastructure, considering the costs of inaction presented herein. Detailed cost benefit analysis could then be undertaken to demonstrate the economic feasibility of the management actions and compare between options as to which provides the greatest return on investment.

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2 Pluvial Inundation

The physical property damage and impacts of pluvial inundation was assessed under the 10 Year ARI scenario and the 100 Year ARI scenario. It is important to note that these flood events are only two select scenarios among then entire spectrum of possible flood events. Eg. Onslow experiences pluvial flooding related to 5 Year ARI events, 20 Year ARI events and so forth. The cumulative expected value of all flooding events in any one year has not currently been determined. A detailed flood profile and curve would need to be developed to estimate this accurately. The two scenarios selected have been used as conservative proxies to establish the order of magnitude costs associated with flooding.

Further, for the purposes of this assessment a number of assumptions have been made to facilitate the estimation of economic values, these include:

> Numerous types of assets are impacted from pluvial inundation, including: buildings; park and recreation grounds; public infrastructure such as fencing, light poles; carparks; roads and footpaths and sheds. For the purposes of this assessment, only buildings (residential and commercial) have been included. By ignoring other assets, this assessment will under-estimate the true damage costs of flooding events;

> The following estimates of affected buildings were utilised as part of the analysis based on the number of buildings and other assets within Onslow, and mapped flood extents:

Table 2-1: Number of buildings affected by pluvial inundation

Scenario	Buildings Impacted
10 Year ARI (current)	102
100 Year ARI (current)	147
10 Year ARI (2110)	147
100 Year ARI (2110)	211

> An assumed damage cost per property has been adopted:

Table 2-2: Flood damage cost

Scenario	Damage Cost per Asset
10 Year ARI (current)	$65,720
100 Year ARI (current)	$67,535
10 Year ARI (2110)	$67,535
100 Year ARI (2110)	$68,871

Damage costs are based on Floodplain Management Guidelines No. 4 Residential Flood Damage Calculation (the then NSW Department of Natural Resources, now Office of Environment and Heritage) and the average flood depth per building impacted. It should be noted that while the inputs to the damage curve (e.g. weekly earnings) are similar to those of the Shire of Ashburton, the development of an Onslow-specific flood damage cost curve is recommended for input in future analyses.

> Assuming the realisation of climate change predictions, a 10 year ARI flood in 2110 will resemble a present day 100 year ARI flood. Similarly, the impact of a 100 year ARI flood in 2110 will be worse, and therefore more costly (affecting more properties and to a greater extent), than a 100 year ARI flood in 2015; and

> An economic evaluation period of 100 years was adopted.

Based on the number of buildings impacted and the damage cost per asset, the damage cost per any one event is presented in **Table 2-3**.

Table 2-3: Pluvial inundation damage cost per single event in 2016

Scenario	Damage Cost per Event
10 Year ARI (current)	$6.7M
100 Year ARI (current)	$9.9M
10 Year ARI (2110)	$9.9M
100 Year ARI (2110)	$14.5M

Table 2-4 presents the expected present value costs (expected value = probability x cost of damage / repair) of each scenario given their likelihood of occurrence over the 100 year period.

Table 2-4: Pluvial inundation damage cost over 100 years

Scenario	Expected value of damage cost over 100 years	Present expected value of damage cost over 100 year assessment period
10 Year ARI	$78.6M	$10.8M
100 Year ARI	$11.6M	$1.6M

The present value cost of the 10 Year ARI event over the 100 year assessment period is approximately $10.8 million. The present value cost of the 100 Year ARI event over the 100 year assessment period is approximately $1.6 million. The 10 Year ARI event is less intense but more frequent and as such is more costly than the 100 Year ARI event. This results also reflects:

1) That the number of properties currently affected under the 100 year ARI, although greater that 10 year ARI, increases at a lower rate over time, in comparison to the 10 year ARI.
2) The coarse damage cost per asset adopted does not adequately gauge the increased damages likely to be incurred, per property, under a 100 yr ARI event in comparison to a 10 year ARI event.

These ongoing damage costs can be compared to the total value of assets impacted (nb. not the cost of impact) by pluvial inundation. The median property price for Onslow over the last five years is $762,000 (REAI, 2016). **Table 2-5** shows the total asset value being affected by flooding under the four scenarios. The values are very high in comparison to the damage incurred under any one event. This suggests that relocation of assets (assuming costs of relocation are roughly similar to asset value) is unlikely to be economically feasible as a management measure.

Table 2-5: Value of assets impacted by pluvial inundation

Scenario	Value of impacted assets	Present value of impacted assets
10 Year ARI (current)	$77.6M	$77.6M
100 Year ARI (current)	$111.7M	$111.7M
10 Year ARI (2110)	$111.7M	$0.2M
100 Year ARI (2110)	$160.9M	$0.3M

Analysis of Results

The results of the economic analysis highlight the high cost of damage / repair related to pluvial inundation events. **Figure 2-1** presents the expected flood damage cost by year for the 10 Year ARI and the 100 Year ARI. The damage cost of the 10 Year ARI increases substantially overtime. The damage cost related to the 100 Year ARI remains relatively stable over time as the probably of this event occurring is low.

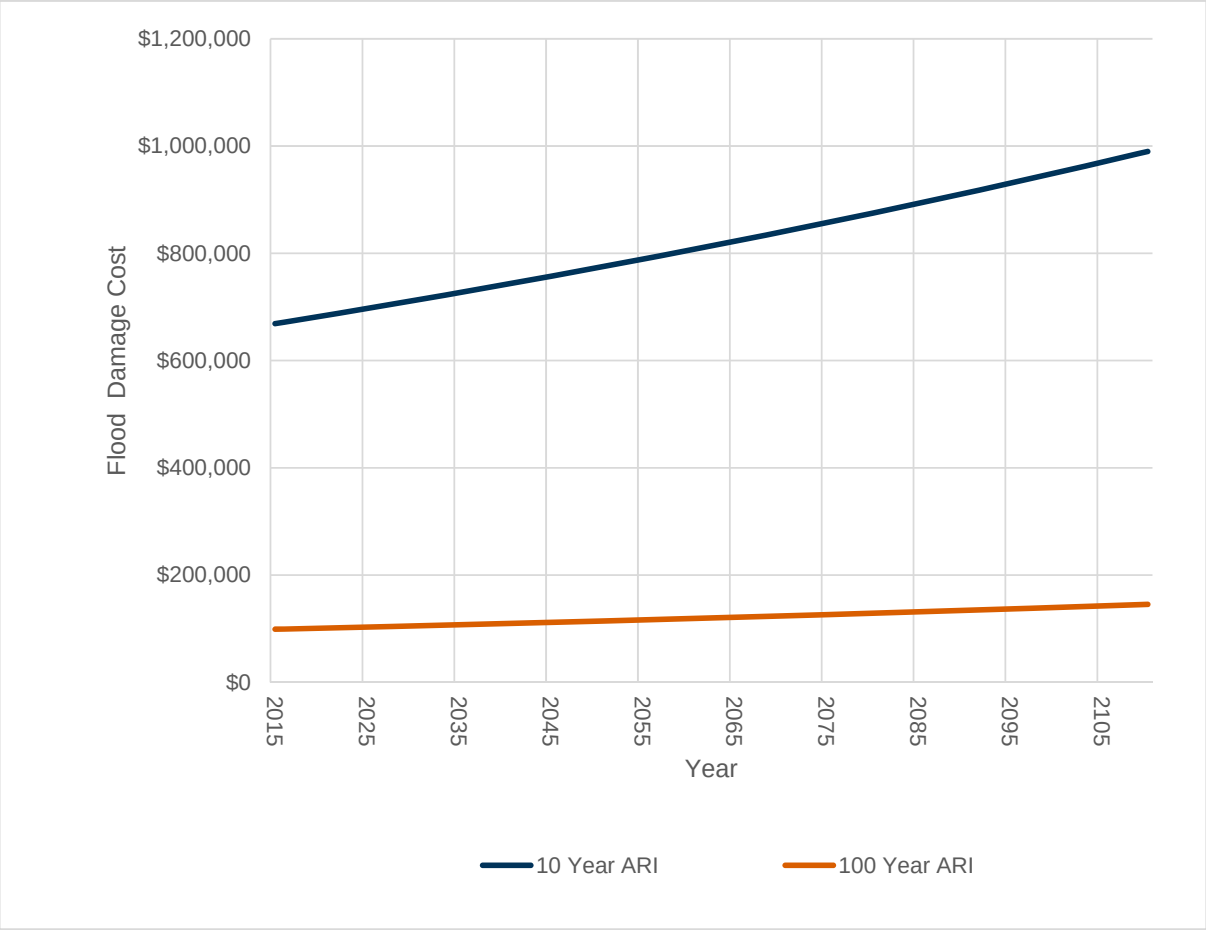

Figure 2-1: Annual flood expected damage cost by year

Figure 2-2 presents the cumulative present value damage cost curves of flood events compared to the total value of the impacted assets under each flood scenario. The present value of annual damage costs are less than the total present value of impacted assets until 2047. After 2047, the present value in 2015 dollars of replacing the assets is less than the cumulative expenditure incurred. However, if you consider the scenario from a 2047 perspective, the savings in damages do not outweigh the replacement cost of impacted assets. If all impacted assets were replaced in 2047, the replacement cost would be approximately $88 million in 2047 dollars and the total savings in damage costs for the 100 year period thereafter would be approximately $12 million (2047$).

Based on this analysis, the costs of maintenance are not high enough to warrant relocation in any one year. However, the current assessed scenario considers the replacement of all impacted assets. It is recommended to undertake a more detailed analysis as it may be economically justifiable to replace only those assets that suffer the greatest damage.

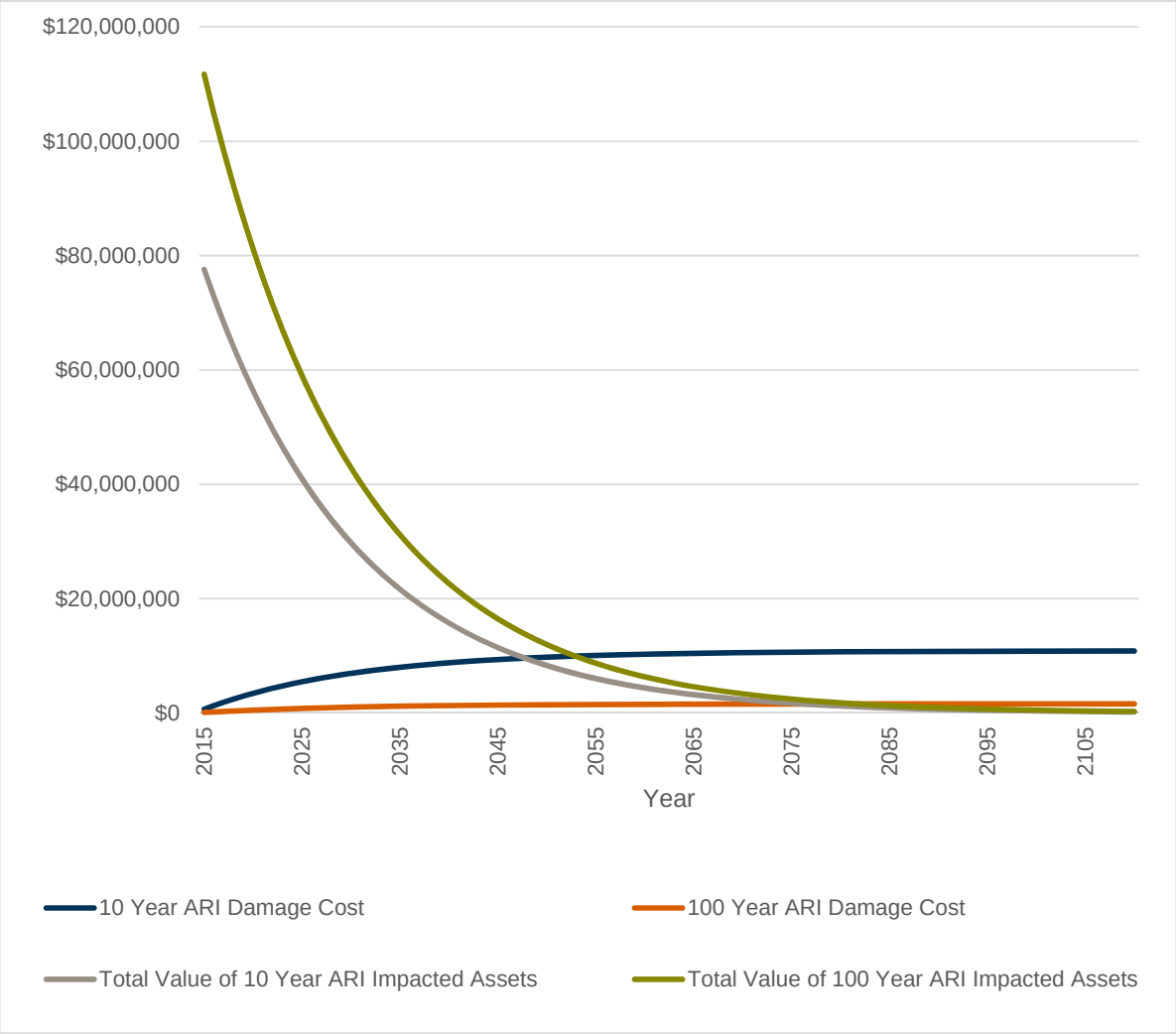

Figure 2-2: Damage cost in comparison to the value of impacted assets

Sensitivity Analysis

As a sensitivity, the flood scenarios have been assessed assuming flood intensity remains constant from present day (ie. no climate change impact) (**Table 2-6**). This is in comparison to the results presented in **Table 2-4** which assumes an increase in the intensity (and associated impact magnitude) of storm events.

Table 2-6: Damage cost per event with and without increasing storm intensity

Scenario	Damage Cost per Event (storm intensity increasing)	Damage Cost per Event (storm intensity constant)
10 Year ARI (current)	$6.7M	$6.7M
100 Year ARI (current)	$9.9M	$9.9M
10 Year ARI (2110)	$9.9M	$6.7M
100 Year ARI (2110)	$14.5M	$9.9M

Table 2-7 presents a comparison of the present value of the expected present value of damages for the two scenarios.

Table 2-7: Sensitivity analysis

Scenario	Present value of damage cost
10 Year ARI – increased storm intensity	$10.8M
10 Year ARI – constant conditions	$10.2M
100 Year ARI – increased storm intensity	$1.6M
100 Year ARI – constant conditions	$1.5M

The results presented in **Table 2-6** reflect the high cost of repair due to pluvial inundation, regardless of climate change. The impact of climate change is seen to be relatively low in present value terms. The increased magnitude of damage and associated costs does not increase fast enough to outweigh the 7% discount rate used to account for the time value of money.

Further sensitivity analyses have been undertaken and are presented in **Table 2-8**. However, a more detailed analysis and understanding of how damage costs vary between flood events would need to be established to gain a robust understanding of climate change impacts and long term management strategies. The comparatively significant expected costs associated with the 10 year ARI events (in comparison to the 100 year ARI) suggests that significant savings could be achieved through implementation of measures that minimise risk of inundation under lower magnitude, higher frequency flooding events.

Table 2-8: Sensitivity analysis

Scenario	Present value of damage cost
10 Year ARI, -20% damage costs	$8.7M
10 Year ARI, +20% damage costs	$13.0M
10 Year ARI, -20% number of buildings	$8.7M
10 Year ARI, +20% number of buildings	$13.0M
100 Year ARI, -20% damage costs	$1.3M
100 Year ARI, +20% damage costs	$1.9M
100 Year ARI, -20% number of buildings	$1.3M
100 Year ARI, +20% number of buildings	$1.9M

3 Coastal Erosion

Table 3-1 presents the results of the risk and vulnerability assessment of assets to coastal erosion, between the present day and 2110. The outcomes presented in this table are used as the basis of the coastal erosion economic assessment.

Table 3-1: Risk and Vulnerability Assessment

For the purposes of this assessment a number of assumptions have been made to facilitate the estimation of economic values, these include:

> Per annum seawall maintenance cost of $300,000;

> A replacement value of the on ground infrastructure at Onslow Salt Jetty of approximately $10 million;

> A replacement value of the Shire of Ashburton Offices equal to the median house value of approximately $762,000;

> The replacement value of the Bindi Bindi community is 23 times the median house value (there are 23 dwellings within the community), or $17.5 million; and

> Beach renourishment cost of $100,000 per annum once impacted by coastal erosion.

Using the timeframes of changes in risk/vulnerability detailed in **Table 3-1**, the present value of relocating/maintaining the assets was determined (**Table 3-2**). It is seen that if assets are replaced when the reach either very high vulnerability or extreme risk (eg. this is in 2070 for seawalls) the present value of implementing the management measure is $0.6 million. In contrast, relocation/maintaining assets once they reach high risk or vulnerability has a greater present value ($3.7 million) as this event occurs earlier in time. In order to determine which response is the preferred strategy a more detailed analysis of the costs of inaction / benefits of maintenance are required to understand how these costs may be offset.

Table 3-2: Replacement costs due to coastal erosion impacts

Scenario	Present value of cost over the 100 year assessment period
Replacement of assets at very high / extreme risk or vulnerability	$0.6M
Replacement of assets at high risk or vulnerability	$3.7M

Analysis of Results

The assets impacted by coastal erosion are costly to replace. However, coastal erosion impacts substantially fewer assets than pluvial inundation. The costs associated with pluvial inundation are over $12.4 million (present value, $2016), compared to the $0.6 to $3.7 million (present value, $2016) associated with coastal erosion.

Based on the existing information, there are not enough costs associated with inaction to justify the relocation of assets. It is recommended to wait as long as possible before incurring replacement costs. However, the limited data available for this analysis restricts its applicability. A more detailed evaluation of costs and benefits of erosion / inundation specific management options is reccommended.

About Cardno

Cardno is an ASX200 professional infrastructure and environmental services company, with expertise in the development and improvement of physical and social infrastructure for communities around the world. Cardno's team includes leading professionals who plan, design, manage and deliver sustainable projects and community programs. Cardno is an international company listed on the Australian Securities Exchange [ASX:CDD].

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