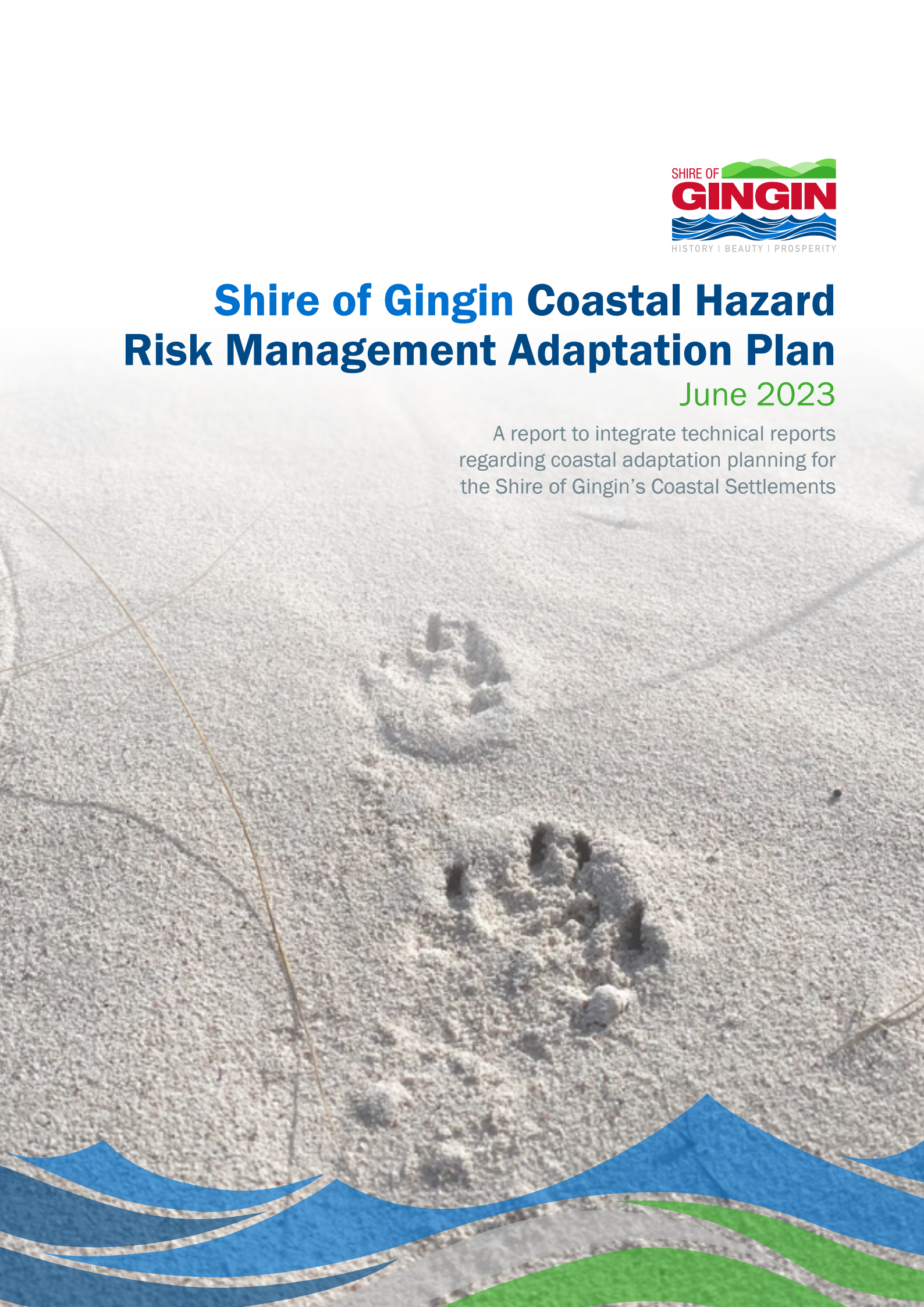
SHIRE OF GINGIN
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Shire of Gingin Coastal Hazard Risk Management Adaptation Plan

June 2023

A report to integrate technical reports regarding coastal adaptation planning for the Shire of Gingin's Coastal Settlements



ACKNOWLEDGEMENTS

Shape Urban acknowledge the Yued Noongar People as traditional custodians of the land on which we have worked for this project. We recognise their cultural heritage, beliefs and relationship to the land, which continue to be important to the Yued Noongar People today.

We pay our respects to Elders past and present, and to the land which they have cared for.

This document has been prepared with the support of many people from the Shire of Gingin community. We wish to acknowledge the community for your contributions.

FOR NOTING

This document acknowledges the challenges associated with managing risks in a dynamic coastal environment, together with the need to balance environmental, social and economic values to ensure the long-term sustainable use and management of the Shire's unique coastline. The CHRMAP process is designed to be ongoing, with regular updates associated with the emergence and collection of new information.

The Shire of Gingin is advised that the CHRMAP should be reviewed within 10 years and that the Shire should consider a single review update for erosion and inundation in all four coastal townsites.

This document combined the inputs from three separate reports. Where those reports are included in this document it is clearly identified. Shape Urban Pty Ltd makes no commitment as the accuracy of the data provided by external organisations, or has been able to verify if the data is accurate. Shape Urban assumes that all data provided by previous organisations is true to the best of their current knowledge and has replicated it as such.

DOCUMENT CONTROL

Shire of Gingin Coastal Hazard Risk Management Adaptation Plan - June 2023

A report to integrate technical reports regarding coastal adaptation planning for the Shire of Gingin's Coastal Settlements

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FREQUENTLY ASKED QUESTIONS

The impact of erosion and inundation on our coastline is expected to increase in the future due to storms and sea level rise. Coastal erosion has already occurred at various locations along the Shire of Gingin's coastline and the Shire wants to ensure that future actions are strategic, not reactive. Under projected climate change and sea level rise scenarios, the risks of these hazards such as erosion and inundation occurring is likely to increase in the future.

In response, the Shire, in partnership with key stakeholders has compiled coastal hazard documents that identify coastal areas that are at risk of coastal erosion and inundation over the next 100 years. A CHRMAP was prepared by Cardno for the Shire in 2019 (the Cardno 2019). Cardno 2019 identified erosion risks and challenges, the vulnerability of assets, and identified and prioritised risk management responses to those coastal hazards for the Lancelin, Ledge Point and Seabird townsites. It did not include the Guilderton townsite. Cardno 2019 also did not include inundation risks for any of the studied townsites.

Baird (2020) produced a Coastal Inundation Study (CIS) for the Lancelin, Ledge Point, Seabird and Guilderton townsites. The CIS identified potential areas subject to coastal inundation risk at Lancelin, Ledge Point, Seabird and Guilderton, however did not identify or prioritise risk management responses to the inundation hazards for the four townsites.

The Shire is now using this information, along with a new Technical Report prepared by Shape Urban (2023) to develop a comprehensive CHRMAP which examines ways in which our community can adapt to these risks.

This 2023 CHRMAP is a comprehensive coastal management plan for all four townsites.

What is a CHRMAP?

CHRMAP is the acronym for a 'Coastal Hazard Risk Management and Adaptation Plan'. It is a study prepared to communicate information about future coastal planning. It includes a technical assessment to understand the existing and predicted coastal processes, includes a social assessment to understand the community values associated with the coastline being studied, and considers financial and environmental implications.

The WA State Government's Coastal Hazard Risk Management and Adaptation Planning Guidelines, established under the Western Australian Planning Commission's *State Planning Policy No. 2.6 - State Coastal Planning Policy*, provides guidance for decision makers to develop and implement effective CHRMAPs.

The CHRMAP will estimate where the coastline is likely to 'move to' in the short, medium and long-term future. By understanding where the coastline is likely to be in the future, it allows us to understand what infrastructure may be impacted by coastal processes and investigate which options for managing these impacts might be appropriate in particular areas.

What are coastal hazards?

The two main coastal processes that are considered hazards are erosion and inundation. A CHRMAP identifies areas that could potentially be impacted by these hazards over the next 100 years, relative to storm events and projected sea level rise. CHRMAP uses 'vulnerability' as a way of identifying impact, which includes and analysis of how likely the impact is to occur (risk), the consequence of the impact, and how easy it is to adapt after the impact..

Please refer to Section 3 for more information.

What are the options for adapting to coastal hazards?

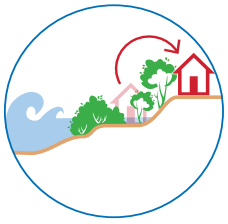
The WA State Government's State Planning Policy 2.6 – State Coastal Planning Policy (SPP 2.6) identifies a hierarchy of four options for adapting to coastal hazards:

Avoid



Identify future 'no build' areas and use planning controls to prevent new development in areas at risk now or in the future

Retreat



Withdraw, relocate or abandon assets that are at risk; ecosystems are allowed to retreat landward as sea levels rise

Accommodate



Continue to use the land but accommodate changes by building on piles, converting land uses or growing food or salt-tolerant plants

Protect



Use hard structures (e.g. seawalls) or soft solutions (e.g. dunes and vegetation) to protect land from the sea. May be prohibitively expensive, especially in the long term

Please refer to Section 5 to learn more about these options and the additional options of No Regrets and Do Nothing that have been considered in the risk treatment assessment.

How will this affect me?

Coastal vulnerability will affect different people in different ways depending on where they live and how they access, use and enjoy the coastline.

I am a Private property owner in a coastal hazard area

Planning Controls - Use of planning controls to allow continued use of current infrastructure until such time that impacts arise but that restrict further or new development will be introduced to indicate to relevant owners that an asset is vulnerable. This will help all landowners to make informed decisions about the level of risk they are willing to accept, that risk management and adaptation is likely to be required, and that the landowner may share the responsibility for that adaptation.

Controls will include new minimum finished floor levels in some areas, which will result in significant changes to the style of development that may be observed over the coming decades, noting that it may be some two-three years before these controls are implemented.

Notification on your Certificate of Title - If a planning or development application is submitted for a lot located in a coastal hazard area, then SPP 2.6 requires a notification to be placed on the certificate of title as a condition of approval, identifying that the lot may be vulnerable to coastal hazards.

Note to Real Estate and Settlement Agents – Local estate agents will be advised on the risks that are predicted, so that prospective purchasers are not surprised by the information in the CHRMAP and CMS.

When property reports are sought from the Shire during the settlement process, a notification in the Shire's database for the property will be communicated to settlement agents.

I am a User of the coastline

Some areas of the Shire's coastline will become vulnerable over the next 100 years. This includes beaches, access ways, footpaths, carparks, toilets, roads and public open space areas.

This document provides a summary of the short-term management actions to be undertaken. These are largely focused on 'behind the scenes' actions to better prepare the Shire for future coastal hazard management

Long term, adaptation strategies such as protection or managed retreat will be required when coastal hazards occur.

In areas identified for potential future protection, the construction of structures such as seawalls will mean that the natural sandy beach will eventually be lost in these locations and that access to those stretches of coastline might be affected.

In areas identified for future managed retreat, existing infrastructure may gradually be permanently removed or relocated if coastal hazards cause damage during storm events. The natural sandy beach and dunes will be retained in these areas.

What will the outcomes of the CHRMAP be?

The CHRMAP outlines a plan to address future risks identified across the four coastal townsites of Lancelin, Ledge Point, Seabird and Gingin. The components of a CHRMAP include:

- Coastal hazard risk identification and assessment;
- Coastal risk evaluation based on community and stakeholder engagement;
- Identification of adaptation options to mitigate coastal hazard risk; and
- Assessment of adaptation options to identify preferred options.

The CHRMAP process takes into account the uncertainty associated with coastal change predictions and provides a flexible decision-making pathway that the Shire can use over time as coastal hazards emerge.

Am I responsible if my property is affected?

This is complex, but the short answer is yes, you are responsible for management of your own property. There is no legal obligation on the State or local governments to protect private assets within coastal hazard areas, or to compensate for any losses incurred due to coastal hazards. Should assets pose a risk to public safety, removal may be required.

State or local Government are also not obliged to protect public assets, although they would need to ensure public safety and so might need to remove assets that would be of danger to the community, if maintaining the asset is not an option.

SPP 2.6 requires that local governments prepare a CHRMAP to identify coastal hazard areas, outline potential adaptation pathways and share this information with the community, so we can all plan together.

Groups of landowners may be willing and have the capacity to fund protection works privately, that the Shire cannot afford or seek funding for via other means. In this case, detailed planning and engineering works will still be required and funding for both capital and maintenance expenses will need to be committed by the landowners. Engineering design would need to prove that the works would not have a negative impact on adjacent coastlines, areas or valued natural assets.

The Shire will prepare a fact sheet for landowners to explain these obligations and describe the approach required to take this pathway.

SPP 2.6 requires that local governments prepare a CHRMAP to identify coastal hazard areas, outline potential adaptation pathways and share this information with the community, so we can all plan together.

Who will pay for adaptation?

There is no current committed funding by state and federal governments to assist local governments in paying for coastal adaptation. A range of grants are available to support local governments to plan and implement sustainable adaptation options and partner with community groups to undertake on-ground management activities, however there is a very limited funding pool across all West Australian coastal local governments.

The Coastwest, Coastal Management Plan Assistance Program (CMPAP), Coastal Adaptation and Protection (CAP) and Hotspot Coastal Adaptation and Protection (H-CAP) grants are managed by the Department of Planning, Lands and Heritage and the Department of Transport's coastal sections. There is no emergency funding and funding is not guaranteed anywhere. Funding can also be sourced locally via rates and levies, where the community accepts that the adaptation measure will benefit all ratepayers.

The State planning policy has defined a pathway for 'User Pays'. This establishes a principle that the beneficiaries of adaptation options should pay, as they stand to gain. Where adaptation options are designed to protect specific sections of coastal land and assets that are primarily to benefit private property, an assessment determines who should contribute and how much.

Knowing that any type of coastal adaptation will be expensive, the Shire use the CHRMAP recommendations to commence planning and budgeting in conjunction with state government agencies and the affected community, to ensure it is well placed to undertake works as necessary, when the times comes.





ABBREVIATION LIST

AHD	Australian Height Datum
ARI	Annual Recurrence Interval
AS	Australian Standard
BDA	Benefit Distribution Analysis
CBA	Cost Benefit Analysis
CHRMAP	Coastal Hazard Risk Management Adaptation Plan
CMS	Coastal Management Strategy
CSEP	Community and Stakeholder Engagement Plan
DPLH	Department of Planning, Lands and Heritage
DoT	Department of Transport
FAQs	Frequently Asked Questions
GSC	Geotextile sand container
HSZ	Horizontal Shoreline Datum
IPCC	International Panel on Climate Change
LPS 9	Local Planning Scheme No. 9
MCA	Multi-criteria analysis
MSL	Mean Sea Level
MU	Management Unit
MWL	Mean Water Level
PSC	Project Steering Committee
SLR	Sea Level Rise
SPP 2.6	State Planning Policy 2.6 – State Coastal Planning Policy
TECs	Threatened Ecological Communities
The Shire	Shire of Gingin
WAPC	Western Australian Planning Commission



COMMON DEFINITIONS

The following definitions apply to these words and phrases through the report:

Adaptation

Changes made in response to the likely threats and opportunities arising from climate variability and climate change.

Acceptable Risk

These are risks that do not need further treatment. The term ‘acceptable risk’ refers to the level at which it is decided that controls (further restrictions or otherwise altering the activity) is not worthwhile.

Adaptation Pathway

Adaptation planning is about being ready to manage the risks and impacts of coastal processes a location experiences, by planning for the most appropriate decisions and options to implement over time.

A flexible adaptation pathway approach enables the establishment of a decision-making strategy that is made up of a sequence of decision points over time, preventing a decisionmaker from being locked into a risk treatment option (and associated risk management measures), which may not be appropriate for dealing with the long-term problem. The intent is for decision-making to be responsive to changing circumstances over time.

Annual Recurrence Interval (ARI)

An annual recurrence interval is sometimes also known as ‘return period’. It is the average number of years that it is predicted will pass before an event of a given magnitude occurs. For example, a 50 year ARI event would on average happen every 50 years.

Assets

Something that has value to the decision-maker, community and stakeholders – this can . tangible or intangible, includes consideration of risk and liabilities, and can be positive or negative at different stages of the assets life. Assets may be natural or man-made and include the beach, foreshore reserve (including dunes, flora and fauna), foreshore reserve amenity (including things like car parks, paths, public ablutions, barbeque/picnic/shade areas, playgrounds, infrastructure for public safety and pedestrian access structures such as ramps, stairs and paths), marinas, recreational boating facilities, facilities to benefit the broader public (such as cafes and restaurants), surf life-saving facilities, commercial and residential land, and protection structures such as groynes, seawalls and sand nourishment.

CHRMAP (Coastal Hazard Risk Management and Adaptation Plan)

A study that identifies the key hazards and assesses the risk to assets of coastal erosion and inundation.

Coastal Processes

Action of natural forces on the coastal environment within the coastal zone.

Coastal Zone

The land areas adjacent to the coastline that may be influenced by coastal processes - this includes tidal reaches of inland waters such as river mouths and estuaries.

Dune Blowouts

Dune blowouts are depressions in a sand dune caused by the removal of sediments by wind. They tend to form when the wind erodes into patches of bare sand where there has been a reduction or damage to vegetation.

Erosion

When sediment is transported away by waves, winds and currents, reducing the size (width) of a coastal foreshore reserve and/or the distance to an asset on the adjoining land.

Habitat

The areas in which an organism and/or assemblage of organisms lives. It includes the abiotic factors (e.g. substrate and topography), and the biotic factors.

Inundation

The flooding of a portion of previously dry land with ocean water. It may be a temporary occurrence during a storm event or high tide, or permanent for example due to sea level rise.

Intolerable Risk

Risk that is unacceptable in any circumstances or at any level.

Management Unit

Areas of similar coastal behaviour, sediment movement or geology that are grouped for the purpose of defining detail at an appropriate scale for assessment and management.

Multi-criteria Analysis

A decision-making tool that supports the prioritisation of risk management options using multiple criteria as reviewed by the community.

Mean Sea Level (MSL)

Mean sea level (MSL) is an average surface level of the ocean, from which heights such as elevation may be measured.

Project Steering Committee

The role of the Project Steering Committee (PSC) is to provide technical coastal and planning skills and ensure the project progresses in line with milestone reports and progress reports. The PSC is made up of coastal staff from the Department of Planning, Lands and Heritage, the Department of Transport, Elected Members and administrative staff from the Shire and the project's consultant team.

Rehabilitation

The re-establishment of vegetation and other ecological attributes, acknowledging that the area/community will remain modified.

S1

The current risk of storm erosion (based on historical storms).

Sand Nourishment

Sand nourishment is one possible protection adaptation pathway to coastal hazards. It may be a standalone measure for protection, or be used to improve the beach amenity when used in combination with other adaptation measures such as a seawall.

It is considered to be a 'soft' management option and usually mimics natural beach and dune systems.

Sediment Cell

Natural physically based units which identify sections of the coast within which sediment transport processes are strongly related. Each sediment cell is a collection of marine and terrestrial landforms and the sediment transport between them. Sediment cells provide a framework for coastal management by defining 'natural' management units that link the marine and terrestrial environments.

Trigger

A pre-determined point that is set to 'trigger' the commencement of planning and /or implementation action of a risk management option to avoid crossing a 'threshold' of acceptable risk.

Vulnerability

The underlying properties of an 'asset' which result in susceptibility to a risk source that can lead to an event with a consequence.





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1. INTRODUCTION

The Shire of Gingin has approximately 70 kilometres of coastline, with four of its five townships on the coast - Lancelin, Ledge Point, Seabird and Guilderton.

The adjacent land, the coastal zone, supports a variety of recreation, conservation, residential and commercial land uses. The coastal zone is a major asset for the Shire, is highly valued by the community and underpins the Shire's identity and lifestyle.

The Intergovernmental Panel on Climate Change (IPCC) recognises that the mean sea level has been rising globally since the nineteenth century and is predicted to rise at an increasing rate in the future. Rising sea levels and intensifying storm activity will increase the risk of coastal inundation, storm erosion and long-term shoreline recession. As our coastline changes, our planning system needs to respond to both visible and predicted changes. State governments across Australia have introduced statutory obligations that require local governments to consider and plan for these hazards.

The Shire's coastal areas are subject to these erosion and inundation risks, which already have and will continue to have a significant impact on its communities over time. In response, the Shire has been working to develop risk and impact specific planning to help it guide land use and development decision making for its coastal areas into the future.

In Western Australia the governing policy for coastal management is the Western Australian Planning Commission's (WAPC's) State Planning Policy No. 2.6 - State Coastal Planning Policy (SPP 2.6). SPP 2.6 recommends management authorities develop a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) to guide land use and development decision making in coastal zones. The WAPC has also developed specific CHRMAP guidelines to assist the preparation of CHRMAPs – the Coastal Hazard Risk Management and Adaptation Planning Guidelines (July 2019).

SPP 2.6 recommends management authorities develop a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) for land use or development that is potentially vulnerable to coastal hazards. Specific guidelines have been developed to assist in this process (WAPC, 2019).

One of the key objectives of SPP 2.6 is to establish coastal foreshore reserves which include allowances for the protection, conservation and enhancement of coastal values across the state. A risk assessment framework is then applied to identify risks that are intolerable to the community, and other stakeholders such as local governments, indigenous and cultural interests, and private enterprise. Adaptation measures are then developed according to the preferential adaptation hierarchy outlined in SPP 2.6.



A CHRMAP was prepared by Cardno for the Shire in 2019 (Cardno 2019). It summarised previous coastal assessments in the Shire as follows:

- 2012 - the WA Department of Planning commissioned the study The Coast of the Shires of Gingin and Dandaragan (WA): Geology, Geomorphology and Vulnerability (Eliot et al, 2012). This study assessed the sensitivity and exposure of coastal landforms from Guilderton to North Head (north of Jurien Bay) and identified that all town sites are located on landforms that have a moderate or moderate to high vulnerability to changing coastal processes (winds, tides, currents, waves and sea levels). The study recommended detailed investigations to identify the potential extent of long-term coastal erosion and inundation at priority locations.
- 2013 - the Shire partnered with the Shire of Dandaragan and the Northern Agricultural Catchments Council (NACC) to identify the range of data and information required to undertake coastal hazard assessments at the priority locations outlined in the Data and Information Gap Analysis For Coastal Hazard and Risk Management (Coastal Focus, 2013).
- 2014 - in accordance with the recommendations made in Coastal Focus 2013, the Shire partnered with the Shire of Dandaragan, the NACC and the WA Department of Transport (DoT) to undertake a preliminary assessment of coastal hazards at each town site in the study area. The preliminary findings of the assessment identified that:

  1. Adaptation planning for coastal erosion was a priority at Seabird, Ledge Point, Lancelin, Cervantes and Jurien Bay town centre. Guilderton and South Jurien Bay (from Island Point south) were identified as low priority areas, mainly due to the relatively large coastal setback distance between the high water mark and built assets at these locations and, therefore, lack of a short term threat from coastal erosion;
  2. Adaptation planning for coastal inundation was a priority at Lancelin, Cervantes and Jurien Bay. This is mainly due to the low-lying nature of, and proximity of assets to, the shoreline at these locations;
  3. Adaptation planning for coastal inundation at Guilderton requires a detailed investigation of the combined effects of inundation from the ocean and inland rainfall events, due to Guilderton's location on the Moore River estuary.

Cardno 2019 considered the first of the above recommendations with a focus on the areas identified at risk from coastal erosion hazards. It identified erosion risks and challenges, the vulnerability of assets, and identified and prioritised risk management responses to those coastal hazards for the Lancelin, Ledge Point and Seabird townsites. It did not include the Guilderton townsite. The Cardno 2019 also did not include inundation risks for any of the coastal townsites in the Shire.

In 2020 Baird produced a Coastal Inundation Study (Baird 2020) for the Lancelin, Ledge Point, Seabird and Guilderton townsites. The CIS identified potential areas subject to coastal inundation risk at Lancelin, Ledge Point, Seabird and Guilderton, however did not identify or prioritise risk management responses to the inundation hazards for the four townsites.

To fill the gaps, the Shire of Gingin engaged Shape Urban, in partnership with Water Technology Pty Ltd, to complete a Gap Assessment. The Gap Assessment Technical Report (Shape Urban 2023a) completed coastal hazard planning in line with SPP 2.6 for erosion and inundation for Guilderton and for inundation for the three remaining townsites. It also assessed any changes to the analysis of options for erosion for the three townsites.

This 2023 CHRMAP brings together each of these previous reports and presents the combined responses to erosion and inundation from Cardno 2019, Baird 2020 and Shape Urban 2023a.

This 2023 CHRMAP is supported by an easy-to-understand summary document with clear implementation actions for the Shire, other decision makers and the local community (2023 CHRMAP Summary Report).

A critical part of this project has been more in-depth engagement with the local community and stakeholders to inform them about the extent of potential coastal hazards and the adaptation strategies available to respond to those hazards.

Information regarding inundation risks which has been analysed since Cardno 2019 via Baird 2020 changes the necessary response quite significantly.

That process has confirmed community values along the coastline, allowed better communication of state and local government responsibilities and capacity to respond to potential coastal hazards, and enabled the community to bring their local knowledge, expertise and lived experience to the process. These local community and stakeholder participants have provided key input to selection of appropriate adaptation strategies to respond to the risks.

This document acknowledges the challenges associated with managing risks in a dynamic coastal environment, together with the need to balance environmental, social and economic values to ensure the long-term sustainable use and management of the Shire's unique coastline.

The CHRMAP process is designed to be iterative, with regular updates to support the emergence and collection of new information. The Shire should continue to engage with the local community and stakeholders to undertake all updates to this report.





2. ESTABLISHING THE CONTEXT

2.1 Purpose

The purpose of this CHRMAP is to present coastal erosion risks and challenges and develop responses for the each of the Shire of Gingin's coastal townsites; Guildertown Lancelin, Ledge Point and Seabird. A standalone summary document (2023 CHRMAP Summary Report) has also been preapared, as an easy-to-read version of this CHRMAP, recognising that CHRMAP documents are long and comprise multiple layers of technical complexity..

This CHRMAP will be supported by a Coastal Management Strategy (CMS). The CMS will build on the outcomes and recommendations of the CHRMAP and previous coastal studies. It will detail baseline information about the coastal zone, including flora and fauna and the Shire's owned or managed assets, relevant to planning and management of the coastline.

The management responses and implementation pathways to adapt to the changing future oceanic and coastal conditions outlined in these documents aim to ensure the Shire, community and stakeholders are well placed to deal with impacts to the coastal zone at established and defined triggers. The CHRMAP and the CMS will form the blueprint for the future use of the Shire's coastal areas.

2.2 Aims and Objectives

The primary aim of this CHRMAP is to provide a framework of adaptation options for the Shire so that decisions are strategic, well informed and proactive rather than reactive.

This CHRMAP brings together a decision-making framework to allow the Shire and other key stakeholders to:



Ensure that development and the location of coastal facilities takes into account coastal processes, landform stability, coastal hazards, climate change and biophysical elements



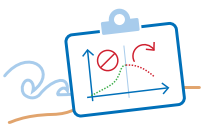
Guide the identification of appropriate areas for the sustainable use of the coast for housing, tourism, recreation, ocean access, maritime industry, commercial and other activities



Provide for public coastal foreshore reserves on the coast and access to them



Protect, conserve and enhance coastal zone values, particularly in areas of landscape, biodiversity and ecosystem integrity, indigenous and cultural significance



Establish decision making triggers and planning horizons to respond to the impact of coastal risks on the community



2.3 Scope, Process and Report Structure

One of the key objectives of SPP 2.6 is to establish coastal foreshore reserves which include allowances for the protection, conservation and enhancement of coastal values across the state. A risk assessment framework is then applied to identify risks that are intolerable to the community, and other stakeholders such as local governments, indigenous and cultural interests, and private enterprise. Adaptation measures are then developed according to the preferential adaptation hierarchy outlined in SPP 2.6.

This CHRMAP report is presented based on the CHRMAP template, logically progressing from the context of the study area through to recommended adaptation options, as illustrated in Figure 1.

Each CHRMAP chapter summarises information from Cardno 2019, Baird 2020 and Shape Urban 2023a.

The 2019 Coastal Hazard Risk Management and Adaptation Plan, 2020 Coastal Inundation Study and CHRMAP Gap Assessment Technical Report form Appendix A, Appendix B and Appendix C to this report.

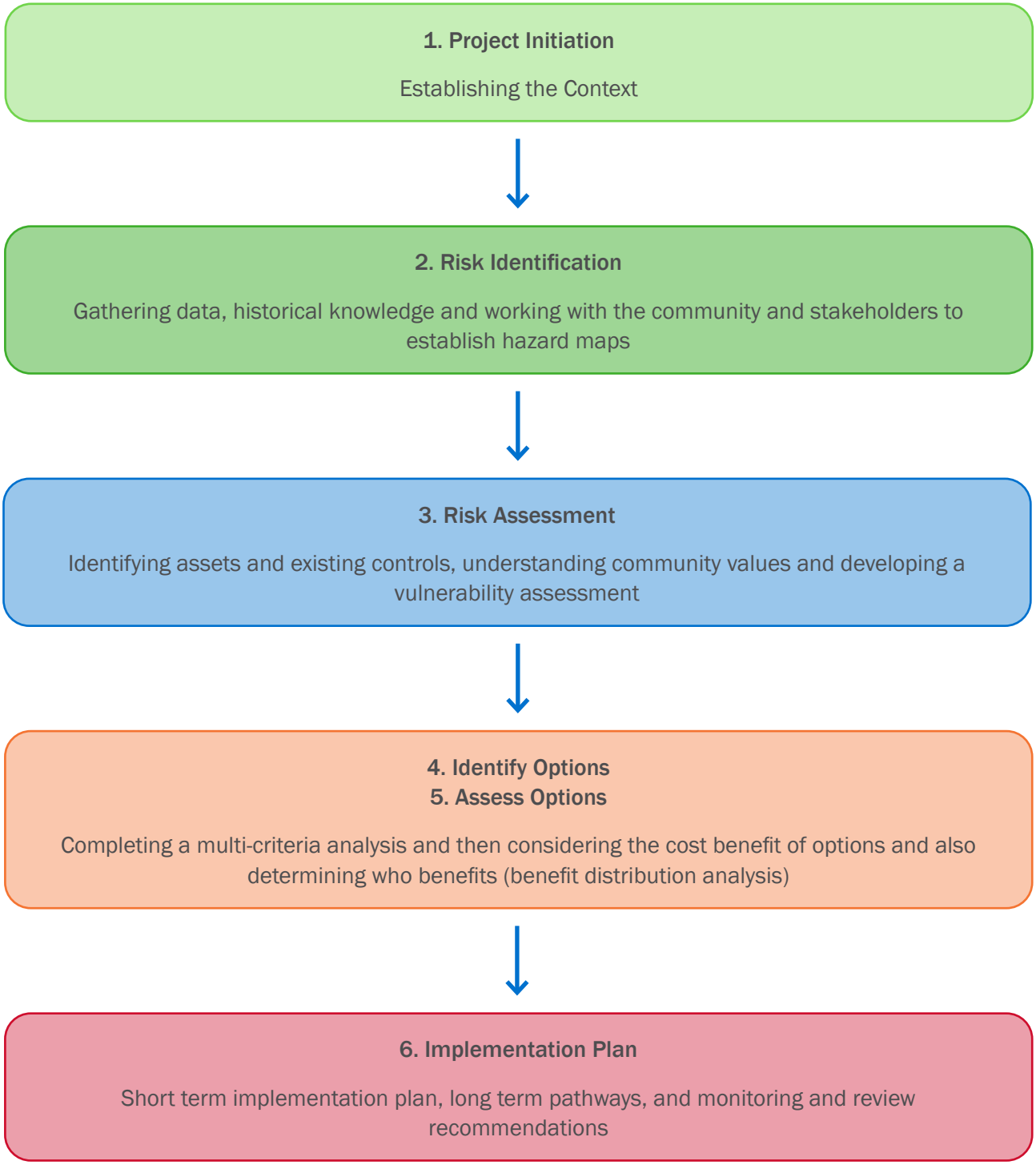


FIGURE 1: CHRMAP STAGES, ADAPTED FROM CHRMAP GUIDELINES (WAPC, 2019)



2.4 Study Area

The Shire of Gingin is located 84 kilometres north of Perth. There are five townships within the Shire; the inland town of Gingin and the coastal towns of Guilderton, Lancelin, Ledge Point and Seabird.

In 2021 there were 5,576 residents, 4,107 dwellings, 618 local businesses, 2,795 local jobs and 2,485 employed residents in the Shire. The largest industries (by employment) were agriculture, iron ore mining and local government administration (ABS, 2021). In addition to these industries, the Shire's economy is also based around tourism, with coastal areas in particular experiencing a large influx of people during the summer holiday season.

The Shire has approximately 70 kilometres of coastline. The adjacent land, the coastal zone, supports a variety of recreation, conservation, residential and commercial land uses. The coastal zone is a major asset for the Shire, is highly valued by the community and underpins the Shire's identity and lifestyle.

This CHRMAP focuses on the coastal zones within the four coastal townsites of Lancelin, Ledge Point, Seabird and Guilderton including future development areas, where the services from human-made and natural assets provide key social, economic and environmental value to the community. The study area encompasses sediment sells that are classified into management units for the purpose of defining detail at an appropriate scale for assessment and management.

The management units for Lancelin, Ledge Point and Seabird are taken from Cardno 2019 and comprise 10 management units. Guilderton was considered in Shape Urban 2023a and is comprised of approximately two kilometres of coastline divided into two (2) management units.

The management units are at Figure 2.

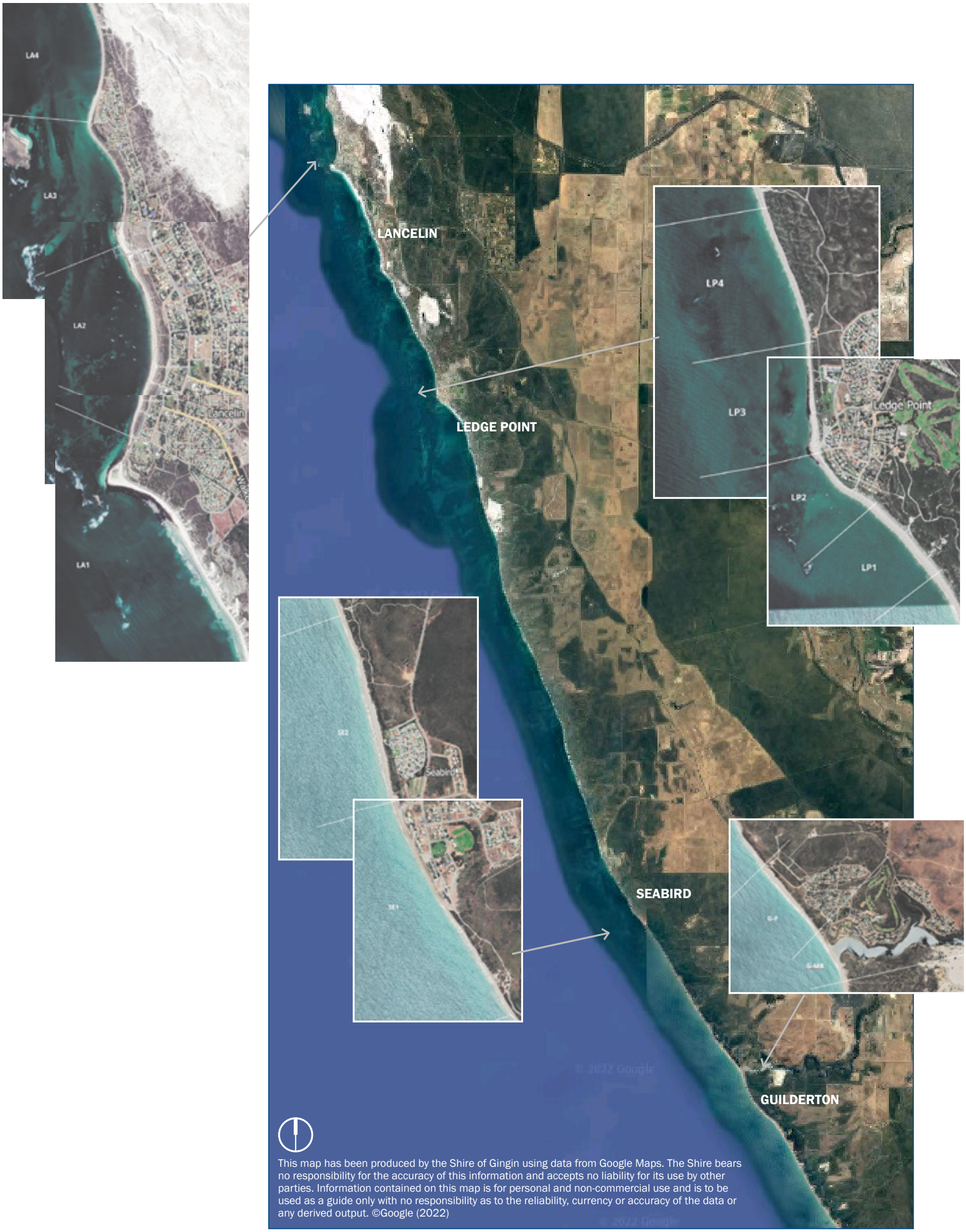


FIGURE 2: CHRMAP MANAGEMENT UNITS FROM 2019 CHRMAP (CARDNO) AND CHRMAP GAP ASSESSMENT TECHNICAL REPORT

A summary of the description of the Lancelin, Ledge Point and Seabird study areas in the Cardno 2019 is provided in this section. The Guilderton section at Section 2.4.4 was developed as part of Shape Urban 2023a to inform this CHRMAP.

2.4.1 Lancelin (Cardno 2019)

The Lancelin township is the regional centre for the Upper Coastal area of the Shire (Shire of Gingin 2016b). Lancelin is well known as a windsurfing venue, hosting the Ledge Point to Lancelin Windsurfing Classic in January each year. Crayfishing is a significant local industry,as well as seasonal tourism. The Lancelin jetty at the end of Miragliotta Street is managed by the DoT.

The Lancelin townsite occupies three sandy headlands formed in the lee of Lancelin Island to the north and Edwards Reef to the south (Short, 2006). There are two islands close to the shore, the smaller, rocky Edward Island and the larger, vegetated Lancelin Island (Figure 3, taken from the 2019 Cardno CHRMAP report).



FIGURE 3: AERIAL VIEW OF LANCELIN, 2022 (SOURCE: PROPAGULE)

Edward Island is connected to an approximately 850m long shallow nearshore reef which provides good protection from wave energy to the adjacent shoreline (MRA, 2016b). There is also a shallow nearshore reef that is approximately 450m long located between the two islands and extending between approximately 500m and one km offshore. Deeper passages exist between the shallow reefs and islands, which allow boat access to Lancelin and also permit wave energy to reach the shoreline (MRA, 2016b).

The Lancelin area lies within three sediment cells (13-15, Eliot et al, 2012), which were assessed as having moderate (cells 13-14) or moderate-high (cell 15) vulnerability. Broad scale geological mapping indicates Coastal Limestone may be present along the coast in this area, however, no rock was visible on the beach or in the dunes during a site visit undertaken in December 2015 (MRA, 2016b). In the absence of detailed geotechnical information, the Lancelin area was classified as a sandy coast for the purpose of coastal hazard assessment (MRA, 2016b).

The five kilometres used in the coastal hazard assessment by MRA (MRA, 2016b) was divided into four management units by Cardno (2019) (see Figure 2). The southern-most management unit is largely undeveloped, with the intention to use the area primarily for sporting and recreation purposes. The area has also been identified for linking the town to future urban development at Lancelin South (Shire of Gingin, 2012a).



2.4.2 Ledge Point (Cardno 2019)

The Ledge Point township has a general store, cafe/fish and chip shop and a country club which has a restaurant, bar, golf course, tennis courts and lawn bowls. Ledge Point is well known as a windsurfing venue, hosting the Ledge Point to Lancelin Windsurfing Classic in January each year. The beach and nearshore waters are used for launching and mooring of boats.

Ledge Point lies at the boundary of two coastal cells; Cell 11 (Green Reef to Ledge Point) and Cell 12 (Ledge Point to South Pacific Reef). The coastline in both these cells was assessed as having moderate vulnerability (Eliot et al, 2012). Broad scale geological mapping indicates coastal limestone may be present along the coast in this area, however no rock was visible on the beach or in the dunes during a site visit in December 2015 (MRA, 2016b).

The Ledge Point townsite is located on a sandy foreland formed in the lee of a shore-parallel reef (Short, 2006). There are no islands offshore, however, both offshore and nearshore reefs protect the Ledge Point beach from wave energy (MRA, 2016b).

The three kilometres used in the coastal hazard assessment (MRA, 2016b) was divided into four management units by Cardno (2019, see Figure 2). There are two groynes, the smaller 'southern groyne' which was constructed in 1975 at the boundary between management units LP2 and LP3 and the larger 'northern groyne' which was constructed in 1985 slightly to the south of the centre of management unit LP3. The southern-most (LP1) and northern-most (LP4) management units are predominantly undeveloped at present, but the potential for development of these areas has been identified in the Shire's LPS 9.

The main coastal node for public recreation and tourism is focused around Key Biscayne Park, to the north of the northern groyne. The park comprises a large grassed park area that has had extensive coast care attention, including dune rehabilitation. The beach area between the two groynes is the main swimming area, with the beach to the south of the southern groyne being used for boat launching, with four-wheel drives and tractors traversing and parking on the beach.

The main coastal erosion risk area is in management unit LP3, where a number of private residences along DeBurgh Street overlook the beach to the south of the southern groyne (see Figure 4).



FIGURE 4: PROPERTIES OVERLOOKING BEACH ALONG DEBURGH STREET ,2022 (SOURCE: PROPAGULE)

2.4.3 Seabird (Cardno 2019)

The Seabird township has been subject to ongoing coastal erosion, which has caused the loss of a substantial portion of the primary coastal dunes and a coastal road (Turner Street). Historically, management of erosion has included beach nourishment and temporary protection works (MRA, 2016a), before a seawall was constructed in 2015 (and extended in 2016) to protect residential properties. Funding for the seawall was provided by the State Government, the Shire and community contributions organised through and sponsored by the Seabird Progress Association.

Ongoing responsibility for maintenance and management of the structure was one of the considerations of the Cardno 2019 (Cardno).

The seawall is currently being managed by the Shire of Gingin under a license issued under section 91 of the Western Australian Land Administration Act 1997 (LAA) by the Department of Lands.

The townsite is on a broad coastal point in a localised area of greater vulnerability relative to the general coastline within its coastal cell, which is considered to have a moderate vulnerability (Eliot et al, 2012). There is some beach rock (Tamala Limestone) visible along the coast in front of the township and scattered offshore reefs which provide some protection from incoming wave energy. Seabird however lacks the significant reefs or offshore islands which are present off Lancelin and Ledge Point.



FIGURE 5: SEABIRD WITH A VIEW OF THE SEAWALL AND THE AREA NORTH, 2022 (SOURCE: PROPAGULE)

Geophysical data collected by Gordon Geological Consultants and the DoT in 2002 confirmed the presence of a limestone cliff of low to medium strength under the dunes to the south of the Coastal Point. It was estimated that this cliff deviates away from the coast in line with the northern end of Turner Street and extends to the junction of McCormick and Edwards Streets.

During a site visit in early 2017, the presence of the seawall was noted to have limited the beach extent in front of the town to the north of the seawall. As the seawall was designed as an interim measure public access to the beach from the top of the seawall has not been allowed for and public open space along the foreshore within the town is subsequently very limited. Public beach access is provided to the north and south of the seawall.

The 2.6 kilometres used in the coastal hazard assessment (MRA, 2016b) was divided into two management units by Cardno (see Figure 2).



2.4.4 Guilderton

Guilderton functions as a tourist destination, with tourism becoming more prevalent and increasing numbers of metropolitan Perth-based residents becoming property owners of coastal holiday homes. The main economic activity for the town is tourism, with land use adjacent to the river mouth comprising a caravan park, kiosk, restaurant and associated car parking, recreational playground and boat launching facilities.

The Guilderton township is located at the coast on the northern bank of the Moore River. A sandbar closes off the river mouth, although it is open intermittently. The sandy beach is backed by a vegetated coastal reserve, a bitumen coastal access road and then residential development.

The study area is comprised of two kilometres of coastline that has been divided into two management units (see Figure 2). The ocean coastline has been treated as the primary management unit and the river foreshore has been delineated as a secondary management unit. There is some overlap of the units to represent the transition area of the river mouth. The coastline at Guilderton is exposed to open ocean swell energy, somewhat mitigated by the offshore reef.

Two significant flood events have occurred within the estuary within the last 40 years lasting two to three weeks (Shire of Gingin, 2022). During a riverine flood, outflows break through the sandbar. Anecdotal evidence suggests that the river outlet has moved both north and south of the estuary periodically, resulting in erosion of the foreshore dunes adjacent to the river mouth and an increase in beach vulnerability.

It has also been indicated that since the construction of the groyne in North Guilderton in 1967, the river outlet has not moved north, only flowing out south of the estuary. Significant accretion of the beach has been observed north of the river, while erosion has been observed to the south in conjunction with strong river outflows.

On a site visit in February 2021 the beach was in a stable condition with a wide dry sandy beach and healthy foreshore vegetation. There were some indications of minor erosion at the toe of the primary dune in the past year. A small scarp was present in places. Some outcrops of limestone were present on the beach and in the foreshore reserve. The river foreshore was also in a stable condition with some limestone rock outcropping and protection by a limestone revetment wall and boat launching infrastructure. Figure 6 to Figure 10 depict the site visit conditions.

There are very few vacant lots available in the townsite for development, with the potential for urban expansion on the northern development front of the Moore River limited by a Crown reserve.

On the south side of the Moore River, a large area of land has been zoned Future Development and is anticipated to provide for approximately 2,000 dwellings, and a population of approximately 5,000 people in the medium to long term.



FIGURE 6: MOORE RIVER SHORELINE ALONG THE WALKWAY CONNECTING TO THE CAR PARK



FIGURE 7: LIMESTONE REVETMENT ALONG MOORE RIVER SHORELINE ADJACENT TO CAR PARK



FIGURE 8: SANDBAR BETWEEN MOORE RIVER AND OCEAN



FIGURE 9: MOORE RIVER FLOATING FINGER JETTY AND UNIVERSAL ACCESS RAMP



FIGURE 10: LIMESTONE ROCK OUTCROP ON BEACH BETWEEN TOWN AND GUILDERTON BEACH GROYNE



> We are a welcoming inclusive community that celebrates its unique coastal and inland landscapes with an aim to increase visitation to the region.
>
> ***(Shire of Gingin Vision)***

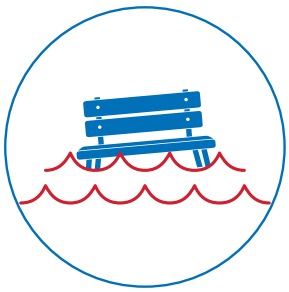
2.5 Assets and Values

For the purpose of this CHRMAP, assets are defined as

- Natural features such as beaches and natural vegetation;
- Buildings and other structures (houses, commercial buildings, community structures);
- Servicing infrastructure relating to drainage, water, sewerage and power;
- Roads, paths and walkways;
- Recreational structures (benches, barbecues, shade structures, playgrounds, sporting equipment)
- Coastal structures such as jetties, boat ramps, seawalls and structures

As defined in the Australian Standard for Climate change adaptation for settlements and infrastructure – A risk-based approach (AS 5334-2013), an asset's value can be tangible or intangible, financial or non-financial. Examples of non-tangible assets include ecological function, coastal views and use of the beach for swimming and fishing.

The value of an asset also includes consideration of risks and liabilities and can be positive or negative at different stages of the asset's life. Established community and stakeholder feedback further encompass the economic, social (including heritage) and environmental values of the coastal zone.




LANCELIN VOLUNTEER
MARINE RESCUE
VMR688
STOP
NO VEHICLES
BEYOND THIS
POINT

2.6 Community and Stakeholder Engagement

It is imperative to complete coastal hazard planning alongside the community and stakeholders affected by the decision-making process. Since 2012, the Shire has worked closely with the Shire of Dandaragan, the Northern Agricultural Catchments Council (NACC), state government agencies, coastal specialists and the local community to investigate the hazards and risks to the Shire's coastline, and to develop strategies for adapting to them (Cardno 2019).

The Shire has provided opportunities for the community and stakeholder groups to learn about the Shire's CHRMAP process through workshops, public information sessions and communication via the Shire website, newsletters, letters, emails and social media. The Shire also produced a series of videos on coastal erosion and inundation and works being undertaken to address the more immediate risks and hazards between 2019 and 2020.

In addition to the above, the engagement process for Cardno 2019 and this CHRMAP have provided multiple opportunities for the community to be involved. For Cardno 2019 development, a community engagement session was held in Lancelin in May 2017 and an online survey was conducted in June 2017.

In accordance with the CHRMAP Guidelines, a community and stakeholder engagement plan was prepared to set out engagement objectives, key stakeholders and the program of engagement activities.

The engagement methods were designed to provide the community and stakeholders with opportunities to 'ground truth' and confirm values provided in previous stages of CHRMAP development, investigate qualitative criteria used in the multi-criteria analysis process, and to examine trade-offs of management options.

For this CHRMAP update, there were three engagement phases:

1. **Risk Identification: launch of project, community values re-establishment, introduction of adaptation strategies and CHRMAP methodology to assess adaptation options**

Information posters and postcards, a Shire website article and social media (Facebook) were used to launch the project, project website and advertise the first set of workshops. Workshops were held in Guilderton on 31 July 2021 and in Lancelin on 1 August 2021.

On the project website at https://getinvolved.mysocialpinpoint.com.au/shire-of-gingin-coastal-planning, community members could read about the project, review erosion and inundation hazard mapping, read the Frequently Asked Questions (FAQs), undertake an interactive mapping exercise, answer a community values survey and register to attend the workshops and to be kept informed.

2. Risk Treatment: discuss re-established coastal values and technical findings, review criteria used to assess management options, and test findings

After technical work by the project team involving the assessment of erosion and inundation risks for Guilderton, a review of the impact of inundation assessments in the CIS on the erosion pathways developed in Cardno 2019, and the confirmation or update of adaptation strategies for the four towns, the second round of stakeholder engagement was commenced.

This involved targeted and deliberate engagement with affected landowners and the community about management options. Engagement comprised an updated website project page, direct meetings with affected landowners in the four towns, and a Community Panel process.



3. Draft CHRMAP: obtain feedback from the community and stakeholders on the draft CHRMAP

Once the Project Steering Committee (PSC) and the Shire Council endorse the draft CHRMAP for advertising, the CHRMAP advertising will be launched. Project communications will be developed including updated FAQs.

Two information sessions will be hosted in Lancelin and Guilderton.

TO BE UPDATED AFTER ADVERTISING

2.6.1 Engagement Objectives

The overall objective of the CHRMAP engagement process is to facilitate an understanding of coastal challenges, hazards and risks, what the appropriate adaptation pathways to respond to the risks are, and what the implications and trade-offs of these adaptation pathways look like and mean for the community.

Specific objectives of the community and stakeholder engagement process for Cardno 2019 were to:

- Inform the community about the extent of potential coastal hazards, adaptation strategies available to respond to those hazards and the need for flexibility in response to future environmental, social and economic changes
- Explain state and local governments' responsibilities and capacity to respond to potential coastal hazards
- Explain the benefits and challenges of each adaptation strategy, in terms of the meaning for residents and landowners, as well as the broader community
- Provide community members with multiple opportunities to provide input into proposed adaptation strategies, and to offer alternative strategies or to voice questions and concerns
- Receive and document feedback and concerns regarding each adaptation strategy from community members and affected residents and landowners
- Report on the feedback, including analysis that highlights the level of community understanding, the principal concerns and preferences concerning the proposed adaptation strategies and funding mechanisms, and preferred methods of continued community engagement.

The engagement undertaken for Cardno 2019 focused on capturing the coastal values of the community, informing the public about coastal hazards and the CHRMAP process, and gauging attitudes towards various adaptation options.

A comprehensive engagement strategy was established for this CHRMAP to re-engage the community on coastal challenges, hazards and risks, confirm and re-establish community values, present the updated adaptation pathways to respond to risks and what the implications and trade-offs of these pathways look like and mean for the community, and get community feedback on the pathways.

Additional engagement objectives for the 2023 CHRMAP were to:

- Invite the community to bring their local knowledge, expertise and lived experience to the process and give them adequate opportunity to contribute in a way that suited their needs and circumstances.
- Ensure that stakeholder advice and recommendations were incorporated into the decisions to the maximum extent possible.
- Undertake fair, equitable, transparent and honest engagement.
- Develop positive relationships between the Shire and the community.



2.6.2 Coastal Values

For Cardno 2019, the survey questions on coastal values showed strongest support for opportunities to use beaches for passive recreation, and ongoing provision of foreshore reserved for current and future generations. Opportunities for commercial enterprises and active recreations (i.e. boat ramps and jetties) received the least support.

The general sentiment of the community was summarised as follows:

- Strong disagreement that protection of private property should be prioritised over preservation of beaches,
- Strong support for relocation of assets and let nature take its course,
- Strong support for limiting intensity of development in hazard areas, and
- Strong support for informing landholders of hazard risk.

It should be noted that most survey respondents were landowners in the Shire, but a majority did not live in areas identified as being vulnerable to coastal erosion. Of the 80 respondents who provided their postcode, the majority (73%) were from either Lancelin, Guilderton or Gingin and the remaining 17% of respondents were from outside the Shire's local government area (Cardno 2019).

During engagement for the 2023 CHRMAP project, there was strong alignment from stakeholders on the following values:

- Beaches along the coastline for activities like walking, exercise, sunset watching, views, picnics, fishing, surfing, swimming and four-wheel driving
- Access to beaches and improvements to access at various beaches
- Coastal erosion is occurring and there is a need to protect the values and assets at these locations
- Protection of threatened ecological communities (TECs), seagrass and coastal vegetation generally
- Sand boarding at dunes
- Opposition to sand mining at Lancelin Sand Dunes due to the detrimental impact in has on the natural cycle that protects the coastlines and the gradually declining sand dunes.

It was recognised that activities such as four-wheel driving will need to be balanced with the need for protection of dunal ecosystems and vegetation on beaches along the coast, with many participants recognising the impacts of recreation activities on the fragile coastline.

A full breakdown of values are included in Appendix D.

2.6.3 Adaptation Options

During engagement for Cardno 2019, survey responses relating to adaptation options showed very strong support for retaining public access to beaches and foreshore reserves and preserving coastal dunes and vegetation for future generations. There was also strong support to not permit more intensive development (such as grouped dwellings where there is a single house) in hazard areas.

Respondents strongly agreed that private landowners should be informed about the risk of erosion when purchasing or developing in hazard areas.

There was a high level of disagreement for protecting private property from erosion, when this results in the loss of the public foreshore reserve and beach access. There was also strong disagreement for allowing the continuation of approved land uses in developed areas until erosion becomes intolerable, suggesting that a “do-nothing” approach is not acceptable.

For this CHRMAP, engagement involved workshops and surveys to test community values in June, July and August 2021. Following ongoing technical investigations, a second phase of engagement was proposed to enable combination of the CHRMAP development with the development of the Coastal Management Strategy.

A Community Panel (panel) was established, from a cross section of the community from Lancelin, Ledge Point, Seabird and Guilderton. The panel met for two days of workshops on 22 and 29 October 2022.

Outcomes included a general consensus / agreement with Cardno 2019 recommendations for Lancelin, Ledge Point and Seabird, and with the consultant team’s draft recommendations for both erosion and inundation for Guilderton and the inundation recommendations for Lancelin, Ledge Point and Seabird.

The complete engagement summaries for this CHRMAP are at Appendix D and Appendix E.



2.7 Existing Controls

2.7.1 Physical Controls

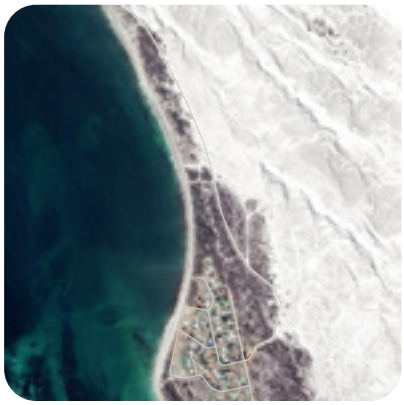
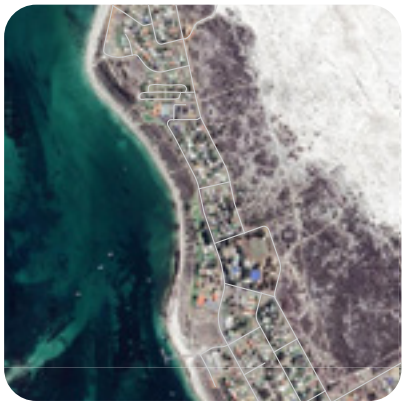
Existing physical controls are detailed in Table 1. Management unit controls and associated comments for Lancelin, Ledge Point and Seabird are taken from Cardno 2019.

In addition to the physical controls detailed in Table 1, the Shire also undertakes various monitoring and management practices along the coast including:

- Visual monitoring after storm events and the collection of field photographs
- Collaboration with DoT for collection of bathymetric and beach survey data for specific projects. DoT also collects aerial photographs to monitor changes to vegetation line position
- Beach access way maintenance including removing sand and rubbish, pruning vegetation, weed control, and reporting any damage to paths and fencing
- Inspection of beach foreshores to monitor vegetation, general beach condition (erosion etc.), sandbar and river mouth
- Grant funding applications
- Beach signage inspections and maintenance.



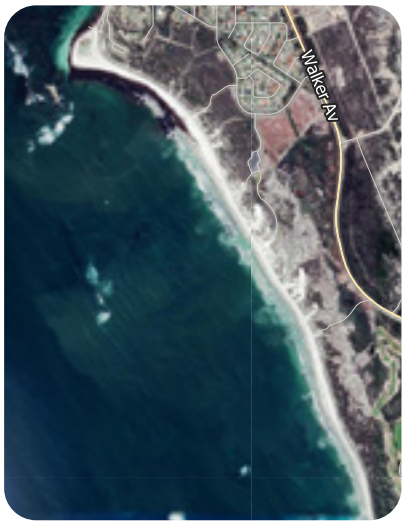
TABLE 1: EXISTING PHYSICAL CONTROLS

MANAGEMENT UNIT	CONTROL	COMMENT
LANCELIN		
LA4: Lancelin Township North of Lancelin Point		
	Lancelin Island and surrounding reefs	
LA3: Lancelin Township Jetty of Lancelin Point		
	Lancelin Island and surrounding reefs	
LA2: Lancelin Township South of Jetty		
	Edward Island and surrounding reefs to the south Lancelin Island to the north Offshore reef	



MANAGEMENT UNIT	CONTROL	COMMENT
LANCELIN		

LA1: Lancelin Township South of Town

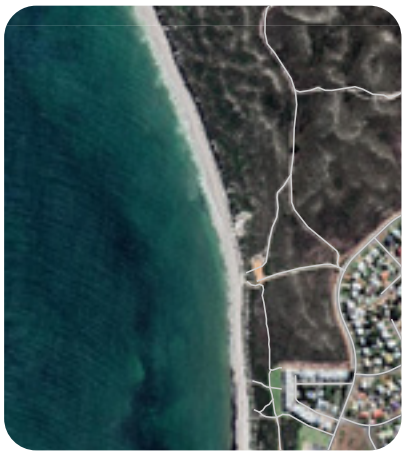


Edward Island and surrounding reefs

Opportunistic beach renourishment during dredging

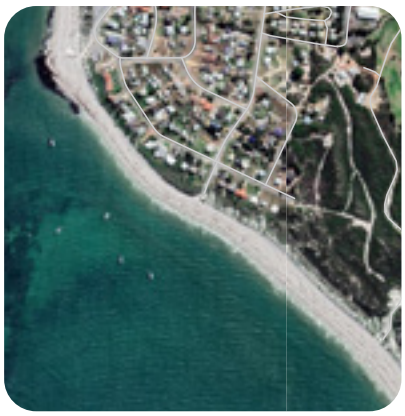
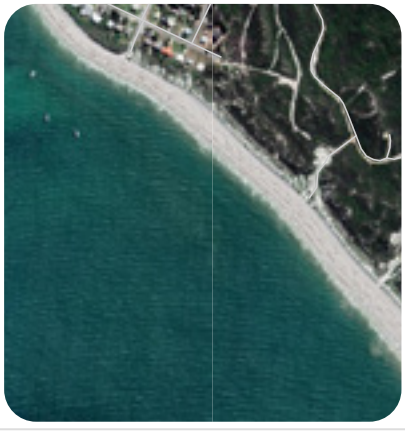
MANAGEMENT UNIT	CONTROL	COMMENT
LEDGE POINT		

LP4: Ledge Point North of Township



Offshore reefs



MANAGEMENT UNIT	CONTROL	COMMENT
LEDGE POINT		
LP3: Ledge Point Township North		
	Offshore reefs 2 groynes	
LP2: Ledge Point Township South		
	NA	
LP1: Ledge Point South of Township		
	Offshore reefs	



MANAGEMENT UNIT	CONTROL	COMMENT
SEABIRD		
SE2: Seabird Township North		
	Small offshore reefs Seawall to the south (SE2) on rock platform, with matting placed over the top	Beach along seawall in SE2 has eroded completely since December 2016 impacting this Management Unit
SE1: Seabird Township South		
	Small offshore reefs Seawall sitting on rock platform, with matting placed over the top	Beach along seawall has eroded completely since December 2016

MANAGEMENT UNIT	CONTROL	COMMENT
GUILDERTON		
G-F: Guilderton Foreshore		
	Guilderton North Groyne	Low crest groyne with random positioning of rocks. In poor condition, with lack of maintenance. Some sand/seagrass accumulation on southern side
G-MR: Moore River		
	Guilderton Holiday Park seawall	Runs approximately 200m along the northern side of the river estuary

2.7.2 Planning Controls

Planning in Western Australia is guided by the State Planning Framework, that outlines the relationships and hierarchy of responsibilities of different levels of government and planning instruments. Strategic planning at State, regional and local levels inform the development of statutory controls. Refers Figure 11.

The 2023 CHRMAP has regard for and is aligned with the following statutory and strategic planning frameworks including:

- State Planning Strategy 2050
- Planning and Development Act 2005
- Planning and Development (Local Planning Schemes) Regulations 2015
- WA Coastal Zone Strategy
- State Planning Policy 2.6 – Coastal Planning
- Coastal Hazard Risk Management and Adaptation Planning Guidelines 2019
- Wheatbelt Regional Planning and Infrastructure Framework 2015
- Shire of Gingin Local Planning Strategy
- Shire of Gingin Local Planning Scheme No. 9
- Local Planning Policy 1.2 Foreshore Protection Areas

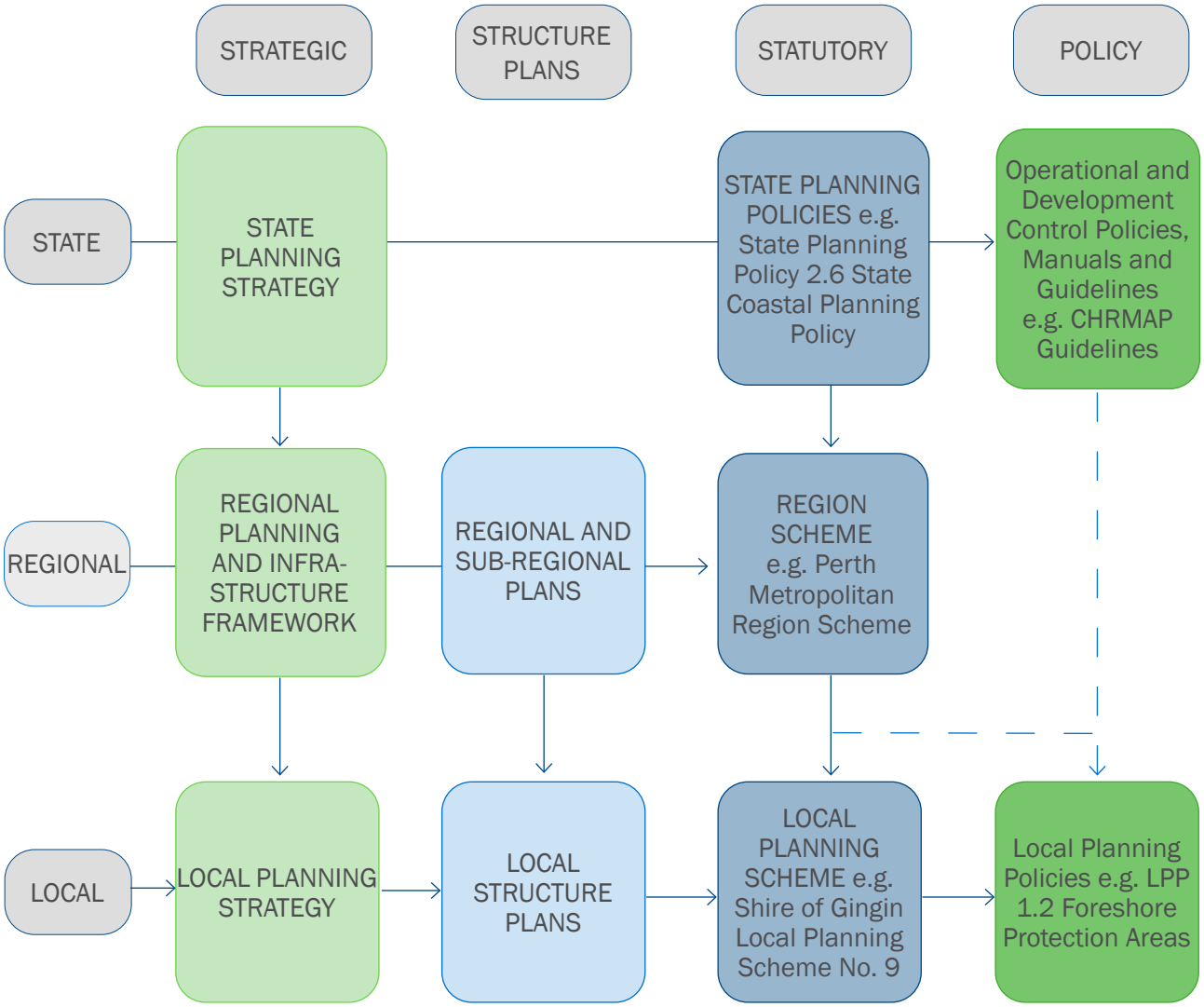


FIGURE 11: PLANNING CONTROL OVERVIEW (ADAPTED FROM CARDNO 2019)

2.7.2.1 Statutory Plans

State Planning Policies (SPPs) provide the highest level of planning policy control and guidance in Western Australia and are prepared under Part 3 of the Planning and Development Act 2005 (the P&D Act). SPP 2.6 is state coastal policy, consistent with the higher order SPP 2 Environmental and Natural Resources Policy.

The key statutory planning document for the Shire of Gingin is Local Planning Scheme No. 9 (LPS 9), gazetted on 27 September 2012 and amended several times since. LPS 9 applies zones and reserves to land within the Shire and outlines permissibility of land uses, requirements for development and processes for seeking proposed development approval.

Relevant amendments to LPS 9, regarding coastal development, planning and hazards, require compliance with the provisions of SPP 2.6, in accordance with the Planning and Development Act 2005. This gives statutory effect to the SPP 2.6 under LPS 9.

Local Structure Plans and Local Development Plans (LSPs and LDPs) can be made under LPS 9 via the mechanisms provided in Part 4 of the Deemed Provisions set out in the Planning and Development (Local Planning Scheme) Regulations 2015. LSPs and LDPs provides guidance for the future subdivision and development of land. The Shire has one LDP relating to coastal land, the Outline Development Plan for Moore River South, which was adopted in August 2014.

This LDP considers the same coastal hazard mapping used for Cardno 2019 and the 2023 CHRMAP, and provides for coastal foreshore reserves and public open space.

2.7.2.2 Strategic Plans

State Planning Strategy 2050

Cardno 2019 describes the State Planning Strategy 2050 as providing a strategic framework, principles, strategic goals and strategic directions for planning and development in Western Australia. In relation to climate change, this strategy identifies the Shire of Gingin coast as being at risk of coastal landform change. It makes the following key statements that are fundamental to the approach taken to coastal hazard risk assessment and adaptation planning, including:

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

Planning and Development Act 2005

The Planning and Development Act 2005 (P&D Act) provides the overarching state planning framework for guiding planning and development within Western Australia. The P&D Act provides the power for creating subsidiary state and local planning frameworks including state planning policies, regional and local planning schemes.

Planning and Development (Local Planning Schemes) Regulations 2015

The Planning and Development (Local Planning Schemes) Regulations 2015 (the P&D Regulations) provides the framework and standard provisions for all local planning schemes in Western Australia.

WA Coastal Strategy

The WA Coastal Strategy provides a whole-of-government integrated framework for collective action to manage and adapt to threats and pressures along the coast, complimenting existing State legislation, strategies and policies, including SPP 2.6. The document identifies all relevant legislation and policies related to coastal management and defines stakeholder roles and responsibilities for coastal stewardship. It provides that all levels of government, as well as individuals, businesses, and the community, each have important and complementary roles in adapting to coastal hazards.

In particular, it outlines the following principles which have relevance to this CHRMAP:

- Private parties are responsible for managing risks to their private assets; and
- Governments (i.e.: the Shire), on behalf of the community, are primarily responsible for managing risks and impacts to public goods and public assets which they own and manage; they should also seek to:

1. Develop local policies and regulations consistent with state adaptation approaches.
2. Facilitate building resilience and adaptive capacity within the local community.
3. Work in partnership with community to identify and manage risks/impacts.

State Planning Policy 2.6 – Coastal Planning

SPP 2.6 provides detailed information to evaluate the risk of coastal inundation and erosion and specifies the storm events to be considered for these analyses. SPP 2.6 is supported by the CHRMAP Guidelines.

The SPP aims to avoid future development within areas identified to be at risk within the planning timeframe, generally 100-years. For areas at risk, all potential adaptation options need to be identified under the risk management categories. The State's coastal planning policy adaptation preferences in order of priority, as outlined in SPP 2.6, are:

Avoid > Planned or Managed Retreat > Accommodate > Protect

The State has a strong preference towards adaptation options that minimise coastal process interference and away from those that may leave legacy issues. Management strategies that preserve the natural coastline and move development away from the active coastal zone are considered ideal.

The hierarchy steers planners away from protection options and provides strict rules for the consideration of protection works. Of particular relevance to the CHRMAP process is the user pays principle, whereby those who benefit most from protection must provide the greatest financial contribution. This arrangement applies to any area of the coast and can include incidences where the coastal foreshore reserve is being protected as a buffer to private assets.

Coastal Hazard Risk Management and Adaptation Planning Guidelines 2019

The CHRMAP guidelines provide a comprehensive CHRMAP process be undertaken to inform and enable the adoption of a planned or managed retreat policy to guide implementation.

The coastal suite of documents (WA Coastal Strategy, SPP 2.6, CHRMAP Guidelines and associated appendices) outline the following planning mechanisms relevant to this CHRMAP to enact planned or managed retreat:

- Local structure planning (SP) – where comprehensive redevelopment of land remains an option
- Local planning scheme (LPS) amendment – to inform the classification of vulnerable areas as Special Control Areas (SCAs) as applicable.
- SCA – establishing an SCA enables land use and development at risk to be identified in the SPP 2.6 100-year planning timeframe, establish intention to retreat from the area and provide the special planning instrument required to implement the approach. Part 5, Schedule 1 of the P&D Regulations provides the template for local governments to follow when amending their LPSs to include an SCA.
- Taking of land – triggers for initiating a taking of land process should be included in any policy arising from the CHRMAP process to support implementation of the planned or managed retreat. The taking of land needs to be in agreement with the requirements under section 168 of the Land Administration Act 1997.
- Special circumstances for state government control – this would be enacted through mechanisms set out in the P&D Act and the relevant Region Scheme and would include a Planning Control Area (PCA) declaration and/or an Improvement Plan and Scheme over/for the relevant area.
- PCA – the Western Australian Planning Commission (WAPC) can declare the requirement for a PCA under Section 112 of the P&D Act to ensure that no development occurs on this land which might prejudice its purpose. The WAPC would take over control of applications within PCA land.

Improvement plans are strategic instruments used to facilitate the development of land in areas identified by the WAPC as requiring special planning. The WAPC can recommend to the Minister for Planning that an improvement plan is made "for the purpose of advancing the planning, development and use" of land. An improvement plan can authorise the making of an improvement scheme.

Wheatbelt Planning and Infrastructure Framework 2015

The Wheatbelt Planning and Infrastructure Framework 2015 (Wheatbelt PIF) identifies the following key regional strategic planning initiatives:

- Identification required planning responses following completion of the Coastal Hazard Risk Management and Adaptation Planning Study being carried out by the shires of Dandaragan and Gingin, and
- Facilitation of long-term strategic planning for the lower Gingin – Indian Ocean Drive corridor, focussing on possible economic and employment opportunities, service provision and the preservation of environmental assets (the latter including coastal assets).

Shire of Gingin Local Planning Strategy 2012

The Cardno 2019 summarises the Shire's Local Planning Strategy as generally alignin g with the Wheatbelt PIF strategy direction, placing importance on both planning for long-term predicted shoreline movement and other impacts of climate variability, such as storm surge.

The Local Planning Strategy identifies coastal erosion and management of coastal dunes as key issues for the Shire, acknowledging that the vulnerability is predicted to worsen as sea level rises in response to climate change. It recognises that a strategic approach is needed in managing coastal land use, future development and the impacts of coastal processes, including dune movement, blow outs and erosion.



2.8 Success Criteria

Cardno 2019 does not explicitly detail success criteria, however references these through the report.

The established success criteria for the CHRMAP are:

1. **The outcomes of the CHRMAP are understood and supported by key stakeholders and decision makers.**

   Measurement: CHRMAP agreed by Project Steering Committee.

2. **The outcomes of the CHRMAP are understood and supported by the community.**

   Measurement: Satisfactory feedback survey outcomes as part of the workshops and information sessions in the engagement program.

3. **The outcomes of the CHRMAP are supported by the Shire Council.**

   Measurement: CHRMAP recommendations were endorsed by Council, with support for relevant recommendations to be incorporated into the Shire's Local Planning Strategy, Local Planning Scheme, structure plans, local planning policies, operational plans and budget.

4. **The lifestyle enjoyed by the people is protected.**

   Measurement: CHRMAP considers priority community values and makes recommendations that enable their protection.

5. **The CHRMAP details roles and responsibilities for proposed coastal risk management measures, to maintain ongoing capability of the Shire as land managers.**

   Measurement: CHRMAP details roles and responsibilities for management actions, endorsed by the Department of Planning, Lands and Heritage and the Shire Council.





3. RISK IDENTIFICATION

The Shire's coast is characterised by variable mixed sandy and rocky offshore bathymetry and sand dunes approximately parallel to the coast. Offshore reefs rise to between 10-5m depth several kilometres offshore with intervening sandy depressions. Dunes reach heights of approximately 40 metres but are more commonly 10-20 metres high and are often present as naturally unvegetated dune "blowouts" migrating landwards, which demonstrates the important wind-driven processes in the area.

A feature of the region is the interruption of sandy beaches by occasional rock outcrops and fringing reef platforms, and the presence of several nearshore islands, often associated with accretionary cusps onshore (Searle and Semenuik, 1985).

The evolution of the coast, including the location of beach waterlines and vegetation lines, occurs over a range of time scales including:

- At the geological scale (10-100,000+years), coastal change is dominated by sea level movements and large-scale geological processes primarily dealing with the location and movement of rock.
- At geomorphic scales (100-10,000years), coastal evolution is determined by the sediment transport driven by regional and local metocean climate and sediment provenance and availability.
- Over planning scales (10-100years), sediment sources and sinks and pathways due to local landform changes and metocean climate and weather events.
- Over coastal management scales (days to 10years), significant changes occur due to storms – generally cross-shore erosion.

Sand dune evolution is continuing at present as sediment is moved along and across the shore which contributes to development of the sand dunes and blowouts. The formation of dunes and their migration currently utilises sediment supply from offshore and along the shore from the south.

Variations in beach erosion, foredune formation and dune development occur because of the complex processes resulting from modern oceanic wind, wave and climate conditions which are reworking the landforms (reefs, islands, rock outcrops).

There are three known erosion hotspots of state significance along the Shire's coastline (DoT, July 2019). These are the Seabird foreshore, Ledge Point township and Grace Darling Park in Lancelin.





3.1 Existing Environment

3.1.1 Climate

The Gingin Shire coast experiences a Mediterranean climate with mild wet winters and hot, dry summers. Mean daily maximum temperatures vary from 33OC in summer and 18OC in winter. Summer is usually very calm and occasionally interrupted by low-pressure ex-tropical cyclones from the north. Winter climate is characterised by mild weather and winds interspersed by winter storms.

Although uncommon, the Shire coast may occasionally experience tropical cyclones (e.g., Mangga, Alby) from the Indian Ocean. These strong storm events are typically stronger than winter storms and bring strong wind gusts and heavy rainfalls along the track of the cyclone and often result in flooding from rainfall, coastal inundation, and major erosion hazards.

3.1.2 Geology and Landform

The Shire's coast is situated on the Swan Coastal Plain bioregion, which is a long coastal strip that extends from Gingin in the north to Dunsburough in the south. The area is dominated by the Quindalup dune system, which is characterised by a series of low sand dunes made of marine sands and Aeolian (windblown) soils. The Quindalup dunes are underlain by Safety Bay Sands which comprises calcareous soils derived from Tamala limestone (Semeniuk 1989).

The area is characterised by mixed sandy and rocky offshore ocean depths and sand dunes that are approximately parallel to the coast. Dunes reach heights of ~40m but are more commonly 10-20m high and are often present as naturally unvegetated dune "blowouts" migrating landwards, which demonstrates the important of wind-driven processes in the area (Searle and Semenuik, 1985).

A feature of the region is the interruption of sandy beaches by occasional rock outcrops and fringing reef platforms, and the presence of several nearshore islands. Offshore reefs rise to between 10-5m depth several kilometres offshore with intervening sandy depressions (Searle and Semenuik, 1985).

3.1.3 Hydrology

The proclaimed Gingin groundwater area covers about 6000 km^2 of the Northern Perth Basin and extends from north of Two Rocks and Muchea in the south to Grey and Moora in the north. Groundwater is sourced from nine aquifers, with most licensees abstracting water from the shallow Superficial aquifer, or the deeper Leederville, Yarragadee and Leederville-Parmelia aquifers.

Groundwater use in the Gingin area is continuing to grow, especially for irrigated agriculture and horticulture. A critical factor influencing water availability in the Gingin groundwater area is climate change. Marked declines in rainfall and groundwater recharge have contributed to declines in groundwater levels in many aquifers and reduced flow in Gingin Brook and the Moore River.



3.1.4 Coastal processes

The geomorphological complexity of the Gingin coastline supports biological diversity and a range of recreational opportunities, encompassing stretches of coastline within the Lancelin, Ledge Point, Seabird and Guilderton townsites. The low lying, sandy coastline comprising coastal dunes, nearshore reefs and islands, seagrass meadows, fishing stocks and rare vegetation communities is at risk to the impacts of coastal processes. As a result, the coastal townsites on these landforms are vulnerable to changing coastal processes as sea level rises (Cardno, 2019).

The Gingin coast can be classified as a Sandy Coast in accordance with SPP 2.6. Although some limestone rock is present in the area it is not dominant. Offshore reefs and islands protect the northern beaches of Lancelin and Ledge Point from wave energy, however there are complex coastal processes around these townsites and the reefs, and a general south to north movement of sand between the sediment cells.

The Seabird townsite is in a localised area of greater vulnerability relative to the general coastline within its coastal cell (Eliot et al, 2012). There is some beach rock (Tamala Limestone) visible along the coast in front of the township and scattered offshore reefs which provide some protection from incoming wave energy. Seabird, however, lacks the significant reefs or offshore islands which are present off the townships further to the north.

The coast at Guilderton alternates between sections of intertidal rocky reef and sandy beaches free of rock. The most significant coastal feature is the Moore River mouth and the sandbar that crosses it. Two lines of offshore reefs shelter the local beach to incoming waves. The low waves produce a steep beach, with a narrow continuous bar, which is cut by rips during periods of larger waves (Beachsafe, 2020).

3.1.4.1 Sediment Cells

A hierarchy of sediment cells is used to assist coastal planning, management, engineering, science, and governance along the coast. Sediment cells are spatially discrete areas of the coast within which marine and terrestrial landforms are likely to be connected through processes of sediment exchange, often described using sediment budgets. They include areas of sediment supply (sources), sediment loss (sinks), and the sediment transport processes linking them (pathways).

Sediment transport pathways include both alongshore and cross-shore processes, and therefore cells are best represented in two-dimensions. They are natural management units with a physical basis and commonly cross jurisdictional boundaries (Stul et al., 2014 & 2015). Figure 12 (Fig 2.3 in Cardno 2019) depicts the primary and tertiary sediment cells for the Shire coast.

A detailed understanding of coastal processes which effectively considers past, present and predicted future shoreline change is critical to effective coastal planning and management. At varying intensities and magnitudes, the interaction of the following key coastal processes impact on coastal landforms and shoreline movement.

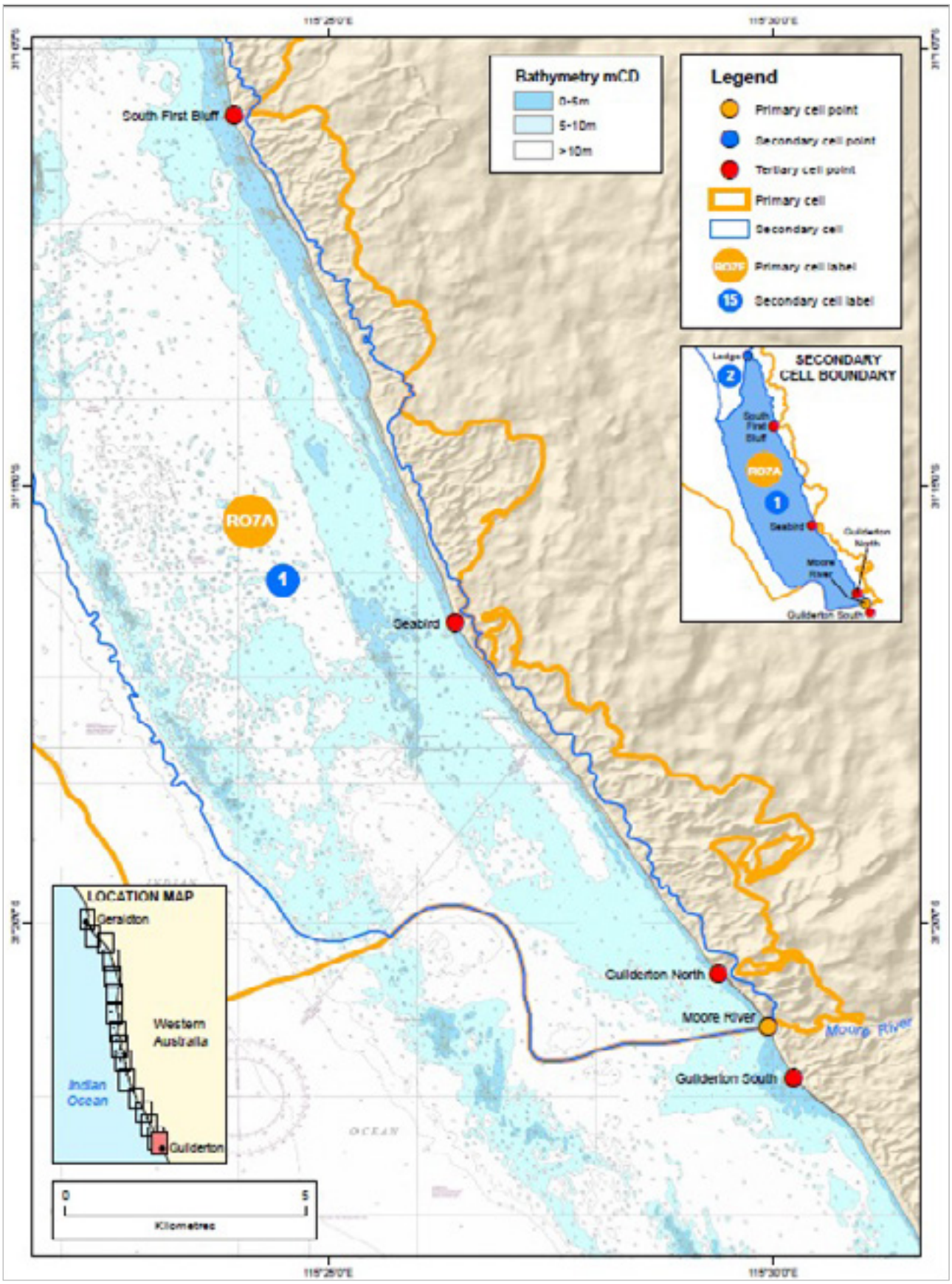


FIGURE 12: SEDIMENT CELLS OF THE SHIRE OF GINGIN COAST (STUL ET AL, 2014)



3.1.4.2 Tides

Tides are caused by the gravitational pull of the sun and moon on the earth. When the sun and moon are aligned, the tidal bulge is large and this is known as a spring tide. When the sun and moon are perpendicular, the tidal bulge is small and this is known as a neap tide.

Water levels along the Shire coast are dominated by the astronomical tide and are diurnal – meaning that the region experiences one high tide and one low tide per day. The region is characterised by a micro-tidal climate, with a range of ~1 m between high and low tides.

3.1.4.3 Storm surge

Variations in water level are caused not only by the astronomical tides, but also by phenomena such as wind setup, wave setup, atmospheric pressure, and oceanographic variations. Wind blowing over the surface of the water causes water to “pile up” against the coast towards which the wind is blowing (wind setup). Wave dissipation and breaking also causes water to “pile up” against the coast (wave setup). Atmospheric pressure leads to local changes in sea level, with high pressure lowering the sea level and low pressure increasing the sea level, a process referred to as the inverse barometric effect.

Along the Western Australian coastline, it has long been recognised that ocean climate variability can have a substantial influence on seasonal and inter-annual variability in coastal sea levels.

There are numerous other oceanic processes that can cause local variations in sea level at the coast. All these mechanisms combine, resulting in observed water level deviations from astronomical tides. They are often grouped under the term “storm surge” since their combined effects are greatest during a storm event.

3.1.4.4 Waves

The wave climate along the Shire coast is dominated by deep-water waves generated by large-scale weather systems over the Indian Ocean. Seasonal variability in the wave climate is driven by the following mechanisms:

- Continuous west to southwest offshore swells from the southern Indian Ocean.
- Seas generated by the local sea breeze pattern with short periods (e.g., <8 seconds (s)) from the west to southwest predominantly from October to April.
- Seas generated by winter storms from various directions.
- Infrequent tropical/extratropical cyclones (e.g., Alby in 1978 and Bianca in 2011).

Reef ridges play a key role to diffuse the wave energy approaching the shoreline. This has notable effects on the nearshore wave climate, alongshore variation of waves and coastal processes.



3.1.4.5 Wind

The Shire coast climate is mainly influenced by typical summer anticyclonic high-pressure systems which are associated with daily sea breezes – easterly winds in the morning and westerly winds in the afternoon.

Summer is usually very calm while occasionally interrupted by periodic low-pressure ex-tropical cyclones from the north. Typical summer wind comprises of a moderate to afternoon sea breeze with wind blowing from the south-south-west. Wind generated by dissipating tropical cyclones in summer can have extremely dramatic but noticeably short term affects.

Winter climate is characterised by mild weather and winds interspersed by winter storms. Winter wind is variable due to the presence of winter storms from various directions. Strong winds are predominantly from the west/north.

Although uncommon, the Shire coast may occasionally experience tropical cyclones (e.g., Mangga, Alby) from the Indian Ocean. These strong storm events are typically stronger than winter storms and bring strong wind gusts and heavy rainfalls along the track of the cyclone and often result in flooding from rainfall, coastal inundation, and major erosion hazards.

3.1.4.6 Sea Level

While tides cause small, predictable changes in sea level, storm surge can also result in short-term sea level rises (SLR) associated with strong winds and barometric pressure changes. In particular, strong winds generate high steep waves which erode higher sections of beach which are not typically vulnerable. The level of beach impact can be substantial, particularly if storm events occur during high tide. Overall, the impact on beach profile is dependent on the magnitude, intensity and duration of the associated storm system.

It is internationally recognised that increasing sea levels and storm intensities due to climate change will intensify coastal hazards such as coastal inundation (temporary coastal flooding), storm erosion, and long-term shoreline recession (IPCC, 2014). The combined impact of climate change will vary around the Western Australian coast and require consideration on a local scale. Consequently, state governments across Australia have introduced obligations that require local governments to consider and plan for the effects of these hazards over various planning timeframes.



SLR is the climate change impact considered in SPP 2.6. The Department of Transport recommends that a vertical SLR of 0.9m be adopted when considering the impact of coastal processes over a 100-year planning timeframe (2010 to 2110). It is recommended for planning timeframes beyond 100 years that a vertical SLR of 0.01m per year be added for every year beyond 2110. Given the slower rate of change between 2010 and 2020, a reasonable adjustment to the total SLR between 2020 and 2120 is 0.98m.

For this CHRMAP, the 0.9m value is extrapolated to a value of 0.98m in 2120 (see Figure 13 & Figure 14).

The primary projected impacts of SLR are its contribution to increased shoreline erosion and inundation. Natural coastlines composed primarily of loose sediment respond to changes in the long-term mean sea level (MSL) by eroding inland until a new equilibrium shoreline is found. SPP 2.6 recommends that for every 0.01m increase in MSL (i.e., 100 times the SLR), a risk zone of 1.0m landward of the existing shoreline location apply.

Planning Time Frame (yrs.)	2010	2020	2030	2050	2070	2070	2120
Sea Level Rise (m)	0	0.04	0.08	0.22	0.42	0.64	0.98

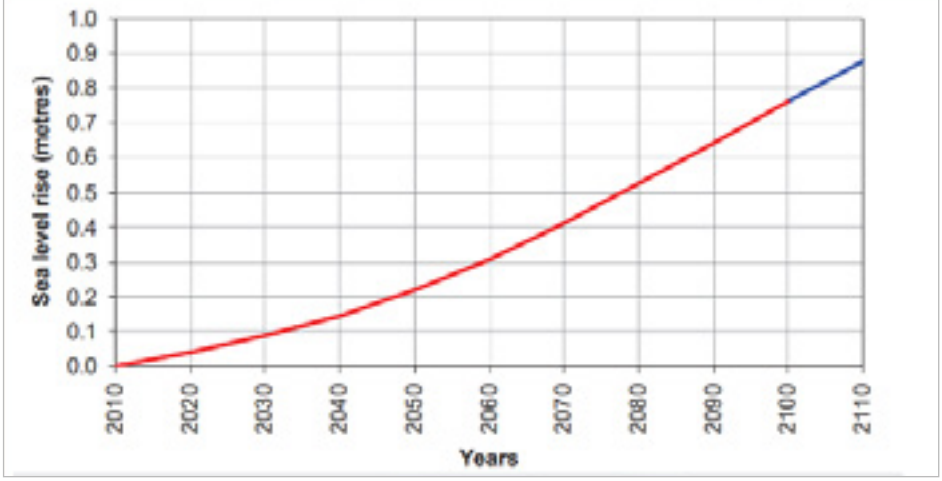


FIGURE 13: SEA LEVEL RISE

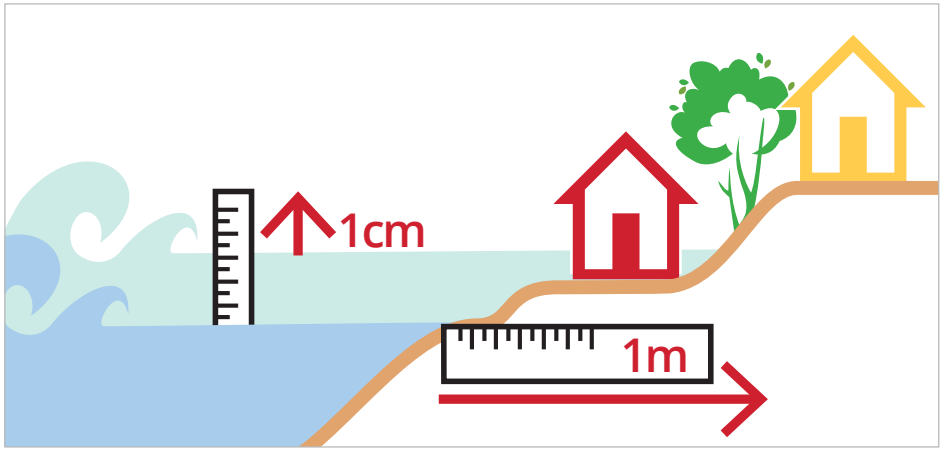


FIGURE 14: REPRESENTATION OF HORIZONTAL EROSION ALLOWANCE FROM PROJECTED VERTICAL SEA LEVEL RISE – A FACTOR OF 100 (ADAPTED FROM COASTADAPT, 2017)

3.2 Coastal Hazards

3.2.1 Risk Assessment Framework

To provide a transparent and logical basis for determining adaptation planning priorities, risk assessments were undertaken based on the Australian Standard guideline Climate change adaptation for settlements and infrastructure – A risk based approach (AS5334-2013), and the CHRMAP guidelines (WAPC, 2019). As illustrated in Figure 15, risk was assessed in relation to likelihood, consequence and adaptive capacity.

Likelihood was assigned using the results of the hazard assessments (MRA, 2016a and 2016b, Shape Urban 2023a) 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 asset's, or group of assets', overall vulnerability to climate change (as defined previously in Section 3.1.4).

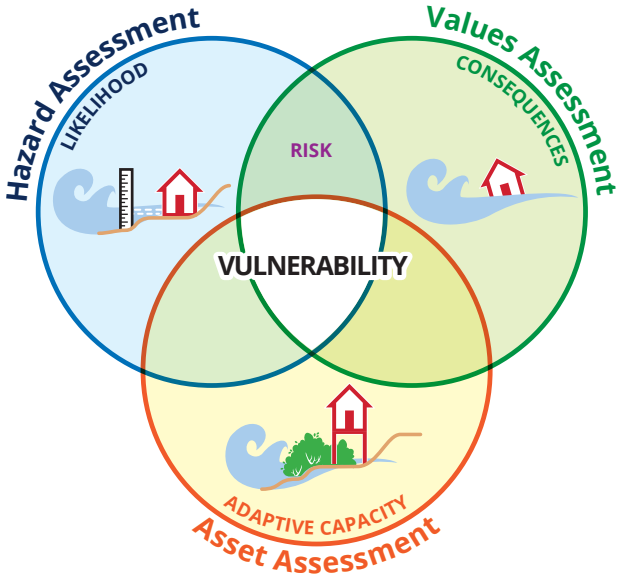


FIGURE 15: VULNERABILITY ASSESSMENT, ADAPTED FROM CHRMAP GUIDELINES (WAPC, 2019)

3.2.2 Coastal Hazard Modelling

Erosion - When sediment is transported away by waves, winds and currents, reducing the size (width) of a coastal foreshore reserve and/or the distance to an asset on the adjoining land.

Coastal erosion is modelled as per the parameters outlined in SPP 2.6, which stipulates allowances for storm events (S1), historic shoreline movements (S2) and future sea level rise (S3). Hazards were assessed relative to projected sea level rise for the planning timeframes of current day (2016 for Cardno 2019 and 2021 for the CHRMAP update), 2030, 2070 and 2110.

The overall hazard extent associated with these processes is calculated by the sum of the above allowances, plus an additional allowance for uncertainty. SPP 2.6 provides for a 0.2m per year allowance for uncertainty for a sandy coast. The values are measured from the Horizontal Shoreline Datum (HSD) which is the active limit of present storm activity.

S1 is based on ocean forces and coastal processes that have a one per cent or 1 in 100 probability of being equalled or exceeded in any given year over the 100-year planning time frame.

Inundation – The flooding of a portion of previously dry land with ocean water. It may be a temporary occurrence during a storm event or high tide, or permanent for example due to sea level rise.

SPP 2.6 requires coastal inundation hazards to be modelled with an allowance for the current risk of storm surge inundation (S4). The storm event for storm surge inundation is based on ocean forces and coastal processes that have at least a 0.2 per cent or one in 500 probability of being equalled or exceeded in any given year plus the predicted extent of sea level rise over the planning time frame (a 500-year ARI water level). for each of the planning timeframes.

The Baird 2020 assessment involved the estimation of coastal inundation water levels based on a combination of estimated ARI water levels from tide gauge measurements, an estimate of wave setup along the Shire's coastline and an allowance for predicted sea level rise over the 100-year planning timeframe.

In addition to the SPP 2.6 allowances, State Planning Policy 2.9 – Water Resources (SPP 2.9) (WAPC, 2006) has been used to assess the erosion allowance along the riverbank of Moore River. SPP 2.9 suggests a 'foreshore reserve width' of 30m for waterways and a 'development setback' of 50 m for estuaries. The 30m allowance has been considered for the riverbank along Moore River for the 100-year planning period as the river mouth is mostly closed (not an estuary).

Groundwater Levels

It is generally accepted that sea level rise will cause groundwater levels adjacent to the coast to also increase. This can have a number of impacts including:

- Seawater intrusion (migration inland of the freshwater/saline water interface);
- Increased salinity in groundwater dependent ecosystems;
- Impacts on drainage infrastructure; and
- Contamination of production bores.

The Shire has an anecdotal observation of high groundwater levels in Lancelin. This has not been studied or documented, and is required. One of the adaptation pathway recommendations is for this groundwater study to be undertaken to confirm how high groundwater levels, particularly in Lancelin, impact coastal hazards.

3.2.3 Coastal Erosion Allowances

3.2.3.1 Lancelin, Ledge Point, Seabird

A summary of Cardno 2019's hazard assessment assumptions and calculated erosion allowances (storm events (S1), historic shoreline movements (S2) and future sea level rise (S3)) are presented in Table 2 (adapted from Table 2-3 of Cardno 2019) for the Lancelin, Ledge Point and Seabird management units.

Erosion allowances and horizontal shoreline datum (HSD) were taken directly from the relevant coastal hazard report:

- Seabird (MRA, 2016a)
- Ledge Point, Lancelin (and Cervantes) (MRA, 2016b).

TABLE 2: CARDNO 2019 HAZARD ASSESSMENT ASSUMPTIONS AND CALCULATED EROSION ALLOWANCES (ADAPTED FROM TABLE 2-3 OF CARDNO 2019

MANAGEMENT UNIT	HSD (M AHD)	S1 EROSION ALLOWANCE (M)	S2 EROSION ALLOWANCE (M)	TOTAL EROSION ALLOWANCE (M)			
				2016 (Present Day)	2030	2070	2110
Lancelin*							
LA4	+1.4	30	0.2 - 2.3	30	43 - 75	93 - 131	161 - 202
LA3	+1.4	11 - 30	0 - 2.3	11 - 30	18 - 75	50 - 131	101 - 202
LA2	+1.4	11 - 14	0 - 3.3†	11 - 14	18 - 74	50 - 126	101 - 197
LA1	+1.4	14 - 22	0.3 - 3.3	14 - 22	37 - 82	89 - 134	160 - 205
Ledge Point‡							
LP4	+1.6	24	0	24	34	74	133
LP3	+1.6	12 - 24	0	12 - 24	22 - 34	62 - 74	121 - 133
LP2	+1.6	12 - 19	0	12 - 19	22 - 2929	62 - 69	121 - 128
LP1	+1.6	19	0	19	29	69	128
Seabird§							
SE2	+1.8	33	0.35 - 0.5	33	49 - 52	105 - 114	181 - 196
SE1	+2.0	15 - 21	0.4 - 1.2¶	15 - 21	15 - 46	16 - 50	21 - 55

* Values for Lancelin are taken from MRA (2016b)
† All but the southern boundary of this management area has an S2 erosion allowance of 0 m/year
‡ Values for Ledge Point are taken from MRA (2016b)
§ Values for Seabird are taken from MRA (2016a)
¶ The application of the S2 erosion allowance in this area is complicated by the presence of rock. Refer to MRA (2016a) for details.

3.2.3.2 Guilderton

The Technical Report at Appendix C undertakes a coastal hazard assessment of the Guilderton foreshore and Moore River management units. The two management units were broken down into six shoreline segments where:

- GT1, GT2, GT3 and GT4 are classified as sandy coast.
- GT5 is classified as shoreline under physical controls e.g., seawall, boating facilities. All physical controls at the foreshore of Holiday Park are in good condition showing no imminent risk of erosion.
- GT6 is classified as inland riverbank where SPP 2.9 should be applied for assessment of erosion risk.

The shoreline segments are depicted in Figure 16.

Total erosion allowance is calculated as follows:

- GT1 - GT 5, total erosion allowance is calculated as S1+S2+S3+Allowance for Uncertainty (represented as AU in Table 3-3 below) as per SPP 2.6. For areas classified as physical controls, no allowance is considered.
- for GT6 (or riverbank), a 30m total allowance has been considered to account for uncertainty of riverbank movement in a 100-year planning period, as per SPP 2.9.

The total erosion allowance is summarised in Table 3.



FIGURE 16: GUILDERTON SHORELINE SEGMENTS CLASSIFICATION, BEACH PROFILES

TABLE 3: TOTAL EROSION ALLOWANCE GUILDERTON (M)

ZONE	PRESENT		2030					2050					2070					2090					2120				
	S1	TOTAL (T)	S1	S2	S3	AU	T	S1	S2	S3	AU	T	S1	S2	S3	AU	T	S1	S2	S3	AU	T	S1	S2	S3	AU	T
GT1	6	**6**	15	0	8	2	**25**	18	0	22	6	**46**	23	0	42	10	**75**	26	0	64	14	**104**	30	0	98	20	**148**
GT2	10	**10**	22	0	8	2	**32**	26	0	22	6	**54**	31	0	42	10	**83**	35	0	64	14	**113**	40	0	98	20	**158**
GT3	3	**3**	3	3	8	2	**16**	6	9	22	6	**42**	10	14	42	10	**76**	13	20	64	14	**111**	17	29	98	20	**164**
GT4	0	**0**	0	0	1	2	**3**	0	0	3	6	**9**	0	0	5	10	**15**	0	0	8	14	**22**	0	0	12	20	**32**
GT5		**0**					**0**				6	**0**					**0**					**0**					**0**
GT6		**0**				3	**3**				9	**9**				15	**15**				21	**21**				30	**30**

3.2.4 Inundation Hazard Assessment

The coastal inundation hazard assessment was completed by Baird in Baird 2020. Extreme water levels are replicated in Table 4 below, including projections of sea level rise.

TABLE 4: INUNDATION LEVELS WITH SEA LEVEL RISE, BAIRD 2020

ARI YEARS	2010	2020	2030	2050	2070	2090	2120
1	0.7	0.8	0.8	0.9	1.1	1.4	1.7
10	0.9	0.9	1.0	1.1	1.3	1.5	1.9
100	1.4	1.4	1.5	1.6	1.8	2.0	2.4
500	1.8	1.8	1.9	2.0	2.2	2.4	2.8

3.2.5 Asset and Values Identification

As introduced in Section 2.5, assets include natural features, buildings and other structures, servicing infrastructure, roads, paths and walkways, recreational structures and coastal structures.

Assets at risk of coastal erosion in the four towns were identified by overlaying the hazard lines on aerial photomaps of each township. Residential property boundaries were drawn from the Shire's GIS cadastral layers, while all other assets were based on interpretation of aerial images with site visits to confirm asset classifications. These were supplemented by the values from local communities and stakeholders.

Assets at risk are:

Lancelin

- LA4: Lancelin Township North of Lancelin Point – beach, coastal/dune vegetation, beach carpark, beach access (Lancelin Island Point) and 41 residential properties.
- LA3: Lancelin Township Jetty to Lancelin Point – beach, coastal/dune vegetation, beach lookout, the park adjacent to Gingin Road, the primary school, Endeavour Tavern, Beach Hotel and Dune Restaurant, 45 residential properties, fuel storage and the caravan park at the north end.
- LA2: Lancelin Township South of Jetty – beach, jetty, Kerfuffle by the Jetty café, the light industrial area, Cunliffe Street and 66 residential properties.
- LA1: Lancelin South of Township – beach, coastal/dune vegetation, foreshore toilet block Back Beach carpark, Grace Darling Park, the Sea Rescue building and the caravan park at Lancelin south end.

Ledge Point

- LP4: Ledge Point North of Townsite – beach, coastal/dune vegetation, beach carpark (unsealed) and an unsealed road.
- LP3: Ledge Point Township North – beaches including the main swimming beach, Lancelin Ocean Classic starting point, coastal/dune vegetation, Jones Street beach access, foreshore BBQ and shelters, playground toilets, De Burgh Street, Key Biscoyne Park, the Holiday Village caravan park and 13 residential properties
- LP2: Ledge Point Township South – beach, boat launching and offshore mooring spot, Jones Street beach access, roads (De Burgh Street, Jones Street, Roe Street) and services in the road reserve.
- LP1: Ledge Point South of Township – beach, coastal/dune vegetation, the unsealed beach carpark and unsealed road.

Seabird

- SE2: Seabird Township North – beach, foreshore reserve, the strata title lots that make up the Seabird Private caravan park and the Seabird Tavern.
- SE1: Seabird Township South – beach, coastal/dune vegetation, beach access, the carpark (Edward Street), the lookout, toilets and picnic area, decommissioned stairs, 22 residential properties, roads and the services in the road reserve.

Guilderton

- G-F: Guilderton Foreshore – beach, coastal/dune vegetation, beach access, foreshore reserve and amenity, carpark, lookout, residential land on Gordon Street between Mortimer Street and Anderson Street and unsealed road to the Guilderton North Groyne.
- G-MR: Guilderton Moore River – beach, riverbank, beach access, the holiday park, toilet block and other foreshore facilities, and roads (Whitfield Street, Silver Creek Road, Guilderton Road, Mill Road, Moore River Drive).

Additional information on the assets at risk, existing coastal erosion controls and planning context /controls are provided for each management unit in the various Appendices.

The asset information in these appendices are grouped per the recommendations of the WAPC (2019):

- Environmental assets such as beach and dune vegetation
- Social assets that have strong community attachment and service
- Economic and infrastructure assets such as residential and commercial properties, utilities that contribute to economy.

In addition, the CHRMAP further groups assets within the coastal hazard zone into the Shire's LPS 9 zones and reserves to aid the implementation of adaptation planning controls for these zones and reserves in the future.

The asset groups are as follows:

- Drainage & Waterways - Within this reserve is the Special Control Area SCA1 'River Environs Management Area'
    - Guilderton - This only relates to Moore River and riverbanks / foreshore area within the coastal hazard zone
- Future Development
    - Guilderton - A small poriton of this zone is in the existing footprint of Moore River. This classifies this area as at-risk of inundation/erosion. It is assumed that this intrusion is for a particular purpose (e.g., jetty/ marina as part of proposed future development) so the results are treated as correct
- General Rural
- Parks and Recreation
    - Guilderton: This includes the public foreshore area, car park, boat ramp and finger jetty.
- Public Use
    - Only Lancelin has assets that are affected in this category. It covers public infrastructure and buildings including aged accommodation, cemeteries, churches, services and infrastructure, state forest. Reserves Public Purposes: Infrastructure Services and Public Use have been grouped together as Public Use also has a Service & Infrastructure sub-category.
- Residential
- Roads
    - Guilderton: There is a widened road reserve on Guilderton Road near the Silver Creek Road intersection. This widened area is the area predicted to be in the inundation hazard zone.
- Tourism
- Town Centre



3.2.6 Hazard Mapping

Cardno 2019 prepared coastal erosion hazard lines for Lancelin, Ledge Point and Seabird at the then-present day (2016), 2030, 2070 and 2110 planning timeframes. Baird 2020 predicted coastal inundation hazard mapping for the four coastal townsites. Shape Urban 2023a predicted coastal erosion hazard lines for Guilderton at the present day (2020), 2030, 2050, 2070, 2090 and 2120 timeframes.

The erosion and inundation hazard maps have been collated as a single appendix for ease of review – these are at Appendix F.

For the purposes of planning, the present-day differences (2016 and 2020) and future timeframes (2070, 2090, 2110 and 2120) should be considered negligible and long term planning is attributed to the 2070 (for 2070 and 2090) and 2110 (for 2110 and 2120) timeframes.

Additionally, it is important to note that these predictions are based on a suite of assumptions and have varying degrees of uncertainty, which may influence the likelihood of the predicted extent of erosion or inundation occurring at each planning horizon.

SPP 2.6 requires revision of the CHRMAP every 10 years (or sooner if required), including an update of hazard estimates using the most up to date information, the findings of specialist investigations undertaken, changes to projected sea level rise, climate change effects and any changes to the use of the foreshore.

The Shire should consider a single review update for erosion and inundation in all four coastal townsites.





4. VULNERABILITY ASSESSMENT

A vulnerability assessment defines the degree of impact coastal hazards are likely to have on coastal assets over the planning timeframe. The vulnerability of coastal assets to coastal hazards is related to its exposure to the hazard, its sensitivity to that exposure, and the ability of the asset to be modified or adapted to manage this exposure.

This is illustrated in Figure 17; the input components are displayed in blue.

In this section the asset ratings are discussed and a vulnerability rating assigned. Inundation and erosion hazards are considered separately for each of the four coastal townsites.

Assets are grouped according to classification for ease of interpretation. Ratings have been presented to and discussed with the community to ensure they are reflective of community views.

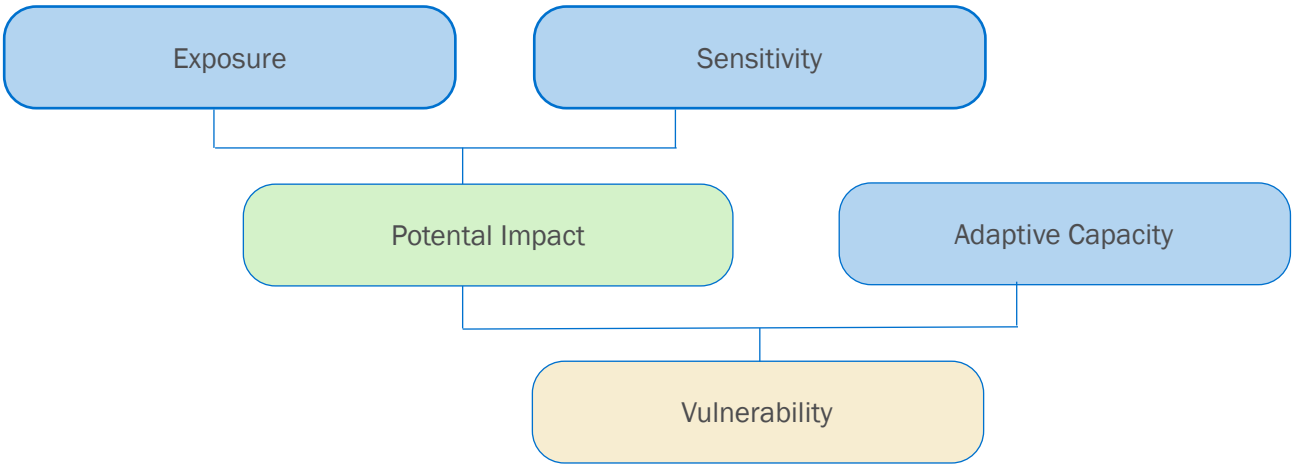


FIGURE 17: VULNERABILITY ASSESSMENT COMPONENTS (REPRODUCED FROM ALLEN CONSULTING, 2005)

4.1 Exposure/Likelihood

The exposure / likelihood of identified assets represents the likelihood of coastal hazards impacting on an asset. That is, the chance of erosion and / or storm surge inundation impacting on existing and future assets and their values (WAPC, 2019). The likelihood scale adopted for this study is presented in Table 5.

Over the years, there has been significant variation in defining the likelihood ratings based on coastal hazard assessment outcomes. The erosion hazard lines were developed based on a number of components, each of which has its own assumptions and degree of uncertainty.

For instance, the assessment of S1 erosion risk has considered a few different likelihood storm events which, by themselves, represent their likelihood of occurrence, however such occurrences change over the different planning timeframes. Likelihood of Sea Level Rise (SLR) and historic shoreline movement are very difficult to define quantitatively by scientific terms. It is therefore important to adopt a straight-forward approach to transfer the information presented in the coastal hazard maps into likelihood of impact to assets.

Through internal discussion and review, the approach recommended by WAPC (2019) as demonstrated in Figure 18 below has been adapted for the likelihood of erosion hazard. The likelihood of the current study for erosion is thereby determined by Table 6.

For the purposes of the inundation assessment, a combination of the 20-year, 100-year and 500-year ARI inundation scenarios was applied. Table 7 presents the probability of each of these events occurring over the planning timeframe. By applying the definitions of the likelihood scale of Table 5, the likelihood of inundation for the current study is presented in Table 8. For each affected asset, the likelihood of all three events was applied to each asset, and the “worst” for each planning timeframe selected for the vulnerability / risk assessment. The inundation likelihood was calculated in this way in particular due to the real risk of inundation for Lancelin. The 20-year ARI event has a much higher likelihood of occurring over the planning timeframe for example (essentially 100% chance of occurring), and this should be accounted for in the risk assessment.

Calculation of the probabilities behind the likelihood ratings is extremely complex and simplification is necessary in order to carry out the vulnerability and risk assessments. Any adaptation measures will consider applying triggers before implementation which reduces the risk of this simplification process. For example, a trigger might be reached by an inundation event with certain consequences occurring twice in a given year.

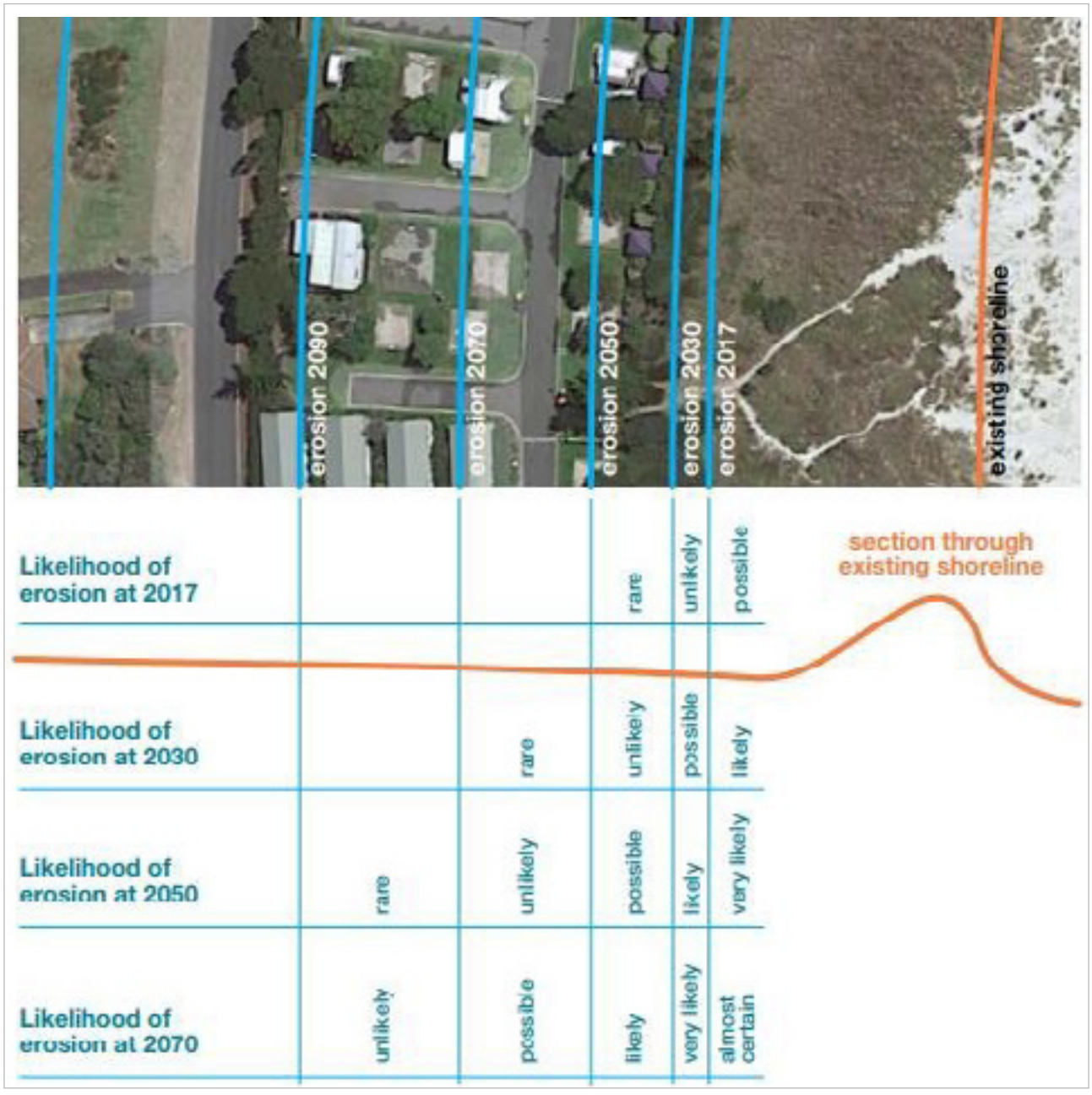


FIGURE 18: EXAMPLE OF LIKELIHOOD RATING BASED ON EROSION HAZARD LINES (ADAPTED FROM WAPC, 2019)

TABLE 5: EXPOSURE / LIKELIHOOD RATING

LIKELIHOOD RATING	DESCRIPTION	ANNUAL EXCEEDANCE PROBABILITY
Almost Certain	Expected to occur in most circumstances	>90%
Likely	Impact to asset shoreline for a given planning timeframe is likely	50-90%
Possible	Impact to asset shoreline for a given planning timeframe is possible	10-50%
Unlikely	Impact to asset shoreline for a given planning timeframe is unlikely	1-10%
Rare	May occur in exceptional circumstances	<1%

TABLE 6: EXPOSURE / LIKELIHOOD OF COASTAL EROSION HAZARDS ACROSS THE PLANNING TIMEFRAME

LIKELIHOOD RATING	LIKELIHOOD OF EROSION					
	2020	2030	2050	2070	2090	2120
HSD-2020	3 - Possible	4 - Likely	5 - Almost Certain	5 - Almost Certain	5 - Almost Certain	5 - Almost Certain
2020-2030	2 - Unlikely	3 - Possible	4 - Likely	5 - Almost Certain	5 - Almost Certain	5 - Almost Certain
2030-2050	1 - Rare	2 - Unlikely	3 - Possible	4 - Likely	5 - Almost Certain	5 - Almost Certain
2050-2070	1 - Rare	1 - Rare	2 - Unlikely	3 - Possible	4 - Likely	5 - Almost Certain
2070-2090	1 - Rare	1 - Rare	1 - Rare	2 - Unlikely	3 - Possible	4 - Likely
2090-2120	1 - Rare	1 - Rare	1 - Rare	1 - Rare	2 - Unlikely	3 - Possible
Beyond 2120	Not assessed					

TABLE 7: INUNDATION EVENT PROBABILITIES OVER PLANNING TIMEFRAMES

PROBABILITY	TIMEFRAME			
	PRESENT DAY	2040	2070	2120
20-year ARI	5%	64%	92%	99%
100-year ARI	1%	18%	39.5%	63%
500-year ARI	0.2%	4%	9.5%	18%

TABLE 8: EXPOSURE/LIKELIHOOD OF INUNDATION HAZARDS ACROSS THE PLANNING TIMEFRAMES

TIMEFRAME	PRESENT DAY	2040	2070	2120
20-year ARI Inundation Event	2 - Unlikely	4 - Likely	5 - Almost Certain	5 - Almost Certain
100-year ARI Inundation Event	1 - Rare	3 - Possible	3 - Possible	4 - Likely
500-year ARI Inundation Event	1 - Rare	2 - Unlikely	2 - Unlikely	3 - Possible

4.2 Sensitivity/Consequence

The sensitivity /consequence is an asset's responsiveness to a coastal hazard. This could be a gradual response or a stepped change in response to discrete events (WAPC, 2019). The sensitivity can be applied to the asset itself, or to the asset's function and the criticality of the service it provides (CoastAdapt, 2017).

For example, the inundation of a road leading into town would be highly sensitive as this would cut off access to the town.

The consequence ranking presented in Table 9 constitutes the physical impact of the event to the asset, as well as impacts to the values attributed to it by the success criteria defined earlier. The economic costs associated with the various consequences have been included quantitatively, and are assessed in greater detail in the multi-criteria analysis (Section 6.3).

For each hazard, the consequence is assessed against the criteria qualitatively, based on experience of the impacts of coastal erosion and inundation, and the examples presented in the consequence scale.

TABLE 9: SENSITIVITY / CONSEQUENCE RANKING

CONSEQUENCE LEVEL	PHYSICAL, ECONOMIC	ENVIRONMENT	COMMUNITY, CULTURE & SAFETY
1 – Insignificant	Minor damage requiring increased maintenance	Negligible to no impact to flora and fauna	Minor instances in which the asset is unable to maintain its services. Short-term inconvenience, <5% community affected
2 – Minor	Damage to assets resulting in restrictions in capability, financial loss of $10,000 to $100,000	Short term loss of flora and fauna. Recovery will be strong	Isolated but noticeable examples of disruption in asset function; <10% community affected
3 – Moderate	Damage to assets resulting in isolated loss of capability, financial loss of $100,000 to $2 million	Medium term loss of flora and fauna. Recovery is likely	General appreciable decline in assets & their function; <25% of community affected
4 – Major	Significant damage to many assets resulting in very limited capability, financial loss of $2 million to $10 million	Long-term damage to flora and fauna. Limited chance of recovery	Severe decline in asset services and corresponding quality of life within the community; <50% of community affected
5 – Catastrophic	Significant damage to most assets resulting in loss of capability, financial loss of over $10 million	Permanent damage to flora and fauna. No chance of recovery	Asset services failure; no chance of repair; >75% of community affected. Long term permanent loss of services

4.3 Potential Impact (Level of Risk)

Risk level, or potential impact, is calculated as the product of exposure and sensitivity (see Table 10). It provides a classification of the potential impact of coastal hazards on identified assets, which should be determined for each considered planning timeframes. Level of risk is evaluated mainly based on its tolerability (i.e., consequence). Definitions are provided in Table 11.

TABLE 10: RISK LEVEL (POTENTIAL IMPACT) MATRIX AS PRODUCT OF SENSITIVITY (CONSEQUENCE) AND EXPOSURE (LIKELIHOOD)

SENSITIVITY / CONSEQUENCE	EXPOSURE / LIKLIHOOD				
	1 - RARE	2 - UNLIKELY	3 -POSSIBLE	4 - LIKELY	5 - ALMOST CERTAIN
1 – Insignificant	Low	Low	Low	Low	Low
2 – Minor	Low	Low	Low	Medium	Medium
3 – Moderate	Low	Medium	Medium	High	High
4 – Major	Medium	Medium	High	Extreme	Extreme
5 – Catastrophic	Medium	High	Extreme	Extreme	Extreme

TABLE 11: RISK PROFILE DEFINITION

RISK LEVEL	DESCRIPTION
Low	Tolerable risk. A level of risk that is low and manageable without intervention outside routine asset maintenance.
Medium	A level of risk that may require intervention to mitigate, such as changes to design standards or asset maintenance. Short to medium term action required.
High	A level of risk requiring significant intervention to mitigate in the immediate to short term.
Extreme	Immediate action required to reduce risk to acceptable levels

4.4 Adaptive Capacity

The adaptive capacity is the asset's ability to adjust/adapt to the identified hazard. It is determined based on the potential for the system to be modified to cope with the impacts from coastal hazards. Assets with high adaptive capacity can easily be adapted or have some capacity to self-adapt with changing conditions.

For instance, beach and dune systems often have higher adaptive capacity than coastal infrastructure and residential land.

The scale of adaptive capacity is provided in Table 12. Rating of adaptive capacity is determined by assets/asset groups as well as opinions from the stakeholders and communities.

TABLE 12: ADAPTIVE CAPACITY

ADAPTIVE CAPACITY	DESCRIPTION
1 - No adaptation required	Potential impact has insignificant effect on asset. Controls are re-established naturally or with ease before more damage would likely occur.
2 - Low	Little or no adaptive capacity. Potential impact would destroy all functionality. Redesign required.
3 - Moderate	Small amount of adaptive capacity. Difficult but possible to restore functionality through repair and redesign.
4 - High	Decent adaptive capacity. Functionality can be restored, although additional adaptive measures should still be considered. Natural adaptive capacity restored slowly over time under average conditions
5 - Very High	Good adaptive capacity. Functionality restored easily. Adaptive systems restored at a relatively low cost or naturally over time.

4.5 Vulnerability

Vulnerability is calculated as the product of potential impact (risk level) and the adaptive capacity of an asset (Figure 19).

As per WAPC (2019), four levels of vulnerability are considered in this study which are assessed for each of the planning timeframes considered by this CHRMAP - Very High, High, Medium and Low.

- An asset with Very High Vulnerability requires adaptation, as the risk is considered intolerable due to its high or extreme risk level and low or moderate adaptive capacity.
- An asset with High vulnerability requires adaptation, unless all stakeholders are aware of and willing to accept the risks.
- An assset with Moderate vulnerability may require adaptation, but should certainly be monitored for potential increase to vulnerability.
- An asset with Low vulnerability is unlikely to cause impact and is tolerable, although monitoring should be undertaken and adaptation measures may need to be introduced at a later time.

Table 13 illustrates how combining risk levels with adaptive capacity produce vulnerability ratings.

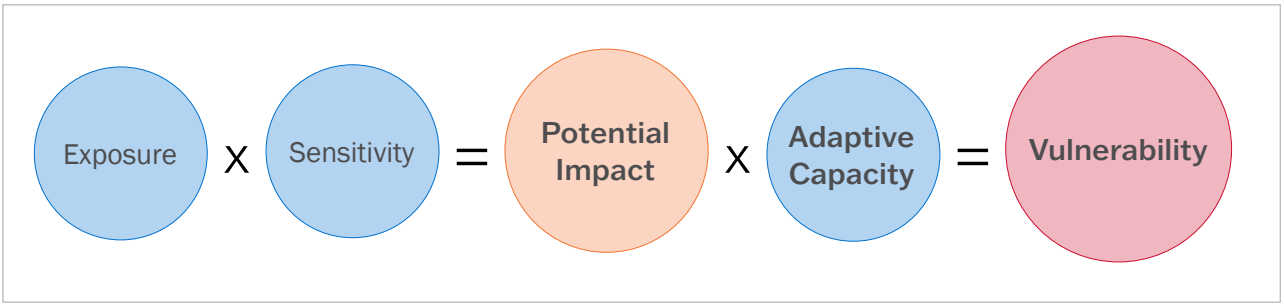


FIGURE 19: VULNERABILITY RELATIONSHIP

TABLE 13: RISK LEVEL (POTENTIAL IMPACT) COMBINED WITH ADAPTIVE CAPACITY TO PRODUCE A MATRIX OF VULNERABILITY

	ADAPTIVE CAPACITY			
RISK LEVEL	VERY HIGH	HIGH	MODERATE	LOW
LOW	Low	Low	Moderate	Moderate
MEDIUM	Low	Moderate	Moderate	High
HIGH	Moderate	Moderate	High	Very High
EXTREME	Moderate	High	Very High	Very High

Cardno 2019 at Appendix A outlines the erosion risk assessment ratings and results for Lancelin, Ledge Point and Seabird.

Shape Urban Gap Analysis Technical Report (2023a) at Appendix C outlines the inundation risk assessment rating and results for the four coastal towns, and for erosion in Guilderton.

An assessment of vulnerability was undertaken for all four towns.

The coastal townsite sections (Sections 4.6 to 4.9) provide an overview of assets with Medium, High or Very High vulnerability to erosion and inundation in the respective townsites, starting at the northern extent of the Shire.

A combination of both erosion and inundation is shown, comprising information from Cardno 2019 and Shape Urban 2023a.

Note: Due to the differing timeframes of each reference document, there are variations on two of the return periods. For the purposes of simplification, this CHRMAP adopts the approach that planning sooner is preferred over delaying action, and the time periods being presented are:

- 2020 (2016 or 2020 in source);
- 2030 (per Cardno 2019);
- 2040 (2040 or 2050 in source);
- 2070 (2070 or 2090 in source); and
- 2110 (2110 or 2120 in source).

The impact of this approach is negligible, as within that timeframe the CHRMAP will need to be reviewed several times.

4.6 Vulnerability - Lancelin

This section presents the assets predicted to be vulnerable to coastal erosion and inundation in Lancelin, as well as their vulnerability level. This section references spatial Management Units shown in Figure 20.

The majority of the Lancelin township is vulnerable to inundation; all asset groups with the exception of General Rural are predicted to have individual assets inundated. Assets adjacent to the coast are also subject to erosion hazards. The vulnerability of assets commences in the present day and increases over the 100-year planning period. Erosion was assessed in Cardno 2019 and inundation in Shape Urban 2023a.

4.6.1 Lancelin North (LA3 and LA4)

Vulnerable assets to erosion and inundation in LA3 and LA4 are shown below. It should also be noted that high vulnerability was not previously idenitfied in Cardno 2019 in the 100-year horizon for Gingin Road and primary school, the unsealed beach car park and beach access (Lancelin Island Point). These have since been identified as vulnerable through Shape Urban 2023a.

Although Medium vulnerability is not shown below, it should be noted that, with the exception of the beach carpark and the primary school, all assets are at a Medium level of vulnerability to erosion by 2030.

VULNERABILITY						
		2020	2030	2040	2070	2110
1.	Beach					
2	Residential					
3	Coastal / dune vegetation					
4	Hotel, Restaurant and Endeavour Tavern					
5	Caravan Park north					
6	Primary School					
7	Roads					
8	Park (Gingin Road)					
9	Beach carpark (unsealed)					

Erosion: Medium High Very High

Inundation: Medium High Very High



FIGURE 20: LANCELIN MANAGEMENT UNITS

4.6.2 Lancelin Centre (LA2)

Vulnerable assets to erosion and inundation in LA2 are shown below. LA2 contains significant environmental, economic and social assets.

Cardno 2019 indicated a number of important assets are vulnerable in the short term, which are already subject to planning control recommendations and have been actively addressed, however, the combined inundation and erosion vulnerability for this management unit are likely to require additional actions, and in shorter time frames.

Adaptation actions in LA2 will need prioritisation due to the short-term nature of vulnerability levels.

VULNERABILITY						
		2020	2030	2040	2070	2110
1.	Beach					
2	Residential					
3	Coastal / dune vegetation					
4	Cunliffe Street and adjacent roads					
5.	Jetty					
6.	Light Industrial / Mixed Business					
7.	Cafe					
8.	Tourism land					
9.	Town Centre					

Erosion: Medium High Very High

Inundation: Medium High Very High

4.6.3 Lancelin South (LA1)

Vulnerable assets to erosion and inundation in LA1 are shown below. LA1 contains important environmental and social assets including Grace Darling Park and large areas of dune vegetation west of Casserley Way that are vulnerable to erosion.

Inundation vulnerability occurs in the short term, with predicted impacts behind the coastal dune increasing beyond the middle of the century on residential, tourism and town centre zoned land.

As adaptation responses for assets immediately adjacent to the coast will be focused on the more urgent issue of coastal erosion in this management unit, inundation vulnerability of these assets (coastal vegetation, Sea Rescue building, Grace Darling Park and the caravan park) are a secondary concern.

VULNERABILITY						
		2020	2030	2040	2070	2110
1.	Coastal / dune vegetation					
2	Sea Rescue building					
3	Grace Darling Park					
4	Caravan park south					
5	Residential					
6	Tourism land					
7	Town Centre					

Erosion: Medium High Very High

Inundation: Medium High Very High

4.7 Vulnerability - Ledge Point

The assets predicted to be vulnerable to coastal erosion and inundation in Ledge Point, and their vulnerability rating are described in this section.

This section references spatial Management Units shown in Figure 21. Erosion was assessed in Cardno 2019 and inundation in Shape Urban 2023a

4.7.1 Ledge Point North (LP3 and LP4)

Vulnerable assets to erosion and inundation in Ledge Point North (LP3 and LP4) are shown below. Inundation has negligible impact at Ledge Point.

VULNERABILITY						
		2020	2030	2040	2070	2110
1.	Beach					
2	Residential					
3	Coastal / dune vegetation					
4	Key Biscoyne Park					
5.	Car park and De Burgh Street					
6.	Holiday Village					

Erosion: Medium High Very High

Inundation: Medium High Very High



FIGURE 21: LEDGE POINT MANAGEMENT UNITS

4.7.2 Ledge Point South (LP1 and LP2)

Vulnerable assets to erosion and inundation in Ledge Point North (LP1 and LP2) are shown below. Inundation has negligible impact at Ledge Point.

For noting are the six residential properties along De Burgh Street which are immediately adjacent to the inundation hazard zone, however, as adaptation responses will be focused on the more urgent issue of coastal erosion in this management unit, inundation vulnerability of assets immediately adjacent to the coast are a secondary concern.

VULNERABILITY						
		2020	2030	2040	2070	2110
1.	Beach		Medium	Medium	High	High
2	Residential	High	Very High	Very High	Very High	Very High
3	Coastal / dune vegetation		Medium	Medium	Medium	High
4	Foreshore recreation area				Medium	High
5.	Roads				High	Very High

Erosion: Medium High Very High

Inundation: Medium High Very High

4.8 Vulnerability - Seabird

The assets predicted to be vulnerable to coastal erosion and inundation in Seabird, and their vulnerability level are described in this section.

This section references spatial Management Units shown in Figure 22. Erosion was assessed in Cardno 2019 and inundation in Shape Urban 2023a

4.8.1 Seabird North (SE2)

Vulnerable assets to erosion and inundation in Seabird North are shown below. There are some concerns that the seawall in SE1 (Seabird South) may be increasing erosion risks in SE2. Inundation has negligible impact at Seabird.

VULNERABILITY						
		2020	2030	2040	2070	2110
1.	Beach					
2	Coastal / dune vegetation					
3	Caravan park (Seabird Private)					
4	Tavern					

Erosion: Medium High Very High

Inundation: Medium High Very High



FIGURE 22: SEABIRD MANAGEMENT UNITS

4.8.2 Seabird South (SE1)

Vulnerable assets to erosion and inundation in Seabird South are shown below. Inundation has negligible impact at Seabird.

The end of Turner Street is located in the close vicinity of the existing seawall and is vulnerable to future inundation. Consideration of future adaptation responses at the end-of-life of the seawall will need to be prioritised.

VULNERABILITY						
		2020	2030	2040	2070	2110
1.	Beach					
2	Residential					
3	Coastal / dune vegetation					
4	Car parks and roads					

Erosion: Medium High Very High

Inundation: Medium High Very High

4.9 Vulnerability - Guilderton

The assets predicted to be vulnerable to coastal erosion and inundation in Guilderton, and their vulnerability level are illustrated in this section.

This section references spatial Management Units shown in Figure 23. The two management units have been treated together for the purpose of simplicity.

Erosion and inundation have been assessed in Shape Urban 2023a. Inundation has negligible impact at Guilderton, reaching only a medium level of vulnerability by 2050 with a high adaptive capacity.

VULNERABILITY						
		2020	2030	2040	2070	2110
1	Residential (Gordon Street)					
2	Parks and Recreation (Moore River car park and foreshore area)					
3	River management area					
4	Gordon Street and Edward Street					

Erosion: Medium High Very High

Inundation: Medium High Very High



FIGURE 23: GUILDERTON MANAGEMENT UNITS





5. RISK TREATMENT

SPP 2.6 provides a hierarchy of adaptation pathways to guide decision making in coastal areas for use by planning authorities and development proponents when considering adaptation options to minimise coastal hazard risks at the local level.

The objectives of SPP 2.6 are to:

- Ensure that 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.

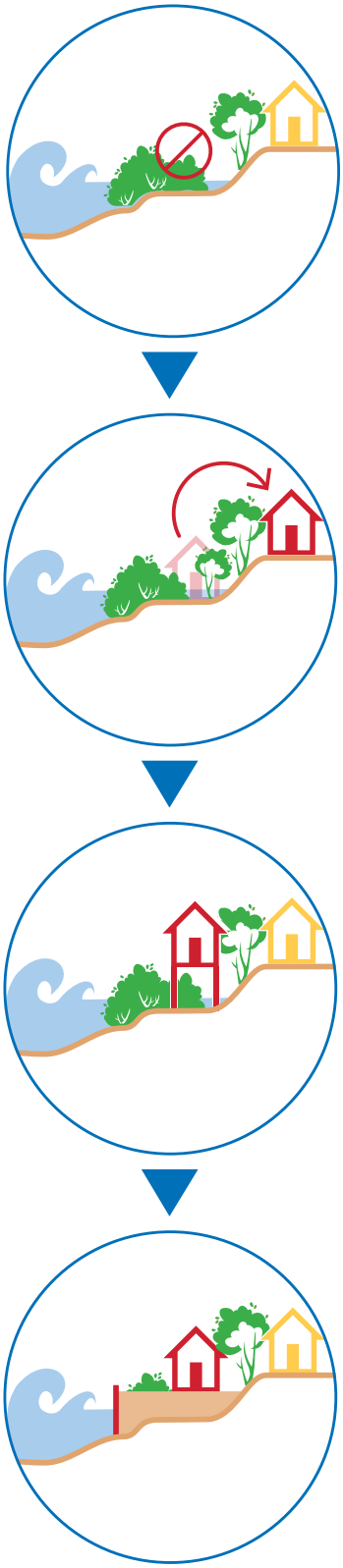
The hierarchy, presented in Figure 24, details risk management categories of 'Avoid', 'Planned / Managed Retreat', 'Accommodate' and 'Protect'. It should be noted that the State Government has no obligation to protect private assets from coastal erosion, with the CHRMAP indicating a clear preference against the adoption of 'Protect' as a long-term adaptation pathway.

This preference is in accordance with the policy directive in SPP 2.6, the policy guidelines, the CHRMAP Guidelines and the WA Coastal Zone Strategy.

Generally, as risk treatment options are selected further down this hierarchy (from avoiding areas with risk to protecting development from those risks), future risk management opportunities will diminish. As such, avoiding the placement of sensitive development within areas that are at risk from coastal hazards provides the most resilience to future risk arising from coastal hazards.

Conversely, using protection structures to allow sensitive development within areas that would otherwise be at risk from coastal hazards reduces the flexibility of future decision-makers to address risk arising from coastal hazard (WAPC, 2019).

Further to the risk management and adaptation hierarchy identified in SPP 2.6 and Figure 24, No Regrets and Do Nothing are two risk treatment options that are relevant to the CHRMAP process and have been considered in the risk treatment assessment.



Avoid

Identify future 'no-build areas', use planning tools to prevent new development, and enhance the natural environment in areas at risk now or in the future.

Retreat

Withdraw, relocate or abandon built assets that are at risk; enhance the natural environment and allow natural ecosystems to retreat landward as sea levels rise.

Accommodate

Continue to use the land but implement changes such as building on piles, converting agriculture to fish farming or growing food or salt-tolerant crops.

Protect

Use hard structures (e.g., seawalls, levees) or soft solutions (e.g. vegetation) to protect built assets. May result in loss of natural environment and be prohibitively expensive, especially in the long term.

FIGURE 24: ADAPTATION HIERARCHY (ADAPTED FROM WAPC, 2019)



5.1 Adaptation Hierarchy

5.1.1 Avoid

This option aims to avoid the construction of new public and private assets within areas identified to be affected by coastal hazards. The project lifetime of a new asset should be a key consideration in deciding the suitability of locating new assets in coastal hazard areas. For example, the construction of new public assets, such as picnic facilities and public toilets, should be avoided where these assets are likely to be impacted by coastal hazards within the lifetime of the asset. Similarly, the construction of new private assets which are likely to be affected by coastal hazards over their projected lifetimes should not be permitted. The option of avoid can be applied to manage coastal erosion and inundation hazard risks.

5.1.2 Planned or Managed Retreat

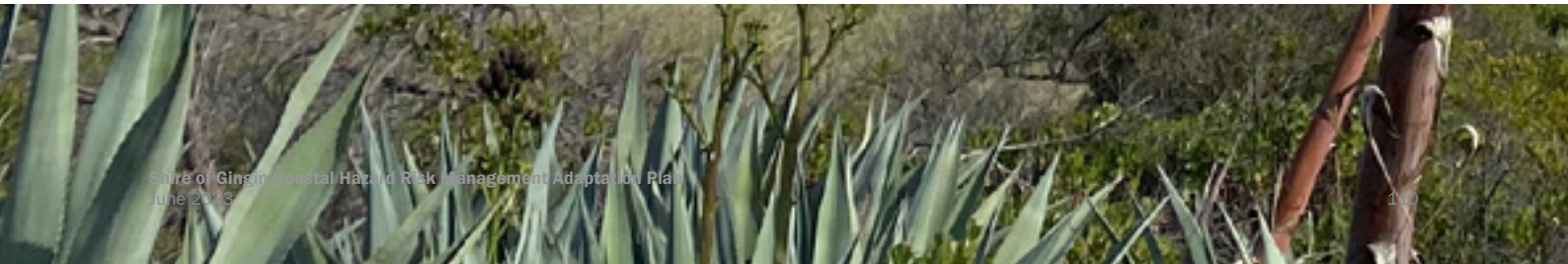
This option aims to relocate or remove assets which are located in hazard areas, in an orderly manner, where hazard risks are likely to be intolerable over relevant planning timeframes. In recognition of the increased risk to assets in the coastal zone, the Department of Planning, Lands and Heritage (DPLH), together with the Western Australian Planning Commission, provides guidance on how to implement a policy of planned or managed retreat through property acquisitions (WAPC, 2019).

Planned or managed retreat is mostly applicable to developed areas, where there is less potential to adapt to coastal hazards through development planning controls, such as setbacks in Greenfield areas. The strategy of retreat is based on social, environmental and economic sustainability, and ties into the SPP2.6 objectives and adaptation hierarchy. It allows for continuing public access to beaches, beach amenity, and the provision of a coastal foreshore reserve.

The CHRMAP Guidelines (WAPC, 2019) suggest a range of mechanisms for achieving managed retreat in developed areas, using compulsory or voluntary acquisition provisions outlined in state legislation. Alternatively, planned or managed retreat can be achieved through the early acquisition and leaseback of private property. This alternative can help to reduce overall implementation costs.

Planned or managed retreat is an option that can be applied to manage coastal erosion and inundation hazards; however, this option requires a significant investment of public resources to fund acquisitions. From a practical perspective, implementation of managed retreat may require the State or Commonwealth to provide the majority of funding to acquire property.

Funding programs offered at the State level do not currently provide amounts which facilitate property acquisitions, and there has been no indication to date that this situation will change in the near future. Therefore, landholders and the broader public should be aware of the risks in any decisions they make about purchasing or developing lands in coastal areas.



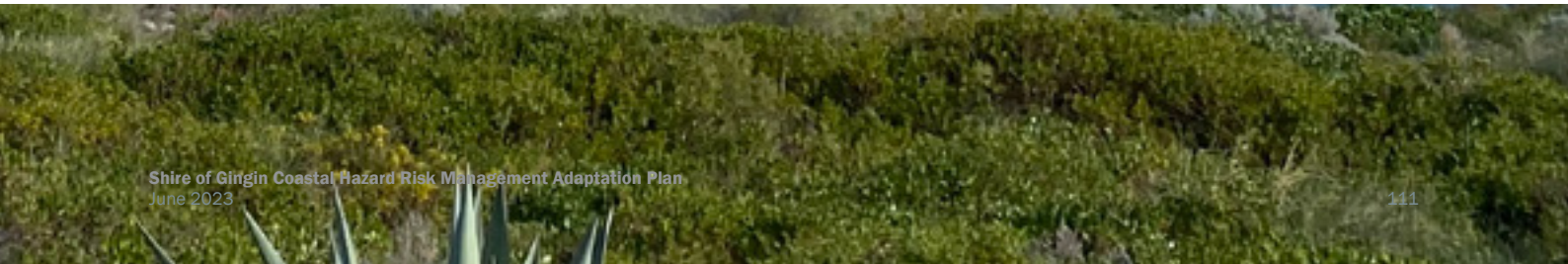
5.1.3 Accommodate

This option aims to utilise design and management strategies which render the risks from identified coastal hazards as acceptable. Design and management strategies include: minimum finished floor levels and elevated electrical circuitry, to minimise inundation risks; or, relocatable structures which can be moved to a different location on- or off-site, as shorelines recede, or regular inundation events make the provision of critical services unviable. In this way, the 'Accommodate' option allows landholders to continue to use land until hazard risks become intolerable, while minimising the current and future risk of legal and financial liability for Council.

Accommodate design and management strategies can be facilitated through modifications to local planning frameworks. These modified planning frameworks need to provide clear direction for planning authorities when assessing applications for new development and for affected landholders. Planning frameworks might include the introduction or modification of the following instruments:

- Special control areas, to ensure planning discretion over new development
- Clear development assessment criteria, to ensure that new development gives due regard to coastal processes
- Notifications on title, to inform current and future property owners of hazard risks
- Time or event limited planning permits, to allow the continued use of land until hazards become intolerable

Accommodate is an option that can be applied to help minimise the effect of coastal erosion and inundation hazards on new development and infrastructure. A key concern with the accommodate option, particularly in regard to managing coastal erosion, is that the current State legislative framework means that permanently inundated private land does not become Crown land, unlike in other Australian states (Robb et al 2017, Robb et all 2018). Therefore, where the shoreline is allowed to recede beyond private property boundaries, issues of public access and trespass may arise. This should be a key consideration when assessing the appropriateness of the Accommodate option.



5.1.4 Protect

This option aims to stabilise the position of the shoreline using hard or soft coastal protection measures such as seawalls, groynes, offshore breakwaters, geotextile sand-containers, sand renourishment and levee banks. Protection is an option that can be applied to manage coastal erosion and inundation hazards.

The adaptation hierarchy considers the construction of new protection measures as the least preferred option of all potential options listed in the hierarchy. Protection measures, particularly hard measures such as rock groynes and seawalls, interfere with local coastal processes and can have detrimental effects on local ecological systems. Protection measures can also inflate property values in hazard areas, create expectations that protection measures will be maintained into the future, and may limit the capacity of future decision makers to change strategies as situations change.

Over the short to medium term, public authorities may need to consider the appropriateness of using interim protection measures to delay shoreline recession. This might be achieved through measures such as geotextile sand containers which can be less costly to remove than rock structures, regular sand renourishment, and revegetating coastal dunes. Where public and private assets are proposed to be constructed inland of interim protection measures, the design life of the protection measure should be a key factor in determining the appropriateness of the proposed asset or development.

5.1.5 No Regrets

No regrets options cover a period of time where assessments are required or are being undertaken to determine a preferred risk treatment option, prior to implementing specific asset risk management measures. This is particularly pertinent where a more costly or difficult risk treatment option, or better understanding regarding the level of risk to an asset, may be required (WAPC, 2019).

No regret options are cost effective in the current day and provide flexibility for more resilient and appropriate long term management options to respond to coastal hazard risks.

5.1.6 Do Nothing

This option assumes that all levels of risk are accepted and that no further action will be taken. A Do Nothing option provides the basis for comparison of all other risk treatment options.

A Do Nothing option may also be reflected in reality where the selection of another option (e.g. protect) and the subsequent trade-off considerations are considered unacceptable to the State Government or other funding bodies and is thus not funded. In this case, the selection of an option that is considered unacceptable results in ‘nothing happening’ despite recommendations in a CHRMAP. This needs to be considered when selecting the most appropriate option to address risk.

5.2 Hierarchy Summary

Maintaining public access to the coast in developed areas is one of the main objectives of SPP 2.6 and identified as a key value of the Shire of Gingin community. As discussed, the current State legislative framework means that where the shoreline recedes beyond private property boundaries, issues of public access and trespass are likely to arise. In this case public authorities have two main adaptation options available to them for preserving public coastal access:

- Planned or Managed Retreat i.e., maintaining a foreshore reserve through public acquisition of private property; or,
- Protect i.e., preventing the shoreline from receding beyond private property boundaries by stabilising the current shoreline position using various protection measures (e.g., rock groynes, offshore breakwaters).

Where public authorities cannot commit to either of these options over the long term, it is likely that public authorities will need to Accommodate, by modifying local planning frameworks to help ensure that new development is appropriately designed and located. Public authorities in this situation may also choose to consider the appropriateness of interim Protection measures to preserve public interests by delaying shoreline recession and minimising the effect of regular nuisance inundation events on existing development and infrastructure.

5.3 Summary for Decision Makers

It is important to note that there is no law requiring public authorities to provide protection of private property from natural hazards, nor compensation when land is lost due to coastal hazards. The CHRMAP process aims to minimise coastal hazard risks and maximise beneficial use of the coast. The principles of this are:

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

6. RISK TREATMENT OPTIONS

SPP 2.6 presents a number of adaptation options to minimise coastal hazard risks at the local level. Not all of these options are suitable in every case.

Table 14 presents a list of generally available adaptation options suitable for most coastal sites. These relate to both short term and long-term adaptation to coastal hazards in general, not just in relation to planning for climate change impacts. The columns on the right-hand side provide some discussion as to the possibility of the options suitability for the study area.

Whilst the risks and their corresponding adaptation options are assessed separately, triggers to implement the option can be modified to suit the circumstances at any given point in time, for example, if risks from erosion or inundation are being experienced sooner, a trigger may bring adaptation response forward in time.



TABLE 14: AVAILABLE ADAPTATION OPTIONS (ADAPTED FROM WAPC, 2019 AND CARDNO 2019)

OPTION CATEGORY	OPTION CODE	OPTION NAME	DESCRIPTION	SUITABILITY AND COST CONSIDERATIONS
Avoid	**AV**	Avoid development	Avoiding new development within the coastal hazard zone and locating assets in areas that will not be vulnerable to coastal hazards	Financial resources will not be required to be spent on risk management
Planned or Managed Retreat	**MR1**	Leave assets unprotected	Accept loss following hazard event. Only implement repairs to maintain public safety.	Saves financial resources for alternative uses, and allows for retreat that enables natural recession of the shoreline over the long-term
	MR2	Remove/ Relocate	Assets located in the hazard zone are permanently removed or relocated.	For residential and commercial property, this option may require voluntary or compulsory acquisition of land, transferrable development rights and land swaps. Enables the social and economic values of assets until such time that the asset needs to be relocated. Can often coincide with asset replacement, and allows the cost of relocation to be shared with the cost of asset replacement. For residential and commercial property, this option may require voluntary or compulsory acquisition of land, transferrable development rights and land swaps
	MR3	Planning controls for managed retreat /Prohibit expanding existing use rights	Use planning controls to allow continued use of the current infrastructure until such time that impacts arise, but restrict further or new development	This enables existing development and use rights to continue without increasing them, until such time that risk arising from coastal hazards is intolerable. Includes mechanisms for ensuring that the Shire, landowners and prospective buyers are made aware of the risk. Generally applicable where protection of assets is not viable
	MR4	Voluntary acquisition	This risk treatment option results in the acquisition of affected properties, on a voluntary basis	This enables removal of private property(s) located within a land use that would otherwise be permitted, to ensure land in the coastal zone is continuously provided for coastal foreshore management, public access, recreation and conservation, and where alternative risk treatment options are not viable for the property and adjacent land. Early acquisition and leaseback could be used as an alternative to help reduce overall costs. May benefit some private landowners more than others
Accommodate	**AC1**	Design assets to withstand impacts	Design of assets to withstand the impact of inundation, for example, building houses on stilts or raising building pads above the expected inundation levels	This is aimed at retaining existing assets in locations but reducing the consequences of the inundation hazard. It is cheaper to mitigate the impacts with initial design outcomes as opposed to retrofitting (adapting) existing assets in the future
	AC2	Planning controls for accommodation	Amend local planning frameworks to require assets to be designed to be able to accommodate hazards	Indicates to current and future landholders that an asset is at risk from coastal hazards over the planning timeframe. and that risk management and adaptation is likely to be required at some stage. Helps owners to make informed decisions about the level of risk they are willing to accept. Low cost option that does not prohibit the use of other management options in the future

TABLE 14: AVAILABLE ADAPTATION OPTIONS (ADAPTED FROM WAPC, 2019 AND CARDNO 2019) (CONT'D)

OPTION CATEGORY	OPTION CODE	OPTION NAME	DESCRIPTION	SUITABILITY AND COST CONSIDERATIONS
Protect	PR1	Dune care/ management	Development of a long-term program for revegetation and rehabilitation of dune system	Program needs to be considered in context of cost of replenishment and resources to undertake actions. Would require continued funding sources.
	PR2	Groyne	Construct rock groynes along the beach approximately perpendicular to the shoreline to restrict longshore sediment movement and stabilise sections of shoreline. This option is often accompanied by beach nourishment.	Hard protection generally diverts erosion issues elsewhere, such as to the down drift side of a groyne, and can have significant impact on coastal ecosystems when accompanied by beach nourishment. Groynes are not effective as a means of managing short-term storm erosion. Can be expensive and rock sources may not be readily available or affordable. Groynes change the nature and appearance of the coast and can impact walking and beach use. Assessment of this option needs to consider long term maintenance, as this will extend the life of the groyne.
	PR3	Seawall	Construct seawall in front of assets or along length of coastline to protect them from coastal hazards.	Hard protection generally diverts erosion issues elsewhere, such as to beaches either side of, and directly in front of, a seawall. They can also have significant impact on coastal ecosystems Seawalls are expensive and change the nature and appearance of the coast, typically resulting in long term loss of the beach in front. Rock sources may not be readily available or affordable. They need to be accompanied by beach nourishment/ replenishment, which adds to the cost of option. Assessment of this option needs to consider long term maintenance, as this will extend the life of the wall.
	PR4	Nearshore reef/ Breakwater/ Artificial Reef	Construct offshore reef(s)/breakwater(s) or raise existing natural nearshore reef structures to maintain level of protection as sea level rises.	Hard protection generally diverts erosion issues elsewhere. The impacts of these structures are relatively unknown, and untested in the local context. May have significant impact on coastal ecosystems in adjacent areas. Reefs are unlikely to be effective over time as sea levels rise, or the crest would need to be raised in height in response. Are very expensive to design, build and maintain and rock sources may not be readily available or affordable. Assessment of this option needs to consider long term maintenance, as this will extend the life of the structure.
	PR5	Beach (sand) nourishment	Addition of sand to the beach, dune and/or nearshore area to replace lost material and/or create additional buffer.	This option is a temporary measure and can be more effective in association with other options. The sand may be from an external source or from a nearby part of that coastal area, as such availability of suitable sand sources may be an issue. Where suitable sources are not readily available or a considerable distance away, costs are increased. If the nourishment sand is significantly finer than the existing beach sand the nourishment sand will be lost quickly
No Regrets	NR1	Monitoring	Long term baseline monitoring and event-based monitoring following storm erosion events	Monitoring enables assessment of the frequency and severity of events, the impact and consequences on various land uses, to revise risk levels and determine the effectiveness or appropriateness of risk management measures over time. Regular monitoring will support the identification of triggers for risk management measures to be implemented
	NR2	Protection structure audit	Involves undertaking an audit of existing protection structures, to determine their current condition, effectiveness and future protection potential	Depending upon the expected life and future protection from existing protection structures, there may be updates to the hazard estimates. This will flow on to affect other risk treatment options, including implementation of risk management measures
	NR3	Notification on title	Using the Planning and Development Act 2005 and the Land Administration Act 1997 to place a notification on the titles of potentially affected properties.	Indicates to current and future landowners that an asset is likely to be affected by coastal erosion and/or inundation over the planning timeframe. Helps current and future owners make informed decision about level of risk they are/may be willing to accept, and that risk management is likely to be required at some stage within the planning timeframe. Allows vulnerability of asset to hazards to be conveyed to existing and future owners. One means of implementation that is low cost, is through subdivision and development decision making
	NR4	Emergency evacuation plans	Establishing emergency evacuation management plans where existing assets may be affected by erosion and/ or inundation to manage the safety of community and stakeholders	This option is a low-cost option in addressing the consequences of erosion / inundation regarding safety to lives as the impact occurs
Do Nothing	DN	Do nothing	This is managed retreat at its most basic form. The asset will be lost after a hazard event. Repairs are carried out for public safety purposes only. Take no action. No limitations on development or implementation of adaptation planning. Accept risk	Does not involve any new actions. Where existing levels of risk are low, accepting the risk may be appropriate. However, it may not be appropriate for high-risk locations/assets. The cost of Do Nothing may be substantially greater in the future than the current cost of implementing planning controls. This is because the value of land at risk continues to increase, as does the cost of mitigating recession impacts over time (such as retrofit, or even abandoning lost lands). Further, as the value of land at risk continues to increase over time, implementation of retreat risk treatment options in the future, to ensure land in the coastal zone is continuously provided for coastal foreshore management, public access, recreation and conservation, become increasingly desirable while more difficult to implement

6.1 Assessment of Adaptation Options

The assessment of adaptation options comprises four key steps;

1. Establishing a multi-criteria analysis (MCA) framework and then assessing options through that framework based on rigorous technical analysis (including rejecting options that are unsuitable if necessary);
2. Utilising the MCA framework to cross-check the assessment with the community;
3. Developing preliminary cost estimates; and
4. Determining implementation timeframes.

Step 1 in the assessment of adaptation options is important in developing any CHRMAP. The suitability of certain measures from an engineering or scientific perspective is imperative.

However, Step 2 is critical to ensure that some rigour and local knowledge is applied to the assessment, as community values are often intrinsic and experienced based and cannot be so easily measured.

The Shire of Gingin committed to a testing of community values with stakeholders in the study area, which included the initial collection of community values and the establishment of a Community Panel to provide a community informed analysis of MCA criteria and the proposed adaptation options.

Costing of options can be challenging, as the changing nature of supply chains and construction costs create unknowns; however, as options are all costed in comparison to each other, it is the relative comparison that is important.

Implementation timeframes (Step 4) are often determined in an iterative manner and through a cost benefit analysis framework, with ongoing coastal monitoring determining the need; these are typically an indication only.

6.2 Multi-criteria Considerations

Successful risk management and adaptation planning requires identification and diligent assessment of suitable options to ensure selection of the best strategy. The chosen option should mitigate risk to an acceptable level whilst maximising the values that were identified as being important to the stakeholders.

It is noted that the assessment criteria used in Cardno 2019 and Shape Urban 2023a differ. This is based on the experiences of each consultant and feedback obtained from the community.

6.2.1 Cardno 2019 Criteria

1. Preliminary Feasibility
    - Effectiveness
    - Governance / Legal / Approval Risk
    - Reversibility / Adaptability
2. Preliminary Acceptability
    - Environment / Social Impact
    - Community Acceptability
3. Preliminary Financial Implications
    - Financial Gain / Avoidance of Cost
    - Capital Cost
    - Ongoing Costs

Cardno 2019 undertook an MCA for erosion hazards in Lancelin, Ledge Point and Seabird.

The MCA results in Cardno 2019 were tested with community members during workshops in October 2022. Community members generally supported the MCA results, however a few members observed that they would prefer the 'environment' to be considered as an independent criterion and given more weight.

Whilst this did not change the recommended options, it is important to recognise the shifting attitudes towards the natural environment since the earlier report was completed.

6.2.2 Shape Urban 2023a Criteria

1. Effectiveness - The ability for the option to mitigate the coastal hazard risk
2. Environmental - The impact on existing native vegetation / dunes / coastal processes. Includes consideration of:
    - Any construction / clearing impacts
    - Impact of maintenance on the environment
3. Social - This considers stakeholder and community impacts, including impact to / on indigenous or historical values (NB: An Aboriginal site with heritage value was identified through the AHIS (DPLH, 2021) covering the town of Guilderton)
4. Economic - This considers the economic impact of the option, and not the cost of the option. Community and stakeholder engagement indicated the impact of coastal hazards to economic prosperity of the towns was a concern. As the towns rely heavily on tourism, this needs to be considered when assessing each adaptation option
5. Aesthetic impacts - The visual appeal of the option and consideration of option aesthetics tying into the wider town vision
6. Future adaptability - Whether the option is easily adaptable in future and if the option limits the availability of other options in future
7. Cost - The upfront capital costs and ongoing maintenance costs.

Shape Urban 2023a combined capital and maintenance costs, as there is a recognised need to allow for the whole of life cycle costs across the planning horizon.

Shape Urban 2023a undertook an MCA for erosion and inundation at Guilderton and for inundation in Lancelin, Ledge Point and Seabird. The Cardno 2019 MCA scores were also reviewed as part of Shape Urban 2023a, primarily to test that the scores remained suitable.

The Shape Urban 2023a MCA was also tested with community members during workshops in October 2022. Community members supported the draft MCA results.

6.3 MCA Results

This section summarises adaptation options identified to respond to erosion and inundation hazards for all four coastal towns, which achieved a positive score in the MCA and are considered suitable for considering in future planning.

These are detailed in Cardno 2019 and Shape Urban 2023a respectively, and replicated here for simplicity. More detail can be found in the source documents.

6.3.1 All Towns

It is recommended for all towns to implement adaptation options in the present day that will facilitate flexible adaptation in the future.

These are reflected in both source documents.

- AV - Avoid development of any new assets in the comnbined hazard zone.
- MR3 - Planning Controls: Prevention of further development / limiting existing use rights.
    - Introduce 'Special Control Area - Coastal Hazard: Inundation' (combined with NR3 Notifications on Titles).
    - Introduce 'Special Control Area - Coastal Hazard: Erosion' (combined with NR3 Notifications on Titles).
- AC2 - Planning Controls for Accommodation. Introduce a local planning policy outlining the Shire's requirements for building construction, land fill, and other relevant matters within the Special Control Area(s).
- PR1-5 - investigate sand and rock sources.
- NR1 - Monitoring. Establish a plan and implement long term coastal monitoring.
- NR2 - Ptotection Structure Audit

6.3.2 Lancelin

The options recommended follow from Cardno 2019 with the exception that Cardno 2019 recommended investigating the suitability of groynes and seawall as erosion mitigation options. As these are not considered effective at managing the combined impacts of erosion and inundation, they are now discounted.

An offshore reef, requested by the community as an option, has also been discounted due to the likely costs associated and lack of certainty.

Shape Urban 2023a includes a recommendation for investigating possible groundwater impacts combined with inundation, as this combination potentially increases vulnerability over the planning timeframe.

Cardno 2019 highlighted the importance of commencing the managed retreat process immediately, which is confirmed in Shape Urban 2023a. All recommendations should be progressed in parallel.

- AV - Avoid Development
- MR2 - Managed Retreat - Commence investigations to determine options for appropriate longer-term relocation / town scale adaptation.
- MR3 - Planning Controls for retreat
- NR4 - Prepare emergency evacuation plans for the affected areas.
- PR1 - Dune care / management.
- PR5 - Beach nourishment - investigate suitability.
- Investigate groundwater and stormwater.

6.3.3 Ledge Point

The options recommended follow from Cardno 2019.

Shape Urban 2023a includes a recommendation for 'DN - Do Nothing' in response to inundation, as inundation is not predicted to be a hazard during the planning timeframe.

All recommendations should be progressed in parallel.

- AV - Avoid Development
- MR1 - Leave Assets unprotected (LP1 and LP4 only)
- MR2 - Managed Retreat - Investigate options for retreat of assets at risk in the planning horizon.
- MR3 - Planning Controls for retreat
- NR4 - Prepare emergency evacuation plans for the affected areas.
- PR1 - Beach nourishment - investigate suitability (LP2 and LP3 only).
- PR2 - Groyne - further investigate suitability and appropriate apportionment of funding, noting that beneficiaries are predominantly private (LP2 and LP3 only).
- PR4 - Seawall - further investigate suitability and appropriate apportionment of funding, noting that beneficiaries are predominantly private (LP2 and LP3 only).
- PR5 - Dune care / management.
- DN - Do Nothing - inundation only.

6.3.4 Seabird

The options recommended follow from Cardno 2019.

Shape Urban 2023a includes a recommendation for 'DN - Do Nothing' in response to inundation, as inundation is not predicted to be a hazard during the planning timeframe.

All recommendations should be progressed in parallel.

- AV - Avoid Development
- MR2 - Managed Retreat - Investigate options for retreat of assets at risk in the planning horizon.
- MR3 - Planning Controls for retreat
- NR4 - Prepare emergency evacuation plans for the affected areas.
- PR2 - Groyne - further investigate suitability and appropriate apportionment of funding, noting that beneficiaries are predominantly private.
- PR4 - Seawall - further investigate suitability and appropriate apportionment of funding, noting that beneficiaries are predominantly private.
- PR5 - Dune care / management.
- DN - Do Nothing - inundation only.

6.3.5 Guilderton

Options recommended are from Shape Urban 2023a. All recommendations should be progressed in parallel.

- AV - Avoid Development
- MR1 - Leave Assets unprotected
- MR2 - Managed Retreat - Investigate options for retreat of assets at risk in the planning horizon.
- MR3 - Planning Controls for retreat
- AC1 - Redesign for inundation
- NR4 - Prepare emergency evacuation plans for the affected areas.
- PR5 - Dune care / management.

6.4 Preliminary Cost Estimates

Preliminary cost estimates were prepared specifically to inform the rating of the 'Cost' criteria in the options assessment.

Costs have been sourced from Cardno 2019 and Shape Urban 2023a. It is recognised that costs may have increased since the completion of Cardno 2019.

Preliminary cost estimates are sufficiently detailed for the purpose of screening options and use unit rates for typical options, factored to the management unit / area they are being applied to. Relevant rating and other information was sourced from the Shire and previous consultancy reports where available.

Adaptation option costs are summarised in Table 15.

TABLE 15: PRELIMINARY ASSET TYPE COST (SEAWARD OF 2030 EROSION LINE)

LOCATION	ASSET TYPE	OPTION	COST
General		Monitoring	$400,000-$500,000
		Specialist investigations	$450,000
		Data / asset management	$80,000
Lancelin	Infrastructure	Sand nourishment	~$48,000 per year
	Private land vacant	Groynes x4	$12,000,000
			$400,000 maintenance cost per decade
	Private land improvements	Seawall (700m length)	$2,700,000
			$300,000 maintenance cost per decade
	Private land commercial (16 properties)	Stormwater management investigation	$200,000
		Dune management and promotion of growth	$450,000
		Local dune surveys and geomorphology investigation	$150,000
		Rehabilitate dune through managed retreat	$800,000

TABLE 15: PRELIMINARY ASSET TYPE COST (SEAWARD OF 2030 EROSION LINE) (CONT'D)

LOCATION	ASSET TYPE	OPTION	COST
Ledge Point	Infrastructure	Sand nourishment	~$400,000-$2,000,000 every 1.5 to 5 years
	Private land vacant	Replace existing rock wall (design life 35-50 years)	$1,000,000-$2,000,000
			+ $50,000-$150,000 maintenance cost per decade
	Private land improvements (16)	New groynes to the south (15 year design life)	$4,000,000
	Private land commercial	Seawall	$1,200,000
			+ $130,000 maintenance cost per decade
Seabird	Infrastructure	Managed retreat	No detailed cost
	Private land vacant	Groynes (decision recommended for 2035 - end of seawall life)	$14,000,000
			+ ~$14,000,000 maintenance including sand nourishment
	Private land improvements (16)	Seawall (existing)	~$3,000,000-$4,000,000 replacement cost
	Private land commercial		$240,000 maintenance cost per decade
Guilderton	Residential and roads	Dune revegetation	$60,000
		Formalise beach access and limit 4WD via fencing	$18,000

6.5 Cost-Benefit Analysis

The purpose of Cost-Benefit Analysis (CBA) as part of this CHRMAP is to examine the selection of adaptation options through an economic analysis. It is applied only where an adaptation option scores positively in the MCA but has a significant financial investment that requires more rigorous economic evaluation to ensure value for money is being accurately assessed. The CBA is included in Shape Urban 2023a.

Cost-benefit was considered in net present value (NPV) terms, to compare options with time-variable costs and benefits. NPV is a standard economic analysis to compare options with time-variable costs and benefits. It allows for the adjustment of all future economic considerations to present day dollars for a more direct comparison.

The CBA was performed over a 100-year period, designed to match the project planning period. No Cost Benefit Analysis (CBA) was completed for Cardno 2019. As such, the CBA assessed cost benefit of positively scoring adaptation responses to the impacts of erosion and inundation at Guilderton, and inundation only at Lancelin, Ledge Point and Seabird.

The CBA has only assessed physical options (e.g., flood damage to property, the cost of seawalls, groynes, or other protection structures, etc.).

Inundation is expected to be negligible in Ledge Point, Seabird and Guilderton with no adaptation options proposed of significance to a CBA, and no adptation measures were further evaluated.

For inundation in Lancelin, the CBA suggests that adaptation works with a NPV of $1.5 million or less (today) are expected to be economically viable and works greater than $3.7 million are highly unlikely to be cost beneficial. This increases substantially if monitoring indicates that risk is more imminent that currently expected.

In Guilderton only erosion adaptation options were assessed in the CBA. the CBA suggests that adaptation works with a NPV of $570,000 or less are likely to be economically viable. Given the timing of the expected losses (later in the century) it is unlikely that any major protection works would be viable at present.

Given that uncertainty around the CBA estimates and assumptions will grow with time, estimates beyond 2040 should be viewed as indicative trends only. Long-term adaptation pathways should always be monitored and updated over time.

CBA information is provided in Shape Urban 2023a at Appendix C.

6.6 Benefit Distribution Analysis (BDA)

This CHRMAP identifies coastal hazards and recognises that the community is vulnerable in some areas to these hazards.

Where coastal hazards are deemed a risk to a community, a range of interventions may occur to mitigate this risk. These includes consideration of options to avoid impacts, retreat, accommodate or to protect.

SPP 2.6 and it's supporting suite of guidance introduces the concept of 'User Pays'. This establishes a principle that the beneficiaries of adaptation options should pay for them, as they stand to gain the most. Where adaptation options are designed to protect specific sections of coastal land and assets that is primarily to benefit private property it is recommended that the Shire determines who should contribute and how much.

A benefit distribution analysis (BDA) was undertaken to systematically estimate benefits to different parties as the result of these possible interventions in the Shire (protection only).

The BDA was developed to:

- Develop a shared understanding of who will benefit from coastal hazard interventions.
- Ensure a broad understanding is developed by capturing a range of benefits from different perspectives.
- Inform any future decision-making relating to funding contributions for interventions.

The BDA quantified relevant proportional benefits accruing to relevant groups of asset holders against a 'Do Nothing' base case, associated with existing and proposed protection works identified in this CHRMAP.

In the BDA benefit is defined as "the continued existence and operation of an asset, at its existing full functionality, landholding, service, or economic/commercial outcome as at the time of the BDA". A key assumption is that coastal management interventions will result in beneficiaries continuing to enjoy these benefits in perpetuity.

6.6.1 The Significance of the BDA

BDA is significant in the context of the substantial expenditure proposed in the CHRMAP. The cost of most adaptation options far exceeds the budgetary capacity of the Shire of Gingin, which means that additional funding will need to be sourced.

Availability of external funding is currently extremely limited and there is significant competition across the State (this is discussed further in Section 8.1). Additionally, most funding available requires the applicant to 'match' funding amounts; i.e. provide half of the required amount.

The BDA considers the current economic value of community amenity, private property (residential and commercial), potential revenue (rates etc) and wages received from commerce (a proportion of which is assumed to be returned to the community through expenditure). It then estimates the percentage benefit to each of these indices, and attributes that percentage as a benefit.

For example, an adaptation option that protects (benefits) $750,000 worth of private residential property, $200,000 worth of community amenity (a park etc) and creates $50,000 worth of revenue (from rates) has a total value of $1million in benefit. 75% of the benefit is attributed to the private residential development, and 25% to the broader community.

Although simplistic, in this case, the cost of the option should be funded at a rate of 75% from those private owners with the balance from other funding sources.

Using the simple example above, this would leave 25% of the funding still to be sourced through other funds which will need to include local rates (i.e. rate payer expenditure) combined with other funding such as State Government grants.

Per SPP2.6, funding applications for an adaptation option will be reviewed against the BDA, and will be viewed more favourably where the beneficiaries contribute to the adaptation option at the rate determined[1].

The BDA is thus very important to the implementation of the CHRMAP, and options presented in the CHRMAP should be understood in the context of how they can be achieved - *and who will need to contribute*.

The BDA is included in full in Appendix G. A summary of beneficiary findings is included for each town in Sub Sections 6.6.2 - 6.6.5.

In these sections the term 'community' can mean the local townsite community, or the community of the Shire, or the community of WA. An assessment of who will need to contribute for the community benefit portion has not been made in the BDA.

6.6.2 Lancelin

Lancelin represents a unique case of the four considered communities, as its vulnerability to inundation is so great that potential interventions other than substantial relocation will be cost prohibitive. Adaptation measures are also likely to be ineffective against the combination of erosion and inundation predicted.

The analysis indicates that approximately $775 million of economic value (community amenity, private property, revenue and wages) will potentially be impacted by inundation in Lancelin over the next 100 years, with the estimated cost of replacement for current infrastructure in Lancelin at $43 million.

The BDA notes that short term interventions are possible to extend the enjoyment of the coastal lifestyle but are likely to be sacrificial in the long term, and should be implemented only where the beneficiaries understand the time limited nature of the intervention.

Notwithstanding, the BDA assesses the value of protection proposed to mitigate the risk of flooding and finds that 90% of the benefit of providing coastal hazard adaptation would be apportioned to private interests, who should be obliged to contribute to temporary protection measures.

The BDA notes that long term relocation means that no intervention is being proposed that assures "the continued existence and operation of an asset, at its existing full functionality, landholding, service, or economic/commercial outcome as at the time of the BDA".

As such, it notes that in the long term BDA is not suitable for considering the preserved benefits of Lancelin; i.e. there is no long term beneficiary.

1. *NB: It should be noted that an application is never guaranteed to be successful; all applications are reviewed against funding criteria.*

In this context, long term adaptation at Lancelin will require a more sophisticated response to funding, including consideration of how best to effect long term relocation through negotiated land agreements.

Short term, existing use rights may be continued, and some flexibility for more temporary living typologies may be appropriate, applying an atypical planning approach for the existing townsite.

6.6.3 Ledge Point

Ledge Point will experience erosion vulnerability within the century.

LP1 and LP4

The analysis indicates that all of the benefit of adaptation in these two management units is of community benefit, and thus that 100% of the cost be borne by the community.

LP2

The BDA assesses the value of protection proposed to mitigate the risk of erosion and finds that 96.2% of the benefit of providing coastal hazard adaptation would be apportioned to private interests, who should be obliged to contribute to protection measures. The balance is community amenity and revenue, to be borne by the community.

LP3

The BDA assesses the value of protection proposed to mitigate the risk of erosion and finds that 93.7% of the benefit of providing coastal hazard adaptation would be apportioned to private interests, who should be obliged to contribute to protection measures. The balance is community amenity and revenue, to be borne by the community.

6.6.4 Seabird

Seabird already experiences erosion impacts and is likely to continue to experience the effects of erosion. In addition, the existing seawall requires funding to support maintenance.

SE1

The BDA assesses the value of protection proposed to mitigate the risk of erosion and finds that 90.7% of the benefit of providing coastal hazard adaptation would be apportioned to private interests, who should be obliged to contribute to protection measures. The balance is community amenity and revenue, to be borne by the community.

In SE1, if the existing seawall is to remain, this obligation extends to the maintenance of the seawall, and should also ensure appropriate management of the adjacent shoreline of SE2, and potential impact to those assets from the continued existence of the seawall.

SE2

The BDA assesses the value of protection proposed to mitigate the risk of erosion and finds that 81.7% of the benefit of providing coastal hazard adaptation would be apportioned to private interests, who should be obliged to contribute to protection measures. The balance is community amenity and revenue, to be borne by the community.

6.6.5 Guilderton

Guilderton will experience erosion vulnerability and limited inundation vulnerability within the century.

GF and GMR

The analysis indicates that all of the benefit of adaptation in these two management units is of community benefit, and thus that 100% of the cost be borne by the community.



7. ADAPTATION RECOMMENDATIONS

7.1 Overarching Recommendations

All assets within the study area become more vulnerable over time...

This requires consideration of other management and adaptation planning options that may be relevant to all assets. This section summarises the key strategic planning, statutory planning, and policy or governance interventions that the Shire will need to implement regardless of the proposed adaptation options chosen per area or asset. These instruments are particularly useful for implementing Accommodate and Planned or Managed Retreat options.

Recommendation 1: Special Control Areas

Amend the local planning scheme to introduce a Special Control Area (SCA) over all land identified as being vulnerable to coastal erosion delineated by the position of the 2120 coastal processes setback line and an SCA over all land identified as being vulnerable to the inundation extent of the 500-year ARI event in the year 2120.

An SCA is a planning layer that applies in addition to the underlying zoning and land use permissibility of the land. It identifies planning controls that apply in addition to any other requirements relevant to the underlying zone. An SCA can facilitate land use changes and development control within that area.

An SCA should be applied to relate specifically to land subject to coastal processes (as recommended in WAPC, 2019).

Each SCA is allocated a number and depicted on the LPS Map.

WAPC (2019) provides draft amendment text including the purpose, objectives and provisions for SCAs (see below). The purpose of the SCA is to provide guidance as to the appropriate scope of land use and development to be permitted within a coastal erosion and inundation hazard risk area.

Its objectives would be:

- To ensure land in the coastal zone is continuously provided for coastal foreshore management, public access, recreation and conservation.
- To ensure public safety and reduce risk associated with coastal erosion and inundation.
- To avoid inappropriate land use and development of land at risk from coastal erosion and inundation.
- To ensure land use and development does not accelerate coastal erosion or inundation risks; or have a detrimental impact on the functions of public reserves.
- To ensure that development addresses the Shire of Gingin CHRMAP prepared in accordance with SPP 2.6.

The SCA would include additional provisions such as:

- All proposed development within the SCA requires approval including development that would not ordinarily require development approval under the LPS (i.e. has an exemption); development provisions would be found within a Local Planning Policy (see Recommendation 2). Non-habitable buildings (e.g sheds), minor extensions and a change of land use may be exempted.

- Grouped and multiple dwellings should be prohibited, even if the allocated residential density code would otherwise allow for such development.
- Subdivision of land should be prohibited, even if the allocated density code would otherwise allow for such development.
- Referral of applications - any planning application should be referred to the Department of Transport, the Western Australian Planning Commission (WAPC) and any other relevant authority for advice and comment on the coastal risk.
- Minimum finished floor levels for habitable rooms should be 2.8 metres AHD (or other agreed minimum. Queenslander style development would be acceptable with non-habitable rooms such as laundries and parking permitted at ground level.
- Other development standards such as minimum AHD of water and power supply outlets.
- That any development proposed and approved in the SCA should be conditional, based on both a time limit and an event limit with a Notification on the Certificate of Title (see Recommendation 3).

Time limited approvals are permitted under the Planning and Development (Local Planning Schemes) Regulations 2015 (Schedule 2, Part 9 Cl. 72). For this CHRMAP, the time proposed on the approval would be the period in which the subject lot is identified as reaching a 'High' level of vulnerability according to the CHRMAP (see Section 4). For most properties this will be beyond 2070.

The applicant could later apply for a further time limited approval, which could be granted if the risk from coastal processes was still considered acceptable.

An event limited approval should be tied to external factors including a public road no longer being available/legal access no longer being available to the property, or when water, sewerage or electricity to the lot is no longer available as they have been removed/decommissioned by the relevant authority due to coastal hazards. The event limited approval should also include damage associated with a storm event that exceeds predicted impacts for the timeframe

This event limited approval would require removal and/or rehabilitation of the development to the way the site was before the approval.

An amendment to the Local Planning Scheme for the introduction of an SCA should also include a change of density for all land, where possible, to the lowest available density codes, which minimises the potential for subdivision and development of grouped and multiple dwellings[1].

It is recognised that this recommendation has the potential to cause concern amongst the community, especially for landowners, which is a natural response from citizens trying to protect property values. However, it must be noted that there is no obligation on Government to compensate land lost due to coastal hazards, and it is much more proactive for the Shire to identify land at risk in the future and take appropriate action. For landowners who may be considering purchasing or developing lands, it is important to note that they should not assume any funds will be forthcoming to support future adaptation responses or retreat.

(Options: MR3 - Planning controls for managed retreat / Prohibit expanding existing use rights, AC3 - Planning controls for accommodation).

1. If this amendment changes the amendment from a simple amendment to complex amendment, this part of the recommendation should be undertaken separately.

Recommendation 2: Coastal / Waterway Local Planning Policy

Prepare or update a local planning policy (LPP) to clarify the Shire's attitude and expectations in relation to coastal development within an identified area, including the type of permanent or temporary assets it is prepared to accept within the coastal reserve and/or on land subject to coastal processes, in line with the SCA.

LPPs are prepared and adopted according to the provisions in Part 2 Division 2 of the Deemed Provisions of LPS 9. The Shire may prepare an LPP in respect of any matter related to the planning and development of the Scheme area.

An LPP can provide more detail and guidance on what sort of development would be acceptable within the SCA and will also assist the Council in making planning decisions on coastal development requiring the exercise of discretion.

For example, on land at risk of erosion within the life of a proposed development the LPP may encourage use of structures that can be disassembled and/or transported should erosion come within a specified distance of the structure, or may encourage short term commercial uses. The policy would identify the Council's intention to require notifications on title as a condition of development approval.

The Shire has two LPPs that deal with coastal and waterway development and management – LPP 1.2 Foreshore Protection Areas and LPP 1.4 Foreshore Reserves along Water Courses. These LPPs should be updated or a new LPP(s) should be prepared by the Shire to reflect these recommendations.

(Options: MR3 - Planning controls for managed retreat / Prohibit expanding existing use rights, AC3 - Planning controls for accommodation).

Recommendation 3: Notifications on Certificate of Title

All freehold land identified as being at risk of impact from coastal processes (in an SCA) should have a notification placed on its certificate of title/s to make the owner and future landholders aware of the potential for the land to be impacted when the appropriate trigger occurs.

Section 165 of the Planning and Development Act 2005 enables a local government or public authority to place a notification on the certificate of title of land to make owners and future owners of land aware of being within or proximate to a future coastal hazard, as determined in accordance with SPP 2.6 and an endorsed CHRMAP, that may affect the use and enjoyment of the land. This is able to occur through placement of a notification to be a condition of development or subdivision approval, but cannot be done in the absence of an application.

However, placement of a notification on the title could take place at any time with owner consent (i.e. with owner's goodwill) under the Land Administration Act 1997.

Current wording recommended by the WAPC and in accordance with SPP 2.6 is as follows:

"This lot is located in an area likely to be subject to coastal erosion and/or inundation over the next 100 years from the date this notification is registered."

With regard to the above wording, the WAPC notes that a shorter timeframe than 100 years may be appropriate where identified in an endorsed CHRMAP.

(Options: MR3 - Planning controls for managed retreat / Prohibit expanding existing use rights, AC3 - Planning controls for accommodation NR3 - Notification on title).

Recommendation 4: Local Planning Strategy – Investigation Area

The Shire is in the process of preparing its Local Planning Strategy, which provides an excellent opportunity to identify the vulnerability in this study area in the strategic planning framework.

This will help to guide ongoing planning and development in the area, and provide an important signal to landowners and developers that the land in the study area has associated risks. This is an important first step to including known vulnerability in the statutory planning framework.

(Options: MR3 - Planning controls for managed retreat / Prohibit expanding existing use rights, AC3 - Planning controls for accommodation).

Recommendation 5: Purchase of Property Investigation

As noted in Recommendation 2, it is suitable to begin contemplating the gradual increase of the foreshore reserve in the vulnerable zone in the medium term. Such a decision could potentially result in an obligation on the Shire to acquire lands under current legislation (Injurious Affection).

It is recommended that the Shire investigate, as an alternative, the opportunity to acquire land as it become available on the public market. Such property could then be converted to a leasable asset and continue to be utilised up to the time when the risk becomes likely/very likely. Lease clauses may include immediate relocation of tenants. This option would result in a more flexible approach to adaptation over time, with assets being the long term responsibility of the Shire rather than private landowners.

(Options: MR3 - Planning controls for managed retreat).

Recommendation 6: Shire Infrastructure Asset Planning

It is recommended that the Shire ensure that all future infrastructure assets placed in the vulnerable zone either be sacrificial or have a design life that ensure the asset will be redundant before risk becomes almost certain. This can be done through the Shire's Asset Management Planning either spatially or via a database.

This will ensure that hard assets such as seating, pathways, toilets, playgrounds etc, as well as soft assets such as landscaping, be developed in such a way as to continue enjoyment of the coastal zone for as long as possible whilst also reducing or removing the risk associated with assets.

An asset management pathway should enable:

- Progressive relocation of non-critical assets (MR2) away from the coastal hazard zone once they reach the end of asset life, or replace assets with suitably durable and/or sacrificial infrastructure.
- Planning for the relocation of critical service infrastructure outside of the coastal hazard zone once they reach the end of asset life, or at a minimum, modify the service infrastructure asset so that it does not run parallel to the coastline and can be progressively removed when exposed to intolerable risk levels.

The Shire should also begin investigating opportunities for leaseback of land and land swaps in the context of planned and managed retreat. Discussions with the State regarding potential financial support is required and legal advice is required regarding the basis of agreements with landholders and whether opt-ins can be time constrained.

(Options: MR3 - Planning controls for managed retreat, NR2 - Protection structure audit).

Recommendation 7: Resilience Planning and Monitoring

A number of the at-risk assets could include management options that are already ongoing Shire management processes. This includes sand nourishment, and dune rehabilitation and protection.

Ongoing dune rehabilitation will be subject to securing grants, which the Shire can continue to apply for, support and manage.

These options were the preferred options across all criteria. This aligns with community preferences for more natural options.

In addition, the Shire will need to liaise with various service authorities to ensure that underground and above ground services are designed and maintained in recognition of the coastal hazards identified in this CHRMAP. The Shire should engage all local service authorities in the short term to understand their respective strategic planning intentions.

It is recommended that the Shire develop a system of assessment for priority resilience planning, which may include an ongoing schedule, as well as an event response criteria and action plan. This plan should include or should form part of a monitoring plan which should address the entire study area.

It is also recommended that the Shire use this plan to support ongoing grant applications through grant bodies such as Coastwest. The development of this plan may be supported by the Federal Coastal Management Plan Assistance Program or the State Coastal Management Plan Assistance Program.

(Options: NR2 - Monitoring).

Recommendation 8: Sand and Rock Source Investigation

A number of the at-risk assets include possible sand nourishment (importing sand from elsewhere) as a management option, however, it is acknowledged that the availability of sand for nourishment is not well understood.

Similarly, but for armour rock suitable for building coastal management structures, some options require rock which needs to be fit for purpose.

It is recommended that the Shire undertake a sand availability analysis to determine the capacity of local sand supplies, including the feasibility of both terrestrial and marine sand sources, and an analysis of the availability of such rock suitable for marine works, with suitable density, quarry yields, proximate location and tolerable costs. Potential environmental impacts should be considered in both studies, as well as any approvals required

(Options: PR1-5 - all Protect Options are supported by this recommendation).

Recommendation 9: Emergency Management Plan

Notwithstanding any of the above recommendations it is also recommended that the Shire prepare emergency management plans to cover unexpected events, significant coastal erosion and/or inundation resulting in emergency asset repair or removal. This plan could be undertaken in line with Recommendation 7 and include resilience planning and monitoring activities.

The development of an emergency management plan may be supported by the Federal Coastal Management Plan Assistance Program or the State Coastal Management Plan Assistance Program.

(Option: NR4 - Emergency evacuation plans).

Recommendation 10: Coastal Management Strategy

A Coastal Management Strategy (CMS) is currently being prepared and is an important mechanism to increase the protective capacity of the natural dune system and should address:

- The requirements of SPP2.6 and its supporting documentation
- The findings of the Shire of Gingin CHRMAP (2023b)
- Potential environmental issues such as biodiversity and environmental impacts, and detail a weed management strategy for the coastline
- Findings of Asset Management Plans as appropriate
- Include recommendations for closing excess beach access points, ensuring appropriately fenced and signed paths, signage for dune repair and clear signage for 4-wheel drive access and permissibility
- Include recommendations for an education strategy for coastal and environmental management, and work to inform the community about coastal planning and hazards. The education strategy should also include appropriate on-ground signage and information for beach access, camping and 4-wheel driving, where applicable.
- Monitoring for impacts of 4WD vehicles (where applicable) and general beach access on nesting habitats and migratory bird species in dune areas
- The need for a bush fire management plan for the dune and coastal areas

Options: MR2 - Remove/Relocate, AC1 - Revegetate, PR1 - Dune care / Sand management PR2 - Beach nourishment, NR1 - Monitoring, NR2 - Protection structure audit).

Recommendation 11: Other Instruments

Other instruments may be useful for implementing adaptation options. These include:

- Restrictive Covenants, which can be used to restrict present and future landholders from constructing protection structures and, to internalise the risk of building in inherently hazardous locations.
- Special Area Rates, which can be used to ensure that the costs associated with protection options are equitably distributed across beneficiaries.
- The requirement for a structure plan setting out development provisions and planning controls consistent with SPP 2.6 for vulnerable areas with new development/ subdivision proposed is essential.
- Communication as soon as practical with all local real estate agents regarding identified hazards so that they will be obliged to share the vulnerability of land in the area.
- Implementation of an internal procedure at the Shire of Gingin, to provide a note regarding identified hazards to settlement agencies to elevate the potential impact to the prospective purchaser, when they seek a property report linked to the sale of land (settlement agencies typically request these and they include details of rates paid, outstanding issues, approved development etc).

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

(Options: MR3 - Planning controls for managed retreat).

Recommendation 12: Shire Fact Sheet

Coastal hazard management is complicated for most people to understand - the modelling is difficult for even the most experienced administrators.

It is recommend that the Shire prepare both a short, simple version of this document, and that the Shire also prepares a short fact sheet for developing in the Shire, once a policy is developed.

7.2 Area-Based Recommendations

This section describes the recommended adaptation actions proposed for the areas which are identified at risk. Recommendations are provided for individual assets as appropriate.

This section introduces the concept of 'triggers'. Triggers are an indicator of increasing risk to an asset and are consistent with the 'S1' factor from SPP 2.6 – the extreme storm erosion factor, which was established for the study area in Cardno 2019 and confirmed in Shape Urban 2023a.

7.2.1 Flexible Adaptation

It should be noted that the CHRMAP policy preferences the most flexible adaptation pathways; the pathways that provide for the broadest possible decision making at the time when a decision becomes necessary.

For this reason, recommended options favour Avoid and Planned Retreat where these are available. Notwithstanding, when an avoid or retreat option is recommended, many other options remain valid.

This is the direct benefit of preferencing more flexible adaptation options, because it retains the greatest possible decision making available for a later time when the trigger has been met.

Regardless of the recommended option, planning can continue to be undertaken on all valid options until the point a decision is to be made. Every option recommended remains subject to detailed design and investigation, which will confirm the specific design and design life, the likely impacts to adjacent areas and detailed costings. In many cases, the onus of the detailed design will be a partnership between private landowners and the Shire, and will need to be predominantly funded by the private sector (see Section 6.6).

The risk treatment recommendations outlined in Section 5 provide a number of tasks that can be undertaken independent of the area or asset based recommendations – this will contribute to providing greater levels of certainty regarding particular options.

This CHRMAP will also require regular review, at which time the recommended pathways should again be considered. It is recommended that future reviews be undertaken comprehensively, for the whole of the Shire of Gingin coastline, where this is possible. The risk treatment recommendations outlined in Section 6.1 provide a number of tasks that can be undertaken independent of the area or asset based recommendations – this will contribute to providing greater levels of certainty regarding particular options.

7.3 Risk Management Pathways

This section describes risk management options and the pathways for the four coastal townsites and the associated triggers for risk management measures to be established. These management pathways provide the Shire with a decision-making strategy pathway that is made up of a sequence of decision points over time and at the appropriate time. This will allow the Shire to be responsive to changing circumstances over time and decisions can be planned, prioritised and prepared for.

Cardno 2019 details adaptation pathways for Lancelin, Ledge Point and Seabird. This CHRMAP reviewed these pathways in the context of the impact of inundation risks outlined in the CIS (Baird 2020) and any coastal changes that have occurred since document publication. It has confirmed that inundation risks apply to Lancelin and Guilderton and that inundation impacts for Ledge Point and Seabird are negligible enough not to impact existing pathways detailed in the Cardno 2019.

Sub-sections 7.3.1 - 7.3.6 outline the adaptation pathways for sections of coastal for the four townsites. These coastal areas reference Cardno 2019 management units for Lancelin, Ledge Point and Seabird.

Each coastal section includes;

- Key vulnerable asset identification to erosion for all sections and inundation for Guilderton and Lancelin sections
- Existing or proposed management pathway summary (depending on whether it reflects Cardno 2019 or this 2023 CHRMAP assessment)
- A visual representation of timing and decision making
- The risk management (adaptation) pathway

The MCA results and management options were tested with the community in Community Panel workshops and stakeholder meetings. Community members supported the MCA results and largely supported the recommended management options in the short term. In the longer term, community members also supported some management options that scored neutrally in the MCA, including protect options.

For the purposes of planning, the difference between 2090, 2110 and 2120 erosion and inundation timeframes in the 2019 Cardno CHRMAP report, the 2020 Baird CIS Study and the CHRMAP Inundation Integration project are considered negligible and the '100 year' planning horizon should be attributed to the 2090 timeframes.

SPP 2.6 and the CHRMAP Guidelines provide guidance on the appropriate triggers or criteria to commence a particular management response. They suggest that planned retreat allows development to remain and be safely used until the coastal hazard risk becomes unacceptable.

Initiation of the process to remove at risk development can be controlled by triggers such as:

Proximity trigger: Where the most landward part of the Horizontal Shoreline Datum (HSD) is within the Storm Erosion Allowance (S1) of the most seaward point of a public asset of interest or private property lot boundary. A proximity trigger can be linked to time limited approvals.

Replacement trigger: Where an existing coastal adapatation option has reached the end of its life cycle and needs either replacement or significant upgrade.

Access trigger: Where a public road is considered no longer available or able to provide legal access to the property. An access trigger is linked to an event limited approval.

Utilities trigger: When water, sewage, communications or electricity to the lot is no longer available as they have been removed/decommissioned by the relevant authority due to coastal hazards. A utilities trigger is linked to an event limited approval.

Damage trigger: Any property within the hazard zone and within a dedicated Special Control Area, that is damaged by a coastal hazard from an extreme weather event requires Shire approval before being repaired. The review process should involve re-fit of minor or moderately damaged assets to accommodate coastal hazards in the future; or removal and redevelopment outside the hazard zone for damaged assets. A damage trigger is linked to an event limited approval.

There is a preference for the list to be sequential. That is, a "proximity trigger" is recommended over a "damage trigger".

The following triggers have been adopted and applied to each management unit, and illustrated in Figure 25.

- Trigger 1: Proximity Trigger, the most landward part of the Horizontal Shoreline Datum (HSD) is within S1 of the most seaward point of a development or structure (noting that S1 changes across the coastal frontage).
- Trigger 2: End of the design life of an implemented accommodation or interim protection measure (replacement). Further accommodation or interim protection may be feasible, or retreat.
- Trigger 3: Event - Access, utility or damage trigger.

For specific sites, the criterion outlined in Trigger 1 has already been exceeded, indicating that action is required immediately (e.g. Grace Darling Park).

Trigger 2 is a future trigger; that is, a trigger identified as likely to occur when an existing or proposed accommodation or protection measure has reached the end of its design life cycle, at which point further decisions will need to be made.

Trigger 3 is relevant to sections of the Shire in the future where roads and services are likely to be impacted, or in the event of storm damage that exceeds expected impacts for the timeframe. In some cases, Trigger 3 may precede Trigger 2.

All triggers are assessed based on how tolerable the risk is; how much impact the community may be willing to experience.

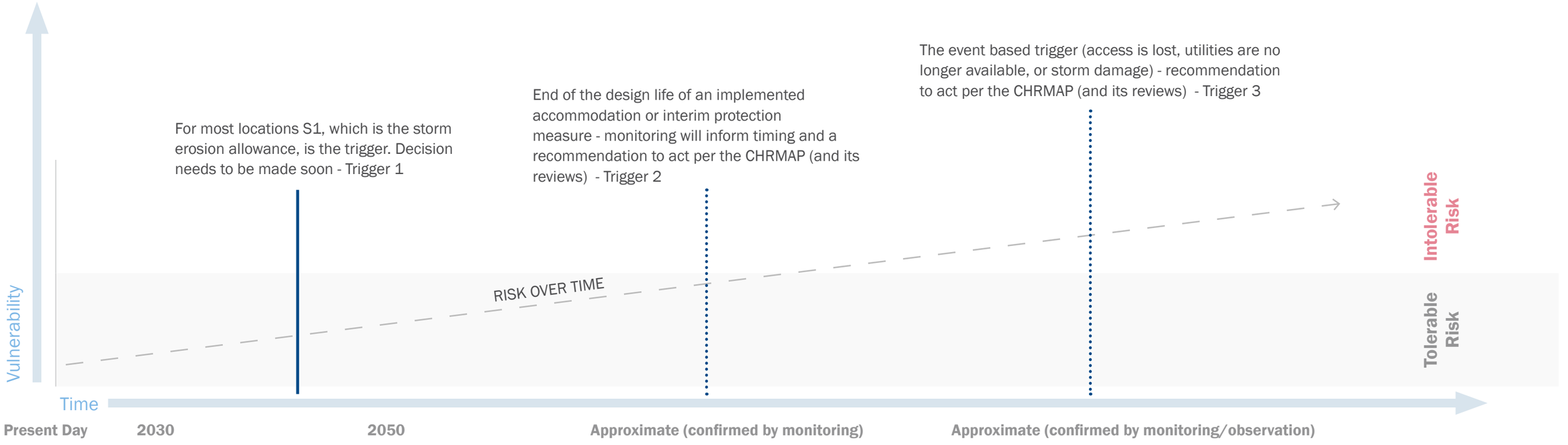


FIGURE 25: TRIGGERS AND HOW THEY APPLY

7.3.1 Lancelin

Recommendations for Lancelin apply to the entire townsite. The assets at greatest risk are described in Section 4.6.1, 4.6.2 and 4.6.3.

The recommended management actions for Lancelin are:

- AV - Avoid further development
- MR2 - Managed Retreat - Commence investigations to determine options for appropriate longer-term relocation/town scale adaptation.
- MR3 - Planning Controls for retreat
- NR3 - Notifications on Certificate of Title
- NR4 - Prepare emergency evacuation plans for the affected areas.
- PR1 - Dune care/management - especially adjacent to Grace Darling Park where a known dune breach point exists at the end of Hopkins Street.
- PR5 - Beach nourishment - investigate suitability.
- Investigate groundwater and stormwater.

In addition, the recommendations in Section 7.1 for the whole of Shire also apply to Lancelin.

The Lancelin adaptation pathway is at Figure 26.

At present day, the Shire can action a number of the recommendations. An important recommendation is to pivot from *only* sand nourishment adjacent to Grace Darling Park to bolstering of the primary dune and the observed breach points at the end of Hopkins Street.

It is now recognised that this location may have implications for inundation control in the short term, and it is worth trialling rehabilitation of the dune here.

Such a trial should be implemented, provided adequate secondary support such as bioengeineering (shade-cloth-and-post fencing, environmentally friendly jute matting) and monitored.

Grace Darling Park and the Sea Rescue Building will become increasingly more vulnerable over time; new coastal park areas shoudl be considered outside of the vulnerable zone.

It is noted that Lancelin's drinking water comes from the Lancelin Water Reserve, an unconfined superficial groundwater formation. This is located adjacent to the town of Lancelin, and extends to the north and east. This needs to be considered during the relocate planning process, as well as the recommended groundwater study.

As part of the retreat process, the Shire will need to consider other utility related issues.

If the dune revegetation measures indicate they may be successful, then these should be carried out as soon as possible.

By 2030, it is recommended that the Shire action the following:

- Notifications on Title and development restrictions
- Monitor for Adaptation Triggers
- Appropriate Foreshore Management

Along with the measures previously noted, by 2050 it is recommended that the Shire be prepared with appropriately zoned land available for relocation of properties/assets. This will remove hazard risk entirely, as illustrated in Figure 26 (subject to staged relocation).

Beyond 2050, the Shire will need to continue to monitor and review triggers and action relocation planning.



Pathways & Actions

Undeveloped Areas	**Avoid** AV - Avoid further development	
Developed Areas	**Managed Retreat** MR3 - Implement planning controls to prevent new development	**Managed Retreat** MR2 - Remove/relocate assets
	Accommodate/No regrets - until beyond 2050 AC3, NR4, NR3 - **Accommodate/No regrets** NR3, NR4 - Notification on Certificate of Title, implement emergency management plans to accommodate risk of inundation, work with settlement and real estate agents to notify of risks Commence land investigations and retreat planning in the short term (by 2050)	
	Protect PR1, PR5 - Dune care/management, including dune bolstering at Hopkins Street, beach nourishment	
Minor Infrastructure	**Managed Retreat** MR1, MR2 - Remove/relocate minor infrastructure as it becomes damaged, irreparable or unsafe	

FIGURE 26: LANCELIN ADAPTATION PATHWAY

7.3.2 Ledge Point - LP1 and LP4

Recommendations for Ledge Point - LP1 and LP4) apply to generally undeveloped areas north and south of the settlement and the same adaptation options are relevant. The assets at greatest risk are described in Section 4.7.1 and 4.7.2.

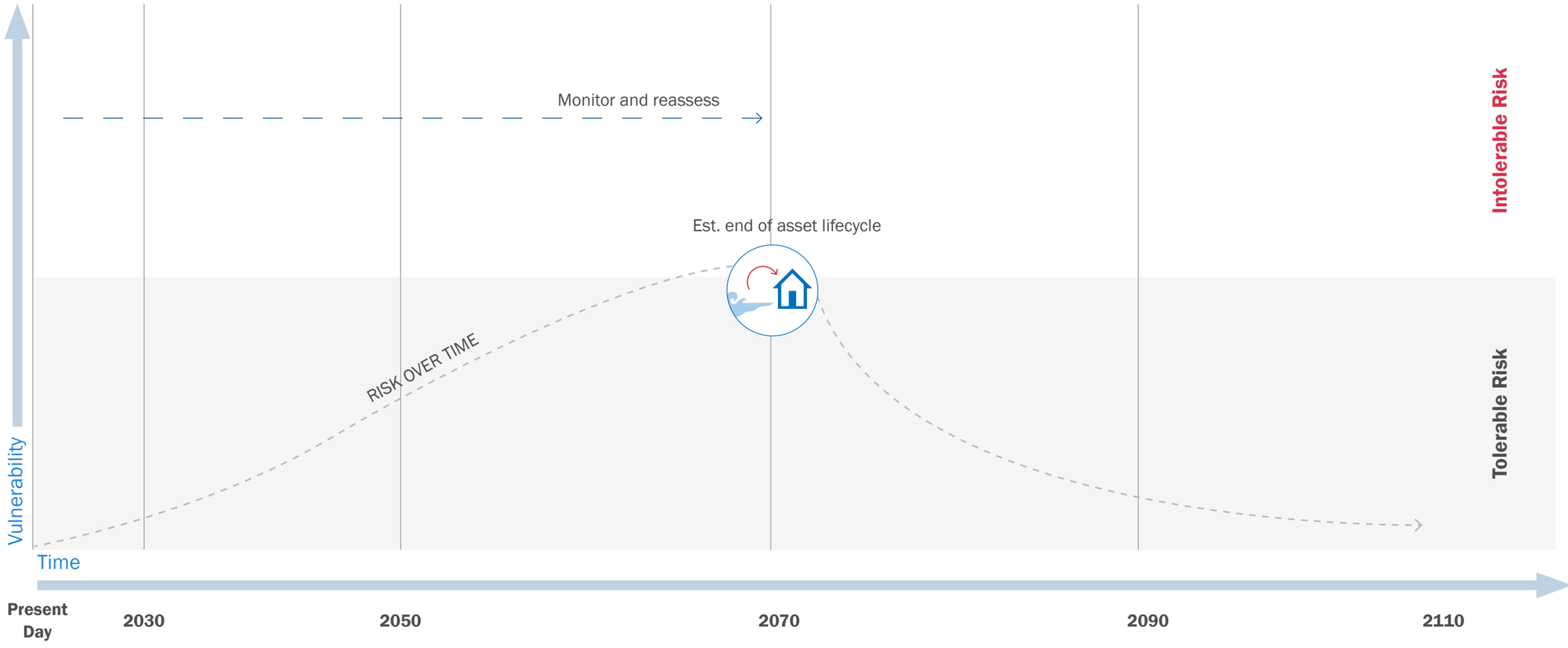
The recommended management actions for Ledge Point LP1 and LP4 are:

- AV - Avoid further development
- MR1 - Leave Assets unprotected
- MR2 - Managed Retreat - Investigate options for retreat of assets at risk in the planning horizon.
- MR3 - Planning Controls for retreat
- NR3 - Notifications on Certificate of Title
- NR4 - Prepare emergency evacuation plans for the affected areas.
- PR5 - Dune care/management.
- DN - Do Nothing - inundation only.

In addition, the recommendations in Section 7.1 for the whole of Shire also apply to Ledge Point.

The staged relocation of assets over the planning timeframe would remove risk. The Ledge Point LP1 and LP4 adaptation pathway is at Figure 27.

At present day, it is recommended that the Shire continue monitoring of the coastal beach and dune (monitoring of beach levels and vegetation quantity/quality).



Pathways & Actions

Undeveloped Areas	**Avoid** AV - Avoid further development		
Developed Areas	**Managed Retreat** MR3 - Implement planning controls to prevent new development	**Managed Retreat** MR2 - Remove/relocate assets	
	Accommodate/No regrets NR3, NR4 - Notification on Certificate of Title, Implement emergency management plans to accommodate risk		
	Protect PR1 - Dune care/management		
Minor Infrastructure	**Managed Retreat** MR1, MR2 - Remove/relocate minor infrastructure as it becomes damaged, irreparable or unsafe		

FIGURE 27: LEDGE POINT LP1 AND LP4 ADAPTATION PATHWAY

7.3.3 Ledge Point - LP2 and LP3

Recommendations for Ledge Point - LP2 and LP3 apply to generally developed areas central to the the settlement and the same adaptation options are relevant. The assets at greatest risk are described in Section 4.7.1 and 4.7.2.

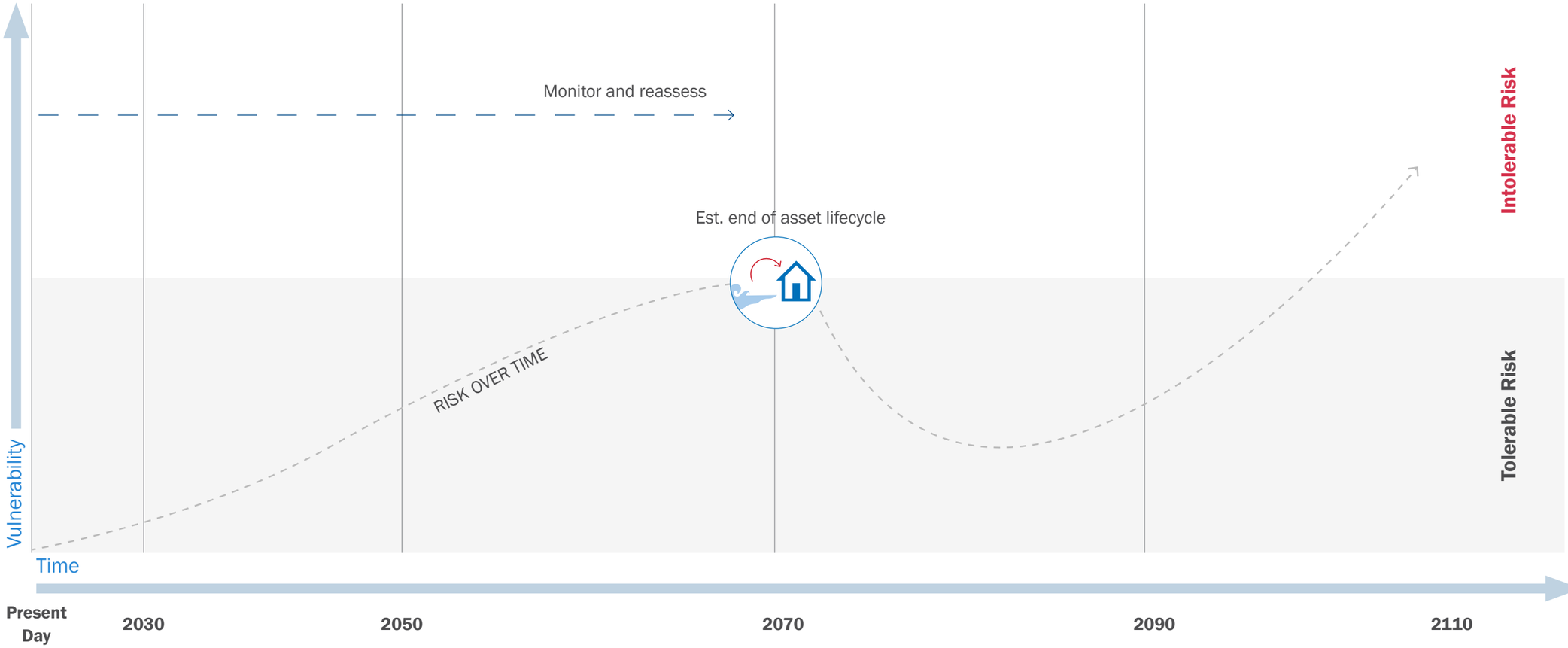
The recommended management actions for Ledge Point LP2 and LP3 are:

- AV - Avoid further development
- MR2 - Managed Retreat - Investigate options for retreat of assets at risk in the planning horizon.
- MR3 - Planning Controls for retreat
- NR3 - Notifications on Certificate of Title
- NR4 - Prepare emergency evacuation plans for the affected areas.
- PR1 - Dune care / management.
- PR2 - Groyne - enable impacted parties to further investigate suitability and appropriate apportionment of funding, noting that beneficiaries are predominantly private .
- PR3 - Seawall - enable impacted parties to further investigate suitability and appropriate apportionment of funding, noting that beneficiaries are predominantly private.
- PR5 - Beach nourishment - investigate suitability.
- DN - Do Nothing - inundation only.

In addition, the recommendations in Section 7.1 for the whole of Shire also apply to Ledge Point.

The staged relocation of assets over the planning timeframe would remove risk, whilst a protect option may require decisions to protect at multiple times over a 100-year horizon, dependent on the quality of the initial construction material, maintenance schedules, and changing climatic conditions. This is illustrated in the Ledge Point LP2 and LP3 adaptation pathway is at Figure 28.

At present day, it is recommended that the Shire continue monitoring of the coastal beach and dune (monitoring of beach levels and vegetation quantity/quality).



Pathways & Actions

Undeveloped Areas	**Avoid** AV - Avoid further development		
Developed Areas	**Managed Retreat** MR3 - Implement planning controls to prevent new development	**Managed Retreat** MR2 - Remove/relocate assets	
	Accommodate/No regrets NR3, NR4 - Notification on Certificate of Title, Implement emergency management plans to accommodate risk		
	Protect PR1, PR5 - Dune care/management, beach nourishment		
	Enable beneficiary investigation of: PR3/PR5 - groynes/seawall + PR2 - Beach nourishment		
Minor Infrastructure	**Managed Retreat** MR1, MR2 - Remove/relocate minor infrastructure as it becomes damaged, irreparable or unsafe		

FIGURE 28: LEDGE POINT LP2 AND LP3 ADAPTATION PATHWAY

7.3.4 Seabird North

Recommendations for Seabird North apply to to the settlement area north of the existing seawall. The assets at greatest risk are described in Section 4.8.1.

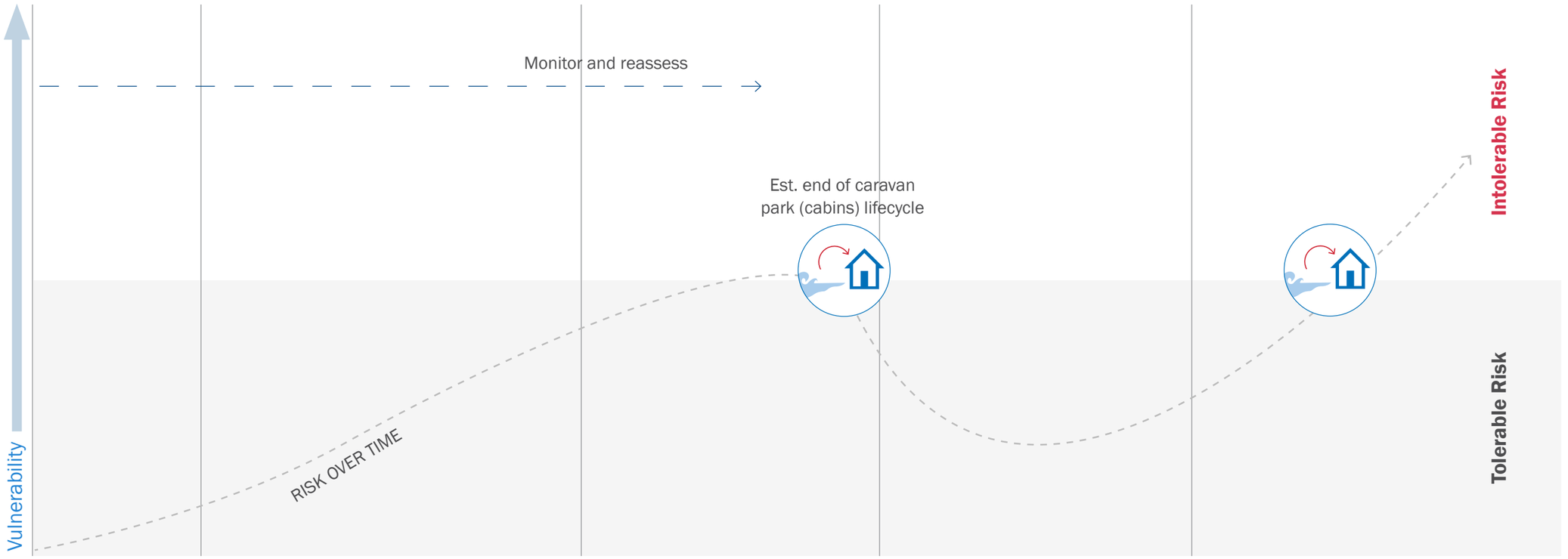
The recommended management actions for Seabird North are:

- AV - Avoid Development
- MR1 - Leave Assets unprotected
- MR2 - Managed Retreat - Investigate options for retreat of assets at risk in the planning horizon.
- MR3 - Planning Controls for retreat
- NR3 - Notifications on Certificate of Title
- NR4 - Prepare emergency evacuation plans for the affected areas.
- PR1 - Dune care/management.
- PR2 - Groyne - enable impacted parties to further investigate suitability and appropriate apportionment of funding, noting that beneficiaries are predominantly private.
- PR3 - Seawall - enable impacted parties to further investigate suitability and appropriate apportionment of funding, noting that beneficiaries are predominantly private.
- DN - Do Nothing - inundation only.

In addition, the recommendations in Section 7.1 for the whole of Shire also apply to Seabird.

As with Ledge Point, the staged relocation of assets over the planning timeframe would remove risk, however, a protect option may require decisions at multiple times over a 100-year horizon, dependent on the quality of the initial construction material, maintenance schedules, and changing climatic conditions. This is illustrated in the Seabird North adaptation pathway is at Figure 29.

At present day, it is recommended that the Shire continue monitoring of the coastal beach and dune (monitoring of beach levels and vegetation quantity/quality).



Pathways & Actions

Undeveloped Areas	**Avoid** AV - Avoid further development			
Developed Areas	**Managed Retreat** MR3 - Implement planning controls to prevent new development	**Managed Retreat** MR2 - Remove/relocate assets		
	Accommodate/No regrets NR3, NR4 - Notification on Certificate of Title, Implement emergency management plans to accommodate risk			
	Protect PR1 - Dune care/management			
	Enable beneficiary investigation of: PR2/PR3 - groynes/seawall			
Minor Infrastructure	**Protect** PR1 - Dune care/management	**Managed Retreat** MR2 - Remove assets as their risk becomes intolerable		

FIGURE 29: SEABIRD NORTH ADAPTATION PATHWAY

7.3.5 Seabird South

Recommendations for Seabird South apply to the settlement area adjacent and south of the existing seawall. The assets at greatest risk are described in Section 4.8.2.

The recommended management actions for Seabird South are:

- AV - Avoid Development
- MR1 - Leave Assets unprotected
- MR2 - Managed Retreat - Investigate options for retreat of assets at risk in the planning horizon.
- MR3 - Planning Controls for retreat, investigate option to remove the wall in the absence of funding being available for maintenance
- NR3 - Notifications on Certificate of Title
- NR4 - Prepare emergency evacuation plans for the affected areas.
- PR1 - Dune care/management.
- PR2 - Groyne - enable impacted parties to further investigate suitability and appropriate apportionment of funding, noting that beneficiaries are predominantly private.
- PR3 - Seawall - enable impacted parties to further investigate suitability and appropriate apportionment of funding, noting that beneficiaries are predominantly private.
- DN - Do Nothing - inundation only.

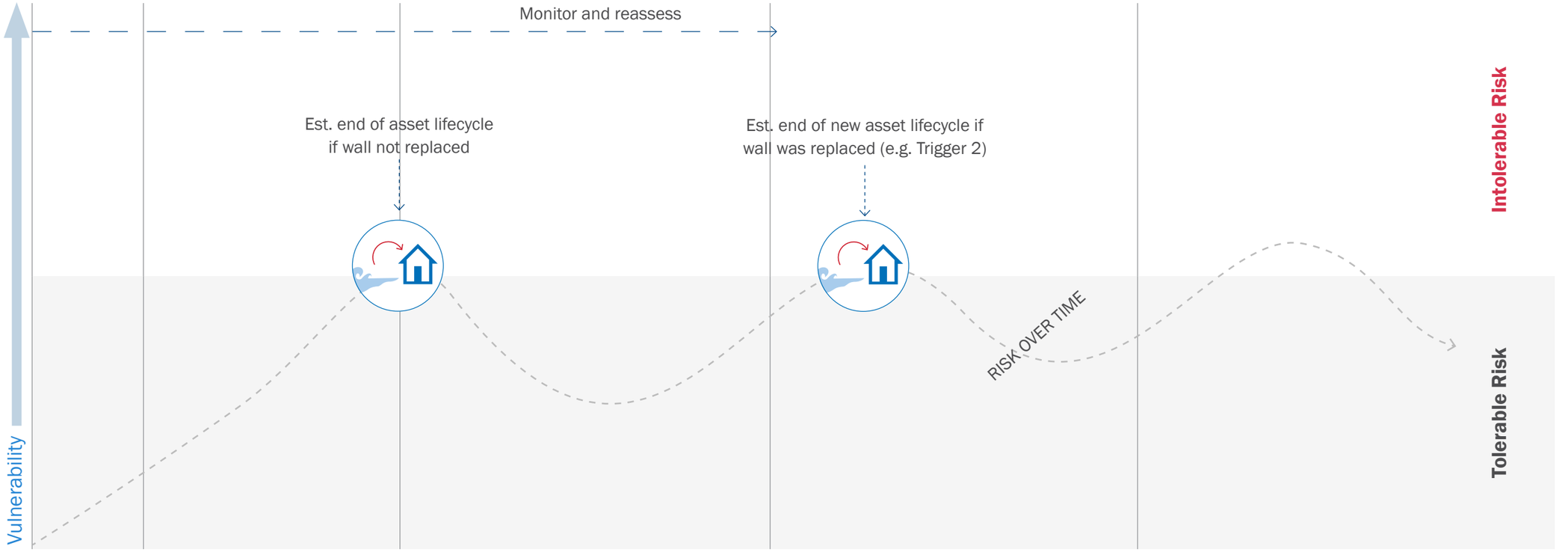
In addition, the recommendations in Section 7.1 for the whole of Shire also apply to Seabird.

This management unit is already protected by a new wall (2016), albeit with a relatively short life-cycle and with recognised maintenance funding challenges. The decision to continue a protect option at such time as the existing wall ceases to be effective will need to carefully weigh up the ongoing committment required to funding the adpatation works, particularly in light of the beneficiaries of the option.

An ongoing protect option may require decisions at multiple times over a 100-year horizon, dependent on the quality of the initial construction material, maintenance schedules, and changing climatic conditions

Alternatively, staged relocation of assets over the planning timeframe would remove risk entirely. The Seabird South adaptation pathway is at Figure 30.

At present day, it is recommended that the Shire continue monitoring of the coastal beach and dune (monitoring of beach levels and vegetation quantity/quality).



Pathways & Actions

Undeveloped Areas	**Avoid** AV, Avoid further development	
Developed Areas	**Managed Retreat** MR3 - Implement planning controls to prevent new development (investigate option to remove wall)	**Managed Retreat** MR2 - Remove/relocate assets
	Accommodate/No regrets NR3, NR4 - Notification on Certificate of Title, Implement emergency management plans to accommodate risk	
	Protect PR1 - Dune care/management	
	Enable beneficary investigation of: PR2/PR3 - groynes/seawall	
Minor Infrastructure	**Protect** PR1 - Dune care/management	**Managed Retreat** MR1, MR2 - Remove/relocate minor infrastructure as it becomes damaged, irreparable or unsafe

FIGURE 30: SEABIRD SOUTH ADAPTATION PATHWAY

7.3.6 Guilderton

Recommendations for Guilderton apply to the the whole townsite. The assets at greatest risk are described in Section 4.9.

The recommended management actions for Guilderton are:

- AV - Avoid Development
- MR1 - Leave Assets unprotected
- MR2 - Managed Retreat - Investigate options for retreat of assets at risk in the planning horizon.
- MR3 - Planning Controls for retreat
- AC1 - Design assets to withstand inundation impacts
- AC2 - Planning Controls
- NR3 - Notifications on Certificate of Title
- NR4 - Prepare emergency evacuation plans for the affected areas.
- PR1 - Dune care / management.

In addition, the recommendations in Section 7.1 for the whole of Shire also apply to Guilderton.

The staged relocation of assets over the planning timeframe would remove risk. The Guilderton adaptation pathway is at Figure 31.

At present day, the Shire can action a number of the recommendations.

By 2030, it is recommended that the Shire action the following:

- Notifications on Title and development restrictions
- Appropriate Foreshore Management

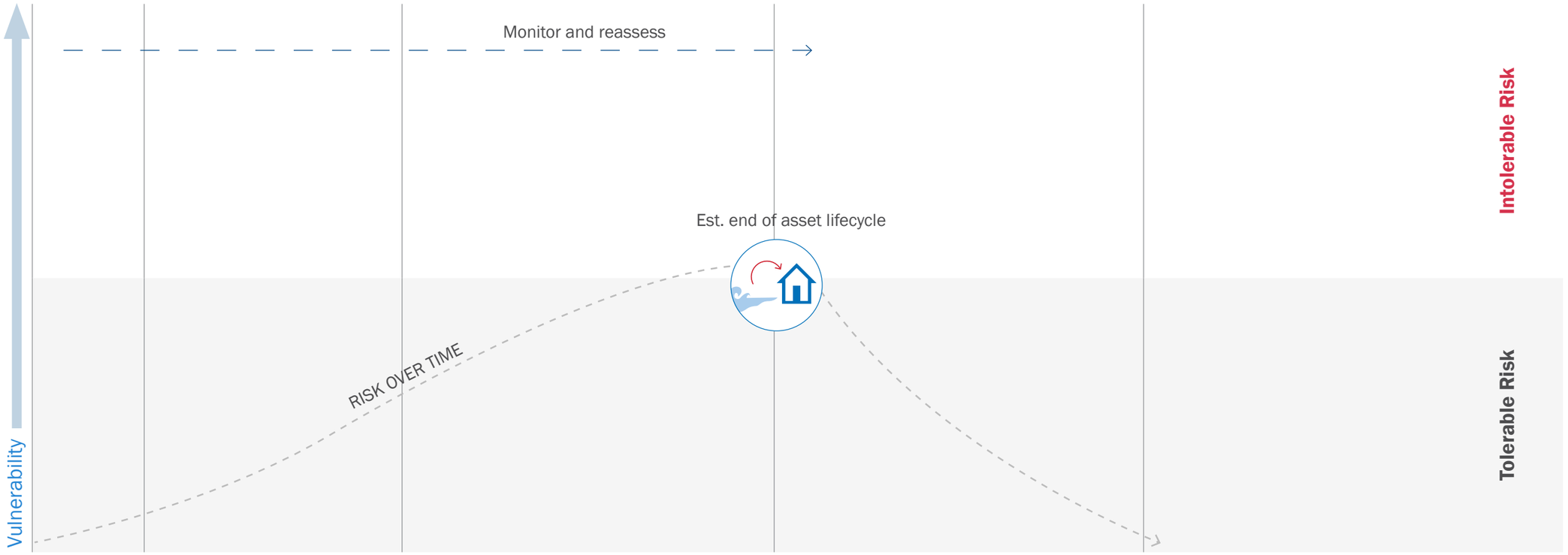
The first asset requiring removal on the open coast will be a section of Gordon Street. Access to properties closest to the coast may then be from Fraser St or the remaining length of Gordon Street. If the private properties in this area become within 40 m of the HSD their relocation should be triggered.

For the public car park, this can be retained within 40 metres of the most seaward point of the car park, as it serves to access the foreshore reserve area. Depending on the condition of the beach access stairs / boardwalk, this trigger may need to be flexible and revised over time.

Along with the measures previously noted, by 2050 it is recommended that the Shire be prepared with appropriately zoned land available for relocation of properties / assets.

By 2070 roads adjacent to Moore River may require significant repair or relocation and foreshore recreational infrastructure may require significant repair or relocation. The Shire should continue previously noted measures.

It is likely by 2120 that some residential properties on Gordon Street will be impacted and may require relocation.



Pathways & Actions

Undeveloped Areas	**Avoid** AV - Avoid further development	
Developed Areas	**Managed Retreat** MR1, MR3 - Leave assets unprotected, Implement planning controls to prevent new development	**Managed Retreat** MR2 - Remove/relocate assets
	Accommodate/No regrets (until approximately 2070) AC1, AC2, NR3, NR4 - Implement planning controls (SCA) for designing to accommodate risk, Notification on Certificate of Title, Implement emergency management plans	
	Protect PR1 - Dune care/management	
Minor Infrastructure	**Managed Retreat** MR1, MR2 - Leave assets unprotected, Remove/relocate minor infrastructure as it becomes damaged, irreparable or unsafe	

FIGURE 31: GUILERTON ADAPTATION PATHWAY



8. SHORT TERM IMPLEMENTATION

The CHRMAP process recognises the difficult decisions that will need to be made in the near future and it is recommended that the CHRMAP be updated each ten (10) years or as new information becomes available that may significantly affect the extent of hazards, such as new state endorsed Sea Level Rise benchmarks. It is recommended that the CHRMAP be updated collectively, that is, for erosion and inundation and for all four coastal townsites to be complete at the same time.

The preceding chapters outline a range of options for addressing the challenges of coastal erosion and inundation and their effects on the coastal zone over the 100-year CHRMAP timeframe.

The implementation actions recommended within this document acknowledge the hierarchy of controls and are guided by the outcomes of the MCA undertaken in Cardno 2019 which were reviewed for appropriateness with the inclusion of the Coastal Inundation Study (Baird, 2020) and the MCA undertaken for Guilderton.

Simplistically the four broad pathways are the four option categories from the hierarchy of controls: Avoid, Managed Retreat, Accommodate and Protect. Long term planning should focus on maintaining as much flexibility as possible, ensuring the community and stakeholders continue to have the opportunity to support appropriate adaptation options at a later date.

Particular focus should be placed on enabling avoid and retreat options in the future, especially given the long term commitment required for protect options as illustrated in Figure 28, Figure 29 and Figure 30.

Where retreat has been identified as an adaptation pathway, for example for Lancelin, planning for retreat should commence immediately even if it is not acted upon immediately.

8.1 Funding

Section 6.4 presents a summary of financial and economic implications to inform the Shire of the potential cost of coastal hazards over the planning timeframe and the cost to implement the recommended treatment options.

This section identifies all revenue-raising mechanisms available for obtaining funds to assist implementation. Funding mechanisms considered include:

- Operating budget, general rates and coastal management fund
- Special area rates / differential rating
- Yearly budgeting
- Levies
- Lease land management
- State grants
- Federal grants

8.1.1 Beneficiary (user) pays Operating Budget, General Rates and Coastal Management Fund

The individual land managers within the study area should consider establishing a coastal management fund that includes specific allowance for managing and adapting to the risk posed by coastal erosion and inundation. The purpose of this fund includes:

- To allocate a percentage of the organisation's operating budget for coastal management (between 1% and 2% is suggested).
- To save funds routinely so that when triggers are met the established management actions can be implemented efficiently.
- Acknowledge coastal management costs are forecast to increase in line with sea level rise.

8.1.2 Levies

It is recommended the Shire investigate the feasibility of establishing a particular levy for coastal management that would be a transparent source of the coastal management fund discussed in Section 8.1.1.

8.1.3 Lease Land Management

Coastal land vested with coastal managers in the study area and leased to third parties represents a unique scenario whereby implementation of some options may require specific lease clauses, but there is also potential to raise funds for coastal management.

During considerations of lease renewal (e.g. Lancelin and Guilderton Caravan Parks), coastal managers should consider the land use, vulnerability of the land, projected timeframe of unacceptable vulnerability, length of lease, recommended implementation options and need for any specific clause around triggers or required management actions by the lessee. Increases in lease amounts may be able to raise funds to help offset the cost of management.

8.1.4 State Grants - CoastWA

CoastWA aims to implement a strategic response to the growing impacts of coastal hazards to ensure sustainable land use and development on the coast for the long-term. For further information visit https://www.wa.gov.au/government/document-collections/coastwa-grants It comprises the following grant programs:

- Coastal Adaptation and Protection grants
- Hotspot Coastal Adaptation and Protection Major Project Fund
- Coastwest grants
- Coastal Management Plan Assistance Program

There are also two other grant programs relevant to coastal hazard risk management in WA:

- Royalties for Regions
- Local Government Financial Assistance Grants

The Department of Transport (DoT) administers the Coastal Adaptation and Protection (CAP) grants and the Hotspot Coastal Adaptation and Protection (H-CAP) Major Project Fund.

CAP grants provide financial assistance for local projects that identify and manage coastal hazards. The program aims to build partnerships with local coastal managers to help coastal hazard adaptation. CAP Grants fund up to 50% of project costs (and must be matched by the aplicant).

H-CAP supports projects which design and implement adaptation options at coastal erosion hotpots identified by the DoT. Invitations to apply for H-CAP are sent directly to eligible coastal managers (those with a completed CHRMAP and an identified erosion hotspot) There are three identified erosion hotspots in the Shire – Grace Darling Park, Ledge Point and Seabird.

Coastwest grants support eligible coastal land managers and community organisations to undertake projects that manage and enhance WA's coastal environments through rehabilitation, restoration and preventative actions. Coastwest grants are administered by the Department of Planning, Lands and Heritage (DPLH).

Coastal Management Plan Assistance Program (CMPAP) grants support eligible coastal land managers to develop adaptation and management plans and strategies for coastal areas that are, or are predicted to become, under pressure from a variety of challenges. CMPAP grants are also administered by the DPLH.

Other WA grant programs which may provide funding for coastal projects include Royalties for Regions and Local Government Financial Assistance Grants.

Royalties for Regions is facilitated by Department of Primary Industries and Regional Development. For further information visit: http://www.drd.wa.gov.au/rfr/whatisrfr/Pages/default.aspx

Local Government Financial Assistance Grants are administered by the Department of Local Government, Sport and Cultural Industries. They are grants funded by the Commonwealth Government and are distributed among 137 local governments in WA each year. The grants allow councils to spend the funds according to local priorities, and could include relocation of community facilities outside of the hazard zone once triggers are reached. For further information visit: https://www.dlgsc.wa.gov.au/local-government/local-governments/financial-assistance-grants

It should be noted that State funding mechanisms require matching cash contributions from the land manager, and as such, funding will still need to be sourced through one or more of the other available measures. State funding grants may also restrict access to funding where public monies would partially or predominantly benefit private landowners or users.

It should also be noted, as an per Section 6.6, that an application is never guaranteed to be successful; all applications are reviewed against funding criteria.

8.1.5 Federal Grants

Federal grants are variable and often unpredictable, but it is important for coastal managers to stay aware of any funding and grant programs available. Early planning and preparation will mean more competitive applications can be prepared quickly when grants are announced.

On 13 February 2022 the Australian Government announced the $50 million Coastal and Estuarine Risk Mitigation Program which is funded by the Emergency Response Fund. This program supports projects that reduce the impact of disasters on coastal communities. Successful applicants were announced on 4 November 2022. The Coastal and Estuarine Risk Mitigation Program will help drive long term resilience and sustainability by delivering priority projects that mitigate the impact of disasters on communities and economies.

Areas of focus for the Program include:

- Adaptation and resilience actions, including investment in grey infrastructure and green-blue infrastructure (which includes nature-based solutions)
- Planning, including local and regional risk assessments and mapping, business case development, preparation of community focused regional coastal management programs; and
- Investment in monitoring infrastructure and activities to understand the coastal and estuarine zone over time.

For more information visit https://nema.gov.au/programs/emergency-response-fund/coastal-estuarine-risk-mitigation-program#Overview

It should be noted that Federal funding mechanisms may also require matching cash contributions from the land manager, and as such, funding may still need to be sourced through one or more of the other available measures. Federal funding grants may also restrict access to funding where public monies would partially or predominantly benefit private landowners or users.

8.1.6 Beneficiary (user) Pays

'User Pays' principles essentially dictate that the beneficiaries of adaptation options should pay for them, as they are the beneficiary. Where adaptation options are designed to protect specific sections of coastal land and assets that is primarily to benefit private property it is recommended that the Shire allocate costs according to a Benefit Distribution Analysis (BDA) to understand who should pay and how much.

A BDA has been prepared for the Shire and was presented at Section 6.6. The BDA identifies where the community (locals and visitors) may contribute, where private interests have already been identified fro contribution or are not relevant.

The rate applied to beneficiaries may vary over the 100-year time line as more properties are impacted. The amount raised should consider the estimated 100-year cost for each option.

Community contribution could be in the form of a levy for locals applied to rates (8.1.2) or levies applied to accommodation, or paid parking at key tourist sites. Community contribution could also be proposed as a whole-of-WA benefit, where the Shire makes the case that protection of a townsite has a state wide benefit. This would support grant funding applications.

It should be noted that the assessment of, and allocation of funding for, the benefit distribution must include both capital and maintenance costs.

8.2 Implementation

The actions recommended for implementation have been categorised as those that are considered to be worth pursuing in the immediate term (0-5 years), the short term (0-10 years), actions that should be reviewed in the medium term after a review of the impact of the short term options (10-50 years) and those that should be considered in the long term (beyond 50 years) after relevant catalyst trigger points are reached with a strategic view of the likely adjustments over the next century, to 2110 and beyond.

For the 100-year planning horizon, timeframes are considered to commence at 2020. Short term pathways are 0-10 years from now (to 2030), medium term pathways consider actions required from 10-40 years from now (to 2070), whilst long term pathways require action beyond 40 years (2070-2120).

The short-term adaptation pathways are as outlined in Section 7. The risk management measures identified in those sections are focused in the shorter-term (25 years), however also include measures that allow the community and stakeholders to choose the most appropriate risk treatment options at future decision points for the medium to long-term risk management pathways.

8.2.1 Key assumptions

The timeframes envisaged in the coastal adaptation pathways are not absolute. These timeframes are related to the current state of local land planning, coastal processes knowledge and climate projections, as outlined in the CHRMAP. Therefore, the timeframes are typically not aligned on “worst-case” or “best-case” scenarios but often framed around planning for the worst in the hope that triggers are not met.

Other options may be envisaged over time, particularly if land planning practices, coastal processes knowledge or climate projections are changed. Therefore, the implementation pathway will evolve.

Options selected have been gathered through all the previous CHRMAP project stages. Community and stakeholder inputs continue to be required as decisions are made over time. Detailed design and planing is often required to implement CHRMAP recommendations, and options should be optimised and modified following such additional investigations.



9. LONG TERM IMPLEMENTATION

Recommended medium and long-term actions are summarised in Section 7.

The focus for longer-term timeframes is to identify broad pathways for future adaptation. For the purposes of planning, the difference between 2090, 2110 and 2120 erosion and inundation timeframes in the 2019 Cardno CHRMAP report, the 2020 Baird Coastal Inundation Strategy and the 2023 CHRMAP are negligible and the '100 year' planning horizon is attributed to any time beyond 2090 timeframes.

The long-term strategy informs future planning instruments, supports monitoring, recommends planning reviews and underpins collaboration between coastal land managers, stakeholders and the community.

The coastal management action mitigating inundation hazards is:

- **Planned / Managed retreat:** Using planning instruments to progressively move assets with low adaptive capacity out of the hazard zone

The two primary coastal management actions mitigating erosion hazards are:

- **Planned / Managed retreat:** Use the planning instruments and long-term plan to systematically move assets with low adaptive capacity out of the hazard zone
- **Protect:** Undertake works as necessary to prevent erosion to assets

As monitoring is undertaken and data is reviewed, long term pathways may change substantially, take longer to be triggered, or occur much sooner.


Photo Point

10. MONITORING AND REVIEW

Coastal monitoring will inform the short-term implementation through tracking of changes to the coastline and observance of trigger points. It can also increase the knowledge base for subsequent CHRMAP revisions and targeted investigations.

A summary of the key monitoring actions, including details of any recommended changes to the existing monitoring program, is included in this section.

10.1 Structures

Condition inspections.

Given the current fair or poor condition of some structures within the study area, an annual condition inspection by consultant engineers is recommended. It is recommended that this be complimented by post storm event inspections by Shire officers.

As repairs/upgrades are undertaken and condition improves, monitoring frequency can be reduced accordingly. Annual condition inspections should identify: condition rating, remaining life, and replacement cost with information added to the Shire's asset database.

Regular monitoring of the coastal management structures – e.g., seawalls, groynes.

These should be undertaken with consistent methodology to allow comparison between inspections. These can be commenced immediately, and the initial assessment would identify an appropriate review schedule for each structure, or if there is an issue with an asset. Such assessment should occur yearly to blend into the existing asset management reporting systems.

10.2 Storm events

In the event a significant storm event is to occur the following monitoring items are recommended:

- If there is sufficient time available undertake pre-storm beach profiles and beach photos.
- Post storm beach profiles and beach photos. If there is a significant change it the profiles, consideration should be given to undertaking full hydrographic survey and 3D beach scan.
- Post storm coastal structures inspection. This can be undertaken initially by a Shire officer, if any significant damage is evident a full condition inspect by a coastal engineer is recommended.

10.3 Beach

Beach profiles.

It is recommended beach profile surveys be undertaken annually, with the objective of capturing pre and post winter profiles. These are required to inform a number of short-term triggers. detailed 3D scanning beach surveys undertaken by DoT when available, nominally on a 2-3 year frequency, to fill in the gaps between the more regular beach profiles. Consideration should be given to the use of drone surveys as they become more readily available. These can be a cost-effective option and can provide a more detailed coverage of both the dunes and beach.

Corresponding monitoring photos should be taken at the same time as beach surveys – particularly for inundation events as it is often impractical to organise detailed survey at short notice. The community can be engaged to support such activies (e.g. the photo on page 158).

Hydrographic survey.

It is recommended that the Shire continues to obtain nearshore surveys to ~10m water depth, currently undertaken by DoT, as and when undertaken. A nominal frequency of 2-3 years would be desirable. The priority survey area remains Lancelin. The Shire should liaise with DoT.

Scanning beach survey.

It is recommended that the Shire continue to obtain detailed 3D scanning beach surveys undertaken by DoT when available, nominally on a 2-3 year frequency, to fill in the gaps between the more regular beach profiles. Consideration should be given to the use of drone surveys as they become more readily available. These can be a cost-effective option and can provide a more detailed coverage of both the dunes and beach.

Aerial photography.

Vertical aerial photography, captured by Landgate, and associated photogrammetry to plot shoreline change is recommended as an important tool for evaluating long-term changes in the position of the coast. It is recommended that the minimum collection frequency of 5 years be continued.

10.4 Data management and sharing

Data storage.

It is recommended that GIS metadata summaries of collected coastal zone data be created to ensure information is well-archived. There is also the opportunity for increased coordination with DoT regarding the collection of coastal photography and hydrographic survey to seek synergies with DoT and the Shire's spatial data team where data sets are shared. The GIS metadata summaries should be updated annual with any additional information collected.

10.5 Review

The CHRMAP should be updated at least every 10 years to maintain currency and should be a "living document". An earlier review should be considered if the following event occurs:

- Substantial storm events generating severe coastal hazards approaching or exceeding the CHRMAP projections
- Significant changes to land-use planning – such as complex amendments to the Local Planning Scheme
- New information becomes available which substantially affects the summary of local community values and assets (natural or built).
- Updates in climate change science, specifically local sea level rise projections
- Triggers are reached

Monitoring of CHRMAP outcomes, actions and future updates should always include consultation with stakeholders and the community to make sure any changes are communicated, and that the stakeholders positions are reflected in the coastal management outcomes.





11. IMPLEMENTATION RECOMMENDATIONS

This section provides a summary of the adaptation pathways proposed to respond to erosion and inundation in the Shire of Gingin's four coastal townsites.

Table 16 summarises the individual recommendations, highlights responsibility, the relevant trigger and the required timeframe. The timeframes used are immediate (now), short term (within 10 years), medium term (10-50 years) and long term (beyond 50 years). All timeframes for asset actions are approximate, as the trigger point is the key determinant of action.

With regard to cost, it should be noted that each individual option would require a detailed cost assessment based on final design and source material availability and cost.

Protection measures should not be implemented if maintenance schedules cannot be adhered to, as this places undue risk on future populations. Protection capital and operation (ongoing) expenditure should be allocated in accordance with the BDA, which should be subject to ongoing review.

Likewise, the identified triggers should be subject to ongoing monitoring and review.

In the first instance, monitoring should be in accordance with the monitoring recommendations which can be found at Chapter 10. However, regular review of the overarching hazard models should also occur. It is recommended that the Shire continue to monitor changes in international scientific understanding, and maintain a working relationship with the DPLH as well as the DoT's coastal planning personnel in this regard.

A review of immediate actions recommended in the CHRMAP should be undertaken within 2 years to confirm progress. A full review should be undertaken within ten (10) years and in conjunction with ongoing reviews of the Shire's Local Planning Strategy and Local Planning Scheme.

TABLE 16: SUMMARY OF CHRMAP RECOMMENDATIONS

NO.	RECOMMENDATION	RESPONSIBILITY	TRIGGER	TIMEFRAME
1	Local Planning Scheme – Special Control Area (all MUs)	Planning	Local Planning Strategy review or Scheme amendment	Immediate
2	Coastal Waterway Local Planning Policy for Shire (all MUs)	Planning and Environment	2026	Short
3	Notifications on Certificate of Title (all MUs)	Planning	Ongoing	Ongoing
4	Local Planning Strategy update (investigation area)	Planning	2024	Short
5	Purchase of Property Investigations (all MUs)	Corporate services	2025	Short
6	Shire Infrastructure Asset Audit (all MUs). Update Asset database to incorporate end of life date to facilitate future management of assets (all MUs)	Infrastructure and Environment	Ongoing	Ongoing
7	Resilience Planning including monitoring (in some cases immediate)	Infrastructure and Environment	Ongoing	Ongoing
8	Sand and Rock Source Investigation	Infrastructure and Environment	2025	Short
9	Emergency Management Plan (all MUs)	Infrastructure and Environment	2025	Short
10	Prepare a Coastal Management Strategy	Infrastructure and Environment	2023	Immediate
11	Avoid further development in hazard zones (all towns)	Corporate services	2023	Immediate/ Ongoing
12	Prepare a 'Developing on the coast in the Shire of Gingin' Fact Sheet	Corporate services	2023	Immediate
13	Stormwater Management Study for Lancelin	Infrastructure and Environment	2023	Immediate
14	Detailed Risk Assessment and Adaptation Cost Estimation Study for Lancelin	Corporate services	2023	Immediate
15	Dune Restoration - strategic vegetation planting, dune bolstering, sand fencing and management (all MUs)	Infrastructure and Environment	2023	Short/ Ongoing

TABLE 16: SUMMARY OF CHRMAP RECOMMENDATIONS (CONT'D)

NO.	RECOMMENDATION	RESPONSIBILITY	TRIGGER	TIMEFRAME
16	Shire Internal Procedure – Settlement Agent Note and real estate agent letter	Corporate services and Planning	2023	Immediate
17	Annual Beach Profile Surveys	Infrastructure and Environment	Ongoing	Ongoing
18	Rates Levy Investigation – Potential Protection Structures (all MUs)	Corporate services	2027	Short
19	Update 4WD Strategy	Infrastructure and Environment	2027	Short/ Ongoing
20	Rationalise and Formalise Pedestrian Access Paths (all MUs)	Infrastructure and Environment	2027	Short
21	Managed Retreat Planning Lancelin	Corporate services	2030	Short/ Ongoing
22	River Mouth Management for Guilderton (G-MR)	Infrastructure and Environment	Ongoing	Ongoing
23	Managed Retreat Planning Ledge Point (LP2, LP3)	Corporate services	2035	Medium
24	Investigate removal of Seabird seawall	Corporate services	2030	Short
25	Managed Retreat Planning Seabird private caravan park (SE2) and Residential Properties and Roads (SE1)	Corporate services	2035	Medium
26	Managed Retreat planning Guilderton - residential properties on Gordon Street, roads (Gordon Street, Edwards Street) and the Moore River front car park and foreshore area	Corporate services	2040	Medium
27	Redesign for inundation for Guilderton (G-MR)	Infrastructure and Environment	As new assets are proposed	Medium
28	Review all lease land and ensure condition of lease provide for coastal hazard management; include notice on property file	Corporate services	2023	Immediate
29	Progress Review	Major Projects	2025	Short
30	CHRMAP Review – Comprehensive	Major Projects	2030	Short



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APPENDICES

Appendix A - Shire of Gingin Coastal Hazard Risk Management and Adaptation Plan (Cardno, 2019)

Appendix B - Coastal Inundation Study (Baird, 2020)

Appendix C - Gingin Coastal Hazard Risk Management Adaptation Plan - Gap Analysis Technical Report (Shape Urban, 2022)

Appendix D - CHRMAP Integration Project Phase 2 Engagement Summary Report

Appendix E - CHRMAP Integration Project + Coastal Management Strategy Phase 3 Engagement Summary Report

Appendix F - Hazard Maps

Appendix G - Benefit Distribution Analysis Report

APPENDIX A

Appendix A - Shire of Gingin Coastal Hazard Risk Management and Adaptation Plan (Cardno, 2019)

Coastal Hazard Risk Management and Adaption Plan

Shire of Gingin

59917806



Prepared for
Shire of Gingin

17 June 2019

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Shaping the Future

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Executive Summary

The Shire of Gingin is preparing for the threats of climate change and sea level rise to the coastal settlements of Guilderton, Seabird, Ledge Point and Lancelin. Historically, the coastal towns were established to service fishing industry, agricultural activities; primarily sheep grazing within the hinterland, and are popular holiday destinations and retirement locations. This Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) has been prepared to provide a long term view of the potential future coastal erosion impacts to the townships of Seabird, Ledge Point and Lancelin and highlight possible strategies to adapt to the changing future oceanic and coastal conditions.

Development of the Gingin CHRMAP has followed the requirements of Western Australian State Planning Policy No. 2.6: State Coastal Planning Policy (SPP2.6) and supporting guideline documents. Previous work had highlighted the three coastal townships within the Shire as being at risk of coastal erosion and these areas form the focus for this CHRMAP. The coastal zones of each township were divided into management units (two at Seabird, four at Ledge Point and four at Lancelin) with similar asset types and exposure to coastal hazards. The risk and vulnerability assesment was applied to each management unit and results highlighted the most vulnerable management unit within each township, for which more detailed assessment of adaptation options were investigated.

A range of options for addressing the challenges of coastal erosion and its effects on the coastal zone over the next decade and century have been outlined. While it is natural that local communities would prefer to protect and preserve the current features of the coastal zone, the reality is that unless some new and innovative protection methods are developed, the costs of maintaining current features will likely become prohibitively expensive at some point in the future, given current sea level rise projections. The interim nature of protect options needs to be recognised across the community and, the adaption options developed and solutions optimised for social, environmental and economic (affordability) drivers.

The complex planning issues around setting the intent and establishing controls such Special Control Areas to either restrict development within currently developed areas and/or rezone currently undeveloped land to avoid future development are discussed for each of the management units within each township. A number of options was identified that aim to protect developed areas under imminent threat of a storm erosion event. An object of the state policy is to implement a beneficiary pays principle to apportion costs for protecting assets within defined coastal hazard areas. It is recommended that a comprehensive community and beach users engagement program be instigated to identify the key beneficiaries of any proposed protection option so the costs for implementation can be apportioned appropriately.

The recently released draft Planned and Managed Retreat Guidelines (WAPC, 2017) suggests the process for implementing future managed retreat may include compensation under provisions in the *Land Administration Act (1997)*. In reality, this is unlikely to occur in the Shire unless the State or Commonwealth Governments provide the majority of funding to acquire property. There is no obligation on Government to adopt a strategy that may invoke a requirement to compensate land owners for loss due to erosion. It is important to note that while the managed retreat option is recommended in this CHRMAP its future implementation will need further investigation of the implications for both Government and Private stakeholders. For Landowners who may be considering purchasing or developing lands in designated Hazard areas it is important to note that they should not assume any funds will be forthcoming to support future retreat.

A plan for implementation of recommended adaptation options over the next decade, to 2030 with a strategic view on the likely adjustments over the next century, to 2110 is outlined in the table below.

Task Name	Start	Finish	Cost Estimate $1,000s
Planning and Development Controls Review	**1 Jan '18**	**28 Oct '20**	**$155**
Review Planning and Development Controls and Recommend Amendments as required	1 Mar '18	27 Sep '19	$80
Amend current zone and SCA boundaries	1 May '18	31 Oct '18	$15
Update SCA special provisions	29 Nov '18	30 Jan '19	$20
Gingin LPS 9 Update and Endorsement by WAPC	17 Jan '20	30 Jun '20	$40
Monitoring	**1 May '18**	**14 May '29**	**$410**
Annual Beach Profile Surveys	4 May '18	14 May '29	$300
Horizontal Shoreline Datum (Aerial Photo Analysis)	1 May '18	2 May '22	$70
Post wave erosion Event (>2 yr ARI wave) Beach Profiles	11 Jan '19	17 Jan '19	$30
Cyclone storm surge flooding Event	15 Mar '20	18 Mar '20	$10
Specialist Investigations	**26 Feb '18**	**28 Jul '25**	**$415**
Comprehensive investigation of each community and visitors be undertaken to identify beneficiaries of proposed protection areas	26 Feb '18	30 Nov '18	$150
Investigate allowance for coastal foreshore reserve width to extend the 2110 Hazard line a sufficient distance to accommodate future relocation of foreshore assets	15 Mar '18	30 Jun '18	$15
Assess Current and Future Sediment Budget in the Secondary Cell	1 Jul '18	30 Jun '21	$80
Analysis of Flood, Storm Surge and Erosion event monitoring	14 May '20	5 Aug '20	$40
Investigate Storm Surge and Coastal Processes Interactions to define triggers, set FFL, CHRMAP, Water Management Plans and Emergency Management Plan overlaps	25 Mar '25	28 Jul '25	$50
Undertake economic analysis of options. Recommendations:	17 May '18	19 Sep '18	$80
Operational	**1 Feb '18**	**30 Nov '22**	**$80**
Establish Data Management and GIS system (time series, spot levels and remote sensing) relating to shoreline monitoring and general flooding in each Township to allow identification of trends over time, and Trigger assessment	1 Feb '18	26 Mar '19	$50
Update Asset database to incorporate end of life date to facilitate future management of assets	1 Feb '18	26 Mar '19	$20
Notifications - Potentially affected land owners by direct contact and property titles	1 Feb '18	30 Nov '22	$10
CHRMAP Review and Update (2022)	**1 Jan '19**	**30 Nov '22**	**$210**
Review Hazard line estimates (S1, S2, S3 and S4)	18 Feb '21	21 Apr '21	$25
Review Risk Assessment and Future Pathway Options	29 Apr '21	30 Jun '21	$40
Community and Stakeholder Consultation	1 May '21	31 Jan '22	$50
Update CHRMAP	24 Jun '21	2 Mar '22	$80
CHRMAP 2022 Endorsement by WAPC	7 Jul '22	30 Nov '22	$15
CHRMAP Review and Update (2027)	**8 Oct '26**	**8 Nov '28**	**$210**
Review Hazard line estimates (S1, S2, S3 and S4)	8 Oct '26	6 Jan '27	$25
Review Risk Assessment and Future Pathway Options	1 Jun '27	2 Aug '27	$40
Community and Stakeholder Consultation	1 Nov '26	31 Aug '27	$50
Update CHRMAP	24 Jun '27	1 Mar '28	$80
CHRMAP 2027 Endorsement by WAPC	6 Jul '28	8 Nov '28	$15

Abbreviations and Acronyms

Abbreviation	Description
AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
AS	Australian Standard
CHRMAP	Coastal Hazard Risk Management and Adaption Plan
DoP	Department of Planning (now part of DoPLH)
DoPLH	Department of Planning, Lands and Heritage
DoT	WA Department of Transport
HSD	Horizontal Shoreline Datum (see SPP2.6)
IPCC	International Panel on Climate Change
LAA	Land Administration Act (1997)
LGA	Local Government Area
LIDAR	Light detection and ranging
LPS	Local Planning Strategy
MCA	Multi-criteria analysis
MRA	M P Rogers and Associates
MSL	Mean sea level
NACC	Northern Agricultural Catchments Council
SCA	Special Control Area
SLR	Sea Level Rise
SPP	State Planning Policy
SPP2.6	State Planning Policy No 2.6: State Coastal Planning Policy (2013)
TEC	Threatened Ecological Community
The Shire	Shire of Gingin
WA	Western Australia
WAPC	Western Australian Planning Commission
Wheatbelt PIF	*Wheatbelt Planning and Infrastructure Framework 2015*

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1 INTRODUCTION

1.1 Purpose

Globally, mean sea level (MSL) has risen since the nineteenth century and is predicted to continue to rise, at an increasing rate, through the twenty first century (Intergovernmental Panel on Climate Change [IPCC], 2014), bringing changes to the Western Australian (WA) coastline over the coming decades. To prepare for sea level rise (SLR) induced coastal hazards, such as coastal erosion and inundation, all levels of government are putting processes in place to ensure that communities understand the risks to values and assets on the coast, and to plan to adapt over time.

Changes to MSL over the past century have been observed for the coastline between Fremantle and Jurien Bay. *Sea Level Change in Western Australia – Application to Coastal Planning* (DoT, 2010) reviews information relating to SLR at a local scale and recommends an allowance for SLR be adopted for planning purposes. The WA State Government revised the State Coastal Planning Policy (SPP2.6) in 2013 to incorporate a projected SLR for WA of 0.9 m between 2010 and 2110 (**Figure 1-1**).

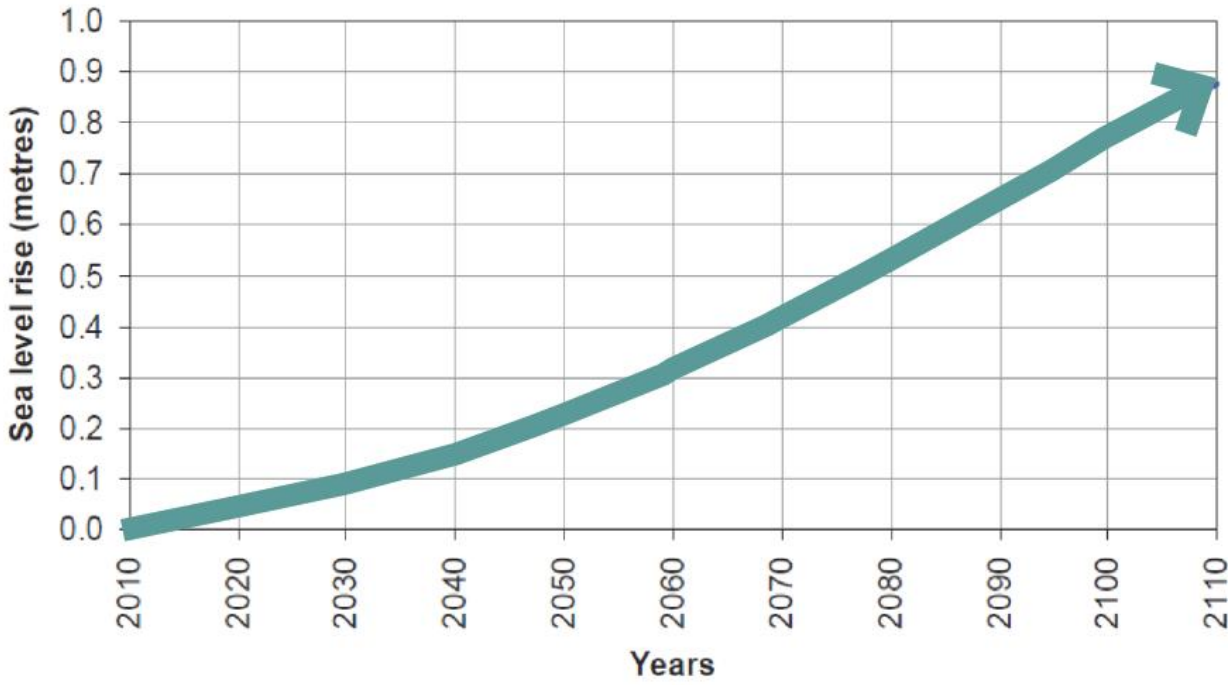


Figure 1-1 Recommended allowance for SLR in coastal planning for WA (source: DoT, 2010)

Gingin's coastline is low lying and sandy, featuring coastal dunes, nearshore reefs and islands, seagrass meadows, fishing stocks and rare vegetation communities. Eliot et al. (2012) describes the coastline of the Hill Primary Coastal Compartment (Guilderton to Jurien Bay) as low lying sandy coastal landforms, identified as being at risk to the impacts of coastal processes and hence, the town sites located on these landforms are vulnerable to changing coastal processes as sea level rises. Coastal processes include a complex set of interactions between atmosphere (climate change) and ocean scale phenomena that interact with the coastal landforms resulting changes to beach shape and form. These processes are often summarised as coastal erosion events associated with short-lived intense storms, shoreline recession associated with climate change-induced sea level rise and oceanic extreme water level events that cause flooding of the coastal areas by sea water. For sandy coastlines, increases in local MSL generally result in shoreline recession, with a "rule of thumb" often used, that a 1 cm rise will result in 1 m of landward recession of the shoreline (**Figure 1-2**; CoastAdapt, 2017).

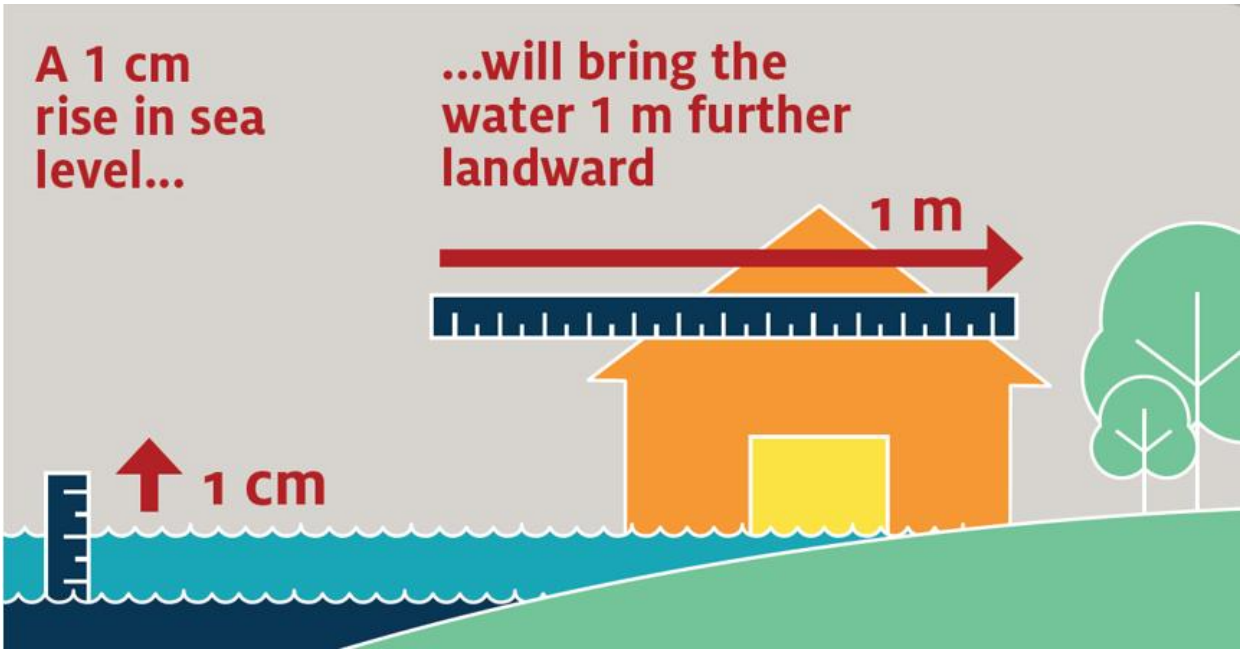


Figure 1-2 Influence of sea level rise on coastal erosion (source: CoastAdapt, 2017)

Development of this Coastal Hazard Risk Management and Adaption Plan (CHRMAP) is being undertaken by Cardno on behalf of the Shire of Gingin (hereafter called 'the Shire') to identify risks and plan adaptation responses to natural variability in coastal erosion and the expected impacts of SLR for the Shire's 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;

> Guide 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.

This CHRMAP focuses on the impacts of coastal erosion and shoreline recession processes while the impacts of coastal inundation caused by high sea level events associated with, for example, cyclones tracking down the west coast will be addressed by The Shire in future.

1.2 Overview of CHRMAP Process

The key policy governing coastal planning in WA is the *State Planning Policy No. 2.6: State Coastal Planning Policy* (Western Australian Planning Commission [WAPC], 2013a) (herein referred to as 'SPP2.6' or 'State Coastal Planning Policy'). The SPP2.6 policy 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 WAPC (2014a) has also developed the *Coastal hazard risk management and adaptation planning guidelines* which are less prescriptive, but are aimed to ensure that planning is carried out using a risk based approach with due regard to 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 *Statement of Planning Policy No. 2: Environment and Natural Resources Policy* (WAPC, 2003) and *Statement of Planning Policy No. 3: Urban Growth and Settlement* (WAPC, 2006).

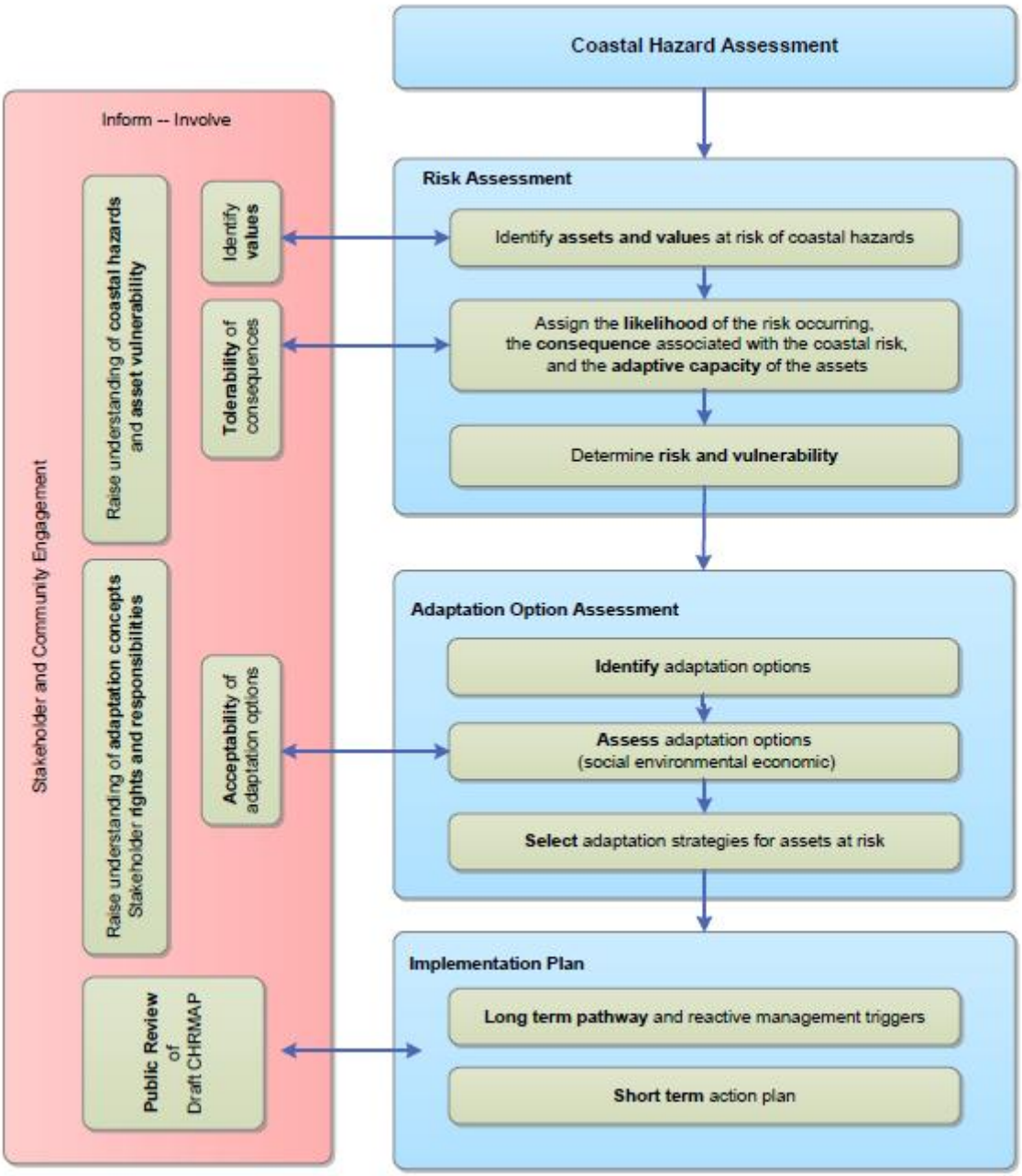


Figure 1-3 CHRMAP methodology flow chart (adapted from the WAPC, 2014a, CHRMAP Guidelines)

1.3 Guiding Principles and Concepts

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

1.3.1 Equity

Equity is a concept central to the purpose of the CHRMAP process. Australia's coastline is highly valued by the community as a public asset, with stakeholders ranging from individual property owners adjacent to the coast, to all levels of government, ratepayers within the local government area (LGA), taxpayers in general and users both within and outside of jurisdictional boundaries.

Responsibility for coastal planning lies with both the State and Local Governments, and in making decisions these authorities need to consider equity of access, equity of enjoyment and equity in terms of who benefits, who pays and the allocation of public resources.

Equity is also relevant to considerations about how a protection structure (for example a groyne) might impact 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. Protection structures can also result in significant impacts to coastal ecosystems, well beyond the local area in which the structures are installed (Gittman et al., 2016). Coastal protection may create beneficiaries (those who are protected from hazards) and potentially disadvantage others who may be considered to be affected 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 not considered fair and equitable. In a future of eroding coastlines due to SLR, sand can be a valuable commodity. The challenge is to ensure that planning and management is as transparent and equitable as possible.

1.3.2 Coastal Foreshore Reservation

The coastal foreshore provides beach access, public space for recreation and conservation, is a tourist attraction and provides habitat for native flora and fauna. Importantly, it can also provide a buffer to protect built assets, such as buildings and infrastructure, from coastal hazards.

SPP2.6 Schedule One provides guidance for calculating the component of the coastal foreshore reserve required to allow for coastal processes, to be contained in an appropriate coastal foreshore reserve (determined in accordance with SPP2.6 Clause 5.9) of greater width. This should ensure that, at the end of the planning timeframe, a coastal foreshore reserve is still present and not exposed to the adverse impacts of erosion and inundation. It is behind this reserve that development is able to be considered. Having said this, Schedule One also contains Clause 7 – Variations that outlines specific instances where certain types of development may be considered appropriate within a coastal foreshore reserve, regardless of the allowance for physical coastal processes.

The allowance for physical processes is based on the 100 year hazard line, determined in accordance with SPP2.6. In addition to the allowance for physical processes, such as erosion, the foreshore reserve includes land allocation for maintaining the values, functions and equitable use of the coast over the 100 year planning timeframe (see **Figure 1-4**).

Permanent and easy public access to the beach and coastal foreshore reserves is a fundamental coastal planning objective. The coast and coastal foreshore reserves are public assets which should not, now or in the future, become the exclusive domain of private landowners by virtue of the erosion of coastal reserves or other coastal processes. Coastal reserves should be wide enough to 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 SLR.

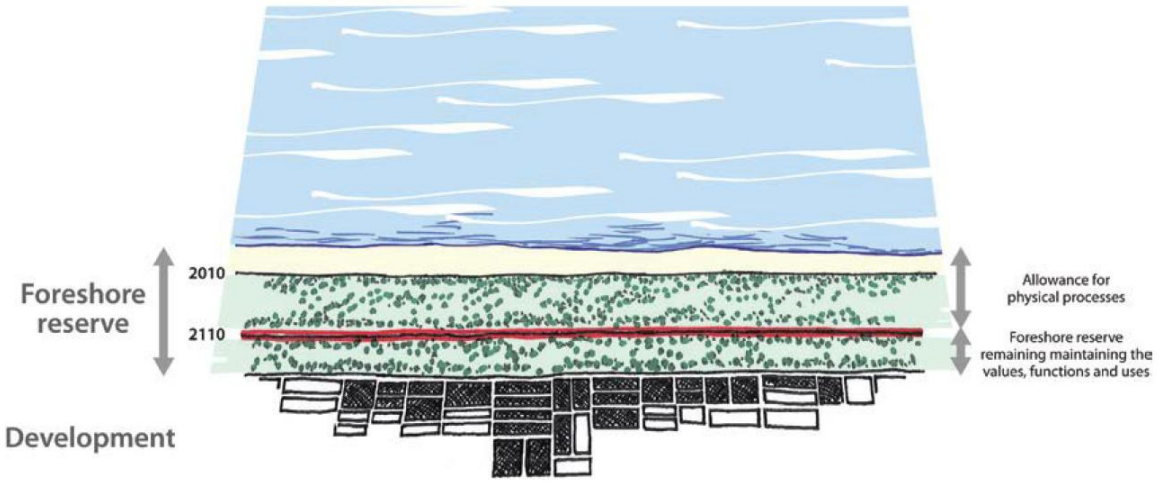


Figure 1-4 Coastal foreshore reserve – sandy coast example (source: WAPC 2013b)

1.3.3 Rights and Responsibilities

In WA, landowners own the rights to develop and use land as granted by land use regulations; they do not own the land itself. 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 that 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 maximise beneficial use of the coast from an economic, social and environmental perspective. Mechanisms for managed retreat may require public expenditure and in some instances, where public good can also be demonstrated, protection may also be publicly funded. Where the benefits of a particular coastal protection measure are limited to private beneficiaries, there is an expectation that the cost will be borne by those beneficiaries under the "user pays" principle.

1.3.4 Hazards and Risks

A hazard is a potential source of harm or adverse impact. Sea level rise is predicted to result in hazardous erosion and coastal inundation along the Gingin coastline. Coastal erosion and inundation hazards are calculated in accordance with SPP2.6 and may be used to identify assets and values at risk of coastal hazards (see **Figure 1-3**). This current CHRMAP focuses on coastal erosion hazards. Hazards associated with coastal inundation will be included in future CHRMAP reviews and updates, as resources to carry out these assessments become available.

Details of relevant coastal hazard assessments are provided in the Coastal Erosion Hazard Assessment Reports (MP Rogers and Associates [MRA], 2016a and b). Key outcomes are summarised in **Section 2**, and hazard maps derived from these reports are presented in **Appendix A**.

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) (see **Section 2.9.1**).

1.3.5 Assets and Values

An asset is defined as a useful or valuable entity. In the current CHRMAP, assets include:

> Natural features such as beaches and native vegetation;

> Approved buildings and other structures (houses, sheds, shade structures);

> Infrastructure such as fences, lighting, water and sewerage;

> Roads, paths and walkways; and

> Coastal structures, such as jetties, boat ramps, seawalls and groynes.

As defined in *Climate change adaptation for settlements and infrastructure – A risk based approach* (AS 5334-2013) an asset's value can be tangible or intangible, financial or non-financial. Examples of non-tangible assets include ecological function and coastal views. The value of an asset includes consideration of risks and liabilities, and can be positive or negative at different stages of the asset's life. Economic assets can be further categorised as public or private.

Values in the context of the CHRMAP further encompass the economic, social (including heritage) and environmental values of the coastal area.

1.3.6 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 (2014a) 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 (for example coastal climate change impacts).

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

1.3.7 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 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 (see the 'Risk Assessment' component of **Figure 1-3**).

1.3.8 Temporal scales

Coastal hazard assessment and management needs to 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 (also described as 'long term' in this report). Practical planning for implementation, from the Shire's point of view, requires a focus on the 'short term' (up to the 2030 planning timeframe). 'Medium term' is also used throughout this report to refer to the period up to the 2070 planning timeframe.

The need for identifying potential long term risks is important to ensure that these risks are taken into consideration in the Shire'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 prior notice of the associated hazards.

This CHRMAP includes an assessment of immediate to long term vulnerability of coastal assets, associated with predicted sea level rise. Long term adaptation pathways have been developed for areas of the coast being assessed, as required by SPP2.6. Short term implementation plans have also been developed, focusing on areas where assets have been assessed as vulnerable by the 2030 planning timeframe. These short term implementation plans are designed such that they do not prevent the long term pathway from being realised.

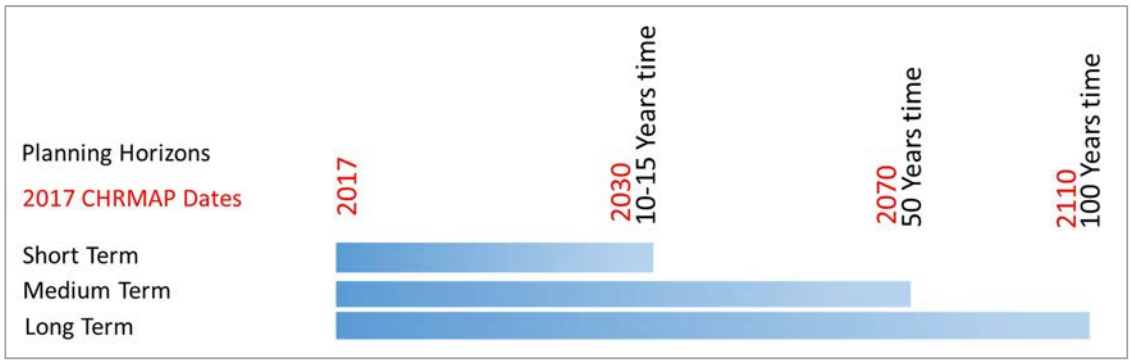


Figure 1-5 Coastal planning timeframes used in this report

1.3.9 Spatial scales

In accordance with SPP2.6, the coastal hazards along the Shire's coastal zone have been identified at a coastal sediment cell scale (MRA, 2016a and b). The policy requires assessment at this scale to account for the impact of existing controls and future management techniques on areas of the coast that are away from the direct area of interest (a common example of this is erosion down-drift of a groyne or marina). For more information on the classification of coastal sediment cells, and their function, within the Shire see Stul et al., 2014.

Using the hazard lines derived for the broader sediment cell scale this CHRMAP then looks at finer spatial scales, to assess the vulnerability of assets and to simplify management planning. 'Management units' have been defined based on the physical attributes of the coast. Within each management unit assets are considered individually or grouped according to the type of asset and in consideration of current land use. The risks and vulnerability of individual or groups of assets within each management unit have then been assessed.

1.3.10 Adaptive management

'Adaptive management' is a term given to a structured, iterative process of robust decision making in the face of uncertainty (Allan & Stankey, 2009). In the context of this CHRMAP, it allows for predictions of coastal hazards and the development of long term planning pathways to mitigate against risks, while at the same time acknowledging that predictions are likely to change over time. Management pathways have been developed based on predictions of present and future coastal erosion hazards, but implementation of management techniques should be driven by appropriate triggers (**Figure 1-6**). This approach ensures the timing of management (or changes in management) is appropriate to the actual sea level rise effects as and when they occur in future (for example, if shoreline recession is occurring faster than predicted, the management action to retreat may be implemented earlier than predicted).

The CHRMAP, therefore, recommends appropriate triggers to guide management. Monitoring programs are also recommended to identify when triggers have been reached, and to validate the current predictions of shoreline recession and the extent of coastal erosion hazards. Recommendations for further investigation and review are also made to better inform the refinement of management pathways in the future.

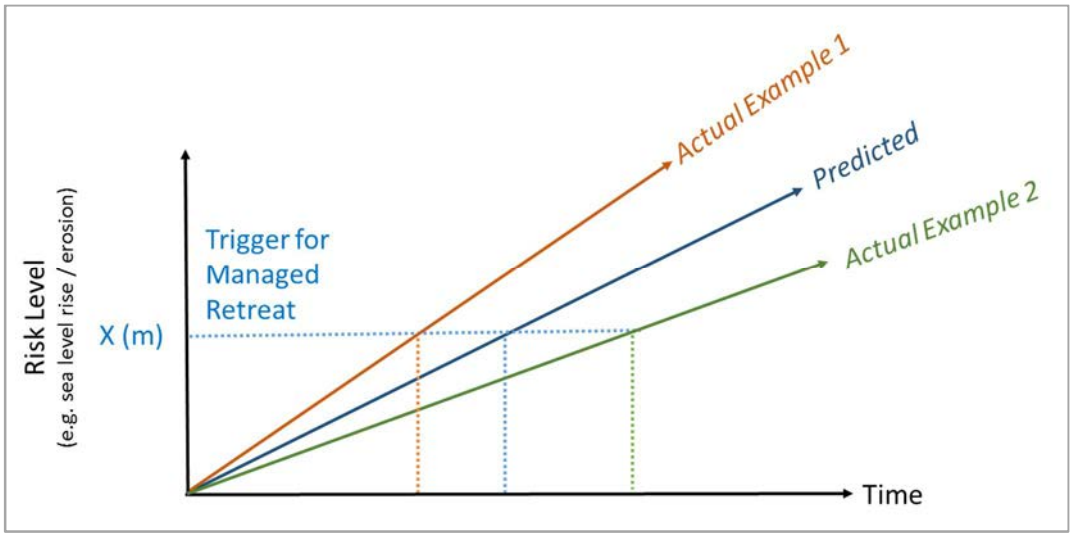


Figure 1-6 Conceptual timing for managed retreat in relation to predicted coastal hazards

1.4 Key Coastal Processes Concepts

A basic understanding of coastal processes is important for understanding the issues and constraints associated with managing the hazards of sea level rise and coastal erosion. **Figure 1-7 a)** illustrates the multiple processes involved in adding (accretion; yellow) and removing (erosion; red) sediment from the shoreline. The size of the arrows broadly represent the volume of sediment movement involved in each process. **Figure 1-7 b)** shows how a storm can remove sediment from the beach and reshape the shoreline profile, due to a combination of elevated water level and wave action. As mean sea level increases, storms can have a greater inland 'reach' and less of the removed sediment returns to the beach, leading to long term recession.

A key step in the coastal hazard identification is the definition of a horizontal shoreline datum (HSD) along the coastline, which "should define the active limit of the shoreline under storm activity" (WAPC, 2013a). Effectively the HSD is the shoreline at a particular point in time that can then be used as a bench mark or reference for assessing historic and future potential shoreline movement. For the Shire's predominantly sandy coastline, this has generally been determined from the 2012 LIDAR survey data as the point of intersection of the local peak still water level (determined at each town) with the beach/foredune surface level profile. This point is typically close to the seaward margin of coastal vegetation at the time of assessment (see MRA, 2016a and b and GHD, 2015). The HSD is the bench mark from which the extent of coastal hazards, at each planning timeframe, is measured. The HSD presented in hazard mapping for this CHRMAP has been defined for the 'present day' at the time that each coastal hazard assessment was undertaken (generally based on the 2012 LIDAR survey information). The HSD is constantly moving and its position, relative to assets and future monitoring of the shoreline position and determination a future HSD is one of the key triggers for implementing management responses. It must be noted that future revisions of this CHRMAP will be based on new information, and the HSD and hazard lines will be recalculated accordingly.

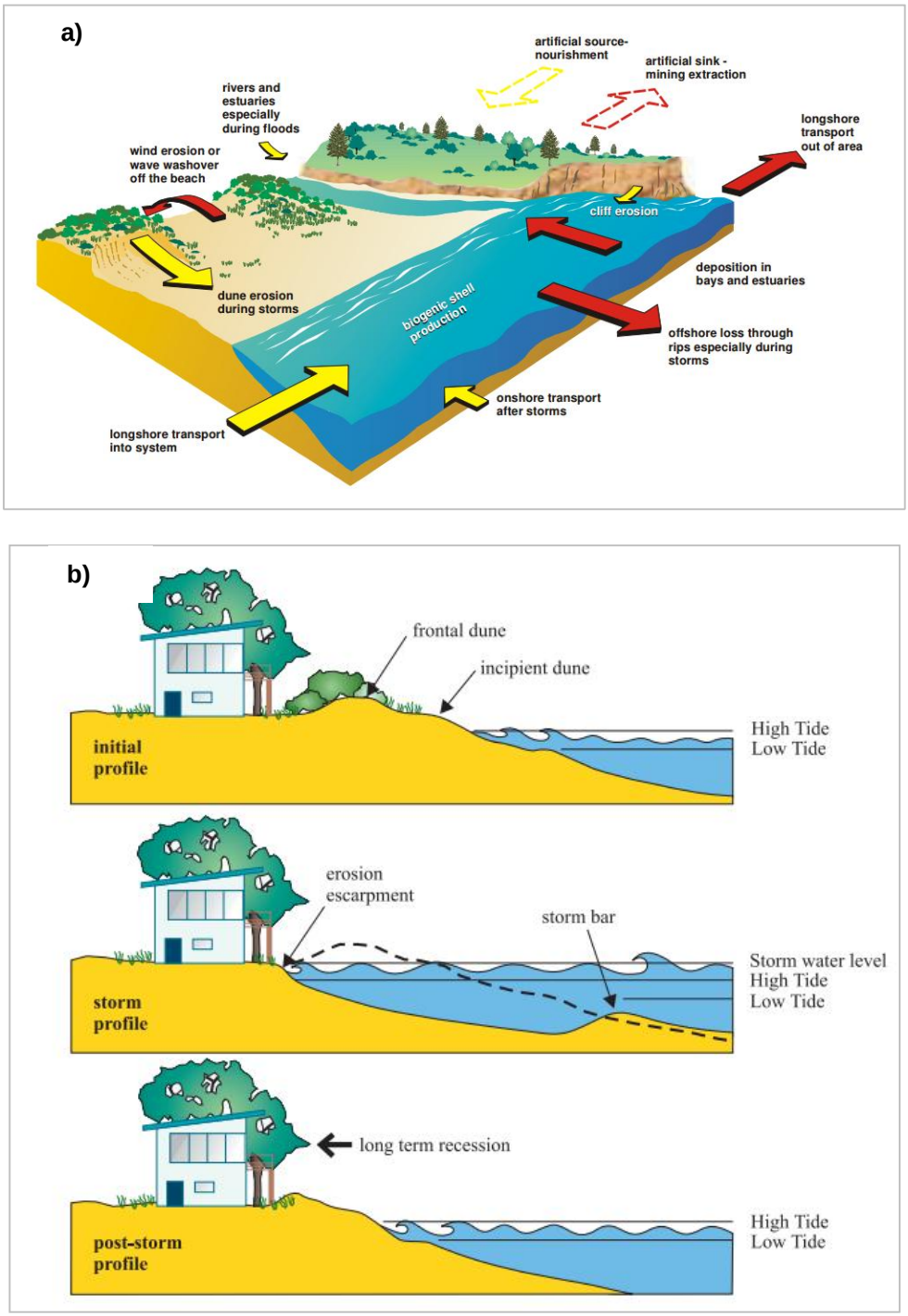


Figure 1-7 Conceptual representation of key coastal erosion concepts; a) sediment transport processes and b) long term beach recession due to permanent sand loss (source: NSW Department of Land and Water Conservation, 2001)

1.5 Previous Assessments

In 2012 the WA Department of Planning commissioned the study *The Coast of the Shires of Gingin and Dandaragan (WA): Geology, Geomorphology and Vulnerability* (Eliot et al, 2012). This study assessed the sensitivity and exposure of coastal landforms from Guilderton to North Head (north of Jurien Bay) and identified that all town sites along this stretch of coast are located on landforms that have a moderate or moderate to high vulnerability to changing coastal processes (winds, tides, currents, waves and sea levels). The study recommended detailed investigations to identify the potential extent of long term coastal erosion and inundation at priority locations.

In 2013 the Shire partnered with the Shire of Dandaragan and the Northern Agricultural Catchments Council (NACC) to identify the range of data and information required to undertake coastal hazard assessments at the priority locations outlined in the *Hill Primary Coastal Compartment Information and Data Gap Analysis* (Danese, 2013).

In 2014, in accordance with the recommendations made by Danese (2013), the Shire partnered with the Shire of Dandaragan, the NACC and the WA Department of Transport to undertake a preliminary assessment of coastal hazards at each town site in the study area. The preliminary findings of the assessment identified that:

1. Adaptation planning for coastal erosion is a priority at Seabird, Ledge Point, Lancelin, Cervantes and Jurien Bay town centre. Guilderton and South Jurien Bay (from Island Point south) were identified as low priority areas, mainly due to the relatively large coastal setback distance between the high water mark and built assets at these locations and, therefore, lack of a short term threat from coastal erosion;
2. Adaptation planning for coastal inundation is a priority at Lancelin, Cervantes and Jurien Bay. This is mainly due to the low lying nature of, and proximity of assets to, the shoreline at these locations;
3. Adaptation planning for coastal inundation at Guilderton requires a detailed investigation of the combined effects of inundation from the ocean and inland rainfall events, due to Guilderton's location on the Moore River estuary.

This current 2017 CHRMAP addresses the first of these recommendations with a focus on the areas identified at risk from coastal erosion hazards.

1.6 CHRMAP Format

This document has been designed to inform the community and provide direction to the Shire for planning for climate change-induced coastal erosion risks facing the coastal townships of the Gingin Shire. An overview of the CHRMAP process and how it has been covered in the structure of this document is provided in **Figure 1-8**. The structure of the document also allows for the information base and 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. The Appendices are as follows:

> **Appendix A** – Hazard Maps by Management Unit

> **Appendix B** – Value Maps

> **Appendix C –** Asset Information for each of the Management Units

> **Appendix D** – Technical Note on Risk Assessment Methods

> **Appendix E** – Risk Assessment Ratings and Results

> **Appendix F** – Multi-Criteria Analysis Results

> **Appendix G** – Multi-Criteria Analysis Summary

> **Appendix H** – Planning Controls Discussion

> **Appendix I** – Long Term Pathways

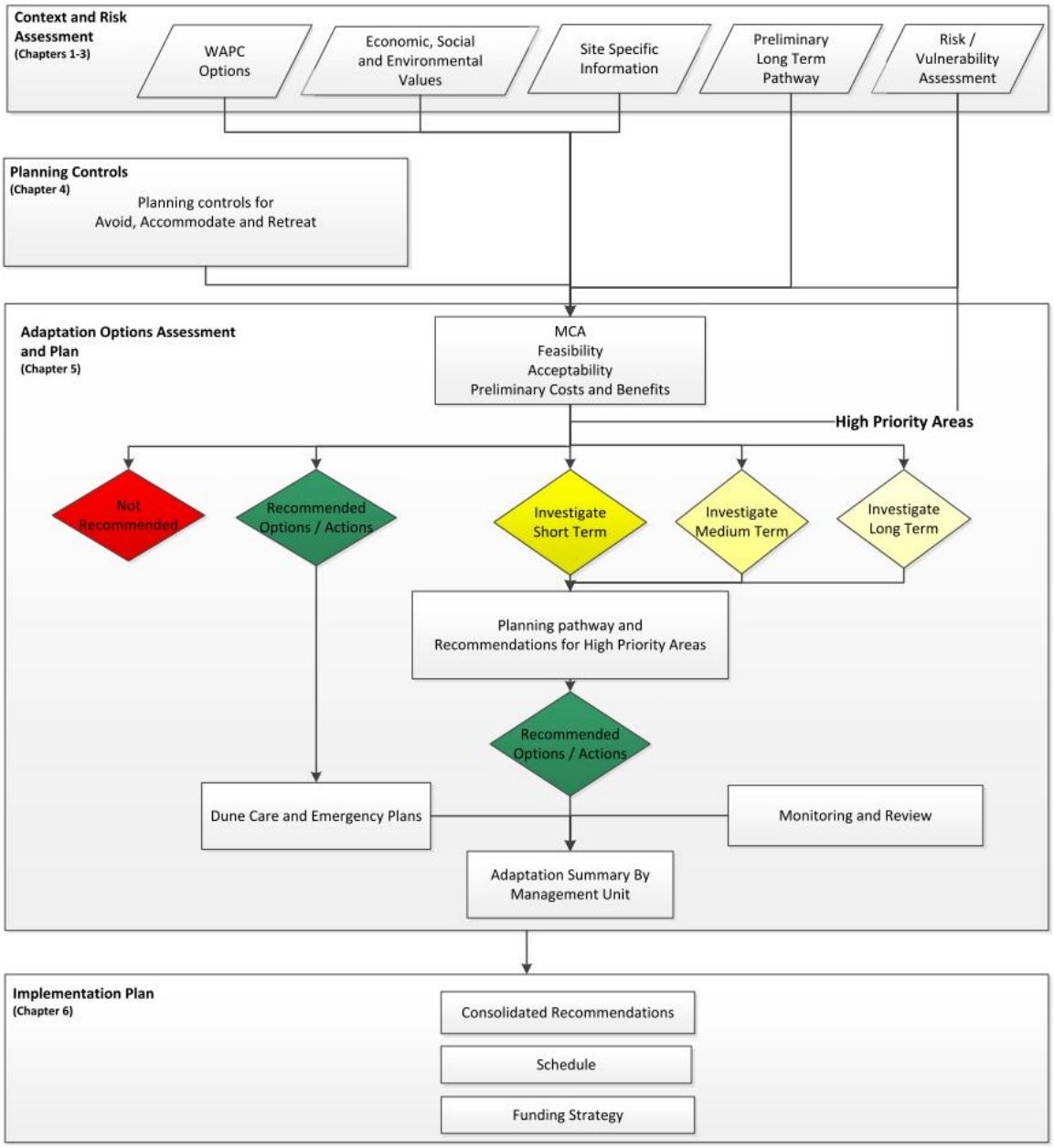


Figure 1-8 Overview of the CHRMAP process and its relationship to the chapters in this document.

2 ESTABLISHING THE CONTEXT

2.1 Shire of Gingin

The Shire of Gingin is located 84 kilometres north of Perth. There are five townships within the Shire: the inland town of Gingin, and the coastal towns of Guilderton, Lancelin, Ledge Point and Seabird, of which only the latter three are considered in this CHRMAP (**Figure 2-1**).

Gingin is one of the fastest growing rural areas in Western Australia and it is anticipated that the Shire's population will grow from 5,000 to approximately 6,600 by 2023, increasing to 7,900 by 2031 (Shire of Gingin, 2017). Agriculture (more recently including horticulture) is the Shire's primary economic contributor. In addition to rural industries the Shire's economy is also based around tourism, with coastal areas in particular experiencing a large influx of people during the summer holiday season. Annual Shire rate revenues are in the order of $7M.

The Shire of Gingin (2016a) Strategic Community Plan (2015-2025) lists the dominant demographic in the Shires coastal towns are "empty nesters" aged 60 – 69 (around 20% of the population), with around 40% of households having no children. This is in contrast to rural areas which are dominated by parents and home builders (24%) aged between 35 and 40.

This CHRMAP focuses on the coastal zones within the existing gazetted town sites including future development areas, where the services from human-made and natural assets provide key social, economic and environmental values to the community. Coastal areas outside of the towns may also be exposed to the potential impacts of coastal hazards. Any future development outside of the study areas should avoid potential coastal hazards. The absence of human-made assets in these locations is likely to allow for the natural adaptation of the coastline to sea level rise. A brief description of each of the townships is provided in the following three sub-sections and a summary of their key attributes is presented in **Table 2-1** and the coastal management units boundaries and zoning of properties located seaward of the 2110 Hazard Line are presented in the maps shown in **Appendix A**.

Table 2-1 CHRMAP location key attributes

CHRMAP Area	Number of Ratepayers [1]	Estimated Number of Residents[#]	Approximate coastline length assessed (km)	Number of Management Units
Seabird	*140*	80	1.7	2
Ledge Point	*379*	200	3.1	4
Lancelin	*754*	600	5.1	4

[1] Estimated as the number of improved blocks, [#] Estimated

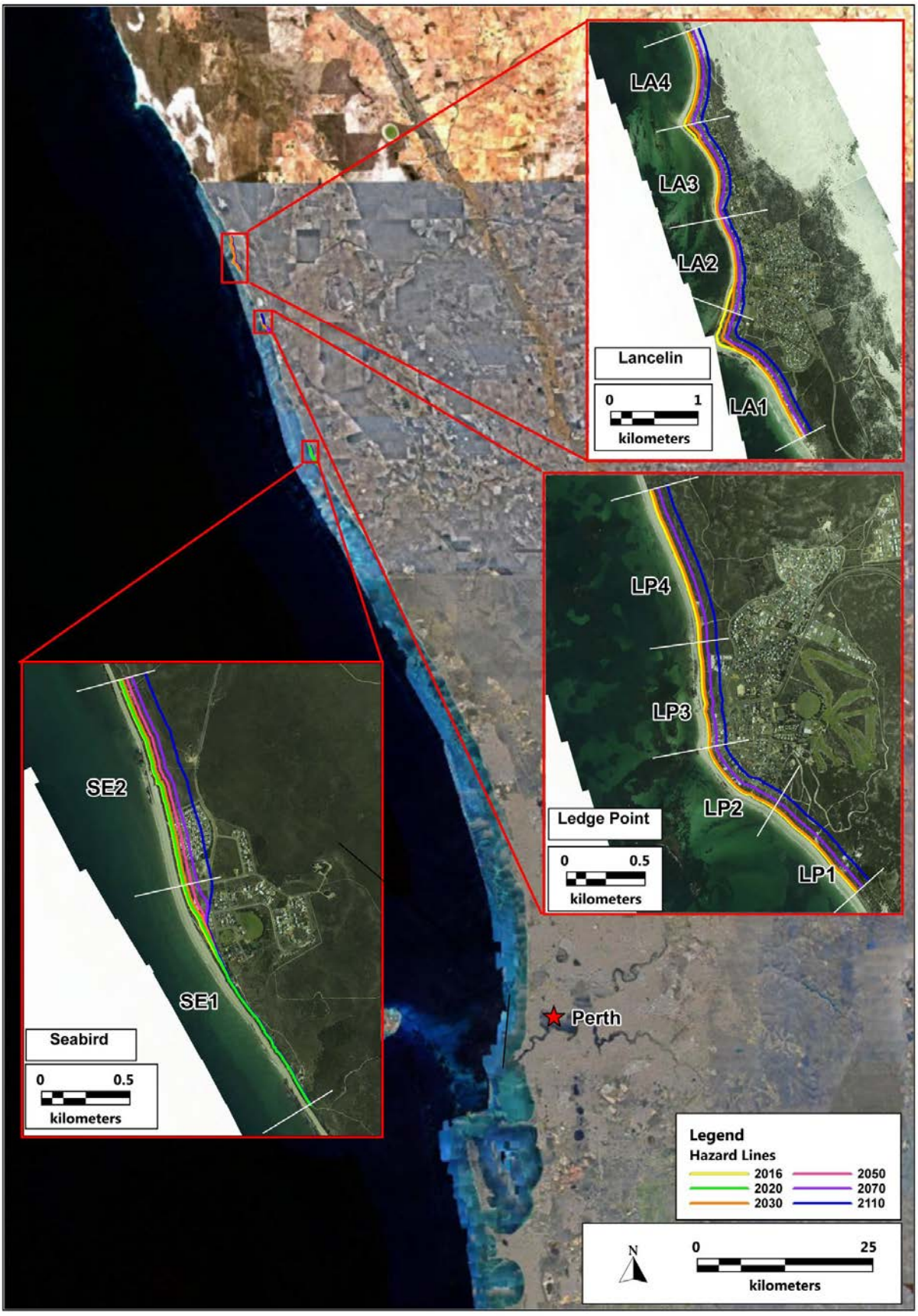

LA4
LA3
LA2
LA1
Lancelin
0 1
kilometers
LP4
LP3
LP2
LP1
Ledge Point
0 0.5
kilometers
SE2
SE1
Seabird
0 0.5
kilometers
Perth
Legend
Hazard Lines
2016
2020
2030
2050
2070
2110
N
0 25
kilometers

Figure 2-1 CHRMAP location map, townships and management unit boundaries

2.2 Seabird

Seabird is located approximately 40 km north of the Perth Metropolitan area (**Figure 2-1**). The townsite was gazetted in 1968 and currently has an estimated population of around 80 (**Table 2-1**).

The township has been subject to ongoing coastal erosion, which has caused the loss of a substantial portion of the township's primary coastal dunes and a coastal road (Turner Street). Historically, management of erosion has included beach nourishment and temporary protection works (MRA, 2016a), before a seawall was constructed in 2015 (and extended in 2016) to protect residential properties. Funding for the seawall was provided by the State Government and ongoing responsibility for maintenance and management of the structure will be one of the considerations of this CHRMAP. The seawall is currently being managed by the Shire of Gingin under a license issued under section 91 of the Western Australian *Land Administration Act (1997)* (LAA) by the Department of Lands.

The townsite is on a broad salient (coastal point) in a localised area of greater vulnerability relative to the general coastline within its coastal cell, which is considered to have a moderate vulnerability (Eliot et al, 2012). There is some beach rock (Tamala Limestone) visible along the coast in front of the township and scattered offshore reefs which provide some protection from incoming wave energy. This site lacks, however, the significant reefs or offshore islands which are present off some townships further to the north. MPR (2016a) collated geophysical data collected by Gordon Geological Consultants and the DoT in 2002 to confirm the presence of a limestone cliff, of low to medium strength, under the dunes to the south of the Coastal Point. It was estimated that this cliff deviates away from the coast in line with the northern end of Turner St and extends to the junction of McCormick and Edwards Streets. This geological feature has been taken into consideration in the risk assessment process (see **Section 3.2.1**).

During a site visit in early 2017, the presence of the seawall was noted to have limited the beach extent in front of the town to the north of the seawall. As the seawall was designed as an interim measure public access to the beach from the top of the seawall has not been allowed for and public open space along the foreshore within the town is subsequently very limited. The coastal values for Seabird are presented in **Appendix B** and the map shows public beach access to the north and south of the seawall.

The hazard assessment extended for 2.6 km along the coast (MRA, 2016a), and for risk assessment and adaptation planning purposes, this CHRMAP has divided the Seabird coastal area into two management units (**Figure 2-1**). Development potential beyond the existing township has not been identified in the Shire's Local Planning Scheme (Shire of Gingin, 2012a) (see maps in **Appendix B**).



Figure 2-2 Photograph of seabird in 2016 following construction of the seawall (source: DoT)

2.3 Ledge Point

The township of Ledge Point is located approximately 70 km north of the Perth Metropolitan area (**Figure 2-1**) and has an estimated population of around 200 (Table 2-1). The townsite was gazetted in 1955, intended for retirees and holiday housing and to service the local fishing and crayfishing industries (Landgate, 2017). It is understood that many of the properties in the town are holiday houses, owned by farmers from inland parts of the Shire. The township has a general store, cafe/fish and chip shop and a country club which has a restaurant, bar, golf course, tennis courts and lawn bowls. Ledge Point is well known as a windsurfing venue, hosting the Ledge Point to Lancelin Windsurfing Classic in January each year. The beach and nearshore waters are used for launching and mooring of boats.

Ledge Point lies at the boundary of two coastal cells; Cell 11 (Green Reef to Ledge Point) and Cell 12 (Ledge Point to South Pacific Reef) and the coastline in both these cells was assessed as having moderate vulnerability (Eliot et al, 2012). Broad scale geological mapping covering the Ledge Point townsite indicates coastal limestone may be present along the coast in this area, however no rock was visible on the beach or in the dunes during a site visit in December 2015 (MRA, 2016b).

The Ledge Point townsite is located on a sandy foreland formed in the lee of a shore-parallel reef (Short, 2006). There are no islands offshore, however, both offshore and nearshore reefs protect the Ledge Point beach from wave energy (MRA, 2016b).

The hazard assessment extended approximately 3 km along the coast (MRA, 2016b), and for risk assessment and adaptation planning purposes, the CHRMAP has divided this area into four management units (**Figure 2-1**). There are two groynes, the smaller 'southern groyne' (constructed in 1975 at the boundary between management units LP2 and LP3) and the larger 'northern groyne' (constructed in 1985 slightly to the south of the centre of management unit LP3). The southern-most, LP1, and northern-most, LP4, management units are predominantly undeveloped at present, but the potential for development of these areas has been identified in the Shire's Local Planning Scheme (Shire of Gingin, 2012a). A map depicting the coastal values for Ledge Point is presented in **Appendix B**.

The main coastal node for public recreation and tourism is focused around Key Biscayne Park, to the north of the northern groyne. The park comprises a large grassed park area that has had extensive coast care attention, including dune rehabilitation. The beach area between the two groynes is the main swimming area, with the beach to the south of the southern groyne being used for boat launching, with four wheel drives and tractors traversing and parking on the beach. A new boat-launching facility/marina has been proposed for a location to the south of the study area.

The main coastal erosion risk area is in management unit LP3, where a number of private residences along DeBurgh Street overlook the beach to the south of the southern groyne.



Figure 2-3 Aerial view of Ledge Point in 2016 (source: DoT)

2.4 Lancelin

The township of Lancelin is located approximately 100 km north of the Perth Metropolitan area (**Figure 2-1**) and has an estimated residential population of around 600 (**Table 2-1**). The townsite was used in the late 1940s for camping and as a port for the lobster fishery. The townsite was declared in 1950 and gazetted in 1953 (Landgate, 2017). The township is the regional centre for the Upper Coastal area of the Shire (Shire of Gingin 2016b). Lancelin is well known as a windsurfing venue, hosting the Ledge Point to Lancelin Windsurfing Classic in January each year. Crayfishing is a significant local industry, as well as seasonal tourism. The town has a jetty managed by the DoT.

Lancelin townsite occupies three sandy forelands formed in the lee of Edwards Reef to the south and Lancelin Island to the north (Short, 2006). There are two islands close to the shore, the smaller, rocky Edward Island and the larger, vegetated Lancelin Island to the north (**Figure 2-4**). Edward Island is connected to an approximately 850 m long shallow nearshore reef which provides good protection from wave energy to the adjacent shoreline (MRA, 2016b). There is also a shallow nearshore reef that is approximately 450 m long, located in between the two islands and extending between approximately 500 m and one km offshore. Deeper passages exist between the shallow reefs and islands, which allow boat access to Lancelin and also permit wave energy to reach the shoreline (MRA, 2016b).

The Lancelin area lies within three sediment cells (13-15, Eliot et al, 2012), which were assessed as having moderate (cells 13-14) or moderate-high (cell 15) vulnerability. Broad scale geological mapping covering the Lancelin townsite indicates Coastal Limestone may be present along the coast in this area, however, no rock was visible on the beach or in the dunes during a site visit undertaken in December 2015 (MRA, 2016b). In the absence of detailed geotechnical information, the Lancelin area was classified as a sandy coast for the purpose of coastal hazard assessment (MRA, 2016b).

The hazard assessment (MRA, 2016b) extended approximately five km along the coast, and for risk assessment and adaptation planning purposes, the CHRMAP has divided this area into four

management units (**Figure 2-1**). The southern-most management unit is largely undeveloped, with the intention to use the area primarily for sporting and recreation purposes. The area has also been identified for linking the town to future urban development at Lancelin South (Shire of Gingin, 2012a). A map depicting the coastal values for Lancelin is presented in **Appendix B**.



Figure 2-4 Aerial view of Lancelin in 2009 (source: Birdseye View Photography, http://www.birdseyeviewphotography.com.au/lancelin.shtml)

The Shire's local planning strategy identifies three coastal nodes for public recreation at Lancelin. The first is at Edward Island Point and includes Grace Darling Park. The second is in the coastal foreshore park in the town centre and the third is at Lancelin Point. Grace Darling Park, in management unit LA2, has been affected by erosion over recent years, causing public concern and highlighting coastal erosion issues.

2.5 Stakeholder and Community Engagement

2.5.1 Objectives

Community and stakeholder engagement is an important element of the CHRMAP process, as depicted in **Figure 1-3**. It is necessary to identify the values provided by the study area, to determine the tolerability of risks and to assess the acceptability of adaptation options designed to preserve the area's value.

The objectives of the community and stakeholder engagement process include:

- To inform the community about the extent of potential coastal hazards, adaptation strategies available to respond to those hazards and the need for flexibility in response to future environmental, social and economic changes;
- To explain the State and local governments' responsibilities and capacity to respond to potential coastal hazards;
- To explain the benefits and challenges of each adaptation strategy, in terms of the meaning for residents and landowners, as well as the broader community;
- To provide community members with multiple opportunities to provide input into proposed adaptation strategies, and to offer alternative strategies or to voice questions and concerns;

> To receive and document feedback and concerns regarding each adaptation strategy from community members and affected residents and landowners; and

> To report on the feedback, including analysis that highlights the level of community understanding, the principal concerns and preferences concerning the proposed adaptation strategies and funding mechanisms, and preferred methods of continued community engagement.

2.5.2 Methods

Since 2012, the Shire has worked closely with the Shire of Dandaragan, the NACC, State Government agencies, coastal specialists and the local community to investigate the hazards and risks to the Shire's coastline, and to develop strategies for adapting to them. In 2013 and 2014 the Shire provided opportunities for the community and stakeholder groups to learn about the Shire's CHRMAP process through workshops with government agencies and public information sessions. Key stakeholders identified and engaged throughout the engagement process in listed in **Appendix B**.

Stakeholder and community engagement undertaken for this CHRMAP has focused on capturing the coastal values of the community, informing the public about coastal hazards and the CHRMAP process, and gauging attitudes towards various adaptation options (**Figure 2-5**). A community engagement session was facilitated by the Shire in Lancelin on the 28th of May 2017. This was followed by an online survey that was conducted in June 2017.

2.6 Social and Environmental Values

An ecosystems services approach has been used to identify the natural and social values of the coast (**Figure 2-5**). The results of recent community engagement highlighted the strong sentiment regarding the natural values of the beach. Respondents sometimes struggled to find words to describe the importance of the beach to them and their sense of health and wellbeing. When asked if there were any other values the coast provided them, an example answer was:

"Yes too many to list, e.g. aesthetics, relaxing, peacefulness, regeneration, good sources for juvenile aquatic animals, space for all animals including those pesky humans, preservation for, & adaptability for climate variability"

It is difficult to place an economic value on natural coastal assets such as the beach and dune systems. Identifying the value of natural assets through community engagement, and maintaining a focus on these values throughout the CHRMAP process is critical to its success. Maps showing social, cultural and environmental values for the CHRMAP study areas are provided in **Appendix B**. The maps provide a broad indication of threatened ecological communities, rare and endangered flora and fauna potentially present (noting that, as required by government agencies, the locations are only approximate to within the Management Unit).

While the results of the surveys are discussed in the following section 2.7 the general sentiment of the community may be summarised as follows:

- Strong disagreement that protection of private property should be prioritised over preservation of beaches,
- Strong support for relocation of assets and let nature take its course,
- Strong support for limiting intensity of development in hazard areas, and
- Strong support for informing landholders of hazard risk.



Figure 2-5 Ecosystem services approach to defining coastal values

2.7 Survey Results

2.7.1 Context

Contextual information from the online survey is provided in **Figure 2-6**. The results show that more than 50% of respondents visit the beach on a daily or weekly basis, with the most common answer for which beach is visited being the "Lancelin main beach". Indicative beach usage by management unit based on the survey results is provided in **Table 2-2**.

While most respondents believed they have some idea of the causes of coastal erosion, only around 10% considered themselves to be very well informed. Slightly more than half had viewed the hazard maps, but there was a high level of concern (45% very concerned and 35% somewhat concerned) about coastal erosion.

Most respondents were between 60 – 75 years of age and were landowners in the shire, but a majority did not live in areas identified as being vulnerable to coastal erosion. As introduced in **Section 2.1**, "empty nesters" aged 60 to 69 are the dominant demographic in the coastal towns of the Shire, and it is a positive result that the survey reflects this.

Of the 80 respondents who provided their postcode, the majority (73%) were from either Lancelin, Guilderton or Gingin and the remaining 17% of respondents were from outside the Gingin LGA.

Table 2-2 Indicative beach usage by management unit based on survey results

Seabird (SE)		Ledge Point (LP)		Lancelin (LA)	
Management Unit	Number	Management Unit	Number	Management Unit	Number
SE1	13	LP1	0	LA1	40
SE2	11	LP2	8	LA2	54
		LP3	6	LA3	32
		LP4	2	LA4	12

2.7.2 Coastal Values

The questions on coastal values showed strongest support for opportunities to use beaches for passive recreation, and ongoing provision of foreshore reserved for current and future generations (**Figure 2-6**). Opportunities for commercial enterprises and active recreations (i.e. boat ramps and jetties) received the least support.

2.7.3 Adaptation Options

The responses relating to adaptation options showed very strong support for retaining public access to beaches and foreshore reserves and preserving coastal dunes and vegetation for future generations (**Figure 2-7**). There was also strong support for not allowing more intensive development (such as units where there is a single house) in hazard areas.

Respondents strongly agreed that private landowners should be informed about the risk of erosion when purchasing or developing in hazard areas.

There was a high level of disagreement for protecting private property from erosion, when this results in the loss of the public foreshore reserve and beach access. There was also strong disagreement for allowing the continuation of approved land uses in developed areas until erosion becomes intolerable, suggesting that a “do-nothing” approach is not acceptable. The responses to these questions have been taken into consideration in formulating the adaptation plans discussed in **Section 4**.

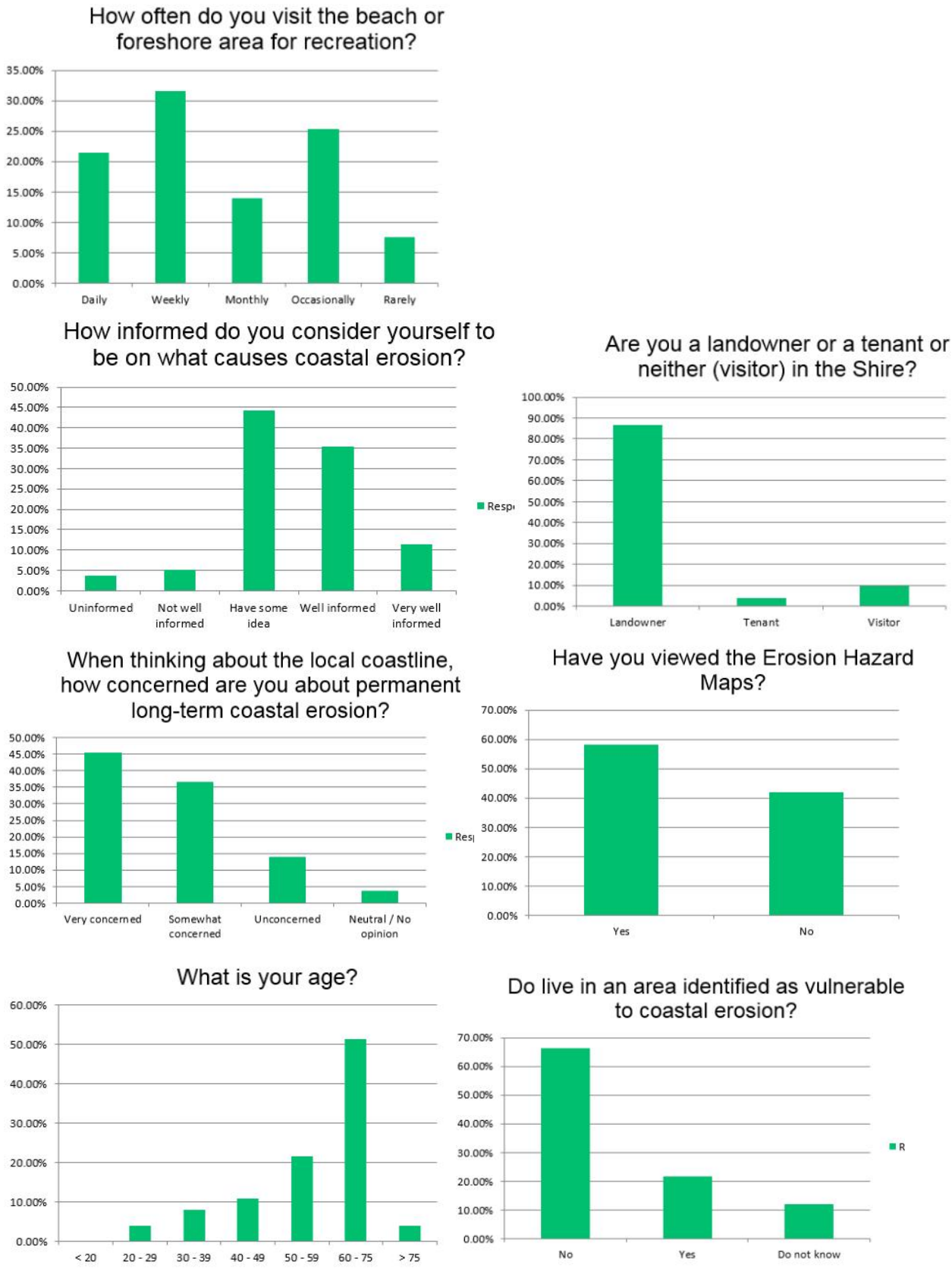


Figure 2-6 Summary charts of online survey questionnaire responses

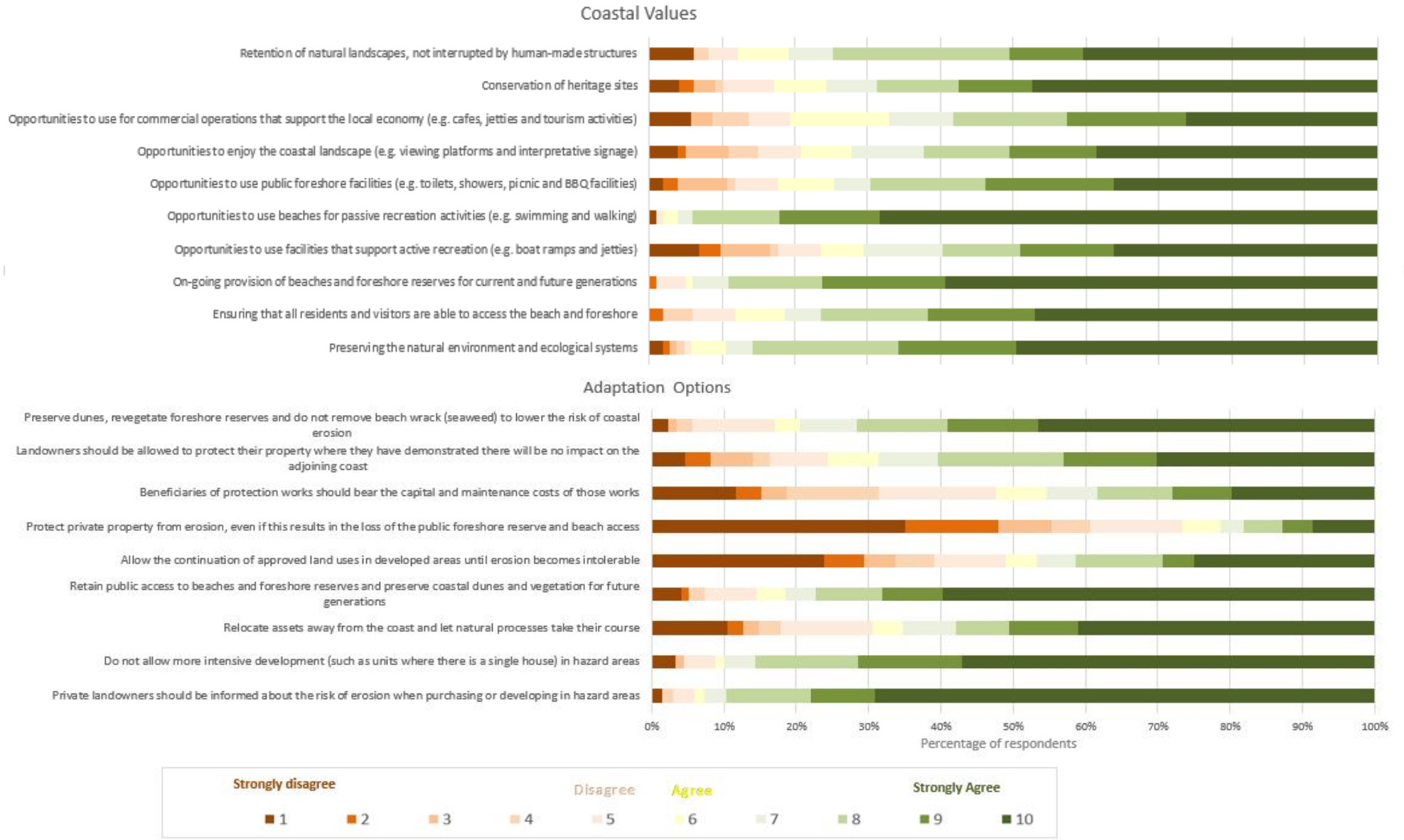


Figure 2-7 Responses to questions "what do you value about the coast" and "how strongly do you support the following erosion management approaches". Generally, more green indicates more agreement and more red indicates more disagreement.

2.8 Planning Framework

Planning in Western Australia is guided by the *State Planning Framework*, that outlines the relationships and hierarchy of responsibilities of different levels of government and planning instruments, as summarised in **Figure 2-8**. Strategic plans at State, regional and local levels inform the development of statutory controls.

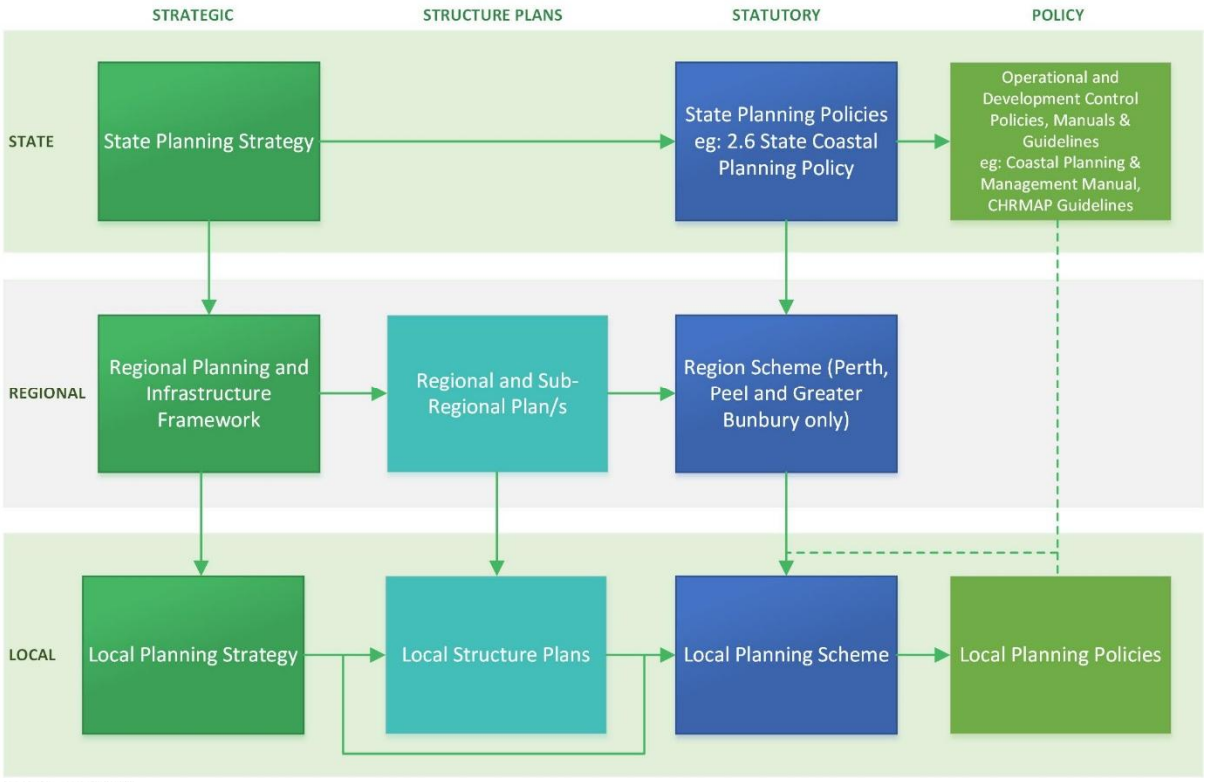


Figure 2-8 Planning context overview

The key strategic planning documents that have guided development of the coastal towns within the Gingin shire are:

- State Planning Strategy 2050 (State)
- Wheatbelt Planning and Infrastructure Framework 2015 – (Regional)
- Shire of Gingin Local Planning Strategy 2012 (Local)

In addition to these strategic guidance documents the following Structure Plans and Policies provide the context for development in the local areas:

- Local Planning Scheme No. 9 (LPS 9)
- State Planning Policy: Coastal Planning Policy (SPP 2.6)
- Local Planning Policy 1.2 Foreshore Protection Areas (LPP1.2)
- Local Planning Policy 1.4 Foreshore Reserves along Water Courses (LPP1.4)

The requirement for Local governments to produce a CHRMAP is described in SPP2.6 and the WAPC (2014a) guidelines outline the steps for local government to develop the CHRMAP document. The CHRMAP is a local level policy document that can provide recommendations for implementation of local planning adjustments, if required and adopted by the Shire, to bring about change in line with mitigating the future effects of sea level rise and coastal erosion on coastal infrastructure.

The planning process, in relation to Gingin, is outlined in the following sections.

2.8.1 Strategic Plans

The *State Planning Strategy 2050* provides a strategic framework, principles, strategic goals and strategic directions for planning and development in Western Australia. In relation to climate change, this strategy identifies the Shire of Gingin coast as being at risk of coastal landform change. It makes key statements

that are fundamental to the approach taken to coastal hazard risk assessment and adaptation planning, including:

> *Retaining natural bushland and coastal areas that are accessible is essential to human health and a sense of wellbeing*, and

> *All decisions about sustained growth and prosperity must strike the appropriate balance between environmental issues, economic conditions and community wellbeing*.

At the regional level the *Wheatbelt Planning and Infrastructure Framework 2015* (Wheatbelt PIF) identifies the following key regional strategic planning initiatives:

> *Identification required planning responses following completion of the Coastal Hazard Risk Management and Adaptation Planning Study being carried out by the shires of Dandaragan and Gingin*, and

> *Facilitation of long-term strategic planning for the lower Gingin − Indian Ocean Drive corridor, focussing on possible economic and employment opportunities, service provision and the preservation of environmental assets (the latter including coastal assets)*.

The *Shire of Gingin Local Planning Strategy 2012*, generally aligns with the Wheatbelt PIF strategy direction, placing importance on both planning for long-term predicted shoreline movement and other impacts of climate variability, such as storm surge.

The *Local Planning Strategy* identifies coastal erosion and management of coastal dunes as key issues for the Shire, acknowledging that the vulnerability is predicted to worsen as sea level rises in response to climate change. It recognises that a strategic approach is needed in managing coastal land use, future development and the impacts of coastal processes, including dune movement, blow outs and erosion. This strategy also maps general areas identifying 'Coastal setbacks required in accordance with State Planning Policy'. These areas include the coast north of Lancelin, coast in the southern parts of Ledge Point, Guilderton north of the Moore River, and Seabird. Since the strategy's adoption in 2013, more detailed coastal studies (MRA, 2016a and 2016b, GHD, 2015) have provided improved definition of vulnerable areas.

Within the coastal areas designated at risk from sea level rise and coastal erosion at the 100 year planning horizon the preparation of this CHRMAP assumes the more recent strategies and adaption hierarchy outlined is SPP2.6 (2013) and the WAPC CHRMAP guidelines (2014a) will take precedence when considering the appropriate adaptation strategies for the Gingin Shire coastline.

2.8.2 Statutory Plans & Policies

State Planning Policies (SPPs) provide the highest level of planning policy control and guidance in Western Australia and are prepared under Part 3 of the Planning and Development Act (2005) (PDA). The State Coastal Policy (SPP 2.6) is an environmental sector policy consistent with the higher order SPP 2 Environmental and Natural Resources Policy.

The key statutory planning document for the Shire of Gingin is Local Planning Scheme No. 9 (LPS 9), gazetted on 27 September 2012 and amended several times since. LPS 9 applies zones and reserves to land within the Shire and outlines permissibility of land uses, requirements for development and processes for seeking proposed development approval.

Recent relevant amendments to LPS 9, regarding coastal development, planning and hazards, require compliance with the provisions of SPP 2.6, in accordance with the PDA. This amendment thereby effectively gives statutory effect to the SPP 2.6 under LPS 9.

2.8.3 Local Structure Plans

Local Structure Plans, also referred to as Outline Development Plans (ODPs) can be made under LPS 9 via the mechanisms provided in Part 4 of the Deemed Provisions set out in the Planning and Development (Local Planning Scheme) Regulations 2015 (the Regulations). In the context of planning control and guidance, an ODP is the same as a structure plan. A structure plan, while not a statutory document, provides guidance for the future subdivision and development of land.

The Shire has only one structure plan relating to coastal land, the ODP for Moore River South adopted following the completion of a Foreshore Management Plan in August 2014. This ODP considers the same

coastal hazard mapping used for this CHRMAP, and provides for coastal foreshore reserves and public open space. Moore River South is not an area addressed by this CHRMAP.

2.8.4 Local Planning Policies

Under the provisions of LPS 9 local planning policies can be developed to affect the type of developments permissible within the designated zones/reserves of LPS 9. These provisions are outlined in Division 2 of Part 2 of the Regulations. The Shire have several local planning policies relevant to development of coastal land, including two adopted on 15 January 2013:

- Local Planning Policy 1.2 Foreshore Protection Areas (LPP1.2), and
- Local Planning Policy 1.4 Foreshore Reserves along Water Courses (LPP1.4)

Additionally, while not addressing coastal development, Local Planning Policy 1.3 *Interim Position on Seabird Coastal Erosion,* is general policy regarding the management and monitoring of coastal erosion at Seabird.

2.8.5 Local Planning Horizons

Local planning schemes require a review every five years to ensure the scheme remains current with respect to current issues, trends and policy and the strategy context. Local planning strategies, which provide the broader planning direction within which the local planning scheme operates, typically have a planning horizon of 10 to 15 years. The CHRMAP establishes strategy for adapting to sea level rise and coastal erosion over the next 100 years at a range of time scales from short term (next 5-10 years), medium term (10 to 40 years) and long term (40 to 100 years).

As development itself has a much longer horizon, coastal hazard assessment uses a 100-year horizon. Therefore, when assessments indicate zoned land may be impacted by coastal processes within the next hundred years (even if the likelihood of the hazard having an impact may be beyond the horizon of current planning instruments, including LPS 9) local government has a responsibility to the future community to direct new development away from high risk areas.

2.9 Risk Assessment Inputs

To effectively assess the risks and plan for the future management of the coastal zone, as illustrated in **Figure 2-9**, information is needed on:

> Present and predicted future coastal hazards;

> Existing assets, their value and lifecycles; and

> Community and stakeholder values.

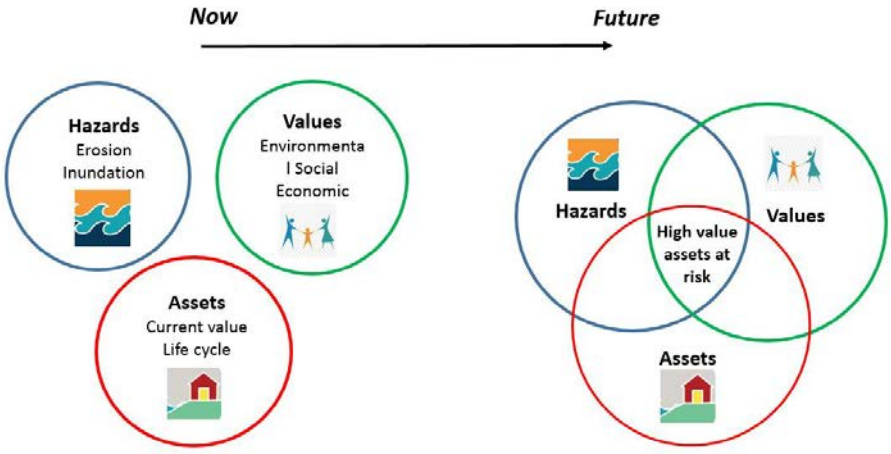


Figure 2-9 Conceptual relationship between key inputs to the coastal risk assessment process

The changing interrelationship between these components over time is the key to defining the priorities for future adaptation planning.

2.9.1 Hazards in each Management Unit

SPP2.6 Schedule One, outlines the methodology for defining appropriate physical processes allowances, to ensure the use of coastal land accounts for coastal hazards over the next 100 years. Calculation of these allowances is based on a pragmatic approach to characterising coastal processes and includes four elements: storm erosion from a potential one in 100 year storm event (S1), historical erosion trends (S2) and predicted sea level rise (S3), and an allowance for uncertainty.

Coastal hazard assessments were undertaken for Seabird (MRA, 2016a) and Ledge Point, Lancelin (and Cervantes) (MRA, 2016b). The assessments were reviewed and accepted for adaptation planning purposes by the WA Department of Transport and are available at the Shire's website. In accordance with SPP2.6, coastal erosion hazard lines have been collated for the present day (2016), 2030, 2070 and 2110 planning timeframes. The hazard maps are presented in **Appendix A**. A summary of the hazard assessment assumptions and calculated erosion allowances are presented in **Table 2-3** for each management unit. Erosion allowances and horizontal shoreline datum (HSD) were taken directly from the relevant coastal hazard report (MRA, 2016a and 2016b).

Table 2-3 Coastal processes erosion allowance for present day and predicted conditions

Management Unit	HSD (m AHD)	S1 Erosion Allowance (m)	S2 Erosion Allowance (m/year)	Total Erosion Allowance (m)			
				Present-day (2016)	2030	2070	2110
Seabird*							
SE1	+2.0	15 - 21	0.4 – 1.2[%]	15 - 21	15 - 46	16 - 50	21 - 55
SE2	+1.8	33	0.35 – 0.5	33	49 - 52	105 - 114	181 - 196
Ledge Point[#]							
LP1	+1.6	19	0	19	29	69	128
LP2	+1.6	12 – 19	0	12 - 19	22 - 29	62 - 69	121 – 128
LP3	+1.6	12 – 24	0	12 - 24	22 - 34	62 - 74	121 – 133
LP4	+1.6	24	0	24	34	74	133
Lancelin[#]							
LA1	+1.4	14 – 22	0.3 – 3.3	14 - 22	37 - 82	89 - 134	160 – 205
LA2	+1.4	11 – 14	0 – 3.3^	11 - 14	18 - 74	50 - 126	101 – 197
LA3	+1.4	11 – 30	0 – 2.3	11 - 30	18 - 75	50 - 131	101 - 202
LA4	+1.4	30	0.2 – 2.3	30	43 - 75	93 - 131	161 - 202

* Values for Seabird are taken from MRA (2016a)
[#] Values for Ledge Point and Lancelin are taken from MRA (2016b)
^ All but the southern boundary of this management area has an S2 erosion allowance of 0 m/year
[%] The application of the S2 erosion allowance in this area is complicated by the presence of rock. Refer to MRA (2016a) for details.

2.9.2 Assets

As introduced in **Section 1.3.5**, assets include both natural and built features of coastal areas. Assets at risk of coastal erosion were identified by overlaying the hazard lines on aerial photomaps of each township. Residential property boundaries were drawn from Council's GIS cadastral layers, while all other assets were based on interpretation of aerial images only. A site visit was conducted to confirm asset classifications. Information on the assets at risk, existing coastal erosion controls and planning context/controls are provided for each management unit in **Appendix C**.

2.9.3 Values

The estimated value of assets has been derived, in the first instance, from their economic value or replacement cost. This economic value can be easily estimated for physical infrastructure and property, but not always for natural assets that provide a range of values and services. It is clear that the community and visitors to the Shire place a high value on the natural coastal assets and foreshore amenities in each town. These values have been expressed on numerous occasions in the past through formal public consultations with the Shire, such as during the development of local planning documents and through feedback on development proposals. In establishing the values of assets and coastal areas for risk assessment, this social and environmental value has been fully considered, alongside economic value.

A summary of the values associated with assets at risk is provided for each management unit in **Appendix C**.

3 COASTAL HAZARD 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 the Australian Standard guideline *Climate change adaptation for settlements and infrastructure – A risk based approach* (AS5334-2013), and the CHRMAP guidelines (WAPC, 2014a). As illustrated in **Figure 3-1**, risk was assessed in relation to likelihood, consequence and adaptive capacity. Likelihood was assigned using the results of the hazard assessments (MRA, 2016a and 2016b) 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 asset's, or group of assets', overall vulnerability to climate change (as defined previously in **Section 1.3.6**).

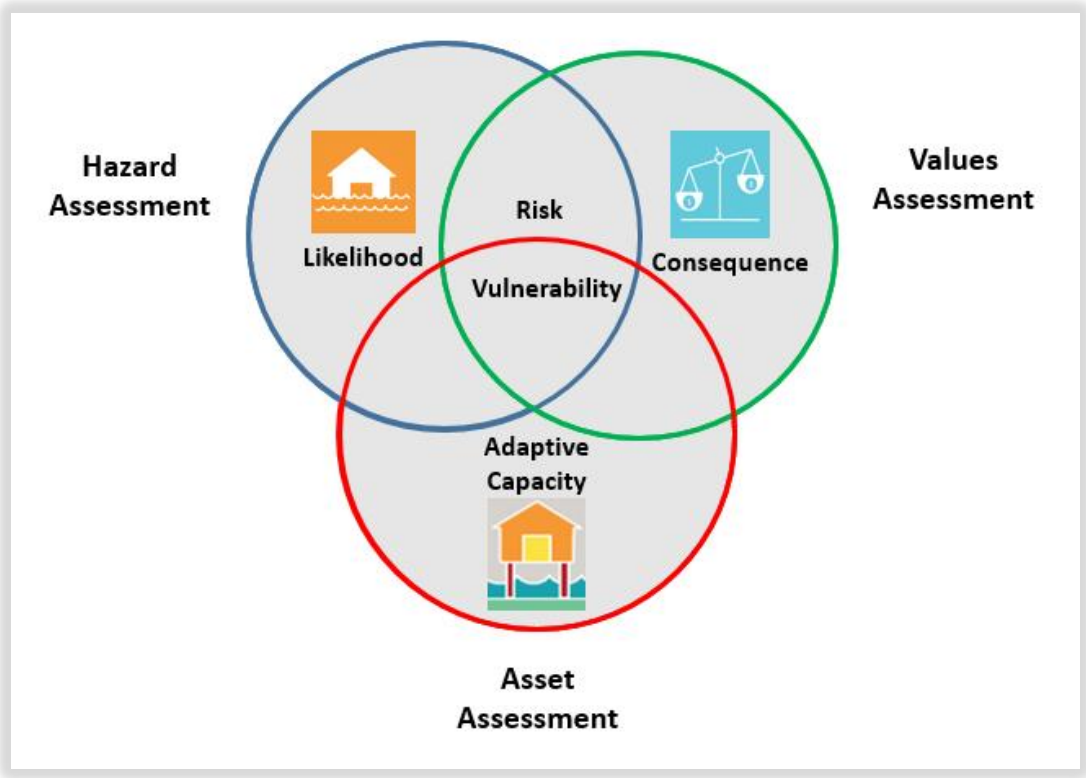


Figure 3-1 Conceptual relationship between risk assessment elements

Consequence and adaptive capacity criteria used in this assessment are presented in **Table 3-1**. A full description of the risk assessment process is provided in **Appendix D**. Summary tables of the assigned likelihood, consequence and adaptive capacity ratings, as well as the resultant risk and vulnerability profiles over time are provided in **Appendix E** for assets within each management unit.

Table 3-1 Risk and adaptive capacity criteria used in the risk assessment

Consequence			
Scale	**Safety and Social**	**Economic**	**Environment and Heritage**
Catastrophic	Loss of life and serious injury. Large long-term or permanent loss of services, public access/amenity, employment, wellbeing or culture. No suitable alternative sites exist within the LGA.	Permanent and/or entire loss or damage to property, plant and equipment, finances >$10 million	Permanent loss of flora, fauna, conservation or heritage area (no chance of recovery).
Major	Serious injury. Medium term disruption to services, public access/amenity, employment, wellbeing or culture. Very limited suitable alternative sites exist within the LGA.	Permanent and/or large scale loss or damage to property, plant and equipment, finances > $2 - $10 million	Long-term and/or large scale loss of flora, fauna, conservation or heritage area (limited chance of recovery) with local impact.
Moderate	Minor injury. Major short term or minor long-term disruption to services, public access/amenity, employment, wellbeing or culture. Limited suitable alternative sites exist within the LGA.	Permanent loss or damage to property, plant and equipment, finances > $100,000 - $2 million	Medium-term and/or medium scale loss of flora, fauna, conservation or heritage area (recovery likely) with local impact.
Minor	Small to medium disruption to services, public access/amenity, employment, wellbeing or culture. Many suitable alternative sites exist within the LGA.	Permanent loss or damage to property, plant and equipment, finances > $10,000 - $100,000	Short-term and/or small scale loss of flora, fauna, conservation or heritage area (strong recovery) with local impact.
Insignificant	Minimal short term inconveniences to services, public access/amenity, employment, wellbeing or culture. Many suitable alternative sites exist within the LGA.	Permanent loss or damage to property, plant and equipment, finances < $10,000	Negligible to no loss of flora, fauna, conservation or heritage area (strong recovery) with local impact.

Adaptive Capacity			
Scale	**Physical / Engineering**	**Economic**	**Social and Environmental**
Low	Little or no adaptive capacity. Potential impact would destroy all functionality. Not possible to relocate asset.	Cost to relocate or modify design of property, plant and equipment >$10 million	Adaptation would significantly damage or negate current environmental and or social values
Moderate	Small amount of adaptive capacity. Difficult but possible to restore functionality through repair, redesign or relocation.	Cost to relocate or modify design of property, plant and equipment > $2 - $10 million	Limited natural adaptive capacity. Current environmental / social values would be negatively impacted.
High	Decent adaptive capacity. Functionality can be restored, although additional adaptive measures should still be considered. Natural adaptive capacity restored slowly over time under average conditions.	Cost to relocate or modify design of property, plant and equipment > $100,000 - $2 million	Current environmental / social values may be affected. Natural adaptive capacity restored over time under average conditions.
Very High	Good adaptive capacity. Functionality restored easily by repair, redesign or relocation.	Cost to relocate or modify design of property, plant and equipment > $10,000 - $100,000	Adaptation has little or no impact on current environmental and or social values.
Insignificant	Potential impact has insignificant effect on asset. Controls are re-established naturally or with ease before more damage would likely occur.	Cost to relocate or modify design of property, plant and equipment < $10,000	Adaptation may improve current environmental and or social values.

3.2 Risk Assessment Outcomes

The outcomes of the risk assessment for each management unit are discussed in the sub-sections below. The inputs to the risk assessment and the tabulated outcomes of the risk assessment process are presented in **Appendix E**.

3.2.1 SE1 - Seabird South

The Seabird South management unit extends along 1400 m of coastline and the southern half fronts undeveloped land. The management unit contains 22 residential properties in the northern half that are fully or partly located seaward of the 2110 coastal hazard line, as well as a number of roads, carparks and public assets (**Figure 3-2**). There is a lack of foreshore reserve width to facilitate public amenity and beach access along the section of coast adjacent to the township. To the south of the township, natural assets comprising the beach and vegetated dunes are not bounded by development. **Appendix C** provides more information on the assets and their values in this management unit.



Figure 3-2 Photograph of the Seabird seawall during construction in the SE1 management unit (source, watoday.com.au)

A limestone ridge lying beneath the dunes and extending along the majority of this management unit forms a significant existing control on potential future erosion. This ridge has been considered in the coastal hazard assessment (MRA, 2016a) and this current risk assessment process. The seawall, constructed in 2016 (subsequent to the Coastal Hazard Assessment, MRA 2016a) and extending along the northern half of the management unit, forms another control on future erosion of the coast. Scattered offshore and nearshore reefs also influence current and future sediment transport and accretion/erosion of the coast within this management unit. The presence of the limestone ridge acts a barrier to erosion and limits the inland extent of the 2110 hazard line to less than 50 m width for the majority of the management unit. At the northern end the limestone ridge dips lower and the coastline has been classified as sandy for the purpose of coastal hazard assessment (MRA, 2016a). At the northern end the 2110 coastal hazard line extends to about 200m inland (see **Appendix A** and **Table 2-3**).

Residential properties in the northern portion of the management unit have been deemed very highly vulnerable at present, due to their value and proximity to potential coastal erosion hazards. It must be noted that a seawall is currently in place protecting these properties, which should prevent them from being impacted for the duration of its assessed 20-year design life. However, responsibility for maintaining the seawall is still uncertain, and the possibility of it being removed if responsibility cannot be allocated must be considered. Other built assets, such as carparks and roads, have a medium vulnerability at present increasing to high by 2030. Natural assets, such as the beach and coastal dunes/vegetation, have increasing vulnerability ratings across the planning timeframes, becoming very highly vulnerable by 2050. The adaptive capacity of these assets diminishes over time as they are restricted by existing development, particularly in the northern portion of the site (see **Appendix E**). The key outcomes of the risk assessment for management unit SE1 are:

> Residential properties have a very high vulnerability rating at present;

> Carparks and roads in the management unit have a medium vulnerability at present, increasing to a high vulnerability rating by 2030; and

> The beach has a high vulnerability rating by 2030 and both the beach and coastal dunes/vegetation have very high vulnerability ratings by 2050.

3.2.2 SE2 - Seabird North

This Seabird North management unit contains the Seabird Tavern, a number of roads, carparks and public assets and the strata titled caravan park (**Figure 3-3**). The width of the 2110 coastal hazard line is typically 190 m for the 1200m of coastline the above assets are all partially or fully located seaward of the 2110 hazard line. As with SE1, there is a lack of foreshore dune width to facilitate public amenity and beach access along the, roughly 400m section of coast adjacent to the township. To the north of the township, the coast fronts natural assets comprising the beach and vegetated dunes and there is no development within the 2110 hazard line. See **Appendix C** for more information on assets and their values in this management unit.



Figure 3-3 Photograph of the northern section of the Seabird town site SE2 (source: DoT, 2016)

Scattered offshore and nearshore reefs, and visible beach rock along the shore form existing controls that might affect future erosion within this management unit and which have been considered in the risk assessment process. The coastal hazard assessment (MRA, 2016a) treated the coast as sandy and coastal hazard lines advance steadily landward over the planning timeframes (see **Appendix A** and **Table 2-3**).

The caravan park (Seabird Private) in the southern portion of the management unit has an increasing vulnerability over time, becoming high by 2050 and very high by 2070. Natural assets, such as the beach and coastal dunes/vegetation, have increasing vulnerability ratings across the planning timeframes, becoming highly vulnerable by 2050. The adaptive capacity of these assets in front of the town diminishes over time as they are restricted by existing development, particularly adjacent to the caravan park. The tavern has increasing vulnerability over time as the risk of erosion increases, becoming highly vulnerable by 2070 (see **Appendix E**). The key outcomes of the risk assessment for this management unit, SE2, are:

> The caravan park has a high vulnerability rating by 2050 and a very high vulnerability rating by 2070;

> The beach and coastal dunes/vegetation have medium vulnerability ratings by 2030 and high vulnerability ratings by 2050; and

> The tavern has a high vulnerability rating by 2070.

3.2.3 LP1 - Ledge Point South of Township

The Ledge Point South of Township management unit contains predominantly natural assets such as the beach and vegetated dunes (**Figure 3-4**). There are unsealed roads and an unsealed coastal carpark lying seaward of the 2110 coastal hazard line and the values of these assets are described in **Appendix C**.

The coastal hazard assessment treated this coastline as sandy (MRA, 2016b) and the hazard lines advance steadily landward (see **Appendix A** and **Table 2-3**) to the 2110 width of approximately 130 m.



Figure 3-4 Photograph of the Ledge Point South of Township LP1 management unit (source: DoT, 2016)

Although the current beach and vegetated dune system is likely to be eroded over time, this dunal ecosystem extends over broad areas of the coast and hence the consequence of future erosion within this management unit is considered insignificant to minor. The adaptive capacity of these natural assets is also considered high through their ability to migrate inland. The risk profile and vulnerability of natural assets in this area are therefore low to medium across the planning timeframes. The medium to high rating for coastal dunes/vegetation towards the end of the century is based on the assumption that inland migration of the dune habitat is likely, but it is not certain that all ecological functions will be retained. The vulnerability of unsealed roads and carparks is generally low across the planning timeframes, due primarily to their low value (see **Appendix E**) and ability to be relocated. The key outcomes of the risk assessment for this management unit, LP1 are:

> The beach has a low vulnerability rating across the planning timeframes and the coastal dunes/vegetation have a low vulnerability rating to 2030, medium vulnerability rating by 2070 and high vulnerability rating by 2110; and

> The beach carpark and road have low vulnerability ratings up to 2070.

3.2.4 LP2 - Ledge Point Township South

The Ledge Point Township South management unit has about 600 m of ocean front and contains beach and foreshore reserve, 33 residential properties, roads and associated public infrastructure that are located either partially or fully within the 2110 coastal hazard line (**Figure 3-5**). The natural beach and vegetated foreshore reserve is bounded on the landward side by residential development. A small recreational area at the northern end of the management unit is located seaward of the 2070 hazard line. The values of these assets are described in **Appendix C**.



Figure 3-5 Ledge Point Township South LP2 management unit (source: DoT, 2016)

The groyne and headland feature at the northern boundary of the management unit and the scattered nearshore and offshore reefs structures form existing controls to sediment transport and erosion. The coastal hazard assessment treated this coastline as sandy (MRA 2016b) and the estimated hazard lines advance steadily landward (see **Appendix A** and **Table 2-3**) to the 2110 width of approximately 130 m.

Residential properties in the management unit are highly vulnerable at present and predicted to be very highly vulnerable by 2030, due to their value and proximity to potential coastal erosion hazards. Roads associated with these properties have high vulnerability by 2070. Natural assets, such as the beach and

foreshore recreation area, have increasing vulnerability ratings across the planning timeframes, becoming highly vulnerable by 2070. The adaptive capacity of these assets diminishes over time as their ability to adapt is restricted by existing development (see **Appendix E**). The key outcomes of the risk assessment for this management unit, LP2 are:

> Residential properties have a high vulnerability rating at present and a very high vulnerability rating by 2030;

> Roads have a high vulnerability rating by 2070; and

> The beach and foreshore recreation area have medium vulnerability ratings by 2030 and high vulnerability ratings by 2070.

3.2.5 LP3 - Ledge Point Township North

The Ledge Point Township North management unit contains a mixture of residential and commercial properties (i.e. the Holiday Village), as well as roads and carparks, located either partially or fully seaward of the 2110 coastal hazard line (**Figure 3-6**). This foreshore area contains the town's main swimming and recreation beach. A large portion of coastal land is allocated for recreation use and tourism, including Key Biscayne Park, beach access paths and car parking at De Burgh Street. The values of these assets are highlighted in **Appendix C**.



Figure 3-6 Ledge Point Township North LP3 management unit (source: DoT, 2016)

Two groynes: one at the southern boundary and one located slightly south of the centre of the management unit shoreline form important controls for coastal erosion. The coastal hazard assessment treated this coastline as sandy (MRA 2016b) and the estimated hazard lines advance steadily landward (see **Appendix A** and **Table 2-3**) to the 2110 width of approximately 130 m.

Residential properties and the Holiday Village are predicted to be very highly vulnerable by 2070 as the risk of coastal erosion increases. All other built and natural assets are predicted to have medium vulnerability by 2070 and high or very high vulnerability by 2110 (see **Appendix E**). The key outcomes of the risk assessment for this management unit, LP3 are:

> Residential properties have a very high vulnerability rating by 2070;

> The Holiday Village has a high vulnerability rating by 2070 and very high vulnerability rating by 2110; and

> All other assets have medium vulnerability ratings by 2070 and high or very high vulnerability ratings by 2110.

3.2.6 LP4 - Ledge Point North of Township

The Ledge Point North of Township management unit contains predominantly natural assets with the beach and vegetated dunes as well as unsealed tracks and a sailing club (reportedly at the end of its lifecycle) lying seaward of the 2110 coastal hazard line (**Figure 3-7**). The values ascribed to these assets are provided in **Appendix C**.



Figure 3-7 Ledge Point North of Township LP4 management unit (source: DoT, 2016)

There are some scattered nearshore and offshore reef structures but the coastal hazard assessment treated this coastline as sandy (MRA 2016b) and the estimated hazard lines advance steadily landward (see **Appendix A** and **Table 2-3**) to the 2110 width of approximately 130 m

Although the current beach and vegetated dune system is likely to be eroded over time, this dunal ecosystem extends over broad areas of the coast and hence the consequence of future erosion within this management unit is considered insignificant to minor. The adaptive capacity of these natural assets is also considered high through their ability to migrate inland. The risk profile and vulnerability of natural assets in this area are therefore low to medium across the planning timeframes. The medium to high rating for coastal dunes/vegetation towards the end of the century is based on the assumption that inland migration of the dune habitat is likely, but it is not certain that all ecological functions will be retained. The vulnerability of unsealed roads and carparks is generally low across the planning timeframes, due primarily to their low value (see **Appendix E**) and ability to be relocated. The key outcome of the risk assessment for this management unit, LP4 is:

> All assets within the management unit have low vulnerability ratings across the planning timeframes.

3.2.7 LA1 - Lancelin South of Township

The Lancelin South of Township management unit contains predominantly natural assets such as the beach and vegetated dunes. The northern part of the management unit contains a caravan park and Grace Darling recreation that lie partially or wholly, respectively, seaward of the 2110 coastal hazard line (**Figure 3-8**). The values of assets are described in **Appendix C**.

Scattered nearshore reef, Edward Island and the Edward Island Point headland towards the northern end of the management unit form controls on the sediment transport and erosion processes considered in the risk assessment process. The coastal hazard assessment treated this coastline as sandy (MRA 2016b) and the estimated hazard lines advance steadily landward (see **Appendix A** and **Table 2-3**) to the 2110 width of varying from 160 to 200 m.



Figure 3-8 Lancelin South of Township LA1 management unit (source: DoT, 2016)

Grace Darling Park and the Sea Rescue building have been assessed as highly vulnerable at present, and very highly vulnerable by 2030 and 2070, respectively. This is due to the current and increasing risk of erosion impacts, because of their proximity to the coast. The caravan park is seen to have a medium vulnerability at present, becoming highly vulnerable by 2070. The beach and coastal dunes/vegetation have

been assessed as having low vulnerability across the planning timeframes, due to their ability to adapt to ongoing erosion impacts (see **Appendix E**). The key outcomes of the risk assessment for management unit LA1 are:

> Grace Darling Park has a high vulnerability rating at present and a very high vulnerability rating by 2030;

> The Sea Rescue building has a high vulnerability rating at present and a very high vulnerability rating by 2070; and

> The beach, coastal dunes/vegetation and Back Beach Carpark have low vulnerability ratings across the planning timeframes.

3.2.8 LA2 - Lancelin Township South

The Lancelin Township South management unit contains roads, 53 residential properties and associated public infrastructure that are located either partially or fully within the 2110 coastal hazard line (**Figure 3-9**). The natural beach and foreshore reserve are bounded on the landward side by public infrastructure and residential development. Commercial assets include a Lobster receival depot and restaurant at the northern end. The values of these assets are highlighted in **Appendix C**.



Figure 3-9 Lancelin Township South LA2 management unit (source: DoT, 2016)

Extensive nearshore reefs form existing controls within this management unit and have been considered in the risk assessment process. The coastal hazard assessment treated this coastline as sandy (MRA 2016b) and the estimated hazard lines advance steadily landward (see **Appendix A** and **Table 2-3**) to the 2110 width of varying from 100 to 200 m.

Commercial assets in the light industrial area at the northern end are seen as having medium vulnerability at present and are predicted to be highly vulnerable by 2070, due to their value and proximity to coastal erosion hazards. Residential properties and the associated road are predicted to be highly vulnerable by 2070 and 2110, respectively. The beach and coastal dunes/vegetation are predicted to become highly vulnerable by 2070, as coastal erosion risk increases and their ability to adapt diminishes, due mainly to development restricting inland migration (see **Appendix E**). The key outcomes of the risk assessment for this management unit, LA2 are:

> The light industrial area and Café have medium vulnerability ratings at present and have high vulnerability ratings by 2070;

> The beach and coastal dunes/vegetation have low vulnerability ratings at present and high vulnerability ratings by 2070; and

> Residential properties have high vulnerability ratings by 2070 and very high vulnerability ratings by 2110.

3.2.9 LA3 - Lancelin Township North

The Lancelin Township North management unit contains 41 residential properties, roads and associated public infrastructure located partially or fully within the 2110 coastal hazard line (**Figure 3-10**). The beach and coastal dunes/vegetation are bounded to various extents on the landward side by public infrastructure and residential development. Commercial assets include the Endeavour Tavern, the Lancelin Beach Hotel and a caravan park at the northern end. A foreshore recreation area and a small portion of the Primary School also lie seaward of the 2110 coastal hazard line. The values of assets are described in **Appendix C**.



Figure 3-10 Lancelin Township North LA3 management unit (source: DoT, 2016)

Extensive nearshore reefs, Lancelin Island offshore the northern boundary and the Lancelin Island Point headland at the northern boundary form existing controls to future erosion considered in the risk assessment process. The coastal hazard assessment treated this coastline as sandy (MRA 2016b) and the estimated hazard lines advance steadily landward (see **Appendix A** and **Table 2-3**) to the 2110 width of varying from 100 to 200 m.

Due to the value of residential properties in this management unit and the increasing risk of coastal erosion impacts, the assets are predicted to be highly vulnerable by 2030 and very highly vulnerable by 2070. The beach and coastal dunes/vegetation have increasing vulnerability across the planning timeframes as their ability to adapt is restricted by development on their landward side. These natural assets are predicted to be highly vulnerable by 2070. Other valuable assets, such as the Caravan Park, Lancelin Beach Hotel, park and Endeavour Tavern are predicted to be highly vulnerable by 2070, as the risk of coastal erosion impacting them becomes high (see **Appendix E**). The key outcomes of the risk assessment for this management unit LA3 are:

> Residential properties have a high vulnerability rating by 2030 and very high vulnerability rating by 2070;

> The beach and coastal dunes/vegetation have high vulnerability ratings by 2070 and very high vulnerability ratings by 2110; and

> The Caravan Park, Lancelin Beach Hotel, park and Endeavour Tavern have high vulnerability ratings by 2070.

3.2.10 LA4 - Lancelin North of Township

The Lancelin North of Township management unit contains 40 residential properties that are located partially or fully within the 2110 coastal hazard line, as well as roads and associated public infrastructure (**Figure 3-11**). Natural assets include the beach and foreshore reserve, which are well used for recreation near Lancelin Island Point. The beach and dunes are bounded inland by development in the southern portion of the management unit, but unbounded to the north. See **Appendix C** for more information on assets and their values in this management unit.



Figure 3-11 Lancelin North of Township LA4 management unit (source: DoT, 2016)

Nearshore reefs, Lancelin Island offshore the southern boundary and the Lancelin Island Point headland at the southern boundary form existing controls considered in the risk assessment process. The coastal hazard assessment treated this coastline as sandy (MRA 2016b) and the estimated hazard lines advance steadily landward (see **Appendix A** and **Table 2-3**) to the 2110 width of varying from 160 to 200 m.

The beach and coastal vegetation/dunes are predicted to be increasingly vulnerable into the future, particularly in the south of the management unit where their ability to migrate inland is restricted by existing development. These natural assets are predicted to become very highly vulnerable by 2070. Residential properties at the south of the management unit are predicted be highly vulnerable by 2030 and very highly vulnerable by 2070, as the risk of erosion increases across planning timeframes. Existing beach access is predicted to be highly vulnerable by 2070. The key outcomes of the risk assessment for this management unit, LA4 are:

> Residential properties have a high vulnerability rating by 2030 and very high vulnerability rating by 2070;

> The beach and coastal dunes/vegetation have very high vulnerability ratings by 2070; and

> Beach access ways have a high vulnerability rating by 2070.

3.3 Management Units for Priority Consideration of future Options

The risk assessment process has resulted in predictions of vulnerabilities for the assets within each management unit at the three townships, discussed in the preceding sections.

Management units containing assets assessed as having ‘High’ or ‘Very High’ present day vulnerability and/or ‘Very High’ vulnerability by 2030 have been identified to take priority when developing adaptation options for the current CHRMAP process. The priority management units identified include:

> SE1: Seabird Township South (Residential (houses and land));

> LP2: Ledge Point Township South (Residential (houses and land)); and

> LA1: Lancelin South of Township (Grace Darling Park and Sea Rescue building).

4 PLANNING CONTROLS

The risk assessment process highlighted the key areas vulnerable to coastal erosion over the next decade to 2030 as well the longer term vulnerability to 2070 and 2110. The Shires Local Planning Strategy requires that development within the coastal zone follow the requirements of the SPP2.6 and the WAPC (2014a) guidelines for development of a CHRMAP that effectively focuses on two time scales:

- the long term strategic pathway over the next 100 years, and
- planning for implementation of management actions in the shorter term, the next decade, for priority management units.

As discussed in **Section 2.8** and in greater detail in **Appendix H** there exists a complex set of documents and rules that have influenced the evolution of the Shire's coastal townships. Historically, it was assumed that cadastral boundaries enclosed reasonably permanent areas suitable for developing residential and commercial assets ad-infinitum. The notion that the land and assets within these boundaries is now subject to erosion and potentially becomes unusable triggered the establishment of SPP2.6 and the need for careful planning to determine future develop directions of coastal townships.

The essential aim of SPP2.6 is to recognise that SLR and coastal erosion are threatening, currently fixed, coastal zone assets at an increasing rate into the future and to commence the process of adjusting community expectations about life in the future, diminishing coastal zone. Preliminary estimates of protecting property and beach amenity across the State into the future are prohibitively expensive and hence the SPP2.6 policy aims to implement responsible long term planning strategies to develop affordable solutions that satisfy a range of key drivers including intergenerational equity.

As per SPP2.6 and WAPC (2014a) guidelines, and recent *draft Planned or Managed Retreat Guidelines* (DoPLH, 2017c) the long term priority is to adopt a strategy hierarchy of:

- *Avoid*;
- *Managed Retreat*;
- *Accommodate;* and, as a last resort
- *Protect* (to be funded under the beneficiary pays principle).

Ultimately, the aim of SPP2.6 is to manage retreat from vulnerable areas before assets are threatened. This will require a shift in the strategy from, for example, initially protect to managed retreat. The *Protect* strategy proposes that protection be funded by the beneficiaries while the transition from a *Protect* to *Retreat* strategy may trigger funding for removal or relocation under the LAA. The LAA empowers the Minister for Lands to take interests in land on behalf of the State or any "acquiring authority". An "acquiring authority" may include a local government. A number of issues arise out of these strategies, for example;

- Who are the beneficiaries?
- What is a reasonable method for apportioning costs to the beneficiaries?
- Who is responsible for funding managed retreat, in accordance with the mechanisms described in the *draft Planned or Managed Retreat Guideline*?

It is recommended that a comprehensive investigation of each township community and visitors be undertaken to identify beneficiaries of the proposed protection areas. Further, an economic assessment of mechanisms for recouping costs from beneficiaries (e.g. parking fees, visitor entry fee, increased council rates or levy and other options) is required to inform the future review of the strategy options outlined in this CHRMAP.

The following planning framework is similar to that outlined in the *draft Planned or Managed Retreat Guideline*, is to be adopted for this CHRMAP and can be modified as clarity around financial implications of options and funding arrangements evolve. This planning framework includes the following instruments and considerations:

Special Control Area (SCA), to ensure discretion over development proposed in hazard areas. The SCA will show on the scheme map, as required by the Planning and Development (Local Planning Schemes) Regulations 2015 (WA), Schedule 1, Part 5.

Notifications on Title, to inform current and future landholders of coastal hazard risk, as recommended by State Planning Policy 2.6: State Coastal Planning Policy (SPP2.6).

Time Limited Planning Consent Conditions, to allow where appropriate, the temporary use of land in hazard areas until hazards materialise, while ensuring that Councils maintain a level of discretion over development in these areas. Time limits would be identified using coastal hazard mapping projections. If the consent expires before hazards materialise, the proponent may apply for an extension to the consent. If hazards materialise before the time limit expires, Council will consider requiring the demolition or removal of compromised structures under relevant legislative provisions (predominantly the LAA).

Interim Coastal Protection, where development is proposed behind a protection structure, the design life of the protection structure would determine the time limit permitted on planning consents. Maintenance and capital costs of protection are to be funded by the beneficiaries of protection works. Protection would only be considered as a last resort where all other options have been considered, as per SPP2.6.

Assessment Criteria, to ensure consistency when assessing applications for development proposed in hazard areas, for inclusion into a Local Planning Policy.

Development applications for subdivision and zoning beyond existing scheme allowances, are not encouraged and will generally not be approved.

Ultimately the aim of the CHRMAP is to plan for adaption to the effects of rising sea levels and coastal erosion. The general strategy shifts that are likely to be required in future, as assets currently situated in the eroding coastal zone become unviable, is outlined in **Figure 4.1**.

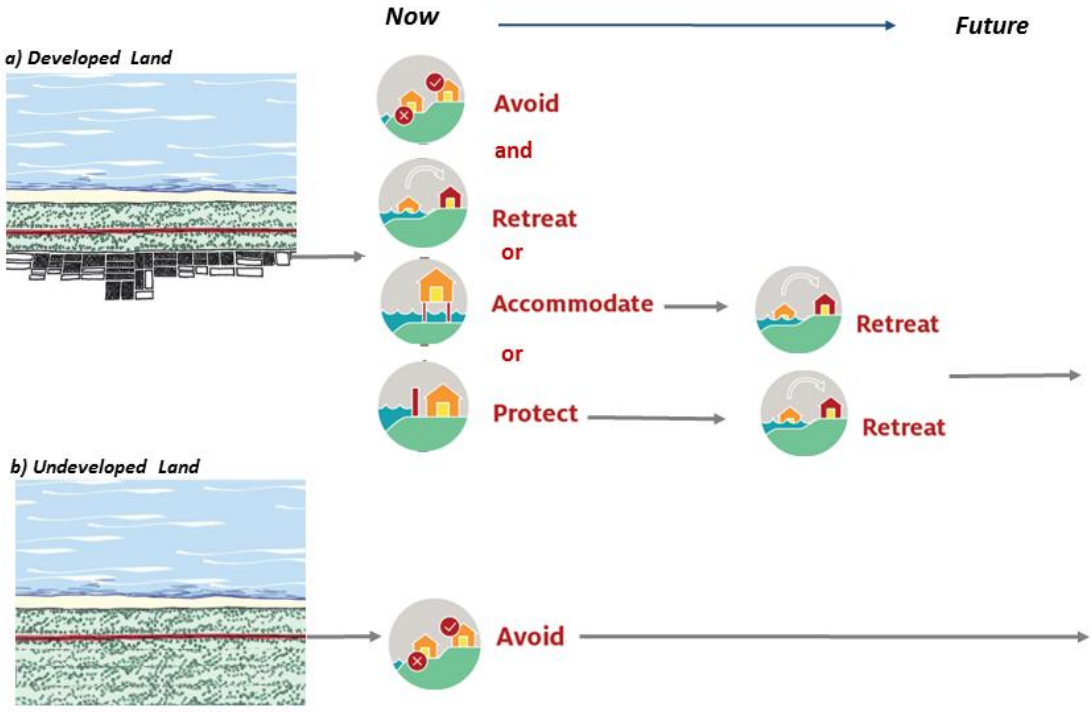


Figure 4-1 Long-term pathways for a) developed and b) undeveloped land

From a practical perspective implementation of managed retreat as suggested in the recent *draft Planned or Managed Retreat Guidelines* (DoPLH, 2017c) would require the State or Commonwealth to provide the majority of funding to acquire property likely to be required under the compensation provisions of the LAA and/or PDA. Clearly, there is no obligation to adopt a policy that effectively forces government to compensate. The general public and landowners should be aware of the risks in any decisions they make about purchasing or developing lands in these coastal areas. The potential financial burden of a Managed Retreat policy are more likely to see Local Government adopt an 'Avoid' or ‘Do Nothing’ policy that

effectively shifts the burden of costs of sea level rise and coastal erosion impacts to landowners and beach users.

The Planning Framework outlined above recognises the complexity of the issues surrounding the adaptation to sea level rise and coastal erosion. The framework:

- allows for the continued use of hazard areas,
- allows landholders to propose development to suit their own needs and recognise the future risks,
- limits future hazard and liability risk to the Shire and State government,
- considers the limited public funding available,
- largely accords with SPP2.6 Policy and Guidelines and the Planning & Development Regulations 2015, and
- is cognisant of community feedback and other local governments.

5 ADAPTATION OPTIONS

5.1 Adaptation Options Overview

Effective adaptation planning involves the identification, development and evaluation of options suitable to manage the risk of coastal hazards. Adaptation options were evaluated in relation to each of the management units, with multiple options identified as potentially suitable for implementation within each unit. For the longer term, strategic planning options are discussed while options for the 3 priority managements units are considered in more detail.

In accordance with SPP2.6 and the CHRMAP guidelines (WAPC, 2014a), potential options have been identified under the risk management categories of 'Avoid', 'Managed retreat', 'Accommodate' and 'Protect' (**Table 5-1**). Note that the government has no obligation to protect private assets from coastal erosion and hence the Protect management category is deemed the least preferred option for implementation, as recommended by the guidelines (see **Flowchart** below, adapted from CoastAdapt, 2017). The range of adaptation and management options were based on WA's CHRMAP guidelines (WAPC, 2014a) and are described in **Table 5-1**.

'Avoid' is seen as the preferred strategy but is generally only applicable to undeveloped coastal land and areas of the coast where intensification of development in hazardous areas might be proposed. This option is underpinned by the implementation of planning controls, which should prevent inappropriate use of land in areas identified as potentially at risk from coastal hazards.

'Managed retreat' is a preferred long term strategy for areas of existing development at risk. This option aims to remove assets from the risk of coastal hazards and is economically responsible over the long term, although it may involve significant expenditure during implementation. The planning mechanisms around implementing 'avoid' and 'managed retreat options' have been discussed in **Section 4**.



'Accommodate' options aim to re-design existing infrastructure to mitigate potential impacts as they occur, and allow for land use of a low risk (for example temporary) nature. This option is rarely applicable to areas, at risk of coastal erosion but is suitable to some areas prone to coastal inundation, where assets can be elevated above flooding to maintain land use in a designated hazard area. The ability for substantial, built assets to be redesigned to accommodate coastal erosion hazards is generally limited.

'Protect' options range from temporary 'soft' protection, such as sand nourishment, to semi-permanent 'hard' protection options, such as groynes and seawalls. It should be noted that no protection option is considered permanent, and all have associated ongoing expense to implement or maintain. This ongoing expense and the inability of protection options to permanently mitigate the risks associated with coastal hazards are the primary reasons why these options are considered the least favourable in the preferential planning hierarchy. Hard protection options also have the potential to divert coastal erosion hazards elsewhere, increasing risk for adjacent areas or assets and potentially creating liability for those responsible for the structures.

SPP2.6 Clause (5.5 (iii)) states that the employment of protection options should be sought only 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*

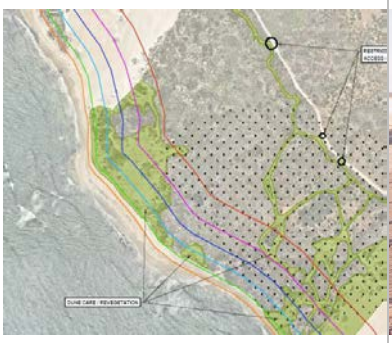
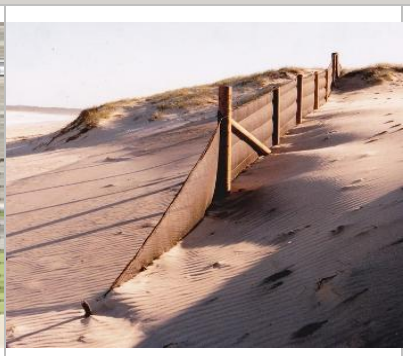
there is a need to preserve the foreshore reserve, public access and public safety, property and infrastructure that is not expendable."

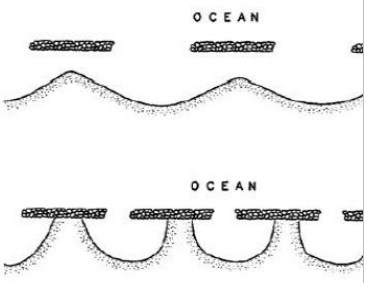
Table 5-1 Adaptation and Management Options (adapted from WAPC, 2014a)

Option Category	Option Name	Option Code	Description
Avoid	Avoid development	**AV**	Avoidance of freehold residential or commercial development within the coastal foreshore reserve.
Managed Retreat	Leave unprotected / repair	**MR1**	Assets are left unprotected and loss is accepted following hazard event. Repairs may be implemented to extend life and for public safety in the short term. In the case of natural assets, such as beaches and vegetation, allow the impacts of hazards to occur.
	Remove / relocate	**MR2**	Assets located in the hazard zone are permanently removed or relocated. For residential and commercial property, this option may require voluntary or compulsory acquisition of land, transferrable development rights and land swaps.
	Planning controls for Managed Retreat	**MR3**	Use of planning controls to allow continued use of the current infrastructure until such time that impacts arise, but restrict the development of further infrastructure (densification) as the area/asset is known to be vulnerable. This option also includes mechanisms for ensuring that Local Government, land owners and prospective buyers are made aware of the risk.
Accommodate	Planning controls for accommodation	**AC1**	Indicates to current and future landholders that an asset is at risk from coastal hazards over the planning timeframe. Helps owners to make informed decisions about the 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 assets/areas that are at risk of coastal erosion. Have procedures in place for before, during and after the events for safety. E.g. signage/barriers to prevent access.
Protect	Dune care / sand management	**PR1**	Development of a long term program for revegetation and rehabilitation of the dune system. Sand fencing to manage wind-blown erosion also falls under this category (also see **Table 5-2**).
	Beach nourishment / sand management	**PR2**	Addition of sand to the beach, dune and/or nearshore area to replace lost material and/or create additional buffer. This option is a temporary measure and can be more effective in association with hard protection options, such as groynes. The sand may be from an external source or from a nearby part of that coastal area (i.e. via sand bypassing or back passing) (also see **Table 5-2**).
	Groyne	**PR3**	Construct groynes along the beach to restrict longshore sediment movement and stabilise sections of shoreline. This option is often accompanied by beach nourishment. Hard protection generally diverts erosion issues elsewhere, such as to the down drift side of a groyne, and can have significant impact on coastal ecosystems (also see **Table 5-2**).
	Nearshore reef / breakwater	**PR4**	Construct offshore reef(s)/breakwater(s) or raise existing natural nearshore reef structure to maintain level of protection as sea level rises. Hard protection generally diverts erosion issues elsewhere, such as to beaches either side of the nearshore structures, and can have significant impact on coastal ecosystems (also see **Table 5-2**).
	Seawall	**PR5**	Construct seawall in front of assets or along length of coastline to protect them from coastal hazards. Hard protection generally diverts erosion issues elsewhere, such as to beaches either side of, and directly in front of, a seawall. They can also have significant impact on coastal ecosystems (also see **Table 5-2**).
Do nothing	Do nothing	**DN**	Take no action. No limitations on development or implementation of adaptation planning. Accept risk.

Although protection measures are the least favoured option, particularly as a long-term mitigation measure, they remain the most commonly employed coastal risk mitigation strategy globally. There are several effective protection techniques that can be employed to manage the risks of coastal erosion in the short to medium term. **0** provides additional detail on protection options available.

Table 5-2 Overview of protection options considered in the CHRMAP

a) Dune Care		
		Dune care is a "soft" protection option that is relatively low cost and can assist by stabilising dune systems. It involves actively revegetating dunes or preventing degradation by restricting access, for example with fencing and signage. Dunes form a natural buffer to coastal erosion, which can protect areas and assets located behind them. Dune vegetation helps to prevent wind-blown erosion of dunes and stabilises the dune structure. Dune care is often undertaken by local volunteer groups.
b) Beach Nourishment		
		Beach nourishment is a "soft" protection option that provides temporary protection against coastal erosion. Sand can be sourced from another area of the beach, from an inland source, such as inland dunes or a sand quarry, or from offshore. Nourishment generally involves placement of sand on the upper beach face to act as a buffer during extreme events. Nourishment is often combined with other protection options such as groynes or offshore protection, which enhance its longevity. A nourished beach profile may provide protection for between 18 months and five years, before the beach returns to its original state.
c) Groynes		
		Groynes are "hard" protection options that extend from above the high water mark, across the active shoreline and into the nearshore area. They are usually constructed perpendicular to the beach and can take various shapes such as T or L shapes. They can be constructed of rock, geotextile sand containers, timber or concrete. Groynes act to interrupt alongshore sediment transport which results in a build-up of sand on the up drift side of the groyne and an erosion on the down drift side. Groynes may be constructed as single groynes or in a groyne field to protect a larger area. Groynes have minimal impact on cross-shore sediment transport, such as that associated with storm-based erosion, outside of their immediate vicinity. Groynes are often complimented by additional beach nourishment, to increase the beach width on their up drift side.

d) Nearshore Reef / Breakwater		
		Artificial nearshore reefs or breakwaters are "hard" protection options. They can be constructed of rock, concrete or geotextile sand containers. They function by diverting wave energy either side of the structure, which pushes sediment onto the shore inside of the structure. This results in the formation of a salient or even a tombolo in the lee of the structure, which results in an increase in beach width and an increased buffer against coastal hazards. Nearshore reefs or breakwaters affect both longshore and cross-shore sediment transport but do not fully interrupt either. Their feasibility is often determined by the nearshore water depth and the bottom type. They are generally more expensive to construct (per metre) than groynes, due to deeper water requiring a larger volume of construction material and leading to higher construction costs.
e) Seawall		
		A seawall is a "hard" protection option, which can be constructed of rock, geotextile sand containers or concrete, and can be either exposed or buried to improve visual amenity. A seawall is a solid barrier constructed parallel to the coast at the land-sea boundary, which functions by acting as a physical barrier to coastal erosion, protecting areas and assets on its landward side. Seawalls can also provide protection against inundation. Seawalls generally focus wave energy in front of them and to their sides, due to reflection off the structure. This usually leads to a more rapid loss of beach in the vicinity of the structure, leading to a "hardened" shoreline with poor useability and public amenity.

5.2 Adaptation Options Assessment Process

Each of the adaptation options presented in **Table 5-1** has been considered for each of the three priority management units identified in the risk assessment for this study. As recommended in the State CHRMAP Guidelines, a multi-criteria analysis has been used as a preliminary step to identify potentially suitable adaptation options for each management unit, as well as to discount unviable options. The analysis uses a broad range of criteria and a simple 'traffic light' rating system to evaluate the acceptability of each option. The assessment considers the effectiveness of options at reducing risk and performing their function in relation to governance, environmental, social and economic aspects. Information gained through the stakeholder and community engagement process has been used to reflect the community in the assessment. Options have also been assessed in terms of their restriction on future planning and risk management opportunities, with options that allow for a wide range of future strategies considered more favourably. The analysis takes into consideration the following criteria:

Preliminary feasibility:

- Effectiveness;
- Governance, legal implications and approval risk; and
- Reversibility / adaptability.

Preliminary acceptability:

- Environmental and social impact; and
- Community acceptability.

Preliminary financial implication:

- Financial gain / avoidance of cost;
- Capital cost; and
- Ongoing cost.

The criteria and a description to guide the assignment of a rating for each criteria considered is presented in **Table 5-3**. Ratings have been assigned by taking into account information gathered prior to, and during, the CHRMAP process. This information includes feedback from ongoing stakeholder and community consultation, planning considerations (outlined in **Section 4**), previous investigations of the study areas and the outcomes of the coastal hazard assessments and risk assessment process. The analysis has also been guided by coastal engineering, management and planning expertise, and knowledge of other coastal management projects and techniques.

Based on the ratings assigned under each criteria for a particular adaptation option, a qualitative judgement is then made as to whether that option is recommended, not recommended or requires further investigation. It should be noted that red lights do not necessarily exclude an option, and it still may be recommended that such an option be investigated further. The outcomes of the multi-criteria analysis, for each management unit, are presented and discussed in **Section 5.3**, below.

For priority management units (as defined in **Section 3.3**) those options recommended for further investigation have been assessed in greater detail. This additional detail is discussed for each of priority management unit in **Sections 5.4** to **5.6**, respectively. Recommendations as to whether these options should be implemented and, if so, the details around this implementation are discussed in the Implementation Section (**Section 6**). Recommended options for long term pathways across all management units are also considered in **Section 6**.

Table 5-3 Multi-criteria assessment and qualitative cost benefit input ratings and assessment outcome categories

	Preliminary Feasibility			Preliminary Acceptability		Preliminary Financial Implication			Outcome
	Effectiveness	Governance / 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 governance or 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 governance or 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									

5.3 Multi-criteria Analysis Results

The detailed results of the multi-criteria analysis for each management unit are presented in **Appendix F**, with the final recommendations for each option summarised in tables presented in **Appendix G**. The following subsections discuss the outcomes of the analysis, with respect to the assets and their vulnerabilities, at each town site.

5.3.1 Seabird South (SE1 and SE2)

The outcomes of the multi-criteria analysis are consistent for the two management units within Seabird (SE1 and SE2).

The multi-criteria analysis recommended further investigation of the following options:

- MR2, the process of implementing managed retreat of assets;
- PR3, using groynes as a protection measure; and
- PR5, extending the recently constructed seawall and/or maintaining it beyond its 20-year design life to provide ongoing protection to assets.

The options recommended for implementation in the short term include:

- AV, avoiding further development in identified hazard areas;
- MR3, implementing planning controls to facilitate future managed retreat from these areas;
- AC1, planning controls to accommodate risk;
- AC2, the preparation of emergency plans and controls; and
- PR1, low cost protection options such as dune care and sand management.

An assessment of adaptation options recommended for further investigation is discussed in **Section 5.4** and the implementation plan presented in **Section 6**.

5.3.2 Ledge Point

LP1 and LP4

Ledge Point South of Township (LP1) and Ledge Point North of Township (LP4) management units are characterised by undeveloped natural assets and the outcomes of the multi-criteria analysis are consistent for both management units. It is recommended that substantial residential and commercial development is avoided (AV) in these units. Planning controls (MR3, AC1) are recommended for implementation to prevent inappropriate development. Low cost protection options such as dune care and sand management (PR1) are recommended.

Beach nourishment (PR2) and hard protection options (PR3, PR4 and PR5) have been assessed as expensive and inappropriate with respect to the existing assets and nature of the risk in these management units, so are not recommended.

LP2 and LP3

The outcomes of the multi-criteria analysis are consistent for both this and the Township North management unit (LP3).

Options recommended for further investigation included:

- MR2, the process of implementing managed retreat of assets; and
- PR2, PR5, and PR3, protection options of beach nourishment, groyne(s) and a seawall require further investigation to assess their suitability for implementation.

The options recommended for implementation in the short term include:

- AV, avoiding further development in identified hazard areas;
- MR3, implementing planning controls to facilitate future managed retreat from these areas,

- AC1, planning controls to accommodate risk;
- AC2, the preparation of emergency plans and controls; and
- PR1, low cost protection options such as dune care and sand management.

An assessment of adaptation options recommended for further investigation is discussed in **Section 5.5** and the implementation plan presented in **Section 6**.

5.3.3 Lancelin

Identifying suitable adaptation options and determining an adaptation pathway for the priority management unit at Lancelin South of Township (LA1), is considered urgent. The outcomes of the multi-criteria analysis are consistent among all management units within Lancelin (LA1, LA2, LA3 and LA4).

The multi-criteria analysis recommended further investigation of the following options:

- MR2, the process of implementing managed retreat of assets;
- PR2, beach nourishment; and
- PR3 and PR5, groynes and a seawall, respectively, require further investigation to assess their suitability and cost (initial capital and ongoing maintenance costs).

The options recommended for implementation in the short term include:

- AV, avoiding further development in identified hazard areas;
- MR3, implementing planning controls to facilitate future managed retreat from these areas;
- AC1, planning controls to accommodate risk;
- AC2, the preparation of emergency plans and controls; and
- PR1, low cost protection options such as dune care and sand management.

An assessment of adaptation options recommended for further investigation is discussed in **Section 5.6**, for LA1 and the implementation plan presented in **Section 6**.

5.4 Adaptation Options – Seabird Township South (SE1)

The coastal hazard assessment (MRA, 2016a) was undertaken prior to construction of the recently constructed seawall. The present day and 2030 coastal hazard extents should be reassessed during the next round of review of the CHRMAP, particularly for the area adjacent to the seawall. This risk assessment and multi-criteria analysis processes, however, have considered the protective structure.

The current seawall was installed as a temporary protection device while the broad range of issues on the management of the coastal zone are considered and implemented at some point in future. The seawall was not designed as a permanent solution and it is likely that it will fail under extreme events at some point in the future. If this was to occur, the presence of the limestone ridge is likely to reduce the risk of erosion landward of McCormick Street as shown by the hazard map (**Appendix A**) but properties seaward of McCormick St would be affected.

The coastal hazard risk to built assets has been mitigated for the short term (up to ca. 2030) by the construction of the seawall. This seawall has, however, impacted (and is likely to continue to impact) the adjacent beach to the north of the seawall, the public amenity and associated coastal access. The long term tenure and management arrangements for the seawall are still undecided and continue to be the subject of discussions between the State and the Shire. Planning for management of this area should consider the following:

> Tenure of land and management responsibility;

> Design life of the current seawall (estimated to be 20 years);

> Economic value of assets at risk from coastal processes / benefiting from the seawall;

> Investigation of medium to long term adaptation options:

- managed retreat (MR2);

- groyne(s) (PR3);
- seawall extension and/or maintenance (PR5); and

> Equity implications and sources of funding.

Government has no legal responsibility to protect this area but in the recent past the State provided funding for the seawall. Potential funding sources, including private property owners, the State or the Shire will need to be carefully considered during the investigation of solutions to this issue.

5.4.1 Land Tenure and Seawall Management

The Seabird seawall was constructed on Shire road reserve (the portion of Turner St that previously existed in front of some of the houses) and unvested (or unallocated) Crown land (UCL) on the seaward side of the road reserve. Management of the UCL is the responsibility of the Department of Planning, Lands and Heritage.

The seawall is currently being managed by the Shire of Gingin under a license issued under section 91 of the LAA by the Department of Lands. The license authorises temporary use to other parties. The Licence has been extended for 3 years to 2020; however, this arrangement is not considered to be a long term management solution. Tenure of the land, and therefore management responsibility for the seawall, should be transferred to the Shire for ongoing control, monitoring and maintenance of the structure until a long term solution is considered during the CHRMAP review process in 5 to 10 years.

5.4.2 Value of Assets at Risk

An estimate of the economic value (2015 $) of built assets lying seaward of the 2030 coastal hazard line is presented in **Table 5-4** (draft CHRMAP, Shire of Gingin 2016b). The value of assets protected by the seawall at the 2030 planning timeframe is around $8M. To provide context for subsequent discussion of the application of a beneficiary pays system to fund future coastal management the Shire's revenue base, in 2105 dollars, for the 15-year period (2015 to 2030) is also estimated in **Table 5-4**. The Shire's current revenue is allocated to a broad range of Council activities across the Shire. The current budget does not include provision for current or future allocation of funds to address coastal management issues nor respond to coastal erosion events.

Table 5-4 Summary of estimated value (2015 $) of vulnerable built assets in the Seabird Township South management unit (from draft CHRMAP, Shire of Gingin, 2016b)

Asset type			2030	
	unit	Rate($)	#	value ($)
Roads (main)	m	800	0	0
Roads (secondary)	m	500	174.7	$ 87,350
Footpaths / Cycleways / Beach Access	m	350	123.5	$ 43,225
Carpark	m^2	70	1150	$ 80,500
Private properties: residential				
- land vacant	#	250,000	0	$ 4,000,000
- houses and improvements	#	250,000	16	$ 4,000,000
Private properties: commercial, holiday accommodation				
- land	m^2	150	0	0
- improvements (chalets)	#	180,000	0	0
Total				**$ 8,211,075**
Rate Base Revenue over 15 years, 2015 to 2030 (in 2015 $)				
Affected properties	#	$997	16	$239,280
Township	#	$997	140	$2,093,700
Shire	#	$997	1273	$19,037,715

* includes S2

The Shire is reliant upon the State for emergency response assistance and limited funding of ongoing coastal projects through the State's coastal program which is subject to competitive bidding process. Options for increasing equitable enjoyment of the ocean frontage aspect enjoyed by properties positioned above the seawall, for example rezoning of some areas to allow for commercial use may also be considered.

5.4.3 Remove and Relocate (MR2)

There are currently no specific mechanisms for implementing government funded managed retreat in the CHRMAP context. Further, government has no legal obligation to maintain property or access. Noting that the State funded the seawall construction its present maintenance arrangements (eg., to maintain its structural intregrity as a protection for hinterland property against extreme erosion events) are subject to negotiation between the Shire and the State. Under the present arrangements the likely scenario is that as extreme events erode the shoreline and private assets, access to properties in SE1 would be prohibited as they become unsafe and/or illegal to occupy. The mechanism to implement a managed retreat policy including legal and financial/economic considerations as well as agreement on the future of the seawall, its costs (maintenance or removal) and its role in ongoing protection needs further investigation. For example, the development of a managed retreat policy that seeks to invoke the provisions of the LAA or the PDA, regarding voluntary or compulsory acquisition, will need to carefully consider the cost implications and apportionment of costs prior to adopting such an approach.

Triggers for retreat might include:

> Distance of the asset from the HSD datum is less than S1 (noting that this has not been recalculated to include the presence of the seawall);

> Loss of legal access to property; or

> Loss of essential services

R_SE1.1: It is recommended that a comprehensive economic study, including detailed economic analysis and proposed costs apportionment to identified beneficiaries, be undertaken by the Shire and the State to guide eventual managed retreat from hazardous areas.

5.4.4 Groynes (PR2)

A groyne, or groynes, could be considered as part of a future protection strategy for assets at risk in this management unit. Given that an existing protection measure is already in place (seawall (PR5)) and expected to provide protection for at least the next 20 years, a detailed assessment of the suitability of a groyne(s) for this area is not required in the immediate term.

Groynes could be implemented as a protection measure after the seawall has reached the end of its lifecycle. Material from the seawall could potentially be used in the construction of the groynes, reducing supply and transport costs. Installing groynes in addition to the existing seawall, as some community members have suggested, would not be recommended at this time. The presence of the seawall would reduce the effectiveness of groynes in retaining sediment and stabilising the shoreline in the area.

It should be noted that the installation of groynes, beyond the lifecycle of the seawall, would not be expected to provide protection for all existing assets. A loss of functionality (or the removal) of the seawall would likely trigger a need for managed retreat of multiple residential properties, due to a high risk of impact from coastal hazards. Installing groynes could help restore the useable beach, which has been eroded in front of the seawall, and provide temporary protection for some built assets.

MRA (2015) undertook a preliminary assessment of the feasibility and cost implications for protecting vulnerable assets using groynes up to 2030, prior to the construction of the seawall. They estimated a total cost of approximately $14 million, the majority of this being associated with initial and ongoing sand nourishment required in addition to the groynes. The cost of implementing this protection measure for a 15-year period (for example) beyond the lifecycle of the seawall is likely to have similar cost implications to this amount. The benefit of implementing this management strategy should be assessed in detail, alongside the expected benefit it will provide, prior to the end of the seawall's lifecycle. The equitable apportionment of costs among beneficiaries of such an option would also require a detailed assessment to justify its viability for the Shire.

R_SE1.2: It is recommended that the feasibility and suitability of groynes be assessed in detail, prior to the end of the seawall's lifecycle (presently estimated to be 2035). It is not recommended that groynes be considered for implementation as a management strategy in the immediate term.

5.4.5 Seawall Maintenance (PR5)

A "temporary" seawall has been implemented in this management unit, to provide protection to residential properties (particularly in the northern part of this unit) that would otherwise highly vulnerable to coastal erosion hazards. The design life of the structure is estimated to be 20 years, meaning the protection measure is expected to be in place until at least 2035. Land tenure and management responsibility associated with the seawall is discussed in **Section 5.4.2**. Ongoing seawall monitoring and maintenance costs need to be considered, and these are likely to be between $100,000 and $300,000 per decade.

The acceptability of the seawall to the community should also be monitored over the lifecycle of the structure and results reported as part of future reviews (each 5-10 years) of the CHRMAP. Feedback from community engagement associated with this CHRMAP has indicated that some community members are concerned with the loss of beach amenity and its accessibility caused by the seawall. Observations during a site visit in February of this year showed the beach in front of the seawall had receded, giving it limited accessibility and useability. Should this current and potentially ongoing, loss of public amenity be deemed unacceptable to the overall community, with respect to the benefit provided by the seawall, removal of the seawall before the end of its lifecycle (also see **Section 5.4.4**) could be triggered.

R_SE1.3: It is recommended that the seawall is monitored and maintained for the duration of its (estimated) 20 year design life, provided the consequences of its presence are acceptable to the overall community throughout this period. An assessment should be made prior to (approximately) 2035 to decide how this area should be managed beyond this timeframe. Options may include:

> Continue monitoring, maintaining and retrofit (if required) the seawall to extend its useful life;

> Completely remove the seawall (and by implication either manage retreat or do nothing and allow eventual abandonment);

> Remove the seawall and use material (if appropriate) to implement groynes as a protection measure (see **Section 5.4.4**); and

> Leave the seawall in place, discontinue monitoring and maintenance and allow it to deteriorate in future (do nothing and allow future abandonment).

It must be noted that depending upon the policy position adopted by the Shire the last three options are likely to trigger either abandonment (Do Nothing), or managed retreat of some assets that are presently behind the seawall (see **Section 5.4.4**), or a Protection policy. The cost and viability implications of adopting either these policy positions requires detailed assessment to inform optimal decision. The associated costs of maintaining the wall and equitable apportionment of these costs to beneficiaries creates a difficult issue for the Shire and the community that also needs to be considered as part of an investigation.



Figure 5-1 Photographs of the Seabird seawall taken during a site visit in February 2017

5.5 Adaptation Options – Ledge Point Township South (LP2)

There are 33 residential properties lying seaward of the 2110 coastal hazard line in this management unit, with six properties intersected by the present day hazard line (**Appendix A**). The economic value associated with these properties has led to their high vulnerability rating at present, meaning immediate implementation of adaptation measures is required. Examination of Landgate cadastral information indicates that some property boundaries extend seaward of the current vegetation line. Public access along top of the dunes across private property is possible, due to a lack of property boundary fencing, but there is no allocated public foreshore reserve and direct public access to the beach is limited.

The beach in this management unit is well used, particularly with vehicles accessing the beach and launching vessels from the shore. The preservation of this public amenity should be considered when assessing the suitability of adaptation options.

As described in **Section 2.3**, there are two rock groynes, one at the northern boundary of the management unit and one approximately 250 metres north of this. Historical aerial imagery suggests that, since their construction in the 1970s groynes have been effective in retaining sediment in the area. Recent aerial imagery suggests the groynes have become saturated with beach sand. It is important to note that the groyne structures themselves do not provide a protective function. Generally, the additional sediment they trap provides a greater buffer against coastal erosion impacts. Note, however, that trapping sediment that is part of a longshore transport system exacerbates the beach erosion down-stream (to the north) of the groyne. **Figure 5-2**, below, illustrates how a sediment buffer can be eroded during storm activity.

Preliminary plans by the Department of Transport for a boat ramp/marina to the south of the Ledge Point township are currently being considered. Assessing the potential impacts of such a development is beyond the scope of this CHRMAP project.

R_LP2.1: It is recommended that the planning of the boat ramp/marina consider the short term implementation plan and long term management pathways for Ledge Point articulated in this CHRMAP. Similarly, the Shire should carefully review any plans for such a development with respect to the outcomes of this CHRMAP.



Figure 5-2 Photo monitoring images (NACC 2017) from LP2 showing erosion following storm events in September 2009 (left) and redevelopment and revegetation of dune slope by June 2016 (right).

5.5.1 Value of Assets at Risk

An estimate of the economic value (2015 $) of built assets lying seaward of the 2030 coastal hazard line is presented in **Table 5-5** (draft CHRMAP, Shire of Gingin, 2016b). Note that this table only includes assets in LP2 impacted by 2030. The apportionment of costs on a beneficiary pays principle suggests that there needs to be significant assessment of the beneficiaries and the value each derives from retaining the beach.

5.5.2 Remove and Relocate (MR2)

Removal of properties at risk of erosion to the west of DeBurgh Street is an option in LP2.

There are currently no specific mechanisms for government funded managed retreat in the CHRMAP context, however voluntary or compulsory acquisition may be implemented under the provisions of the LAA or the PDA (See **Section 4.1**).

It is reasonable to assume that triggers for retreat might include:

> distance of the asset from a datum such as the HSD is less than a yet to be determined set distance (for example 40 m);

> distance of the asset from the HSD is less than S1 (i.e. 12 m for LP2);

> Loss of legal access to property, or

> Loss of essential services.

Since the distance of the assets from the HSD is around 20 m for most of the seafront properties in this area, the need for retreat in relation to S1 would not yet be triggered, however this could change in a single storm event.

In the event of voluntary or compulsory acquisition of the affected property, the total cost (assuming a future valuation of the property would be similar to its present estimated value) presented in **Table 5-5**, is estimated at about $250,000.

Table 5-5 Summary of estimated value (2015 $) of vulnerable built assets in Ledge Point (from draft CHRMAP, Shire of Gingin, 2016b)

Asset type			2030*	
	unit	Rate($)	#	value ($)
Roads (main)	m	800	0	0
Roads (secondary)	m	500	0	$0
Footpaths / Cycleways / Beach Access	m	350	66	$23,100
Carpark	m^2	70	0	$0
Private properties: residential				
- land vacant	#	250,000	0	$0
- houses and improvements	#	250,000	1	$250,000
Private properties: commercial				
- land	m^2	150	0	0
- improvements (chalets)	#	180,000	0	0
Total				**$523,100**
Rate Base Revenue over 15 years, 2015 to 2030 (in 2015 $)				
Affected properties	#	$997	33	$493,515
Township	#	$997	379	$5,667,945
Shire	#	$997	1273	$19,037,715

* all assets impacted by 2030 are located in LP2

5.5.3 Beach Nourishment (PR2)

Beach nourishment should aim to increase the profile of dunes at the back of a beach, providing additional buffer against storm-based erosion to protect assets inland. It is generally more effective when used amongst groynes, which help to retain the sediment in situ. Beach nourishment is a temporary protection measure that can provide additional buffer to areas inland for varying lengths of time, depending on the rate of ongoing nourishment and severity of storm event erosion. This variability makes it difficult to assess the predicted benefit of nourishment, with respect to the cost.

Sand nourishment could be used in front of vulnerable assets to provide additional protective buffer against coastal hazards and to help maintain the useable beach width and amenity in this area. The longevity of such nourishment would probably be assisted by the presence of an existing groyne at the north of the study area. Refurbishment and/or extension of this groyne (discussed below in **Section 5.5.5**) would also be likely to improve the effectiveness of any sand nourishment.

MRA (2015) suggested an initial nourishment volume of approximately 40,000 m^3 for this area. The cost of such nourishment could range from approximately $400,000 to $2 million, depending primarily on the location of the sand source. A rough assumption would be that this nourishment provides additional protection to the area for a period of 18 months to 5 years, before the beach returns to its original state and additional nourishment is required to continue the protection technique. As nourishment sand is redistributed (offshore and alongshore) subsequent to its placement, the level of protection of areas behind the beach diminishes and progressively exposes these assets to severe storm events.

R_LP2.2: Beach nourishment would be recommended for this area if funding is available and can be allocated. Such funding could be sought from the 33 residential property owners who stand to benefit from beach nourishment. Should it wish to pursue this option, it is recommended that the Shire identify a suitable sediment source and refine a cost per cubic metre, to extract, transport and place material from this source. An affordable volume of nourishment can then be assessed and an appropriate beach profile can be designed to guide sand placement.

5.5.4 Groynes (PR3)

An existing groyne is in place at the northern boundary of this management unit. The installation of this groyne in the 70s was effective in reconfiguring and stabilising the shoreline to the south. The groyne now appears to be saturated and is unlikely to provide additional protection beyond this point in time. The effective use of groynes in the area previously suggests that this protection technique could continue to be used effectively into the future. A variety of groyne placements could be considered, including refurbishing existing groynes and installing up to two new groynes.



Figure 5-3 Existing rock groyne at northern boundary of the Ledge Point Township South management unit

In the immediate term, as a first stage, it is recommended that a detailed investigation of the sediment transport processes and sediment budget of the past 50 years be carried out to inform the selection of appropriate groyne/sand nourishment options. Pending the outcome of such an investigation, it may be recommended that the existing groyne at the northern boundary of the management unit be refurbished and extended seaward (see **Figure 5-3**). The cost of designing and constructing the extended groyne is likely to cost $1-2 million. Monitoring and maintenance costs for the groyne are likely to be in the order of $50,000 to $150,000 per decade. A typical rock groyne structure would be expected to have a design life of 35 to 50 years.

Extending this groyne would help retain additional sediment (as additional protective buffer) on the beach in front of residential properties at the northern end of the management unit. The assets in this area have the highest vulnerability to coastal hazards at present. Extending the groyne would be more effective if associated with initial and ongoing beach nourishment, similar to that described in **Section 5.5.4** (also see **Figure 5-3**).

Partial or full funding for the protection works should be sought from the 33 residential property owners who stand to benefit from the management strategy.

It must be noted that the extension of this groyne is likely to exacerbate seasonal erosion to its north. The full extent of this erosion is difficult to predict. The additional management measures, and their costs, that may be required to the north of this management unit should be properly considered before this management technique is adopted.



Figure 5-4 Conceptual representation of existing groyne refurbishment and extension, with sand nourishment and potential locations for future groynes

Beyond this first stage, the installation of additional groynes could be considered to provide protection for assets further to the south of this management unit, as their vulnerability increases (**Figure 5-4**). MRA (2015) assessed an option to install two additional groynes in the management unit. They estimated the construction of groynes and associated beach nourishment, providing protection for 15 years, would cost approximately $4 million. The suitability of installing additional groynes can be investigated at a later stage, and should be based on ongoing beach monitoring in the short term and also the performance on the first stage groyne extension, should that option be implemented.

5.5.5 Seawall (PR5)

A seawall could be considered as a protection measure in this area and has been investigated previously by MRA (2015) who estimated the cost to install a seawall at approximately $1.2 million. The concept location is shown in **Figure 5-5**. They noted that the approach and costing was of a preliminary nature and that detailed design would need to be carried out based on site specific data and further, the potential impacts on the amenity of the beach and potential to increase erosion in adjoining areas would need to be investigated. Ongoing maintenance of the rock seawall would cost approximately $130,000 per decade.

The above costings are also representative of “best practice” for a long term structure design and more cost effective options may be adequate for medium term protection of assets in LP2.



Figure 5-5 Conceptual representation of seawall

5.6 Adaptation Options - Lancelin South of Township (LA1)

The key asset at risk in management unit LA1 is Grace Darling Park (**Figure 5-6**). This is a grassed recreation area and is a very popular spot for both tourists and locals. It offers sheltered, shallow waters with some protection from southerly winds, and the grass is used as a rigging area for kite and windsurfers. Built infrastructure includes a Sea Rescue Building, an ablution block and picnic facilities. The erosion of the park has generated considerable concern in the community, and raised local awareness of coastal erosion threats to adjacent residential areas.

There is some conjecture that the grassed nature of the area has contributed to localised erosion, however this is unsubstantiated. It is more likely that the localised erosion is due to wave energy and currents formed due to the presence of Edward Island (see Section 5.6.3). The grassed area is slightly elevated in relation to the natural dunes to the north, which may be significant in relation to coastal inundation in later revisions of the CHRMAP.

Inland from Grace Darling Park is the Lancelin South Caravan Park (hereafter referred to as the caravan park) which is vested in the Shire. Hazard lines also intersect parts of the leased area, including some on-site infrastructure and semi-permanent structures. Lease arrangements for new management of the caravan park are currently close to finalisation. The new lessees are required to provide a plan demonstrating how coastal hazards will be managed and public foreshore reserve will be maintained over time.

In previous years, short-term management of erosion has been carried out through nourishment. The beach was renourished by placing sand in front of the erosion scarp in November 2014 and May 2015 (Seashore Engineering, 2015). It is understood sand was sourced locally from Aglime Australia's lime sand pit, with a bobcat used to distribute sand in front of the erosion scarp. A portion of this material was lost rapidly. It is also understood that some opportunistic renourishment has occurred in recent years when sand from dredging operations carried out by DoT at the town jetty became available.

The Lancelin coastal zone is predominantly low lying, and coastal inundation will be a major factor that needs to be carefully assessed during the next stage of adaptation planning.

R_LA1.1: It is therefore recommended that major investment decisions with regards to coastal infrastructure are reserved until after the coastal inundation impact assessment mitigation planning has been completed.

a)  b) 

Figure 5-6 Grace Darling Park a) during a storm event (May 2015) and b) February 2017

5.6.1 Value of Assets at Risk

An estimate of the economic value (2015 $) of built assets lying seaward of the coastal hazard lines for each planning timeframe is presented in **Table 5-4** (draft CHRMAP, Shire of Gingin, 2016b). Note that this table only includes assets in LA1 impacted by 2030. The apportionment of costs on a beneficiary pays principle suggests that there needs to be significant assessment of the beneficiaries and the value each derives from the retaining the beach and park. Note that this table encompasses all management units in Ledge Point, however for 2030 only assets in LA1 are impacted.

Table 5-6 Summary of estimated value (2015 $) of vulnerable built assets in Lancelin (from draft CHRMAP, Shire of Gingin, 2016b)

Asset type			2030*	
	unit	Rate($)	#	value ($)
Roads (main)	m	800	111	$88,800
Roads (secondary)	m	500	150	$75,000
Footpaths / Cycleways / Beach Access	m	350	755	$26,4250
Carpark	m^2	70	3676	$25,7320
Private properties: residential				
- land vacant	#	250,000	1	$25,0000
- houses and improvements	#	250,000	0	0
Private properties: commercial				
- land	m^2	150	0	0
- improvements (chalets)	#	180,000	16	$2,880,000
Total				**$3,815,370**
Rate Base Revenue over 15 years, 2015 to 2030 (in 2015 $)				
Affected properties	#	$997	0	$0
Township	#	$997	754	$11,276,070
Shire	#	$997	1273	$19,037,715

* all assets impacted by 2030 are located in LA1

It is important to note that the primary values of Grace Darling Park are of a social nature, and may not be captured by the above cost estimates. The current assessment has not placed an economic value on the natural assets of the beach and the social aspects of the grassed area, however for cost benefit analyses in relation to specific proposals, these factors would need to be included to produce a holistic assessment. In particular, the area has tourism benefits with flow on economic benefit to local businesses.

5.6.2 Remove and Relocate (MR2)

Removal of infrastructure and allowing natural erosion to occur is an option for management unit LA1. Grace Darling Park is vested in the Shire (foreshore Parks and Recreation Reserve – see **Appendix C**) and its long term plan is to remove and relocate the facilities following severe erosion. In the interim ongoing repairs for minor damage following storm events is likely to continue until repairs are no longer viable. For the caravan park, mechanisms for retreat will be provided upon assessment of a development application for the site.

It is reasonable to assume that triggers for retreat might include:

> distance of the asset from a datum such as the Horizontal Shoreline Datum (HSD) is less than a yet to be determined set distance (for example 40 m); or

> distance of the asset from the HSD datum is less than S1 (i.e. 14 m for this part of LA1);

> Damage repair following storm event exceeds maintenance budget allocation;

> Loss of legal access to property; or

> Loss of essential services.

The distance of built assets from the HSD is greater than 14 m for the built assets in the caravan park, but some of the infrastructure in Grace Darling Park (including the sea rescue building) is currently less than 14 m from the HSD. These structures could therefore be impacted by a single storm event.

R_LA1.2*:* It is recommended that the sea rescue building is removed, however the ablution block and shade structures should remain until unserviceable.

Ongoing provision of a grassed recreation area which has the same appeal as the existing grassed area (including sheltered shallow water and seafront position) is contingent upon land being available which is currently part of the caravan park lease area. The caravan park in turn is constrained from expanding due to the presence of a Threatened Ecological Community (TEC) to the south. Removal of dunes to create a grassed area to the north of the existing park is an option but is likely to be unacceptable due to damage this would cause to dunes that are currently protecting public and private assets. If the toilet facilities are removed from this location, then alternative facilities will need to be built in the vicinity to cater for visitors. These issues will need to be explored further to reach an optimal solution.

5.6.3 Sand Nourishment

A study of potential engineering options for the protection of Grace Darling Park was undertaken by Seashore Engineering in 2015. This report recommended:

> *"Following conventional coastal practice, and due to the relatively low costs of obtaining sand, the interim management option of sand renourishment appears to be appropriate, albeit likely needing higher volumes of material than has been placed recently. Some improved performance of the renourishment could be achieved by ensuring the use of sand which is as coarse as practically available. It is understood that the most recently used source (from Aglime) is slightly smaller sized than the in situ beach material, which may substantially reduce its retention."*

Seashore's (2015) estimated requirement for annual renourishment was 3000 m^3, which at \$16/m^3 would cost \$48,000 per year.

It is important to note that localised sediment transport at Grace Darling Park may often be from north to south, due to circulation and wave diffraction patterns caused by Edward Island (**Figure 5-7**, from Sanderson and Eliot, 1999). Assuming this model is still largely correct, then an alternative source of sand for renourishment may be the Edward Island salient. Sourcing sand that has previously moved past the Grace Darling Park beach could be considered to be "back passing" – a technique where sediments are routinely moved upstream on the understanding that they will migrate back to the place of origin. This may be a cost effective approach and it is recommended that this be investigated further.

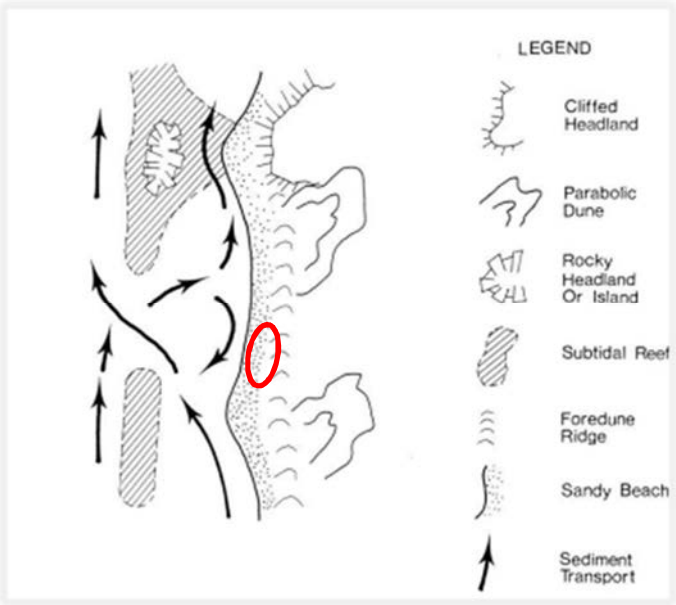


Figure 5-7 Circulation pattern in relation to salient formations from Sanderson and Eliot (1999) and the relative position of Grace Darling Park (red oval)

5.6.4 Accommodate (AC2)

Infrastructure in the caravan park is generally of a relocatable nature and it is therefore better able to accommodate the risk of erosion than other land uses. It is understood that the new managers will be required to prepare a plan for management of coastal hazards, which includes mechanisms for relocation in relation to erosion triggers, and ongoing provision of a public foreshore reserve.

5.6.5 Groynes (PR3)

A preliminary costing of structural protection options for Lancelin was undertaken by MRA in 2015. A best practice approach was adopted and recommended the following components for protection up to 2030:

- 4 groynes;
- Additional width of beach profile required: 20 m;
- Total length of 280 m; and
- Sand nourishment volume 168,000 m^3.

The cost estimate for this option was estimated at $12M. In addition to the capital cost, ongoing groynes maintenance costs were estimated to be around $400,000 per decade.

Note this is a preliminary estimate based on concept designs and would require further detailed design and investigation of the impacts on adjoining areas prior to being adopted. The above costings are also representative of “best practice” for a long term design life and it is possible that more cost effective options may be adequate to protect assets in the short term.

It is assumed that the above option aims to protect the caravan park as well as Grace Darling Park. Smaller scale options in the vicinity of Grace Darling Park might cost considerably less than the above amount. Assessment of potential impacts from groynes would require careful investigation due to a range of uncertainties associated with the nature of cuspate headlands.

5.6.6 Seawall (PR5)

Preliminary costings, based on concept designs, for construction of a 700 m long rock seawall at Lancelin (**Figure 5-8**) were estimated at $2.7M and ongoing maintenance estimated at $300,000 per decade (MRA, 2015). This preliminary estimate was based on concept designs and would require further detailed design and investigation of the impacts on adjoining areas prior to being adopted.

The above costings are also representative of “best practice” for a long-term design life and more cost effective options may be adequate to protect assets in the short term.

a) 

b) 

Figure 5-8 Indicative positions of a) new groynes and b) seawall options costed for LA1

Seashore Engineering (2015) carried out an assessment of three additional seawall options for the Grace Darling Park foreshore. These focused on the use of Geotextile Sand Container (GSC) revetments (**Figure 5-9**). Three options were examined which ranged in price from $710,000 to $920,000.

A GSC revetment is thought to provide advantages over a rock seawall (for example as constructed at Seabird) due to their lesser visual impact and greater retention of beach amenity however they are less durable and generally have a shorter design life. Seashore Engineering (2015) note that the nature of the GSC revetment is to provide a 'back stop' to acute erosion events, providing protection to existing infrastructure. However, performance of a revetment is likely to be compromised if the rate of progressive erosion observed since 2011 continues.



Figure 5-9 GSC revetment example and conceptual layout from Seashore Engineering (2015)

Regardless of the type, seawalls have the potential to result in negative impacts to surrounding areas, including scour in front of and increased erosion to either side of the structure. In addition, it may hinder beach access and diminish the current amenity of the area.

6 IMPLEMENTATION

A range of options for addressing the challenges of coastal erosion and its effects on the coastal zone over the next decade and century have been outlined in the preceding chapters. While it is natural that local communities would prefer to protect and preserve the current features of the coastal zone, the reality is that unless some new and innovative protection methods are developed, the costs of maintaining current features will likely become prohibitively expensive at some point in the future. The interim nature of protect options needs to be recognised across the community and, the adaption options developed and solutions optimised for social, environmental and economic (affordability) drivers. This section first discusses the issues around funding and equity then addresses the plan for implementation of recommended adaptation options up to the 2030 timeframe with a strategic view of the likely adjustments over the next century, to 2110.

The CHRMAP process recognises the difficult decisions that will need to be made in the near future and the CHRMAP document is intended to be updated each 5 to 10 years or as new information becomes available that may significantly affect the extent of hazards, such as new state sea level rise benchmarks.

6.1 Funding and Equity

In accordance with the CHRMAP guidelines, equity implications are considered with a particular focus on identifying who may benefit and who may be disadvantaged by proposed management options. This then raises the question of who would be expected to bear the cost of implementation.

6.1.1 Seabird SE1

As introduced in **Section 2.2**, the presence of the limestone ridge should protect the majority of the township (excluding the Holiday Park) from coastal erosion for some decades. Along the southern beach the seawall was constructed as an interim measure in 2015/16 to protect the 16 houses deemed under immediate threat of coastal erosion during storm events. As a consequence, the original beach is no longer accessible during high water levels and moderate wave conditions and access to this area has effectively been restricted by the seawall. The beach to the north and south of the seawall remain accessible to the community, albeit with some added inconvenience. The key beneficiaries of the seawall are therefore the 16 property owners immediately behind the seawall. The present values of these ocean front properties (while remaining viable) are likely to be worth significantly more than Seabird properties with limited or no ocean views.

The cost of maintaining the seawall was estimated at $24,000 p/a (**Section 5.4.5**). Applying the beneficiaries pay principle suggests an annual contribution from the 16 beneficiaries of around $1,500 each may be sufficient to cover the cost of maintenance. This could be charged in the form of a specified area rate or levy.

The lifecycle of this temporary seawall is assumed to be around 20 years and the cost of building a new seawall is estimated to be around $2.4 M (2015 $). This equates to a capital expense of around $150,000 per property owner when it falls due in about 2035. The State and Shire may consider contributing to this seawall beyond the recent capital outlay but this will need to be explored further. For the longer term, and given current day knowledge of coastal processes and protection measures, the implementation plan aims to exercise either the retreat or avoid option, pending the outcomes of an investigation into the implications of adopting the approach outlined in the draft Guidelines for Planned or Managed Retreat (DoPLH, 2017c).

The likely increase in erosion along SE2 should be monitored into the future and options considered now. While residents behind the seawall are beneficiaries of the structure, owners of property in the Holiday Park may be disadvantaged. An equitable mechanism for determining apportionment of costs to the beneficiaries of the seawall needs to be investigated should the managed retreat option by adopted. Landowners must note, however, that there is no obligation on government to compensate losses associated with shoreline erosion and if adopted, an Avoid or Do Nothing policy position would ultimately lead to abandonment of property.

6.1.2 Ledge Point

In contrast to Seabird, there is no known underlying rock present in the hazard zone at Ledge Point, and the hazard lines reflect the likely future erosion of the sandy coast. Two rows of housing and De Burgh St fall within the 2110 hazard line in LP2 and the southern section of LP3. Should a protect strategy be adopted then the capital cost of around $2M for the seawall or groynes options may be spread over a larger group of beneficiaries within the local community. If adopted, it is likely that a protect strategy would transition to retreat or do nothing strategy at the end of the design life of the seawall/groynes around 2070, by which point the removal/relocation of De Burgh St and utilities infrastructure would need to be considered.

The complex coastal processes around Ledge Point and its offshore reefs and the general south to north movement of sand between the sediment cells around Ledge Point will need to be monitored to inform the need for sand nourishment in future, within both LP2 and LP3. Both the local community and visitors to the township would benefit from sand nourishment and it is recommended that the mechanisms available to generate revenue from these beneficiaries be investigated.

6.1.3 Lancelin

In the case of Grace Darling Park, the beneficiaries of any protection actions would primarily be the broader community. The protection measures may also have benefits for Cunliffe Street residents, however there may also be negative impacts if the presence of a seawall increases erosion. Ongoing provision of a grassed recreation area which has the same appeal as the existing grassed area (including sheltered shallow water and seafront position) is contingent upon land being available which is currently part of the caravan park lease area. The caravan park in turn is constrained from expanding due to the presence of a Threatened Ecological Community (TEC) to the south. Removal of dunes to create a grassed area to the north of the existing park is an option but is likely to be unacceptable due to damage this would cause to dunes that are currently protecting public and private assets. If the toilet facilities are removed from this location, then alternative facilities will need to be built in the vicinity to cater for visitors. These issues will need to be explored further to reach an optimal solution.

Maintaining the current features of the shoreline will require some form of coastal protection and renourishment in the short to medium term. Alternatively, retreating or relocating the assets to accommodate the rising sea level and ongoing erosion may better be implemented sooner, pending an acceptable outcome of investigations into the cost implications of the managed retreat strategy. The estimated costs for protecting the Park, maintaining beach amenity by constructing groynes and the initial sand nourishment is around $12M, with ongoing costs of around $50,000 per annum. This infrastructure would likely last for around 50 years before the retreat option would need to be implemented and decommissioning costs would need to be considered.

It would thus appear reasonable to apportion the costs for maintaining the Park across the local community and visitors to the Park, both of whom benefit, the latter group particularly during summer holidays and at wind and kite surfing events. Funding for such works may be sought from the State Government, or via a levy on the local rate payers and/or fees for non-local visitors to the park. As an example, if the 754 local ratepayers (**Table 5-6**) were to completely fund the capital cost ($12M) over a 10 year period then a levy of approximately $1,600 per annum per rate payer would be required.

6.2 Long Term Pathways and Short Term Implementation

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 of coastal hazards in the immediate to short term, with consideration of the long term 100 year planning horizon.

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

The long-term pathway for each management unit is both an input and an output to the adaptation option assessment. For example, in a management unit containing few built assets the long term strategic

pathway is one of avoiding development. By contrast, in areas containing built assets under threat in the long term decisions about when to transition from a protect strategy to a retreat or do nothing strategy need to be made.

It is clear that planning decisions made decades and even centuries in the past, prior to understanding the implications of sea level rise and coastal erosion, are a key contributor to the current situation where assets close to the coast are now at risk. Asset owners need to appreciate past government decisions on property boundaries do not imply an obligation to maintain these areas and that ultimate abandonment of property and assets without any form of compensation is a strategy option that may be considered.

R1 - It is recommended that a comprehensive investigation of each community and visitors be undertaken to identify beneficiaries of proposed protection areas. The investigation should assess the economic stimulus provided by tourism and mechanisms for recouping costs from identified beneficiaries (e.g. parking fees, visitor entry fee, increased council rates or levies, etc.) to inform the future review of strategies and options outlined in this CHRMAP.

In the shorter term, roughly the next decade up to 2030, there are a number of specific recommendations that may be implemented. These range from investigations to provide more detailed analyses to inform balanced decisions, monitoring to assess whether the predicted threats of coastal erosion actually occur, community consultation to better educate the community about the impending threats and need to plan for their eventuality and consequences.

6.3 Triggers

The Draft Guidelines for Planned or Managed Retreat (DoPHL, 2017c) provide a guidance on the appropriate triggers or criteria to commence actioning a particular management response. The guidelines suggest the following:

> *Planned retreat allows development to remain and be safely used until the coastal hazard risk becomes unacceptable. Initiation of the process to remove at risk development can be controlled by triggers such as:*
>
> *Trigger 1. Where the most landward part of the Horizontal Shoreline Datum (HSD) is within 40 metres of the most seaward point of a development or structure.*
>
> *Trigger 2. Where a public road is no longer available or able to provide legal access to the property.*
>
> *Trigger 3. When water, sewage or electricity to the lot is no longer available as they have been removed/ decommissioned by the relevant authority due to coastal hazards.*
>
> *The trigger distance determines when planned retreat is activated for a particular development.*

For the specific sites within The Shire the criterion outlined in Trigger 1 has already been exceeded. Triggers 2 and 3 are relevant to sections of management units SE1, SE2, LP2, LP3, LA2 and LA4 where public roads and potentially utilities services are located seaward of the 2110 Hazard line, but landward of the 2070 hazard line. Given that the projected risk to these assets is half a century away, and there appear to be more pressing issues in the shorter term, it is prudent to adopt a set of triggers based on the immediate term recommendations and around the HSD shoreline movement criteria. For the purpose of this CHRMAP the following triggers have been adopted and applied to each management unit (**Appendix I**):

Trigger 1: CHRMAP recommendation

Trigger 2: HSD plus S1 reaches 2030 vulnerability line

Trigger 3: HSD plus S1 reaches 2070 vulnerability line

In the above triggers it is assumed that the HSD line will be determined annually or at least soon after major storm erosion events to inform the ongoing assessment of the Trigger criteria. Hazard line estimates for interim planning horizons at 2050 and 2090 have also been generated. Finer temporal resolution of the triggers may be implemented using these lines during future revision of the CHRMAP, each 5-10 years. At this time it is important to agree the concepts and implementation process before getting too detailed on the trigger values.

Specific long term pathways and short term implementation recommendations for the priority management units are discussed in the following sections.

6.4 Seabird

6.4.1 Long Term Pathway

The long term pathway for the Seabird Township should aim for the eventual managed retreat of built infrastructure, as it becomes vulnerable to coastal hazards and/or interferes with the maintenance of an appropriate coastal foreshore reserve (as defined in Section 5.9 of SPP2.6). For major infrastructure, such as residential property, this retreat should occur when the risk to infrastructure becomes intolerable and it is no longer viable or acceptable to the Shire's community to implement protection measures. For undeveloped areas, the long term pathway should focus on avoiding inappropriate development, to prevent unnecessary future cost and potential liability for the Shire.

Proposed long term pathways for the individual Management Units within Seabird (SE1 and SE2) are provided in **Appendix I**. The key tools that will underpin the achievement of these long term pathways are planning controls, which were discussed in **Section 4**. There is currently an interim protection mechanism (seawall) in place for a large portion of Seabird's coastline. The transition from this protection approach to one of managed retreat or do nothing will need to be carefully considered in line with the draft Guidelines for Planned or Managed Retreat (DoPHL, 2017c) and guided by appropriate triggers for the transition.

6.4.2 Short Term Implementation – Seabird Township South (SE1)

The following adaptation pathway is proposed:

Short to Medium term: Protect for life cycle of the current seawall; investigate the land tenure and future management arrangements for the seawall; investigate the mechanism for planned retreat of the affected properties; and Implement Planning changes to avoid future development in currently undeveloped areas.

Recommendations arising from the above assessment for SE1 are provided in **Table 6-1**.

Table 6-1 Recommendations and adaptation planning recommendations for SE1

ID	Recommendation
R_SE1.1	The Shire and State to undertake comprehensive study, including detailed economic analysis and proposed costs apportionment to identified beneficiaries, to guide eventual retreat from or abandonment of assets in hazardous areas. This needs to assess managed retreat versus a do nothing and ultimate abandonment strategy.
R_SE1.2	The feasibility and suitability of groynes be assessed in detail, prior to the end of the seawall's lifecycle (presently estimated to be 2035). It is not recommended that groynes be considered for implementation as a management strategy in the immediate term.
R_SE1.3	The seawall be monitored and maintained for the duration of its (estimated) 20 year design life, provided the consequences of its presence are acceptable to the overall community throughout this period. An assessment should be made prior to (approximately) 2035 to decide how this area should be managed beyond this timeframe. Options may include: > Continue monitoring, maintaining and retrofit (if required) the seawall to extend its useful life; > Completely remove the seawall; > Remove the seawall and use material (if appropriate) to implement groynes as a protection measure; and > Leave the seawall in place but discontinue monitoring and maintenance. It must be noted that the last three options are may to trigger managed retreat of some assets that are presently behind the seawall. The implications of triggering managed retreat should be assessed in detail to understand the implications of selecting one of these management options. The associated costs of maintaining the wall and equitable apportionment of these costs to the beneficiaries creates a difficult issue for the Shire and the community that also requires further investigation.

R_SE1.4	Long term tenure arrangements and management responsibility for the seawall should be established through negotiated agreement between the State and the Shire.
R_SE1.5	Options for increasing equitable enjoyment of the ocean frontage aspect enjoyed by properties positioned above the seawall, for example rezoning of some areas to allow for commercial use, should be investigated.
R_SE1.6	Undertake annual beach surveys to monitor the change in beach profile
R_SE1.7	Investigate current and future sediment budget in the Secondary Cells to inform likely future nourishment and protection options assessment

6.5 Ledge Point

6.5.1 Long Term Pathway

The long term pathway for the Ledge Point Township should aim for the eventual retreat of built infrastructure, as it becomes vulnerable to coastal hazards and/or interferes with the maintenance of an appropriate coastal foreshore reserve (as defined in Section 5.9 of SPP2.6). For major infrastructure, such as residential property, retreat should occur when the risk to infrastructure becomes intolerable and it is no longer viable or acceptable to the Shire's community to implement protection measures. The long term pathway for undeveloped areas, particularly LP1 and LP4, should focus on rezoning land to avoid inappropriate development to limit potential future liability for the Shire.

Proposed long term pathways for the individual Management Units within Ledge Point (LP1, LP2, LP3 and LP4) are provided in **Appendix I**. The key tools that will underpin the achievement of these long term pathways are planning controls, which were discussed in **Section 4**. Protection mechanisms using hard structures for the Township should be carefully assessed and guided by appropriate criteria to determine their suitability for implementation. Note the implementation of retreat through a managed retreat process or the do nothing and eventual abandonment needs to be carefully considered and implications for the Shire and private property owners addressed.

6.5.2 Short Term Implementation – Ledge Point Township South (LP2)

The following adaptation pathway is proposed:

Short to Medium term: Protect within budget constraints, but with erosion triggers for retreat in place

Recommendations arising from the above assessment are provided in **Table 6-2.**

Table 6-2 Recommendations and adaptation planning recommendations for LP2

ID	Recommendation
R_LP2.1	Planning for the proposed boat ramp/marina needs to consider the short term implementation plan and long term management pathways for Ledge Point articulated in this CHRMAP. Similarly, the Shire should carefully review any plans for such a development to ensure the proposal's long term impacts on adjacent coastline are adequately assessed and are consistent with the CHRMAP pathways.
R_LP2.2	Should the Shire wish to pursue the beach nourishment option, it is recommended that a suitable sediment source be identified and nourishment costs to extract, transport and place material from this source be refined. An affordable volume of nourishment can then be assessed and an appropriate beach profile designed to guide sand placement.
R_LP2.3	Investigate potential efficacy and cost of extending the existing southern groyne to increase salient stability and promote accretion to the south.
R_LP2.4	Commission a high level investigation of cost of an offshore breakwater based on existing natural reef offshore from southern groyne.

R_LP2.5	Evaluate aeolian transport rates and consider use of wind fences and limiting vehicle access at the base of the scarp to promote dune growth followed by dune stabilisation and planting.
R_LP2.6	Manage vehicle use to ensure that vehicles do not exacerbate erosion of existing beach and dune
R_LP2.7	Consider geotechnical investigations to identify if any subsurface rock exists within the 100-year hazard zone. This would increase the accuracy of the hazard assessment, and better inform the broader CHRMAP process.

6.6 Lancelin

6.6.1 Long Term Pathway

The long term pathway for the Lancelin Township should aim for the eventual managed retreat and accommodation of built infrastructure, as it becomes vulnerable to coastal hazards and/or interferes with the maintenance of an appropriate coastal foreshore reserve (as defined in Section 5.9 of SPP2.6). The development of emergency plans and controls should occur for the management of coastal hazards. For major infrastructure, such as commercial and residential property, managed retreat should occur when it is no longer viable to repair damaged property, such as Grace Darling Park, and risk to infrastructure becomes intolerable. For undeveloped areas, the long term pathway should focus on rezoning to avoid inappropriate development in future.

Proposed long term pathways for the individual Management Units within Lancelin (LA1, LA2, LA3 and LA4) are provided in **Appendix I**. The key tools underpinning the achievement of long term pathways are planning controls, which were discussed in **Section 4**. Prior to the adoption of any of the protection options it is recommended that that these be investigated in detail and guided by appropriate trigger projections to determine their suitably for implementation.

6.6.2 Short Term Implementation – Lancelin South of Township (LA1)

Short to Medium term: Protect in a manner that maintains existing social values within budgetary constraints until such time as triggers for retreat are exceeded. Develop the planned retreat strategy to be implemented during the next stage of the CHRMAP (5 to 10 years).

Recommendations arising from the above assessment are provided in **Table 6-3.**

Table 6-3 Recommendations and adaptation planning recommendations for LA1

ID	Recommendation
R_LA1.1	Major investment decisions with regards to coastal infrastructure are reserved until after the coastal inundation impact assessment has been completed.
R_LA1.2	Sea rescue building be removed, however the ablution block and shade structures should remain until unserviceable.
R_LA1.3	Investigate renourishment using sand sourced from the salient.
R_LA1.4	Manage vehicle use in the area to ensure that vehicles do not exacerbate erosion.
R_LA1.5	Continue to involve Caravan Park lessors and local community in decisions regarding coastal management in this area to preserve coastal values and uses.

6.7 Shire of Gingin Monitoring Plan

Monitoring of the ongoing changes in actual shoreline movements and the response to storm erosion events is critical to assess compliance with trigger criteria for the management actions. Assessment and interpretation of monitoring observations will also inform future revisions of hazard lines and the CHRMAP reviews. The *Seabrid, Ledge Point, Lancelin – Coastal Monitoring Action Plan* (Seashore Engineering, 2017) provides a high level of detail on coastal monitoring for the townsites. Consistent with their recommendations the general monitoring, data collation and analysis is to include:

> Annual Beach Profile Surveys;

> Horizontal Shoreline Datum determination from aerial photos;

> Post wave erosion event (>2 yr ARI wave) beach profile surveys;

> Cyclone storm surge post-flood event inundation level surveys; and

> Seawall, groyne and shoreline protection infrastructure condition monitoring after significant events.

The Shire will also require data from updates to the State and Federal programs providing offshore wave data, winds and rainfall, ecological community information, threatened species registers, aerial image updates general statistics on population census, social and financial conditions provided through Australian Bureau of statistics and local land price trends available from Real Estate websites. This information needs to be collated and assessed to inform updates to hazard line projections and revise CHRMAP adaptation strategies as required during the CHRMAP review each 5 to 10 years.

6.8 Shire of Gingin Implementation Plan (to 2030)

The implementation plan for the next decade up to 2030 is shown in the Gantt chart presented in **Figure 6-1** and Tasks listed below in **Table 6-4**. Implementation of the plan is obviously subject to budget considerations and available funding.

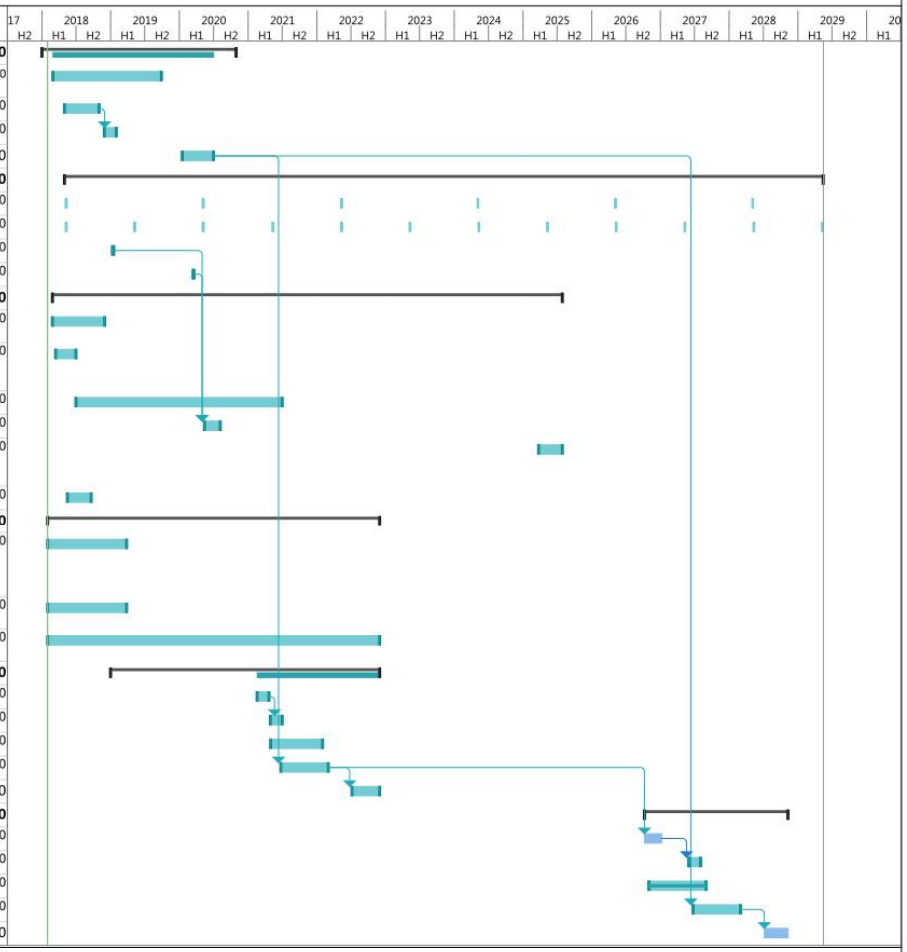
Table 6-4 Tasks for Implementation up to 2030, schedule start and end dates and approximate costs

Task Name	Start	Finish	Cost Estimate $1,000s
Planning and Development Controls Review	**1 Jan '18**	**28 Oct '20**	**$155**
Review Planning and Development Controls and Recommend Amendments as required	1 Mar '18	27 Sep '19	$80
Amend current zone and SCA boundaries	1 May '18	31 Oct '18	$15
Update SCA special provisions	29 Nov '18	30 Jan '19	$20
Gingin LPS 9 Update and Endorsement by WAPC	17 Jan '20	30 Jun '20	$40
Monitoring	**1 May '18**	**14 May '29**	**$410**
Annual Beach Profile Surveys	4 May '18	14 May '29	$300
Horizontal Shoreline Datum (Aerial Photo Analysis)	1 May '18	2 May '22	$70
Post wave erosion Event (>2 yr ARI wave) Beach Profiles	11 Jan '19	17 Jan '19	$30
Cyclone storm surge flooding Event	15 Mar '20	18 Mar '20	$10
Specialist Investigations	**26 Feb '18**	**28 Jul '25**	**$415**
Comprehensive investigation of each community and visitors be undertaken to identify beneficiaries of proposed protection areas	26 Feb '18	30 Nov '18	$150
Investigate allowance for coastal foreshore reserve width to extend the 2110 Hazard line a sufficient distance to accommodate future relocation of foreshore assets	15 Mar '18	30 Jun '18	$15
Assess Current and Future Sediment Budget in the Secondary Cell	1 Jul '18	30 Jun '21	$80
Analysis of Flood, Storm Surge and Erosion event monitoring	14 May '20	5 Aug '20	$40
Investigate Storm Surge and Coastal Processes Interactions to define triggers, set FFL, CHRMAP, Water Management Plans and Emergency Management Plan overlaps	25 Mar '25	28 Jul '25	$50
Undertake economic analysis of options. Recommendations:	17 May '18	19 Sep '18	$80
Operational	**1 Feb '18**	**30 Nov '22**	**$80**
Establish Data Management and GIS system (time series, spot levels and remote sensing) relating to shoreline monitoring and general flooding in each Township to allow identification of trends over time, and Trigger assessment	1 Feb '18	26 Mar '19	$50
Update Asset database to incorporate end of life date to facilitate future management of assets	1 Feb '18	26 Mar '19	$20

Notifications - Potentially affected land owners by direct contact and property titles	1 Feb '18	30 Nov '22	$10
CHRMAP Review and Update (2022)	**1 Jan '19**	**30 Nov '22**	**$210**
Review Hazard line estimates (S1, S2, S3 and S4)	18 Feb '21	21 Apr '21	$25
Review Risk Assessment and Future Pathway Options	29 Apr '21	30 Jun '21	$40
Community and Stakeholder Consultation	1 May '21	31 Jan '22	$50
Update CHRMAP	24 Jun '21	2 Mar '22	$80
CHRMAP 2022 Endorsement by WAPC	7 Jul '22	30 Nov '22	$15
CHRMAP Review and Update (2027)	**8 Oct '26**	**8 Nov '28**	**$210**
Review Hazard line estimates (S1, S2, S3 and S4)	8 Oct '26	6 Jan '27	$25
Review Risk Assessment and Future Pathway Options	1 Jun '27	2 Aug '27	$40
Community and Stakeholder Consultation	1 Nov '26	31 Aug '27	$50
Update CHRMAP	24 Jun '27	1 Mar '28	$80
CHRMAP 2027 Endorsement by WAPC	6 Jul '28	8 Nov '28	$15

Shire of Gingin CHRMAP 2017 10 Year Program

ID	Task Name	Start	Finish	Cost Estimate
1	**Planning and Development Controls Review**	**1 Jan '18**	**28 Oct '20**	**$155,000**
2	Review Planning and Development Controls and Recommend Amendments as required	1 Mar '18	27 Sep '19	$80,000
3	Amend current zone and SCA boundaries	1 May '18	31 Oct '18	$15,000
4	Update SCA special provisions	29 Nov '18	30 Jan '19	$20,000
5	Gingin LPS 9 Update and Endorsement by WAPC	17 Jan '20	30 Jun '20	$40,000
6	**Monitoring**	**1 May '18**	**14 May '29**	**$410,000**
7	Horizontal Shoreline Datum (Aerial Photo Analysis)	1 May '18	2 May '22	$70,000
14	Annual Beach Profile Surveys	4 May '18	14 May '29	$300,000
27	Post wave erosion Event (>2 yr ARI wave) Beach Profiles	11 Jan '19	17 Jan '19	$30,000
28	Cyclone storm surge flooding Event	15 Mar '20	18 Mar '20	$10,000
29	**Specialist Investigations**	**26 Feb '18**	**28 Jul '25**	**$415,000**
30	Comprehensive investigation of each community and visitors be undertaken to identify beneficiaries of proposed protection areas	26 Feb '18	30 Nov '18	$150,000
31	Investigate allowance for coastal foreshore reserve width to extend the 2110 Hazard line a sufficient distance to accommodate future relocation of foreshore assets	15 Mar '18	30 Jun '18	$15,000
32	Assess Current and Future Sediment Budget in the Secondary Cell	1 Jul '18	30 Jun '21	$80,000
33	Analysis of Flood, Storm Surge and Erosion event monitoring	14 May '20	5 Aug '20	$40,000
34	Investigate Storm Surge and Coastal Processes Interactions to define triggers, set FFL, CHRMAP, Water Management Plans and Emergency Management Plan overlaps	25 Mar '25	28 Jul '25	$50,000
35	Undertake economic analysis of options	17 May '18	19 Sep '18	$80,000
36	**Operational**	**1 Feb '18**	**30 Nov '22**	**$80,000**
37	Establish Data Management and GIS system (time series, spot levels and remote sensing) relating to shoreline monitoring and general flooding in each Township to allow identification of trends over time, and Trigger assesment	1 Feb '18	26 Mar '19	$50,000
38	Update Asset database to incorporate end of life date to facilitate future management of assets	1 Feb '18	26 Mar '19	$20,000
39	Notifications - Potentially affected land owners by direct contact and property titles	1 Feb '18	30 Nov '22	$10,000
40	**CHRMAP Review and Update (2022)**	**1 Jan '19**	**30 Nov '22**	**$210,000**
41	Review Hazard line estimates (S1, S2, S3 and S4)	18 Feb '21	21 Apr '21	$25,000
42	Review Risk Assesment and Future Pathway Options	29 Apr '21	30 Jun '21	$40,000
43	Community and Stakeholder Consultation	1 May '21	31 Jan '22	$50,000
44	Update CHRMAP	24 Jun '21	2 Mar '22	$80,000
45	CHRMAP 2022 Endorsement by WAPC	7 Jul '22	30 Nov '22	$15,000
46	**CHRMAP Review and Update (2027)**	**8 Oct '26**	**8 Nov '28**	**$210,000**
47	Review Hazard line estimates (S1, S2, S3 and S4)	8 Oct '26	6 Jan '27	$25,000
48	Review Risk Assesment and Future Pathway Options	1 Jun '27	2 Aug '27	$40,000
49	Community and Stakeholder Consultation	1 Nov '26	31 Aug '27	$50,000
50	Update CHRMAP	24 Jun '27	1 Mar '28	$80,000
51	CHRMAP 2027 Endorsement by WAPC	6 Jul '28	8 Nov '28	$15,000



Project: 5 Year Implementation
Date: 31 Jan '18

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

Figure 6-1 Shire of Gingin CHRMAP 2017: 10 year suggested program of work

Figure 6-1 Shire of Gingin CHRMAP 2017: 10 year suggested program of work

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Shire of Gingin
Coastal Hazard Risk Management
and Adaptation Plan

APPENDIX A

HAZARD MAPS BY MANAGEMENT UNITS

SE1

Legend

Hazard Lines

- 2016
- 2020
- 2030
- 2050
- 2070
- 2110

Public Infrastructure

Private Properties

Commercial

N

0 0.2

kilometers

SE2

Legend

Hazard Lines

2016

2020

2030

2050

2070

2110

Public Infrastructure

Private Properties

Commercial

N

0 0.1

kilometers

LP1

Legend

Hazard Lines

2016

2030

2070

2110

Public Infrastructure

Private Properties

Commercial

N

0

0.1

kilometers

LP2

Legend

Hazard Lines

2016

2030

2070

2110

Public Infrastructure

Private Properties

Commercial

N

0

0.1

kilometers

LP3

Legend

Hazard Lines

- 2016
- 2030
- 2070
- 2110

- Public Infrastructure
- Private Properties
- Commercial

N

0 — 0.1

kilometers

LP4

Legend

Hazard Lines

2016

2030

2070

2110

Public Infrastructure

Private Properties

Commercial

N

0 0.1

kilometers

Edward Island Point

LA1

Legend

Hazard Lines

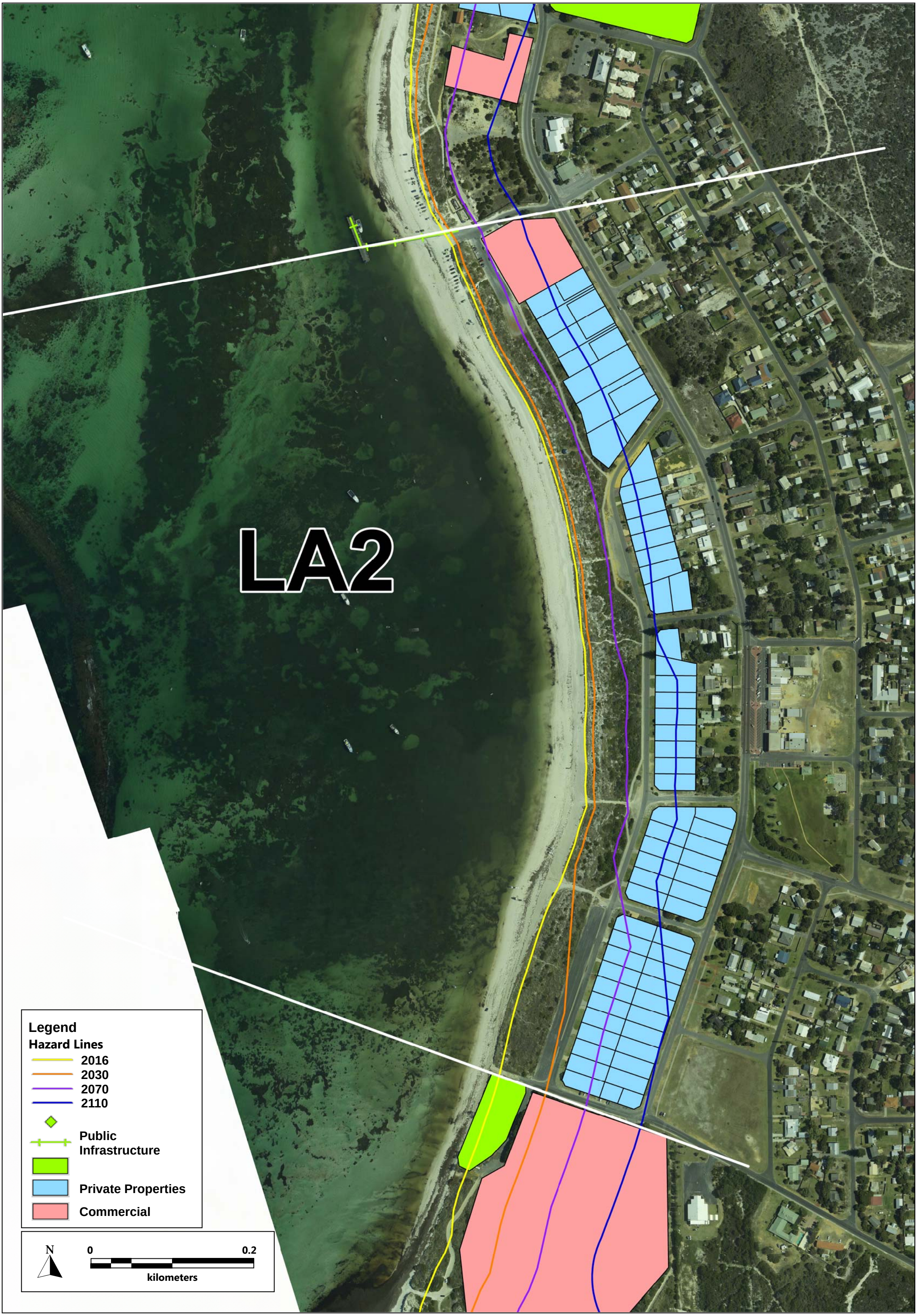
- 2016
- 2030
- 2070
- 2110

- Public Infrastructure
- Private Properties
- Commercial

N

0 0.2

kilometers


LA2
Legend
Hazard Lines
2016
2030
2070
2110
Public Infrastructure
Private Properties
Commercial
N
0
0.2
kilometers

.ancelin Island Point

LA3

Legend

Hazard Lines

2016

2030

2070

2110

Public Infrastructure

Private Properties

Commercial

N

0

0.2

kilometers

LA4

Lancelin Island Poir

Legend

Hazard Lines

- 2016
- 2030
- 2070
- 2110

Public Infrastructure

Private Properties

Commercial

N

0 — 0.2

kilometers

Shire of Gingin
Coastal Hazard Risk Management
and Adaptation Plan

APPENDIX B

VALUE MAPS AND LIST OF KEY STAKEHOLDERS



Please help us understand what you value about the Lancelin coast, where do you like to work, rest and play?

Legend

- Recreational
- Enviromental
- Commercial
- Infrastructure
- Civic
- Heritage
- Threatened Flora, Fauna; Ecological Communities

Our Coastal Values

Cervantes

SHIRE OF DANDARAGAN

Cardno
Shaping the Future

11 Harvest Terrace, West Perth,
WA, 6005, Australia
Phone: +61 8 9273 3888 Web: www.cardno.com

Data Source: Department of Parks & Wildlife (2017) Threatened and Priority Flora/Fauna Database. Search for Cervantes accessed on 8 May 2017. Prepared by the Species and Communities Branch for Cardno for the Shire of Dandaragan CHRMAPS.

SHIRE OF DANDARAGAN

DATE	DRAWING NO	ISSUE
25/05/17	LA-001	DRAFT



SHIRE OF DANDARAGAN

Cardno
Shaping the Future

11 Harvest Terrace, West Perth,
WA, 6005, Australia
Phone: +61 8 9273 3888 Web: www.cardno.com

Please help us understand what you value about the Lancelin coast, where do you like to work, rest and play?

Legend

- Recreational
- Enviromental
- Commercial
- Infrastructure
- Civic
- Heritage
- Threatened Flora, Fauna; Ecological Communities

Our Coastal Values

Jurien Bay

Data Source: Department of Parks & Wildlife (2017) Threatened and Priority Flora/Fauna Database. Search for Jurien Bay accessed on 8 May 2017. Prepared by the Species and Communities Branch for Cardno for the Shire of Dandaragan CHRMAPS.

SHIRE OF DANDARAGAN

DATE	DRAWING NO	ISSUE
25/05/17	LA-002	DRAFT



Please help us understand what you value about the Lancelin coast, where do you like to work, rest and play?

Legend

- Recreational
- Enviromental
- Commercial
- Infrastructure
- Civic
- Heritage
- Threatened Flora, Fauna; Ecological Communities

Our Coastal Values

Lancelin

11 Harvest Terrace, West Perth,
WA, 6005, Australia
Phone: +61 8 9273 3888 Web: www.cardno.com

Data Source: Department of Parks & Wildlife (2017) Threatened and Priority Flora/Fauna Database. Search for Lancelin accessed on 8 May 2017. Prepared by the Species and Communities Branch for Cardno for the Shire of Gingin CHRMAPS.

SHIRE OF GINGIN

DATE	DRAWING NO	ISSUE
25/05/17	LA-003	DRAFT



Please help us understand what you value about the Lancelin coast, where do you like to work, rest and play?

Legend

- Recreational
- Enviromental
- Commercial
- Infrastructure
- Civic
- Heritage
- Threatened Flora, Fauna; Ecological Communities

Our Coastal Values

Ledge Point

SHIRE OF GINGIN

11 Harvest Terrace, West Perth,
WA, 6005, Australia
Phone: +61 8 9273 3888 Web: www.cardno.com

Data Source: Department of Parks & Wildlife (2017) Threatened and Priority Flora/Fauna Database. Search for Ledge Point accessed on 8 May 2017. Prepared by the Species and Communities Branch for Cardno for the Shire of Gingin CHRMAPS.

DATE	DRAWING NO	ISSUE
25/05/17	LA-004	DRAFT



Please help us understand what you value about the Lancelin coast, where do you like to work, rest and play?

Legend

- Recreational
- Enviromental
- Commercial
- Infrastructure
- Civic
- Heritage
- Threatened Flora, Fauna; Ecological Communities

Our Coastal Values

Seabird

11 Harvest Terrace, West Perth,
WA, 6005, Australia
Phone: +61 8 9273 3888 Web: www.cardno.com

Data Source: Department of Parks & Wildlife (2017) Threatened and Priority Flora/Fauna Database. Search for Seabird accessed on 8 May 2017. Prepared by the Species and Communities Branch for Cardno for the Shire of Gingin CHRMAPS.

SHIRE OF GINGIN

DATE	DRAWING NO	ISSUE
25/05/17	LA-005	DRAFT

Key stakeholders for engagement in the CHRMAP process

Internal Stakeholders	Community Groups	Impacted stakeholders	Interested External Stakeholder Groups
▪ CHRMAP Steering Group ▪ Elected members and Executive Lead Team ▪ Shire planning and development departments ▪ Communications and marketing departments ▪ Emergency management departments ▪ Infrastructure / Asset Management Section ▪ Community Development	▪ Community and Ratepayers Associations: ▪ Seabird Progress Association ▪ Ledge Point Community Association ▪ Ledge Point Coastcare Group ▪ Friends of Lancelin Coast ▪ Lancelin Ratepayers Association ▪ Kwelena Mambakort Aboriginal Corporation (Yued) ▪ Local Chamber of Commerce	▪ Traditional Owners ▪ Residents, business owners and property owners located in areas vulnerable to coastal hazards. ▪ Residents, business owners and property owners who live in parts of the LGA that are not vulnerable to coastal hazards (e.g. ratepayers who may be subject to charges to fund adaptation works). ▪ Community members that are indirectly impacted by coastal hazards (e.g. users of coastal roads, parks, and other amenities). ▪ Agencies involved in the emergency response immediately prior to, during or after a storm/erosion event (incl. SES, WA Police, Fire Service and Ambulance Service).	▪ Department of Planning, Lands and Heritage (formerly the Departments of Planning, Lands, State Heritage Office and the Aboriginal heritage and land functions of the Department of Aboriginal Affairs) ▪ Department of Transport ▪ Northern Agricultural Catchments Council ▪ Department of Biodiversity, Conservation and Attractions (formerly Department of Parks and Wildlife) ▪ Western Australian Planning Commission ▪ Other WA State Government entities: (for example Main Roads, Department of Aboriginal Affairs, Department of Water, Department of Environmental Regulation, Department of State Development) ▪ Service providers: St Johns Ambulance, Local Police Stations, Bush Fire Brigade, Volunteer Marine Rescue, SES, SLSCs ▪ Utilities (e.g. Synergy, Water Corporation, Telstra) ▪ WA Local Government Association (WALGA) ▪ Local Government Insurers (LGIS) ▪ Developers ▪ Landcorp ▪ Wheatbelt Development Commission ▪ Moore Catchments Council ▪ City of Wanneroo ▪ Shire of Coorow ▪ Insurance Industry Representatives (TBA) ▪ WA Tourism ▪ WA Conservation Council

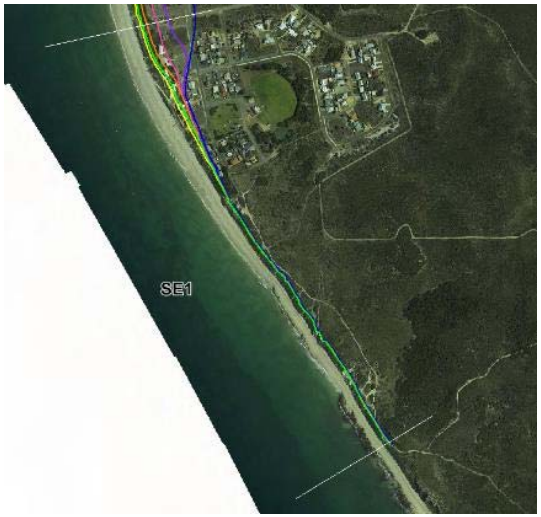
Shire of Gingin
Coastal Hazard Risk Management
and Adaptation Plan

APPENDIX

C

ASSET INFORMATION FOR EACH OF THE MANAGEMENT UNITS

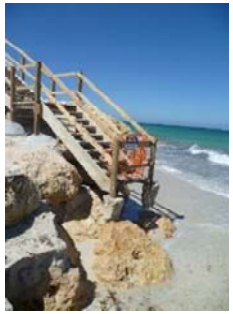
SE1: Seabird Township South













Values	Assets at Risk
Environmental	Beach Coastal/dune vegetation
Social	Beach access Carpark Lookout, toilets and picnic area
Economic - Private	Residential - 22 properties
Economic - Public	Beach Carpark (Edward St) Stairs (decommissioned) Roads Services in road reserve

Existing Coastal Controls

Small offshore reefs
Seawall - sitting on rock platform, with matting placed over the top. Beach along seawall has eroded completely since Dec. 2016.

Existing Planning Controls

Local Planning Scheme No.9 (LPS9)
Reserves and Zoning
- Parks and Recreation Reserve
- Some low-density residential
- Unallocated crown land

Seabird Township Strategic Map

SE2: Seabird Township North









Values	Assets at Risk
Environmental	Beach Foreshore Reserve
Social	Beach Caravan Park (Seabird Private) Tavern
Economic - Private	Caravan Park - strata title lots Seabird Tavern
Economic - Public	Beach

Existing Coastal Controls

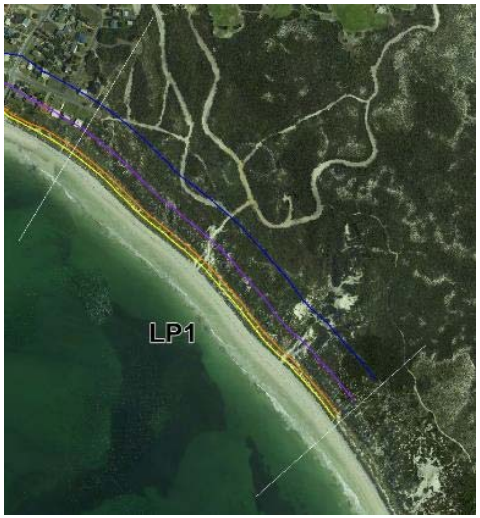
Small offshore reefs
Seawall - sitting on rock platform, with matting placed over the top. Beach along seawall has eroded completely since Dec. 2016.

Existing Planning Controls

Local Planning Scheme No.9 (LPS9)
Reserves and Zoning
- Parks and Recreation Reserve
- Some low-density residential
- Tourism zone

Seabird Township Strategic Map

LP1: Ledge Point South of Township









Values	Assets at Risk
Environmental	Beach Coastal/dune vegetation
Social	Beach Beach carpark (unseasled) Road (Unsealed)
Economic - Private	
Economic - Public	Beach

Existing Coastal Controls
Offshore reefs to north

Existing Planning Controls
Local Planning Scheme No.9 (LPS9) Reserves and Zoning Parks and Recreation Reserve Ledge Point Township Strategic Map Proposed future unban development

LP2: Ledge Point Township South











Values	Assets at Risk
Environmental	Beach
Social	Beach - popular boat launching and offshore mooring spot Beach access (Jones St)
Economic - Private	Residential - 39 properties
Economic - Public	Beach Roads (De Burgh St, Jones St, Roe St) Services in road reserve
Existing Coastal Controls	
Offshore reefs to north	
Existing Planning Controls	
Local Planning Scheme No.9 (LPS9) Reserves and Zoning Parks and Recreation Reserve Ledge Point Township Strategic Map Proposed future unban development	

LP3: Ledge Point Township North













Values	Assets at Risk
Environmental	Beach Coastal/dune vegetation
Social	Beach - Lancelin Ocean Classic starting point Main swimming beach Beach access (Jones St) Coastal/dune vegetation Road (De Burgh St) Key Biscoyne Park
Economic - Private	Caravan Park (Holiday Village) - old caravan park, now town houses Residential -13 properties
Economic - Public	Beach Carparks (De Burgh St) BBQ and shelters Road (De Burgh St) Key Biscoyne Park Playground toilets and BBQs
Existing Coastal Controls	
Offshore reefs 2 Groynes	
Existing Planning Controls	
Local Planning Scheme No.9 (LPS9) Reserves and Zoning Parks and Recreation Reserve Low-density residential Road reserve Tourism zone Ledge Point Township Strategic Map	

LP4: Ledge Point North of Township





Values	Assets at Risk
Environmental	Beach Coastal/dune vegetation
Social	Beach Beach carpark (unsealed) Road (Unsealed)
Economic - Private	
Economic - Public	Beach

Existing Coastal Controls
Offshore reefs

Existing Planning Controls
Local Planning Scheme No.9 (LPS9) Reserves and Zoning Parks and Recreation Reserve General rural zone (?) Ledge Point Township Strategic Map Proposed future unban development

LA1: Lancelin South of Township















Values	Assets at Risk
Environmental	Beach Coastal/dune vegetation
Social	Beach Carpark (Back Beach) Grace Darling Park
Economic - Private	Sea Rescue Building
Economic - Public	Beach Carpark (Back Beach) Caravan Park (Lancelin South End) Grace Darling Park Cap park Toilet block

Existing Coastal Controls

Edward Island and surrounding reefs
Opportunistic beach renourishment during dredging

Existing Planning Controls

Local Planning Scheme No.9 (LPS9)

Reserves and Zoning

- Parks and Recreation Reserve
- Low-density residential
- Tourism

Lancelin Township Strategic Map

- Possible tourist zone expansion
- Linkage area to Lancelin South Development
- Identified as "sporting and recreation"

LA2: Lancelin Township South of Jetty











Values	Assets at Risk
Environmental	Beach
Social	Beach Jetty Café (Kerfuffle By The Jetty)
Economic - Private	Residential - 66 properties Light Industrial Area Café (Kerfuffle By The Jetty)
Economic - Public	Beach Road (Cuncliffe St) Jetty

Existing Coastal Controls
Edward Island and surrounding reefs to the south Lancelin Island to the north Offshore reeef

Existing Planning Controls
Local Planning Scheme No.9 (LPS9) Reserves and Zoning Parks and Recreation Reserve Low-density residential Tourism zone Lancelin Township Strategic Map

LA3: Lancelin Township Jetty to Lancelin Point













Values	Assets at Risk
Environmental	Beach Coastal/dune vegetation Beach Lookout
Social	Beach Park (Gingin Road) Primary School Tavern (Endeavour)
Economic - Private	Beach Hotel & Dune Restaurant Tavern (Endeavour) Residential - 45 properties
Economic - Public	Beach Fuel storage (DoT?) Road (Gingin Rd) Caravan Park (Lancelin North End) Park (Gingin Road) Primary School Beach Lookout
Existing Coastal Controls	
Lancelin Island and surrounding reefs	
Existing Planning Controls	
Local Planning Scheme No.9 (LPS9) Reserves and Zoning Parks and Recreation Reserve Low-density residential Tourism zone Lancelin Township Strategic Map	

LA4: Lancelin Township North of Lancelin Point











Values	Assets at Risk
Environmental	Beach Coastal/dune vegetation
Social	Beach Beach carpark Beach Access (Lancelin Island Point)
Economic - Private	Residential - 41 properties
Economic - Public	Beach

Existing Coastal Controls

Lancelin Island and surrounding reefs

Existing Planning Controls

Local Planning Scheme No.9 (LPS9)

Reserves and Zoning
- Parks and Recreation Reserve
- Road reserve
- Low density residential
- Tourism zone

Lancelin Township Strategic Map
- Development to the north not possible due to sand blowout

States: " Coastal setbacks required in accordance with State Planning Policy"

Shire of Gingin
Coastal Hazard Risk Management
and Adaptation Plan

APPENDIX D

TECHNICAL NOTE ON RISK ASSESSMENT METHODS

APPENDIX D RISK ASSESSMENT METHODOLOGY

1.1 Overview

The risk assessment process uses the outcomes of Part 1 of the CHRMAP to characterise the risk and vulnerability of assets over the planning time frame. An overview of the framework adopted in this assessment is presented in Figure 1-1.

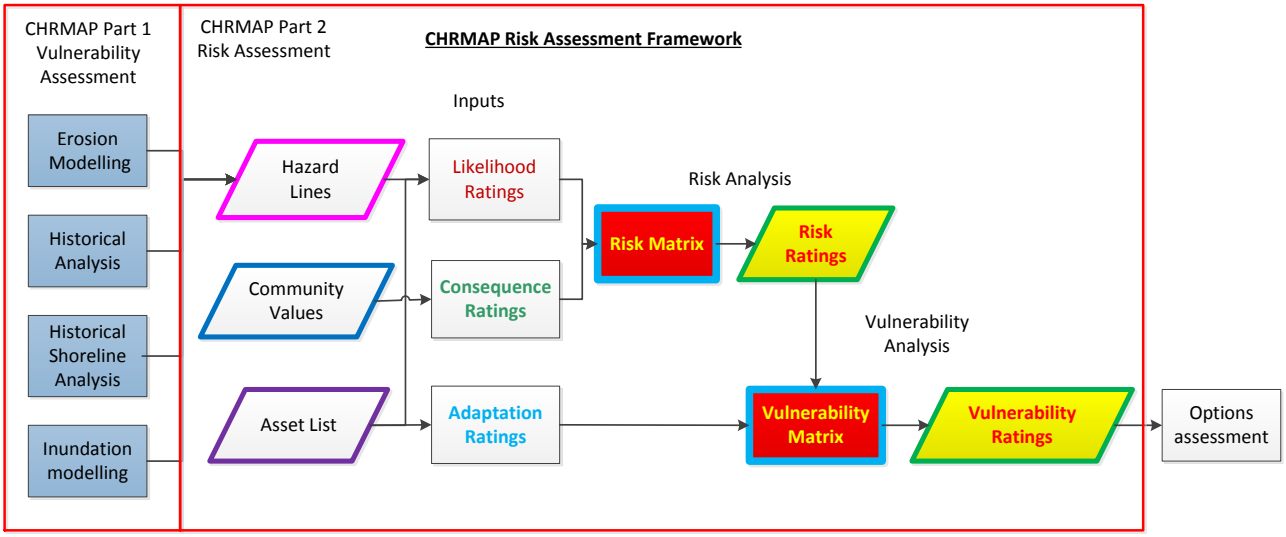


Figure 1-1 Schematic representation of the risk assessment process

There are a number of steps involved in the risk assessment process:

1. Define likelihood categories (ratings)
2. Allocate the likelihood of the risk occurring to specific assets for a particular planning timeframe based on the results of the hazard assessment;
3. Define consequence categories (ratings)
4. Allocate the consequence of the risk occurring to specific assets for a particular planning timeframe based on CHRMAP guidance, AS 5334-2013 and the project specific Success Criteria;
5. Define risk categories (ratings) based on the acceptability (or tolerability); and
6. Allocate the risk ratings for combinations of likelihood and consequence.

The process aims to be objective, logical and transparent. All steps call for interpretation, and allocation of consequence in particular may be based on subjective judgement. However, once the framework has been adopted, specific outcomes can be clearly traced to inputs. The inputs can be updated in response to new information or stakeholder input, and the risk assessment outcomes will be revised accordingly. Additional details on how the input parameters were derived, and the ratings were developed is provided below.

1.2 Risk Analysis

To assess the level of risk, or potential impact, posed to the assets by the identified coastal hazards, this CHRMAP has employed risk analysis techniques outlined in AS 5334-2013. The risk assessment entails the combination of likelihood and consequence of exposure to coastal hazard to produce the risk level, or potential impact, for each asset, as presented in Figure 1-2 below.

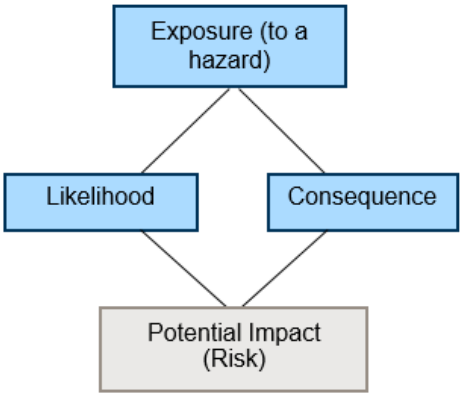


Figure 1-2 Risk analysis structure

The potential impact (risk) has been assessed for each asset at each of the planning timeframes:

- Present Day (2016)
- 2030
- 2070
- 2110

This allows risk prioritisation and assessment of each asset's risk level over the 100 year planning horizon as required by SPP2.6.

For the purposes of this report 'short-term' refers to the period between 2015 and 2030, 'medium-term' refers to the period between 2030 and 2050, and long-term refers to the period beyond 2050. The 'immediate-term' or 'immediately' may also be used, generally referring to within the next 5 years.

1.2.2 Likelihood

According to WAPC (2014) and for the purposes of this study, likelihood is defined as the chance of erosion and storm surge inundation impacting on existing and future assets and their values. The likelihood scale that has been applied at each timeframe is presented in Error! Reference source not found.

Table 1-1 CHRMAP likelihood ratings

Rating	Description
Almost Certain	High possibility of impact to asset shoreline for a given planning timeframe
Likely	Impact to asset shoreline for a given planning timeframe is likely
Possible	Impact to asset shoreline for a given planning timeframe is possible
Unlikely	Impact to asset shoreline for a given planning timeframe is unlikely
Rare	May occur in exceptional circumstances

As outlined in Section 3, the erosion risk is made up of a number of components. Each of these is based on a suite of assumptions and each has a degree of uncertainty which may influence the likelihood of the predicted level of erosion occurring at each planning horizon. For instance, S1 assumes that the probability of a coastal hazard event occurring is the same each year, which is not necessarily the case when considering the effects of climate change and the rise in sea level over time, which underpins the future planning scenarios assessed in this study.

There is considerable scope for confusion in defining and allocating likelihood in terms of recurrence frequency / probability (as per AS 5334) for the purposes of risk assessment, since this terminology has specific meaning in the coastal context. Cardno has therefore adopted the approach presented in Figure 1-3, which is generally consistent with guidance in WAPC (2014). An example of the likelihood rating input format for assets in a particular study site is provided in Table 1-2.

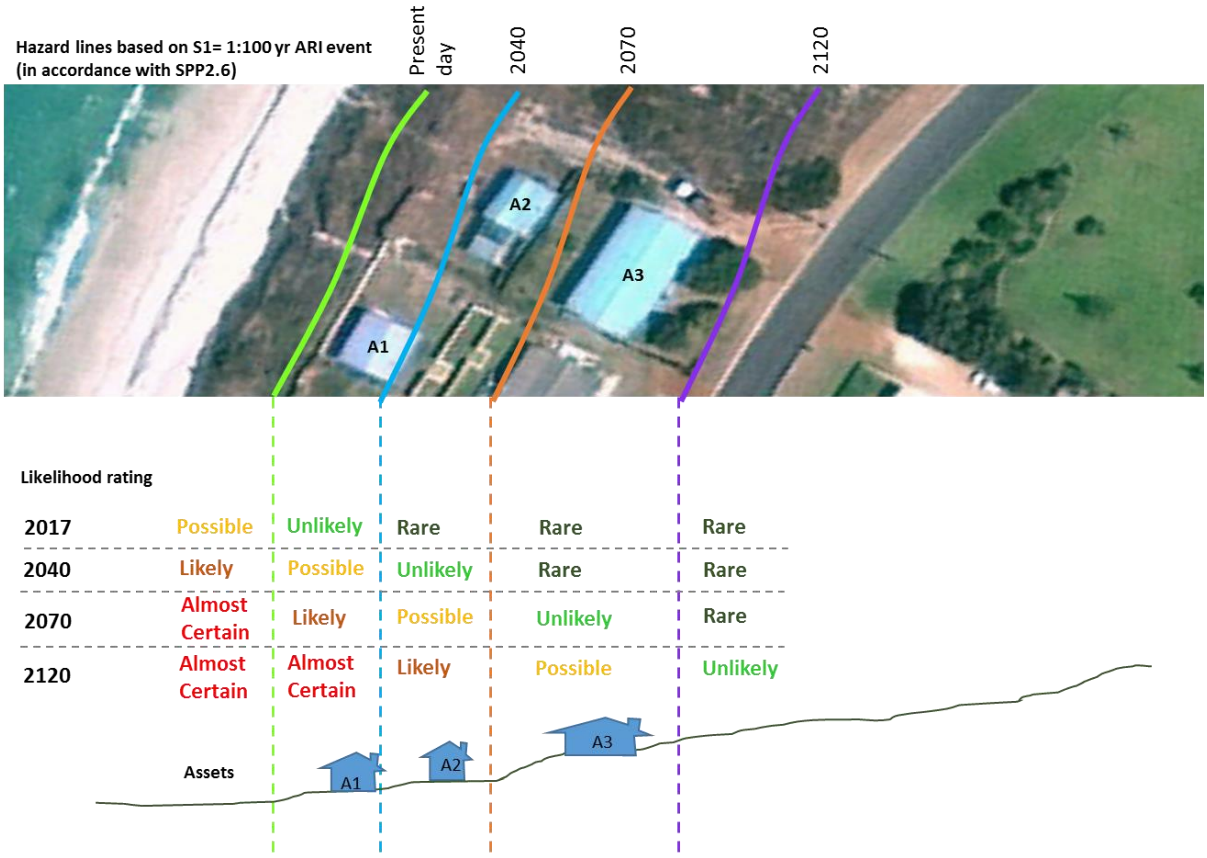


Figure 1-3 Representation of method used to assign likelihood ratings to individual assets for each planning timeframe

Table 1-2 Example likelihood rating inputs table

	Planning timeframe			
	Present Day	2030	2070	2110
Asset	**Likelihood**			
Beach	Unlikely	Possible	Almost Certain	Almost Certain
Car Park	Rare	Rare	Possible	Almost Certain
Road	Rare	Rare	Possible	Almost Certain
Residential Lots	Rare	Rare	Unlikely	Likely

1.2.3 Consequence

Consequence is the result of a hazard impacting an area or asset. For this analysis, consequence has been divided into five ratings ranging from catastrophic to insignificant (Table 1-3). The consequence ratings for this risk assessment have been adapted from those presented in AS 5334-2013, and WAPC (2014), which focus on the social, economic and environmental consequences.

A heritage component has been incorporated alongside environmental impacts to ensure impacts to heritage sites are accounted for in the risk assessment process. The consequence descriptions have also been scaled to be applicable to the local context in which this study is being undertaken, where as previously their higher ratings were associated with consequences on a global scale. Generally, the consequence categories incorporate all of the values outlined by the success criteria and align comparatively between categories with the level of response to these success criteria.

Unless otherwise stated, the consequence ratings are generally associated with the impact of coastal erosion. Generally coastal inundation and coastal erosion will occur at the same time during a storm event. In the majority of circumstances and locations for the City's coastline, the impacts of coastal erosion on infrastructure will be more severe and long-lasting than the impacts of coastal inundation. There are circumstances where coastal erosion will not occur (e.g. where the shoreline is rock) and in these instances only the consequences of coastal inundation are considered

Table 1-3 Consequence ratings (adapted from AS 5334-2013)

Rating	Safety and Social	Economic	Environment and Heritage
Catastrophic	Loss of life and serious injury. Large long-term or permanent loss of services, public access/amenity, employment, wellbeing or culture. No suitable alternative sites exist within the LGA.	Permanent and/or entire loss or damage to property, plant and equipment, finances >$10 million	Permanent and entire loss of flora, fauna conservation or heritage area (no chance of recovery)
Major	Serious injury. Medium term disruption to services, public access/amenity, employment, wellbeing or culture. Very limited suitable alternative sites exist within the LGA.	Permanent and/or large scale loss or damage to property, plant and equipment, finances > $2 - $10 million	Long-term and/or large scale loss of flora, fauna or heritage area (limited chance of recovery) with local impact.
Moderate	Minor injury. Major short term or minor long-term disruption to services, public access/amenity, employment, wellbeing, or culture. Limited suitable alternative sites exist within the LGA.	Permanent and/or medium scale loss or damage to property, plant and equipment, finances > $100,000 - $2 million	Medium-term and/or medium scale loss of flora, fauna or heritage area (recovery likely) with local impact.
Minor	Small to medium disruption to services, public access/amenity, employment, wellbeing, or culture. Many suitable alternative sites exist within the LGA.	Permanent and/or small scale loss or damage to property, plant and equipment, finances > $10,000 - $100,000	Short-term and/or small scale loss of flora, fauna or heritage area (strong recovery) with local impact.
Insignificant	Minimal short-term inconveniences to services, public access/amenity, employment, wellbeing, or culture. Many suitable alternative sites exist within the LGA.	Permanent loss or damage to property, plant and equipment, finances < $10,000	Negligible to no loss of flora, fauna or heritage area (strong recovery) with local impact.

Consequence was allocated for each asset within a vulnerable area, and for each of the planning timeframes. It was possible for the severity of consequence to increase over time, assuming that impacts could be greater as well as more likely to occur. An example of the format of consequence rating inputs is provided in Table 1-4.

Table 1-4 Example consequence ratings applied to a vulnerable area

	Planning timeframe			
	Present day	2030	2070	2110
Asset	**Consequence**			
Impact on Beach	Major	Major	Catastrophic	Catastrophic
Impact on Car Park	Moderate	Moderate	Moderate	Moderate
Impact on Road	Moderate	Moderate	Major	Major
Impact on Residential Lots	Minor	Minor	Minor	Major

1.3 Risk Evaluation

1.3.1 Potential Impact (Risk Rating)

The CHRMAP uses a risk assessment matrix which is based on that provided in AS5334-2013 (Table 1-5). Risk ratings are defined by risk acceptability / tolerance and the urgency of required action (Table 1-6). This will help to prioritise multiple identified risks within the study area. It also provides a mechanism to compare the level of risk after a preferred adaptation option is determined, for example, at present a risk may be “extreme” in the short term, after the implementation of adaption option ‘X’ the risk level is re-evaluated and reduces to “medium”.

Table 1-5 Risk matrix (Based on AS5334-2013)

Likelihood	Consequences				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	L	M	H	E	E
Likely	L	M	M	H	E
Possible	L	L	M	H	E
Unlikely	L	L	M	M	H
Rare	L	L	L	M	M

Table 1-6 Risk levels and tolerances

Risk Level	Action Required	Acceptance / Tolerance
Extreme (E)	Immediate action required to eliminate or reduce risk to acceptable levels.	Unacceptable
High (H)	Immediate to short-term action required to eliminate or reduce risk to acceptable levels.	Tolerable / Unacceptable
Medium (M)	Short to medium term action to reduce risk to acceptable levels, or accept risk.	Tolerable
Low (L)	Accept risk.	Acceptable

The risk evaluation process utilises the outcomes of the risk analysis as inputs. Likelihood and consequence allocated for assets, under each scenario, are combined to derive a risk rating for each asset within each of vulnerable areas. Examples of the derived risk ratings for a particular study site are provided in Table 1-7.

Table 1-7 Example of risk rating results by asset and planning timeframe

	Planning Timeframe			
	Present Day	2030	2070	2110
Asset	**Risk**			
Beach	Medium	Medium	Extreme	Extreme
Car Park	Low	Low	Medium	High
Road	Low	Low	High	Extreme
Residential Lots	Low	Low	Medium	High

1.4 Vulnerability Analysis

As per AS 5334-2013, detailed risk analysis should include a vulnerability analysis to thoroughly examine how coastal hazards and climate change may affect the asset.

Vulnerability analysis involves assessing the asset's existing capacity to adapt to a potential impact; a flow chart for the process of establishing the vulnerability is presented in Figure 1-4. Adaptive capacity and vulnerability are detailed in the following sections

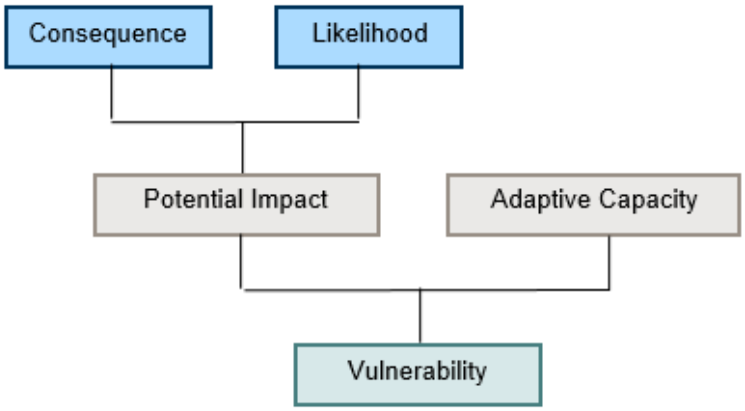


Figure 1-4 Vulnerability assessment structure

1.4.2 Adaptive Capacity

The adaptive capacity (Table 1-8) is based upon the potential for the system to be modified or acclimatise to cope with the impacts of identified hazards. The system of existing controls, such as the dune system and reef, all have an influence on the ability of hazards to affect a study site. The aim of the CHRMAP is to develop options that realise the potential adaptive capacity through techniques such as managed retreat, accommodation, and protection. An asset or group of assets with a high adaptive capacity is one that can easily (i.e. at low cost) be adapted or one that has some capacity to self-adapt with changing conditions (e.g. beaches and dune systems can migrate across shore as the mean sea level (MSL) changes). Assets with a high risk level and low adaptive capacity are deemed vulnerable and management options should be investigated. Examples of the adaptive capacity ratings allocated for a particular study site are provided in Table 1-9.

Table 1-8 CHRMAP adaptive capacity ratings

Rating	Adaptive Capacity
Low	Little or no adaptive capacity. Potential impact would destroy all functionality.
Moderate	Small amount of adaptive capacity. Difficult but possible to restore functionality through repair and redesign.
High	Decent adaptive capacity. Functionality can be restored, although additional adaptive measures should still be considered. Natural adaptive capacity restored slowly over time under average conditions.
Very High	Good adaptive capacity. Functionality restored easily. Adaptive systems restored at a relatively low cost or naturally over time.

Table 1-9 Example of adaptive capacity ratings applied to assets and timeframes

	Planning Timeframe			
	Present Day	2030	2070	2110
Asset	**Adaptive Capacity**			
Beach	High	High	Moderate	Low
Car Park	Moderate	Moderate	Moderate	Moderate
Road	Moderate	Low	Low	Low
Residential Lots	Low	Low	Low	Low

1.4.3 Vulnerability

Vulnerability is the potential for a system to suffer damage or ill effects as a result of coastal hazards or climate change. Vulnerability is a function of the likelihood of an event occurring, the consequences of the event and the capacity to adapt and change. In a similar fashion to the risk methodology, potential impact and adaptive capacity can be combined using a customised matrix (Table 1-10) with the significance of the vulnerability rating listed in relation to acceptability and tolerances provided in Table 1-11. An example outcome from the analysis is provided in Table 1-12.

Table 1-10 Vulnerability Analysis Matrix

Risk Level (Potential Impact)	Adaptive Capacity			
	Very High	High	Moderate	Low
Extreme	H	H	VH	VH
High	M	H	H	VH
Medium	M	M	M	H
Low	L	L	L	L

Table 1-11 Vulnerability levels and tolerances

Vulnerability Level	Action Required	Acceptance / Tolerance
Very High (VH)	Significant further adaption required to ensure asset is not lost. Reconsideration of design if vulnerability cannot be reduced.	Unacceptable
High (H)	Further adaption required. All stakeholders should be fully aware of risks if vulnerability cannot be reduced.	Tolerable / Unacceptable
Medium (M)	Further adaption should be investigated, acceptable in certain circumstances. Monitoring programs recommended.	Tolerable
Low (L)	Acceptable; adaption and monitoring may be required over the asset's lifetime.	Tolerable / Acceptable

Table 1-12 Example of outcome from vulnerability analysis

	Planning Timeframe			
	Present Day	2030	2070	2110
Asset	**Vulnerability**			
Beach	Low	Low	Medium	High
Car Park	Low	Low	Medium	High
Road	Low	Low	Low	Medium
Residential Lots	Low	Low	Low	High

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APPENDIX

E

RISK ASSESSMENT RATINGS AND RESULTS

SE1: Seabird Township South

Assessment Inputs						
	2016	2020	2030	2050	2070	2110
Asset	**Likelihood**					
Beach	Possible	Likely	Almost Certain	Almost Certain	Almost Certain	Almost Certain
Coastal/dune vegetation	Possible	Likely	Almost Certain	Almost Certain	Almost Certain	Almost Certain
Residential (houses and land)	Possible	Likely	Almost Certain	Almost Certain	Almost Certain	Almost Certain
Carparks and roads	Possible	Likely	Almost Certain	Almost Certain	Almost Certain	Almost Certain

Asset	Consequence of Erosion					
Impact on beach amenity	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Impact on ecological buffer	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Impact on residential lots	Major	Major	Major	Major	Catastrophic	Catastrophic
Impact on beach carpark and roads	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate

Asset	Adaptive capacity					
Beach	High	Moderate	Moderate	Low	Low	Low
Coastal/dune vegetation	Moderate	Moderate	Moderate	Low	Low	Low
Residential (houses and land)	Low	Low	Low	Low	Low	Low
Carparks and roads	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate

Risk Assessment						
	2016	2020	2030	2050	2070	2110
	Risk					
Beach	Medium	Medium	High	High	High	High
Coastal/dune vegetation	Medium	Medium	High	High	High	High
Residential (houses and land)	High	High	Extreme	Extreme	Extreme	Extreme
Carparks and roads	Medium	Medium	High	High	High	High

	Vulnerability					
Beach	Medium	Medium	High	Very High	Very High	Very High
Coastal/dune vegetation	Medium	Medium	High	Very High	Very High	Very High
Residential (houses and land)	Very High	Very High	Very High	Very High	Very High	Very High
Carparks and roads	Medium	Medium	High	High	High	High

SE2: Seabird Township North

Assessment Inputs						
	2016	2020	2030	2050	2070	2110
Asset	**Likelihood**					
Beach	Possible	Likely	Almost Certain	Almost Certain	Almost Certain	Almost Certain
Coastal/dune vegetation	Possible	Likely	Almost Certain	Almost Certain	Almost Certain	Almost Certain
Caravan Park (Seabird Private)	Rare	Unlikely	Possible	Likely	Almost Certain	Almost Certain
Tavern	Rare	Rare	Unlikely	Possible	Likely	Almost Certain

Asset	Consequence of Erosion					
Impact on beach amenity	Minor	Minor	Moderate	Moderate	Moderate	Moderate
Impact on ecological buffer	Minor	Minor	Minor	Moderate	Moderate	Moderate
Impact on Caravan Park (Seabird P	Minor	Minor	Moderate	Major	Major	Major
Impact on Tavern	Minor	Minor	Moderate	Moderate	Moderate	Moderate

Asset	Adaptive capacity					
Beach	Very High	Very High	High	Moderate	Moderate	Moderate
Coastal/dune vegetation	High	High	Moderate	Moderate	Moderate	Low
Caravan Park (Seabird Private)	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Tavern	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate

Risk Assessment						
	2016	2020	2030	2050	2070	2110
	Risk					
Beach	Low	Medium	High	High	High	High
Coastal/dune vegetation	Low	Medium	Medium	High	High	High
Caravan Park (Seabird Private)	Low	Low	Medium	High	Extreme	Extreme
Tavern	Low	Low	Medium	Medium	Medium	High

	Vulnerability					
Beach	Low	Medium	High	High	High	High
Coastal/dune vegetation	Low	Medium	Medium	High	High	Very High
Caravan Park (Seabird Private)	Low	Low	Medium	High	Very High	Very High
Tavern	Low	Low	Medium	Medium	Medium	High

LP1: Ledge Point South of Township

Assessment Inputs				
	2016	2030	2070	2110
Asset	**Likelihood**			
Beach	Possible	Likely	Almost Certain	Almost Certain
Coastal/dune vegetation	Possible	Likely	Almost Certain	Almost Certain
Beach Carpark (unsealed)	rare	Unlikely	Possible	Likely
Road (unsealed)	Rare	Rare	Unlikely	Possible

Asset	Consequence of Erosion			
Impact on beach amenity	Insignificant	Insignificant	Insignificant	Insignificant
Impact on ecological buffer	Minor	Minor	Minor	Moderate
Impact on carpark	Minor	Minor	Minor	Minor
Impact on 4WD track	Insignificant	Insignificant	Insignificant	Insignificant

Asset	Adaptive capacity			
Beach	Very High	Very High	Very High	Very High
Coastal/dune vegetation	High	High	Moderate	Moderate
Beach Carpark (unsealed)	High	High	High	High
Road (unsealed)	High	High	High	High

Risk Assessment				
	2016	2030	2070	2110
	Risk			
Beach	Low	Low	Low	Low
Coastal/dune vegetation	Low	Medium	Medium	High
Beach Carpark (unsealed)	Low	Low	Low	Medium
Road (unsealed)	Low	Low	Low	Low

	Vulnerability			
Beach	Low	Low	Low	Low
Coastal/dune vegetation	Low	Medium	Medium	High
Beach Carpark (unsealed)	Low	Low	Low	Medium
Road (unsealed)	Low	Low	Low	Low

LP2: Ledge Point Township South

Assessment Inputs				
	2016	2030	2070	2110
Asset	**Likelihood**			
Beach	Possible	Likely	Almost Certain	Almost Certain
Foreshore recreation area	rare	unlikely	Possible	likely
Residential	Possible	Likely	Almost Certain	Almost Certain
Roads	Unlikely	Possible	Almost Certain	Almost Certain

Asset	Consequence of Erosion			
Impact on beach amenity	Moderate	Moderate	Moderate	Moderate
Impact on recreation area	Minor	Minor	Moderate	Major
Impact on residential lots	Moderate	Major	Major	Catastrophic
Impact on roads	Minor	Minor	Moderate	Major

Asset	Adaptive capacity			
Beach	Very High	Very High	High	Moderate
Foreshore recreation area	High	High	Moderate	Moderate
Residential	Low	Low	Low	Low
Roads	Moderate	Moderate	Moderate	Moderate

Risk Assessment				
	2015	2030	2070	2110
	Risk			
Beach	Medium	Medium	High	High
Foreshore recreation area	Low	Low	Medium	High
Residential	Medium	High	Extreme	Extreme
Roads	Low	Low	High	Extreme

	Vulnerability			
Beach	Medium	Medium	High	High
Foreshore recreation area	Low	Low	Medium	High
Residential	High	Very High	Very High	Very High
Roads	Low	Low	High	Very High

LP3: Ledge Point Township North

Assessment Inputs				
	2016	2030	2070	2110
Asset	**Likelihood**			
Beach	Possible	Likely	Almost Certain	Almost Certain
Coastal/dune vegetation	Possible	Likely	Almost Certain	Almost Certain
Carpark (De Burgh St)	Unlikely	Unlikely	Possible	Almost Certain
Road (De Burgh St)	Unlikely	Unlikely	Possible	Almost Certain
Holiday Village	Rare	Rare	Unlikely	Possible
Residential	Possible	Likely	Almost Certain	Almost Certain
Key Biscoyne Park	Unlikely	Possible	Likely	Almost Certain

Asset	Consequence of Erosion			
Impact on beach amenity	Insignificant	Insignificant	Minor	Moderate
Impact on ecological buffer	Minor	Minor	Minor	Major
Impact on carpark a	Insignificant	Minor	Moderate	Moderate
Impact on De Burg St	Insignificant	Minor	Moderate	Moderate
Impact on Holiday Village	Insignificant	Insignificant	Moderate	Catastrophic
Impact on residential lots	Insignificant	Insignificant	Moderate	Major
Impact on Key Biscoyne Park	Minor	Minor	Moderate	Major

Asset	Adaptive capacity			
Beach	Very High	High	High	Moderate
Coastal/dune vegetation	High	High	Moderate	Low
Carpark (De Burgh St)	Moderate	Moderate	Moderate	Moderate
Road (De Burgh St)	Moderate	Moderate	Moderate	Moderate
Holiday Village	Low	Low	Low	Low
Residential	Low	Low	Low	Low
Key Biscoyne Park	High	High	Moderate	Moderate

Risk Assessment				
	2016	2030	2070	2110
	Risk			
Beach	Low	Low	Medium	High
Coastal/dune vegetation	Low	Medium	Medium	Extreme
Carpark (De Burgh St)	Low	Low	Medium	High
Road (De Burgh St)	Low	Low	Medium	High
Holiday Village	Low	Low	Medium	Extreme
Residential	Low	Low	High	Extreme
Key Biscoyne Park	Low	Low	Medium	Extreme

	Vulnerability			
Beach	Low	Low	Medium	High
Coastal/dune vegetation	Low	Medium	Medium	Very High
Carpark (De Burgh St)	Low	Low	Medium	High
Road (De Burgh St)	Low	Low	Medium	High
Holiday Village	Low	Low	High	Very High
Residential	Low	Low	Very High	Very High
Key Biscoyne Park	Low	Low	Medium	Very High

LP4: Ledge Point North of Township

Assessment Inputs				
	2016	2030	2070	2110
Asset	**Likelihood**			
Beach	Possible	likely	Almost Certain	Almost Certain
Coastal/dune vegetation	Possible	likely	Almost Certain	Almost Certain
Carpark (unsealed)	Rare	Rare	Possible	Almost Certain
Road (unsealed)	Rare	Rare	Unlikely	Possible

Asset	Consequence of Erosion			
Impact on beach amenity	Insignificant	Insignificant	Insignificant	Insignificant
Impact on ecological buffer	Insignificant	minor	minor	minor
Impact on carpark	Insignificant	Insignificant	Insignificant	Insignificant
Impact on 4WD track	Insignificant	Insignificant	Insignificant	Insignificant

Asset	Adaptive capacity			
Beach	Very High	Very High	Very High	Very High
Coastal/dune vegetation	High	High	High	High
Carpark (unsealed)	Very High	Very High	Very High	Very High
Road (unsealed)	Very High	Very High	Very High	Very High

Risk Assessment				
	2016	2030	2070	2110
	Risk			
Beach	Low	Low	Low	Low
Coastal/dune vegetation	Low	Medium	Medium	Medium
Carpark (unsealed)	Low	Low	Low	Low
Road (unsealed)	Low	Low	Low	Low

	Vulnerability			
Beach	Low	Low	Low	Low
Coastal/dune vegetation	Low	Medium	Medium	Medium
Carpark (unsealed)	Low	Low	Low	Low
Road (unsealed)	Low	Low	Low	Low

LA1: Lancelin South of Township

Assessment Inputs				
	2016	2030	2070	2110
Asset	**Likelihood**			
Beach	Possible	Likely	Almost Certain	Almost Certain
Coastal/dune vegetation	Possible	Likely	Almost Certain	Almost Certain
Carpark (Back Beach)	Rare	Rare	Unlikely	Possible
Caravan Park (Lancelin South End)	Unlikely	Possible	Likely	Almost Certain
Sea Rescue	Possible	Likely	Almost Certain	Almost Certain
Grace Darling Park	Possible	Likely	Almost Certain	Almost Certain

Asset	Consequence of Erosion			
Impact on beach amenity	Insignificant	Insignificant	Insignificant	Insignificant
Impact on ecological buffer	Insignificant	Insignificant	Minor	Minor
Impact on Back Beach carpark	Minor	Minor	Minor	Minor
Impact on Caravan park	Moderate	Moderate	Major	Major
Impact on Sea Rescue offices	Moderate	Moderate	Moderate	Moderate
Impact on Grace Darling Park	Major	Major	Major	Major

Asset	Adaptive capacity			
Beach	Very High	Very High	Very High	Very High
Coastal/dune vegetation	High	High	High	High
Carpark (Back Beach)	High	High	High	high
Caravan Park (Lancelin South End)	Moderate	Moderate	Moderate	Moderate
Sea Rescue	Low	Low	Low	Low
Grace Darling Park	Moderate	Moderate	Moderate	Moderate

Risk Assessment				
	2016	2030	2070	2110
	Risk			
Beach	Low	Low	Low	Low
Coastal/dune vegetation	Low	Low	Medium	Medium
Carpark (Back Beach)	Low	Low	Low	Low
Caravan Park (Lancelin South End)	Medium	Medium	High	Extreme
Sea Rescue	Medium	Medium	High	High
Grace Darling Park	High	High	Extreme	Extreme

	Vulnerability			
Beach	Low	Low	Low	Low
Coastal/dune vegetation	Low	Low	Medium	Medium
Carpark (Back Beach)	Low	Low	Low	Low
Caravan Park (Lancelin South End)	Medium	Medium	High	Very High
Sea Rescue	High	High	Very High	Very High
Grace Darling Park	High	High	Very High	Very High

LA2: Lancelin Township South of Jetty

Assessment Inputs	2016	2030	2070	2110
Asset	**Likelihood**			
Beach	Possible	Likely	Likely	Almost Certain
Coastal/dune vegetation	Possible	Likely	Likely	Almost Certain
Residential	Rare	Unlikely	Possible	Likely
Road (Cunliffe St)	Unlikely	Possible	Likely	Almost Certain
Jetty	Possible	Likely	Almost Certain	Almost Certain
Light Industrial	Rare	Rare	Unlikely	possible
Café	Rare	Rare	Unlikely	possible

Asset	Consequence of Erosion			
Impact on beach amenity	Insignificant	Minor	Moderate	Major
Impact on ecological buffer	Insignificant	Minor	Moderate	Major
Impact on residential lots	Insignificant	Minor	Moderate	Major
Impact on Cunliffe St	Insignificant	Minor	Moderate	Moderate
Impact on jetty	Minor	Minor	Moderate	Moderate
Impact on light industrial area	Moderate	Moderate	Major	Major
Impact on café	Moderate	Moderate	Major	Major

Asset	Adaptive capacity			
Beach	High	Moderate	Low	Low
Coastal/dune vegetation	High	Moderate	Low	Low
Residential	Low	Low	Low	Low
Road (Cunliffe St)	Moderate	Moderate	Moderate	Moderate
Jetty	Moderate	Moderate	Moderate	Moderate
Light Industrial	Moderate	Moderate	Moderate	Moderate
Café	Moderate	Moderate	Moderate	Moderate

Risk Assessment	2016	2030	2070	2110
	Risk			
Beach	Low	Medium	Medium	Extreme
Coastal/dune vegetation	Low	Medium	Medium	Extreme
Residential	Low	Low	Medium	High
Road (Cunliffe St)	Low	Low	Medium	High
Jetty	Low	Medium	High	High
Light Industrial	Low	Low	Medium	High
Café	Low	Low	Medium	High

	Vulnerability			
Beach	Low	Medium	High	Very High
Coastal/dune vegetation	Low	Medium	High	Very High
Residential	Low	Low	High	Very High
Road (Cunliffe St)	Low	Low	Medium	High
Jetty	Low	Medium	High	High
Light Industrial	Low	Low	Medium	High
Café	Low	Low	Medium	High

LA3: Lancelin Township Jetty to Lancelin Point

Assessment Inputs				
	2016	2030	2070	2110
Asset	**Likelihood**			
Beach	Possible	Likely	Almost Certain	Almost Certain
Coastal/dune vegetation	Possible	Likely	Almost Certain	Almost Certain
Road (Gingin Rd)	Rare	Unlikely	Possible	Likely
Caravan Park (Lancelin North End)	Rare	Unlikely	Possible	Likely
Hotel & Restaurant	Rare	Unlikely	Possible	Likely
Park (Gingin Rd)	Rare	Unlikely	Possible	Likely
Primary School	Rare	Rare	Unlikely	Possible
Tavern (Endeavour)	Rare	Unlikely	Possible	Likely
Residential	Rare	Unlikely	Possible	Likely

Asset	Consequence of Erosion			
Impact on beach amenity	Minor	Moderate	Moderate	Major
Impact on ecological buffer	Minor	Moderate	Moderate	Major
Impact on Gingin Rd	Minor	Moderate	Moderate	Moderate
Impact on caravan park	Moderate	Moderate	Major	Major
Impact on Beach Hotel & Dunes Restaur	Minor	Moderate	Major	Major
Impact on park on Gingin Rd	Minor	Moderate	Major	Major
Primary School becomes impacted	Moderate	Moderate	Moderate	Moderate
Impact on tavern	Moderate	Moderate	Major	Major
Impact on residential lots	Minor	Major	Major	Catastrophic

Asset	Adaptive capacity			
Beach	High	Moderate	Moderate	Low
Coastal/dune vegetation	High	Moderate	Moderate	Low
Road (Gingin Rd)	Moderate	Moderate	Moderate	Moderate
Caravan Park (Lancelin North End)	Moderate	Moderate	Moderate	Moderate
Hotel & Restaurant	Moderate	Moderate	Moderate	Moderate
Park (Gingin Rd)	High	High	High	High
Primary School	Moderate	Moderate	Moderate	Moderate
Tavern (Endeavour)	Moderate	Moderate	Moderate	Moderate
Residential	Low	Low	Low	Low

Risk Assessment				
	2016	2030	2070	2110
	Risk			
Beach	Low	Medium	High	Extreme
Coastal/dune vegetation	Low	Medium	High	Extreme
Road (Gingin Rd)	Low	Medium	Medium	Medium
Caravan Park (Lancelin North End)	Low	Medium	High	High
Hotel & Restaurant	Low	Medium	High	High
Park (Gingin Rd)	Low	Medium	High	High
Primary School	Low	Low	Medium	Medium
Tavern (Endeavour)	Low	Medium	High	High
Residential	Low	Medium	High	Extreme

	Vulnerability			
Beach	Low	Medium	High	Very High
Coastal/dune vegetation	Low	Medium	High	Very High
Road (Gingin Rd)	Low	Medium	Medium	Medium
Caravan Park (Lancelin North End)	Low	Medium	High	High
Hotel & Restaurant	Low	Medium	High	High
Park (Gingin Rd)	Low	Medium	High	High
Primary School	Low	Low	Medium	Medium
Tavern (Endeavour)	Low	Medium	High	High
Residential	Low	High	Very High	Very High

LA4: Lancelin Township North of Lancelin Point

Assessment Inputs				
	2016	2030	2070	2110
Asset	**Likelihood**			
Beach	Possible	Likely	Almost Certain	Almost Certain
Coastal/dune vegetation	Possible	Likely	Almost Certain	Almost Certain
Residential	Rare	Unlikely	Possible	Likely
Beach Carpark (unsealed)	Rare	Unlikely	Possible	Likely
Beach Access (Lancelin Island Point)	Rare	Unlikely	Possible	Likely

Asset	Consequence of Erosion			
Impact on beach amenity	Minor	Moderate	Major	Major
Impact on ecological buffer	Minor	Moderate	Major	Major
Impact on residential lots	Minor	Moderate	Major	Major
Impact on beach carpark	Minor	Minor	Minor	Minor
Impact on beach access	Minor	Moderate	Moderate	Moderate

Asset	Adaptive capacity			
Beach	High	Moderate	Low	Low
Coastal/dune vegetation	High	Moderate	Low	Low
Residential	Low	Low	Low	Low
Beach Carpark (unsealed)	High	High	High	High
Beach Access (Lancelin Island Point)	High	High	High	High

Risk Assessment				
	2016	2030	2070	2110
	Risk			
Beach	Low	Medium	Extreme	Extreme
Coastal/dune vegetation	Low	Medium	Extreme	Extreme
Residential	Low	Medium	High	High
Beach Carpark (unsealed)	Low	Low	Low	Medium
Beach Access (Lancelin Island Point)	Low	Medium	Medium	Medium

	Vulnerability			
Beach	Low	Medium	Very High	Very High
Coastal/dune vegetation	Low	Medium	Very High	Very High
Residential	Low	High	Very High	Very High
Beach Carpark (unsealed)	Low	Low	Low	Medium
Beach Access (Lancelin Island Point)	Low	Medium	Medium	Medium

Shire of Gingin
Coastal Hazard Risk Management
and Adaptation Plan

APPENDIX F

MULTI-CRITERIA ANALYSIS RESULTS

SE1: Seabird Township South



Asset types Environmental, Social, Economic
Preliminary long term pathway Managed Retreat OR Protect
Vulnerability ranking and timeframe

	2016	2030	2070	2110
	Vulnerability			
Beach	Medium	High	Very High	Very High
Coastal/dune vegetation	Medium	High	Very High	Very High
Residential (houses and land)	Very High	Very High	Very High	Very High
Carparks and roads	Medium	High	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 Cost	Capital Cost	Ongoing Cost	
Avoid	AV	Avoid development									Recommended
Managed Retreat	MR1	Leave unprotected / repair									Not recommended
	MR2	Remove / relocate									Investigate
	MR3	Planning controls for retreat									Recommended
Accommodate	AC1	Planning controls to accommodate risk									Recommended
	AC2	Emergency plans and controls									Recommended
	AC3	Re-design to withstand impact	N/A								
Protect	PR1	Dune care / sand management									Recommended
	PR2	Beach nourishment									Not recommended
	PR3	Groyne									Investigate
	PR4	Nearshore reef / breakwater									Not recommended
	PR5	Maintain / extend seawall									Investigate
Do Nothing	DN	Do Nothing									Not recommended

SB2: Seabird Township North



Asset types Environmental, Social, Economic
Preliminary long term pathway Managed Retreat OR Protect
Vulnerability ranking and timeframe

	2016	2030	2070	2110
	Vulnerability			
Beach	Low	High	High	High
Coastal/dune vegetation	Low	Medium	High	Very High
Caravan Park (Seabird Private)	Low	Medium	Very High	Very High
Tavern	Low	Medium	Medium	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 Cost	Capital Cost	Ongoing Cost	
Avoid	AV	Avoid development									Recommended
Managed Retreat	MR1	Leave unprotected / repair									Not recommended
	MR2	Remove / relocate									Investigate
	MR3	Planning controls for retreat									Recommended
Accommodate	AC1	Planning controls to accommodate risk									Recommended
	AC2	Emergency plans and controls									Recommended
	AC3	Re-design to withstand impact	N/A								
Protect	PR1	Dune care / sand management									Recommended
	PR2	Beach nourishment									Not recommended
	PR3	Groyne									Investigate
	PR4	Nearshore reef / breakwater									Not recommended
	PR5	Seawall									Investigate
Do Nothing	DN	Do nothing									Not recommended

LP1: Ledge Point South of Township



Asset types Environmental, social

Preliminary long term pathway Avoid / Accommodate

Vulnerability ranking and timeframe

	2016	2030	2070	2110
Vulnerability				
Beach	Low	Low	Low	Low
Coastal/dune vegetation	Low	Medium	Medium	High
Beach Carpark (unsealed)	Low	Low	Low	Medium
Road (unsealed)	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 Cost	Capital Cost	Ongoing Cost	
Avoid	AV	Avoid development									Recommended
Managed Retreat	MR1	Leave unprotected / repair									Recommended
	MR2	Remove / relocate	N/A								
	MR3	Planning controls for retreat									Recommended
Accommodate	AC1	Planning controls to accommodate risk									Recommended
	AC2	Emergency plans and controls									Recommended
Protect	PR1	Dune care / sand management									Recommended
	PR2	Beach nourishment									Not recommended
	PR3	Groyne									Not recommended
	PR4	Nearshore reef / breakwater									Not recommended
	PR5	Seawall									Not recommended
Do Nothing	DN	Do nothing									Not recommended

LP2: Ledge Point Township South



Asset types Social, Economic, Environmental

Preliminary long term pathway Managed Retreat OR Protect

Vulnerability ranking and timeframe

	2016	2030	2070	2110
Vulnerability				
Beach	Medium	Medium	High	High
Foreshore recreation area	Low	Low	Medium	High
Residential	High	Very High	Very High	Very High
Roads	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 Cost	Capital Cost	Ongoing Cost	
Avoid	AV	Avoid development									Recommended
Managed Retreat	MR1	Leave unprotected / repair									Not recommended
	MR2	Remove / relocate									Investigate
	MR3	Planning controls for retreat									Recommended
Accommodate	AC1	Planning controls to accommodate risk									Recommended
	AC2	Emergency plans and controls									Recommended
Protect	PR1	Dune care / sand management									Recommended
	PR2	Beach nourishment									Investigate
	PR3	Groyne									Investigate
	PR4	Nearshore reef / breakwater									Not recommended
	PR5	Seawall									Investigate
Do Nothing	DN	Do nothing									Not recommended

LP3: Ledge Point Township North



Asset types Social, Economic, Environmental

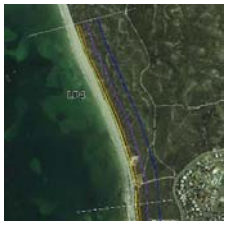
Preliminary long term pathway Avoid and Accommodate then Managed Retreat OR Protect

Vulnerability ranking and timeframe

	2016	2030	2070	2110
	Vulnerability			
Beach	Low	Low	Medium	High
Coastal/dune vegetation	Low	Medium	Medium	Very High
Carpark (De Burgh St)	Low	Low	Medium	High
Road (De Burgh St)	Low	Low	Medium	High
Holiday Village	Low	Low	High	Very High
Residential	Low	Low	Very High	Very High
Key Biscoyne Park	Low	Low	Medium	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 Cost	Capital Cost	Ongoing Cost	
Avoid	AV	Avoid development									Recommended
Managed Retreat	MR1	Leave unprotected / repair									Not recommended
	MR2	Remove / relocate									Investigate
	MR3	Planning controls for retreat									Recommended
Accommodate	AC1	Planning controls to accommodate risk									Recommended
	AC2	Emergency plans and controls									Recommended
Protect	PR1	Dune care / sand management									Recommended
	PR2	Beach nourishment									Investigate
	PR3	Groyne									Investigate
	PR4	Nearshore reef / breakwater									Not recommended
	PR5	Seawall									Investigate
Do Nothing	DN	Do nothing									Not recommended

LP4: Ledge Point North of Township



Asset types Environmental, Social

Preliminary long term pathway Avoid / Accommodate

Vulnerability ranking and timeframe

	2016	2030	2070	2110
	Vulnerability			
Beach	Low	Low	Low	Low
Coastal/dune vegetation	Low	Medium	Medium	Medium
Carpark (unsealed)	Low	Low	Low	Low
Road (unsealed)	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 Cost	Capital Cost	Ongoing Cost	
Avoid	AV	Avoid development									Recommended
Managed Retreat	MR1	Leave unprotected / repair									Recommended
	MR2	Remove / relocate	N/A								
	MR3	Planning controls for retreat									Recommended
Accommodate	AC1	Planning controls to accommodate risk									Recommended
	AC2	Emergency plans and controls									Recommended
Protect	PR1	Dune care / sand management									Recommended
	PR2	Beach nourishment									Not recommended
	PR3	Groyne									Not recommended
	PR4	Nearshore reef / breakwater									Not recommended
	PR5	Seawall									Not recommended
Do Nothing	DN	Do nothing									Not recommended

LA1: Lancelin South of Township



Asset types Social, Environmental, Economic

Preliminary long term pathway Managed Retreat OR Protect

Vulnerability ranking and timeframe

	2016	2030	2070	2110
	Vulnerability			
Beach	Low	Low	Low	Low
Coastal/dune vegetation	Low	Low	Medium	Medium
Carpark (Back Beach)	Low	Low	Low	Low
Caravan Park (Lancelin South End)	Medium	Medium	High	Very High
Sea Rescue	High	High	Very High	Very High
Grace Darling Park	High	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 Cost	Capital Cost	Ongoing Cost	
Avoid	AV	Avoid development									Recommended
Managed Retreat	MR1	Leave unprotected / repair									Not recommended
	MR2	Remove / relocate									Investigate
	MR3	Planning controls for retreat									Recommended
Accommodate	AC1	Planning controls to accommodate risk									Recommended
	AC2	Emergency plans and controls									Recommended
Protect	PR1	Dune care / sand management									Recommended
	PR2	Beach nourishment									Investigate
	PR3	Groyne									Investigate
	PR4	Nearshore reef / breakwater									Not recommended
	PR5	Seawall									Investigate
Do Nothing	DN	Do nothing									Not recommended

LA2: Lancelin Township South of Jetty



Asset types Environmental,

Preliminary long term pathway Avoid and Accomodate, then Managed Retreat OR Protect

Vulnerability ranking and timeframe

	2016	2030	2070	2110
	Vulnerability			
Beach	Low	Medium	High	Very High
Coastal/dune vegetation	Low	Medium	High	Very High
Residential	Low	Low	High	Very High
Road (Cunliffe St)	Low	Low	Medium	High
Jetty	Low	Medium	High	High
Light Industrial	Low	Low	Medium	High
Café	Low	Low	Medium	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 Cost	Capital Cost	Ongoing Cost	
Avoid	AV	Avoid development									Recommended
Managed Retreat	MR1	Leave unprotected / repair									Not recommended
	MR2	Remove / relocate									Investigate
	MR3	Planning controls for retreat									Recommended
Accommodate	AC1	Planning controls to accommodate risk									Recommended
	AC2	Emergency plans and controls									Recommended
Protect	PR1	Dune care / sand management									Recommended
	PR2	Beach nourishment									Investigate
	PR3	Groyne									Investigate
	PR4	Nearshore reef / breakwater									Not recommended
	PR5	Seawall									Investigate
Do Nothing	DN	Do nothing									Not recommended

LA3: Lancelin Township Jetty to Lancelin Point



Asset types Economic, Social, Environmental

Preliminary long term pathway Avoid and Accomodate, then Managed Retreat OR Protect

Vulnerability ranking and timeframe

	2016	2030	2070	2110
	Vulnerability			
Beach	Low	Medium	High	Very High
Coastal/dune vegetation	Low	Medium	High	Very High
Road (Gingin Rd)	Low	Medium	Medium	Medium
Caravan Park (Lancelin North End)	Low	Medium	High	High
Hotel & Restaurant	Low	Medium	High	High
Park (Gingin Rd)	Low	Medium	High	High
Primary School	Low	Low	Medium	Medium
Tavern (Endeavour)	Low	Medium	High	High
Residential	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 Cost	Capital Cost	Ongoing Cost	
Avoid	AV	Avoid development									Recommended
Managed Retreat	MR1	Leave unprotected / repair									Not recommended
	MR2	Remove / relocate									Investigate
	MR3	Planning controls for retreat									Recommended
Accommodate	AC1	Planning controls to accommodate risk									Recommended
	AC2	Emergency plans and controls									Recommended
Protect	PR1	Dune care / sand management									Recommended
	PR2	Beach nourishment									Investigate
	PR3	Groyne									Investigate
	PR4	Nearshore reef / breakwater									Not recommended
	PR5	Seawall									Investigate
Do Nothing	DN	Do nothing									Not recommended

LA4: Lancelin Township North of Lancelin Point



Asset types Economic, Social, Environmental

Preliminary long term pathway Avoid and Accomodate, then Managed Retreat OR Protect

Vulnerability ranking and timeframe

	2016	2030	2070	2110
	Vulnerability			
Beach	Low	Medium	Very High	Very High
Coastal/dune vegetation	Low	Medium	Very High	Very High
Residential	Low	High	Very High	Very High
Beach Carpark (unsealed)	Low	Low	Low	Medium
Beach Access (Lancelin Island Point)	Low	Medium	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 Cost	Capital Cost	Ongoing Cost	
Avoid	AV	Avoid development									Recommended
Managed Retreat	MR1	Leave unprotected / repair									Not recommended
	MR2	Remove / relocate									Investigate
	MR3	Planning controls for retreat									Recommended
Accommodate	AC1	Planning controls to accommodate risk									Recommended
	AC2	Emergency plans and controls									Recommended
Protect	PR1	Dune care / sand management									Recommended
	PR2	Beach nourishment									Investigate
	PR3	Groyne									Investigate
	PR4	Nearshore reef / breakwater									Not recommended
	PR5	Seawall									Investigate
Do Nothing	DN	Do nothing									Not recommended

Shire of Gingin
Coastal Hazard Risk Management
and Adaptation Plan

APPENDIX G

MULTI-CRITERIA ANALYSIS SUMMARY

Table G1 Summary of multi-criteria analysis

Description	Avoid	Managed Retreat			Accommodate		Protect					Do Nothing	Risk Priority	Preliminary long term pathway	Decision timeframe
	AV	MR1	MR2	MR3	AC1	AC2	PR1	PR2	PR3	PR4	PR5	DN			
SE1: Seabird Township South	R	NR	I	R	R	R	R	NR	I	NR	I	NR	**High**	**Managed Retreat or Protect**	**Short term**
SE2: Seabird Township North	R	NR	I	R	R	R	R	NR	I	NR	I	NR	Medium	Managed Retreat or Protect	Medium term
LP1: Ledge Point South of Township	R	R	N/A	R	R	R	R	NR	NR	NR	NR	NR	Low	Avoid	Not Required
LP2: Ledge Point Township South	R	NR	I	R	R	R	R	I	I	NR	I	NR	**High**	**Managed Retreat or Protect**	**Short term**
LP3: Ledge Point Township North	R	NR	I	R	R	R	R	I	I	NR	I	NR	Medium	Managed Retreat or Protect	Medium term
LP4: Ledge Point North of Township	R	R	N/A	R	R	R	R	NR	NR	NR	NR	NR	Low	Avoid	Not Required
LA1: Lancelin South of Township	R	NR	I	R	R	R	R	I	I	NR	I	NR	**High**	**Managed Retreat or Protect**	**Short term**
LA2: Lancelin Township South of Jetty	R	NR	I	R	R	R	R	I	I	NR	I	NR	Medium	Managed Retreat or Protect	Medium term
LA3: Lancelin Township Jetty to Lancelin Point	R	NR	I	R	R	R	R	I	I	NR	I	NR	Medium	Managed Retreat or Protect	Medium term
LA4: Lancelin Township North of Lancelin Point	R	NR	I	R	R	R	R	I	I	NR	I	NR	Medium	Managed Retreat or Protect	Medium term

AV: Avoid development
MR1: Leave unprotected / repair
MR2: Remove / relocate
MR3: Planning controls for retreat
AC1: Planning controls to accommodate risk
AC2: Emergency plans and controls

PR1: Dune care program / Sand management
PR2: Beach Nourishment
PR3: Groyne
PR4: Nearshore Reef / Breakwater
PR5: (Maintain / extend) Seawall

NR	Not recommended
I	Investigate (High Priority Areas - see Adaptation Options in Chapter 5)
R	Recommended (See Implementation Plan - Chapter 6)

Table G2 SE1: Seabird Township South

	MR2 - Remove / relocate	PR3 - Groynes	PR5 - Seawall
Effectiveness	Removal of houses to the west of the natural limestone ridge would be effective in lowering the risk of erosion.	The effectiveness of groynes in maintaining a beach would need to be assessed in greater detail. Ongoing sand renourishment may be required.	Maintenance of the seawall would be effective in lowering the risk of erosion impacts to assets landward of the seawall.
Legal / Approval Risk	At present the mechanisms for implementing managed retreat are not well understood, and may involve legal risk.	Implementing groynes may increase the risk of long term erosion in management unit SE2, thereby exposing responsible entities to future legal action in the event of injurious affection.	The presence of the seawall may increase the risk of long term erosion in management unit SE2, thereby exposing responsible entities to future legal action in the event of injurious affection.
Reversibility / Adaptability	Managed retreat of assets from the hazard zone is the best way of preserving future options for adaptation.	Protective structures tend to encourage investment and intensification of development based on the belief that property will be protected into the future (see Section 1.6). This option is therefore difficult to reverse and limits future adaptation options.	Protective structures tend to encourage investment and intensification of development based on the belief that property will be protected into the future (see Section 1.6). This option is therefore difficult to reverse and limits future adaptation options.
Environmental / Social Impact	Removal of assets and allowing erosion to occur may be considered to have the best environmental outcomes since this is the most natural course of action. Managed retreat would allow for public access to a foreshore reserve and restore use of the beach.	Groynes have the potential to result in negative impacts to benthic habitats, but also have the potential to create new habitat and substrate for marine flora and fauna. The potential environmental impacts from groynes would need to be assessed in greater detail. If successful in creating beach amenity then this would have positive social impacts.	Increased erosion of SE2 would be a negative environmental impact. Maintenance of the seawall would continue to reduce the public amenity of the coast in front of the seawall.
Community Acceptability	This option is likely to be highly unacceptable to the landowners west of the 2030 hazard line, and of limited acceptability to the rest of the Seabird community.	This option is likely to be acceptable to the landowners west of the 2030 hazard line as well as the rest of the Seabird community, however the level of cost contribution required may make this option unacceptable.	This option is likely to be most acceptable to the landowners west of the 2030 hazard line and the rest of the seabird community.
Financial Gain / Avoidance of Cost	This option avoids the cost of seawall maintenance.	This option does not provide immediate financial gain to the broader community, however it may make Seabird a more desirable area thereby stimulating development, increasing tourism potential and raising house values. .	This option provides financial gain primarily for landowners west of the 2030 hazard line. Increased public amenity relating to the seawall would be required to broaden the beneficiary base.
Capital Cost	Compensation to the 16 landowners within the 2030 hazard zone could cost in the order of $16 M.	This option is likely to be prohibitively expensive (estimated best practice approach: $9M) for the ratepayer base of around 200.	N/A

	MR2 - Remove / relocate	PR3 - Groynes	PR5 - Seawall
Ongoing Cost	Expected to be negligible.	Ongoing cost is expected to be around twice that of a seawall alone ($44,000 p/a)	Estimated $24,000 p/a.

Table G3 LP2: Ledge Point Township South

	PR2 - Beach Nourishment	MR2 - Remove / relocate	PR3 - Groynes	PR5 - Seawall
Effectiveness	May reduce risk but residual risk from extreme events would remain. Ongoing nourishment would be required.	Removal of houses seaward of DeBurgh St would reduce the consequences of erosion.	Additional groynes are likely to be effective if sand renourishment is also carried out. The effectiveness of extension of the existing groynes needs to be assessed in greater detail.	Construction of a seawall would be effective in lowering the risk of erosion impacts to assets landward of the seawall.
Legal / Approval Risk	This option is expected to have minimal legal risk.	At present the mechanisms for implementing managed retreat are not well understood, and may involve legal risk.	Implementing groynes may increase the risk of long term erosion in adjoining areas, potentially posing a legal risk.	Construction of a seawall may increase the risk of long term erosion in adjacent management units, thereby exposing responsible entities to future legal action in the event of injurious affection.
Reversibility / Adaptability	This option is highly reversible.	Managed retreat preserves future options for adaptation.	This option is difficult to reverse and limits future adaptation options.	This option is difficult to reverse and limits future adaptation options.
Environmental / Social Impact	Environment impacts are likely to be minimal. Social impacts on beach use may be experienced during construction and may alter the nature of the beach and impact on boat launching activities.	Managed retreat may be considered to have the best environmental outcomes since this is the most natural course of action. Removal of assets and creation of a foreshore reserve would increase public access to the beach.	The potential environmental impacts from groynes would need to be assessed in greater detail. Additional groynes may restrict vehicle access along the beach.	Increased erosion of adjacent management units would be a negative environmental impact. Construction of a seawall may reduce the public amenity of the coast in front of the seawall.
Community Acceptability	Moderate acceptability unless current beach use is significantly impacted.	This option is likely to be unacceptable to the specific landowners required to remove assets/relocate, and be of limited acceptability to the broader Ledge Point community.	This option is likely to be acceptable so long as existing use of the beach can be maintained.	This option may be acceptable so long as existing use of the beach can be maintained.

	PR2 - Beach Nourishment	MR2 - Remove / relocate	PR3 - Groynes	PR5 - Seawall
Financial Gain / Avoidance of Cost	Minimal financial gain anticipated.	This option avoids the cost of coastal protection works.	This option provides financial gain for landowners along DeBurgh Street. This option does not provide immediate financial gain to the broader community, but may raise property values.	This option provides financial gain primarily for landowners west of DeBurgh Street.
Capital Cost	$1.46m for same volume as with groynes but could be considerably less	Compensation to the landowners west of DeBurgh St could cost in the order of $23 million.	Estimated to be $3.9 M for 2 groynes and sand nourishment.	Estimated $1.2 M for 290 m long seawall.
Ongoing Cost	Estimated $40,000 p/a	Expected to be negligible.	Estimated $19,500 p/a.	Estimated $13,500 p/a.

Table G4 LA1: Lancelin South of Township

	PR2 -Beach Nourishment	MR2 - Remove / relocate	PR3 - Groynes	PR5 - Seawall
Effectiveness	Ongoing nourishment would be required to be effective.	Removal of Grace Darling Park and chalets in the caravan park would reduce the consequences of erosion.	The effectiveness of groynes in this location would need to be assessed in greater detail.	Construction of a seawall would be effective in lowering the risk of erosion impacts to assets landward of the seawall.
Legal / Approval Risk	This option is expected to have minimal legal risk.	Minimal legal risk.	Implementing groynes may increase the risk of long term erosion in adjoining areas, thereby potentially exposing responsible entities to future legal action.	Construction of a seawall may increase the risk of long term erosion in adjacent areas, thereby potentially exposing responsible entities to future legal action.
Reversibility / Adaptability	This option is highly reversible	Managed retreat preserves future options for adaptation	This option is difficult to reverse and limits future adaptation options.	A rock sea wall option is difficult to reverse and limits future adaptation options. GSC are more easily reversible with fewer negative impacts.
Environmental / Social Impact	Environment impacts are likely to be minimal. Social impacts on beach use may be experienced	Managed retreat may be considered to have the best environmental outcomes since this is the most natural course of action.	The potential environmental impacts from groynes would need to be assessed in greater detail. Social impacts may occur if groynes have a negative impact on tourism due	Increased erosion of adjacent dune areas may result. Seawalls may reduce the public amenity of the beach in front of the seawall.

	PR2 -Beach Nourishment	MR2 - Remove / relocate	PR3 - Groynes	PR5 - Seawall
	during sand relocation activities.	Social impacts may occur if no allowance for a foreshore reserve with public/tourism access to key areas.	to changes to natural character of the area.	
Community Acceptability	High acceptability.	Community acceptability will depend on provision of a foreshore reserve with public access to key recreation areas.	This option is unlikely to be acceptable as it would substantively change the character of the area.	The GSC option may be acceptable so long as existing use of the beach can be maintained. The rock option is unlikely to be acceptable.
Financial Gain / Avoidance of Cost	Minimal direct financial gain, but some flow-on economic benefits.	This option avoids the cost of coastal protection works.	This option does not provide immediate financial gain to the broader community	This option may provide some financial gain to the broader community so long as the beach and connection to it can be maintained.
Capital Cost	$5.88m for same volume as with groynes but could be less if no groynes constructed.	N/A	Estimated to be $12 M for 4 groynes and sand renourishment. Smaller scale options in the vicinity of Grace Darling Park might cost considerably less.	Estimated $2.7 M for 700 m long rock seawall or $700 -$900 K for 150 m long GSC revetment.
Ongoing Cost	$48,000 or less if sand is sourced from the nearby salient sand spit.	Expected to be negligible.	Estimated $39,000 p/a	Estimated $29,700 p/a.

Shire of Gingin
Coastal Hazard Risk Management
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APPENDIX H

PLANNING CONTROLS DISCUSSION

H PLANNING CONTROLS DISCUSSION

H1 When Planning Controls are Required

As climate change and sea level rise are not 100% predictable, risk assessments are based on likelihood rather than certainty. The clear challenge for responsible planning near the coast is managing development in a way that does not prematurely sterilise otherwise suitable land from being sensitively used. At the same time, the local government must not create a future legal or financial liability by permitting development that is likely to become vulnerable to damage from erosion or inundation.

Planning controls are particularly important for locations affected by coastal processes where avoidance or managed retreat responses are recommended.

The classification of land in a local planning scheme is one of the key planning tools available to manage the use of land. Through the classification of land, land uses and land use intensity can be controlled.

Local planning schemes zone or reserve land for various purposes, and may additionally incorporate 'overlays' that indicate special requirements applicable to affected land regardless of the zone or reserve.

Most land within scheme areas is zoned. Depending on the zone applied, certain land uses may be permitted or excluded, and different development standards or other requirements may apply. Land is generally only 'reserved' in planning schemes to serve some public purpose. For example, foreshore reserves and parks will usually be reserved, as will civic and community uses and important infrastructure such as service utilities and major transport corridors. Reservation of land in a local planning scheme doesn't necessarily mean it is or will ever be publicly owned, although it often is.

The classification of land in a local planning scheme creates expectations for owners and the wider community about what may be permitted to be developed on that land. Therefore, it is preferable for planning schemes to classify land in a way that makes it clear that any further development of land at risk from coastal processes can only occur if the local government considers it to be acceptable in the light of the policy of planned (or managed) retreat. Hence it is important to indicate on scheme maps those areas that are considered to be at risk.

The draft Planned or Managed Retreat Guidelines (WAPC 2017) provide guidance for the preparation of policy for planned or managed retreat, which is based on the principles of social, environmental and economic sustainability and the objectives of the State Coastal Planning Policy. The principles underpin the planning response for coastal risk management and adaptation. The principles are:

a) To ensure land in the coastal zone is continuously provided for coastal foreshore management, public access, recreation and conservation;

b) To ensure public safety and reduce risk associated with coastal erosion and inundation;

c) To avoid inappropriate land use and development of land at risk from coastal erosion and inundation; and

d) To ensure land use and development does not accelerate coastal erosion or inundation risks, or have a detrimental impact on the functions of public reserves.

Not all adaptation and management responses require a planning control. It is necessary to understand that local planning schemes and other planning mechanisms can only address some matters, including those that fall within the definition of 'development' as defined by the Planning and Development Act 2005, that is:

"development or use of any land, including:

(a) any demolition, erection, construction, alteration of or addition to any building or structure on the land;

(b) the carrying out on the land of any excavation or other works;

(c) in the case of a place to which a Conservation Order made under section 59 of the Heritage of Western Australia Act 1990 applies, any act or thing that —

(i) is likely to change the character of that place or the external appearance of any building; or

(ii) would constitute an irreversible alteration of the fabric of any building."

Planning controls include provisions in the local planning scheme relating to certain land use designations and/or development types, preferably supported by appropriate local planning policy or policies to describe the Shire's intentions and the principles that will guide decision making on the matters covered.

H2 Types of Planning Control

Planning controls that may be considered include:

> Zoning or reservation of land in the Local Planning Scheme;

> Special Control Areas;

> Local Planning Policies;

> Structure Plans;

> Approval Conditions.

H2.1 Zones and Reserves

Zones allow for private land uses within the development parameters permitted by the local planning scheme and any related planning policies. Typical zones adjacent to the coast are Residential, Tourism, and Commercial.

Ideally, land at risk from coastal hazards would be contained within a foreshore reserve classified in the local planning scheme for either Parks and Recreation, or Environmental Conservation. However, in practice this may not be appropriate over privately-owned land because local planning schemes reserves typically preclude development for private purposes, and refusal of an application for private development would trigger a claim for compensation that the Shire could ill afford. Furthermore, prohibiting development in the short-term may not be necessary if the risk is forecast to be longer term and beyond the economic life of the proposed development.

Therefore, rather than reserving vulnerable land, the planning recommendations in this CHRMAP seek to facilitate appropriate development on private land according to the applicable zone, for as long as the land and the development can exist without adversely impacting public amenity and safety, and without unacceptable risk to the users of the development or neighbouring developments and land. The most appropriate way of doing this is through the application of a special control area (see H2.2), which is an 'overlay' to the zone (and/or reserve).

H2.2 Special Control Areas

Where land has been assessed as being vulnerable to coastal processes, a Special Control Area (SCA) is the most appropriate classification of land to facilitate land use change and development control, and is preferred by the WAPC as outlined in the draft Planned or Managed Retreat Guidelines.

Special Control Areas apply to land that is significant for some reason (in this case, vulnerability to coastal processes) and where special provisions in the scheme may need to apply. An SCA is shown on the scheme map as an overlay to the zones and reserves, and the special provisions related to the issue apply in addition to the provisions of the underlying zones and reserves. The provisions set out the purpose and objectives of the SCA, any specific development requirements, the process for referring applications to relevant agencies, and matters to be considered in determining development proposals.

Within an SCA the Shire can mandate that all development requires approval including development that is normally exempt from planning approval (e.g.: ordinarily single houses don't require planning

approval). This ensures that only development that the Shire considers to be acceptable to the assessed risk can take place.

An SCA can also provide for time limited planning approvals (ie: temporary approval), which is discussed further in H2.4.

The draft Planned or Managed Retreat Guidelines provide recommended wording for scheme text relating to a SCA.

H2.3 Structure Plans

A structure plan is a plan for the coordination of future subdivision and zoning of an area of land. If comprehensive redevelopment of land is an option, a structure plan should be required before subdivision or development can take place.

Deemed provision 15 of TPS 9 sets out when a structure plan may be prepared, in the following terms:

A structure plan in respect of an area of land in the Scheme area may be prepared if —

(a) the area is —

  (i) all or part of a zone identified in this Scheme as an area suitable for urban or industrial development; and

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

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

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

Other deemed provisions set out the procedure for preparing structure plans. Structure plans consider a range of matters including land requirements to accommodate coastal risks in compliance with the requirements of the State Coastal Planning.

In LPS 9, structure plans are required on land zoned ‘Future Development’. It is for this reason that a structure plan was prepared for Moore River South and other areas further inland.

Local structure plans typically indicate future proposed zones and reserves. A foreshore reserve of adequate dimensions to accommodate coastal processes can be identified, to ensure that there will still be a public foreshore reserve even if/when the extent of forecast erosion is reached.

Structure plans are not statutory documents but the deemed provisions of local planning schemes in the Planning and Development (Local Planning Schemes) Regulations 2015 set out the way they are to be prepared and adopted, and confer a requirement on decision makers to have due regard to them when determining development under the planning scheme.

Structure plans have a life of 10 years from the date of approval (or until 19 October 2025 if they were approved before the Planning and Development (Local Planning Schemes) Regulations 2015 came into force). In due course and as the structure plan is implemented it is expected that reserves and zones shown in the structure plan will be reflected in the local planning scheme via a scheme amendment.

H2.4 Approval Conditions

Provided they are justified and reasonable in relation to the proposal, the decision maker can apply conditions to approvals for subdivision or development. The WAPC is responsible for determining applications for subdivision and in doing so will consult with the local government and consider relevant State Planning Policies including the State Coastal Policy. Applications for development approval are the responsibility of the local government or, where the value of the proposed development exceeds the defined threshold, by the Mid-West/Wheatbelt (Central) Joint Development Assessment Panel (JDAP).

Two possible types of condition of particular relevance to land at risk from coastal processes are to require a notification to be placed on the Title of the land, and to place a time limit on the approval (so that the approval will expire after a defined period).

Notifications on Title

Notifications on Title are made to alert owners and potential purchases of something that applies to the land but which may not be apparent from inspection of the land. The threat of future coastal hazards is a matter that would not be apparent on land unless it had already been eroded.

A notification on the Certificate of Title will ensure that existing and any future landowners (Successors in Title) are made aware of the risk of possible impacts on the land from coastal processes. Owners and potential purchasers would then be able to make an informed decision about the level of risk they are prepared to take on. The notification would also inform them that some form of adaptation or management is likely to be required.

There are two mechanisms by which a notification can be placed on a Certificate of Title:

> Section 165 of the Planning and Development Act 2005; and

> Section 70A of the Transfer of Land Act 1897.

Under Section 165 of the Planning and Development Act 2005 it is the WAPC's responsibility to determine the need for a notification, and to place a condition on a subdivision proposal if necessary. New titles could not then be created until the notification had been placed.

Alternatively, under Section 70A of the Transfer of Land Act 1897 a notification may be lodged to the benefit of a local government or public authority. Such a notification must include the signature of the registered landowner to signify agreement with the notification being lodged. A condition could be placed upon a development approval, if appropriate, to require such a notification to be placed on the Title. Development would then not be able to proceed unless the notification was placed by the landowner/developer.

When there is no application for subdivision or development that could trigger a condition requiring a notification on the Title, it would be necessary to negotiate with landowners to achieve a notification under the Transfer of Land Act. A fee would be payable for each instance, unless a waiver of the fee could somehow be achieved.

Time Limited Approvals

A time limit can be applied to a development approval. For example, if a development is proposed on land that is forecast to be affected by coastal processes in say 30 years, an approval might be limited to within that timeframe. An application for a new approval could be sought at the end of that period and it would be assessed based on the information on risk available at that time. The condition may also identify an 'event trigger' to further limit an approval in case the hazard occurs sooner than predicted.

It is more acceptable to apply a time limit to a development approval where the scheme provides for the possibility, such as would be the case for an SCA for planned retreat.

Time limits on subdivision of land are not possible, as once new Titles are created they can't be extinguished without a lengthy and expensive process of resumption (or 'taking' as it is also known). Hence it is recommended that further subdivision of vulnerable land not be permitted.

H3 Management Responses and Planning Controls

Possible types of planning control relevant to these management responses are described in the following paragraphs.

H3.1 Avoid

Avoiding development means prohibiting development from taking place in locations identified as being at potential risk from coastal hazards.

This can be achieved by zoning or reserving the land to preclude development. If the appropriate zone does not already apply to the land, a scheme amendment would be required to change the designation of the land and introduce any necessary provisions.

Types of scheme amendments to achieve this outcome are discussed further in H4.

H3.2 Accommodate

Accommodation options recognise that there is a hazard, but do not prohibit development. Instead, depending on the nature of the hazard and the timeframe within which it is expected to occur, development may be permitted within defined parameters.

For example, if inundation of land is anticipated it may be acceptable to have development that can accommodate occasional inundation by having a finished floor level that keeps habitable parts of buildings above the expected high-water level. How this elevated floor level is achieved will depend on the particular characteristics of the location but may involve buildings being raised on 'stilts' that allow flood waters to flow underneath with relative ease, or by raising the ground level with suitable fill and protection so that floor levels remain above predicted flood levels.

The local planning scheme will need to identify where these controls would apply, and a local planning policy could outline the types of building that the Shire would be prepared to consider to achieve its objectives. In framing local planning controls, care should be taken not to inadvertently exclude innovative alternative solutions that can be shown to be effective.

An alternative scenario could be to acknowledge that the land might be subject to erosion in the future, but that the planning horizon is sufficiently far off that temporary development could be acceptable until such time as the threat of erosion becomes imminent. In such a situation certain types of construction might acceptable (e.g.: transportable or easily dismountable), and/or certain types of development only might be permitted (e.g.: short term accommodation and tourism activities).

Again, the planning scheme will have to identify these areas and the types of development that will be permitted. A supporting local planning policy could detail the Shire's expectations for the design and/or management of temporary development.

A scheme amendment would be required to introduce any necessary provisions and if necessary to rezone or change the designation of the land. Types of scheme amendments to achieve this outcome are discussed further in H4.

Additionally, notification on the Title of affected land would be advisable so that the owner and/or future owners are aware of the requirements. This was discussed in H2.4.

H3.3 Managed Retreat

Existing development would be permitted to remain for as long as it remains unaffected by coastal hazards, but new development or expansion of existing development would not be permitted as intensification of development would mean more assets at risk. Approval of any development would be time limited, based on the forecast hazard timeframe.

H4 LPS 9 Recommendations

The following sections provide recommendations for incorporation into LPS 9 or any new planning scheme.

H4.1 Introduce a Special Control Area

LPS 9 should be immediately amended to include zoned land seaward of the forecast 2110 hazard line within a Special Control Area (SCA). Where the hazard line cuts across a lot less than one hectare in area, the whole of the cadastral boundary of that lot should be included in the SCA.

Within the SCA development approval would be required for any new development including single houses, outbuildings, fences, retaining walls, and additions or extensions or other structural modifications to existing buildings.

Any new development approved should have a time limit placed upon it, after which time the development should be removed by the landowner unless a subsequent new approval is applied for and granted for a further period. The length of the approval should be related to the forecast hazard lines

Serious consideration should be given to not permitting (avoiding) any new development at all forward of the 2020 hazard line (where this is defined) or the 2030 hazard line (where no 2020 line is defined). If development is contemplated in such areas then it would be preferable not to permit permanent accommodation due to the relatively short timeframe within which serious impacts can be expected.

No development should be permitted on any vacant land between the 2030 and 2110 hazard lines that is not:

(a) capable of accommodating short term inundation that may result from storm surges; and

(b) capable of being relocated if necessary.

The former may involve elevated finished floor levels with 'stilt' construction that will allow water to flow under and around the structure with minimal disturbance. The latter may involve 'lightweight' construction that could be readily disassembled and relocated if necessary.

The Shire may also require a local development plan (LDP) on specific areas of undeveloped land within the SCA to provide detailed guidance for the location and/or construction of any development that may be contemplated. An LDP is a plan that sets out specific and detailed guidance for a future development including one or more of the following —

(a) site and development standards that are to apply to the development;

(b) specifying exemptions from the requirement to obtain development approval for development in the area to which the plan relates.

Recommended wording for an SCA for Coastal Processes is provided by the WAPC within the draft *Planned and Managed Retreat Guidelines* (2017).

H4.2 Local Planning Policy for Coastal Development

A Local Planning Policy (LPP) should be developed and adopted using the procedures of Division 2 of the deemed provisions of LPS 9. Such a policy would cover matters such as the acceptable forms of 'temporary' construction within land forecast to be impacted by coastal processes. The existing LPPs 1.2 and 1.4 do not address these matters and should be updated or replaced with a more comprehensive policy that complements the State Coastal Policy.

A separate corporate policy for temporary development on coastal foreshore reserves might be appropriate to guide the Shire's own operations (eg: provision of beach shelters and other public amenities).

To provide guidance for future planning by the Shire and private landowners it is recommended that the Shire identify a default minimum distance required to accommodate public amenity within any foreshore reserve, for inclusion in the LPP. Depending on the location and purpose of the foreshore reserve public amenities may include beach access, car parking, picnic/barbeque facilities, public toilets, beach kiosks, etc., and the minimum distance required to fit them in will vary accordingly. This allowance for public amenity should be added to the 2110 hazard line to delineate an indicative minimum distance from the coast for the landward boundary of future planning scheme coastal reserves.

H4.3 Subdivision

Undeveloped parcels of zoned or reserved land lying seaward of the 2110 hazard line should not be permitted to be further subdivided. Subdivision includes strata titling. Time limited leasehold might be acceptable in situations where an appropriate temporary development necessitates a smaller parcel of land for management purposes, however this should be carefully considered and only contemplated where there are demonstrable benefits of the proposed development for the community. A lease has a defined expiry date and does not result in permanent fragmentation of the landholding.

Where a structure plan is prepared, coastal foreshore reserve boundaries should be determined in accordance with Section 5.9 of the Coastal Planning Policy, and include an allowance for coastal processes as well as future public amenity at the end of the planning timeframe (2110). This recommendation is also consistent with Section 5.2(i) of the Coastal Planning Policy which encourages urban development around existing settlements and discourages continuous linear urban development along the coast.

H4.4 Reserved Land

Where Crown Land (including reserves as defined under the Land Administration Act 1997) is forecast to be impacted by coastal hazards, the foreshore Parks and Recreation reserve in LPS 9 should be extended as described above. Publicly owned freehold land that is not developed should similarly be included in the foreshore reserve, if possible. In either case this would be subject to negotiation with the public agency that has the management order (in the case of Crown Land) or that owns it (in the case of freehold land) and the Lands section of the Department of Planning, Lands and Heritage.

Shire of Gingin
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APPENDIX I

LONG TERM PATHWAYS

Cardno

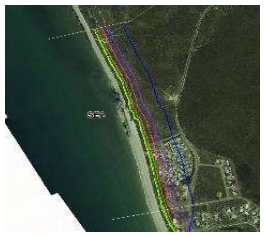
SE1: Seabird Township South



Timeframe	2016	2030	2070	2110
Vulnerability Ratings				
Beach	Medium	High	Very High	Very High
Coastal/dune vegetation	Medium	High	Very High	Very High
Residential (houses and land)	Very High	Very High	Very High	Very High
Carparks and roads	Medium	High	High	High
Asset lifecycle		Estimated end of Seabird Seawall lifecycle		
Indicative Pathway				
Undeveloped Areas	*Avoid*			
Developed Areas	*Protect*		*Managed Retreat*	
Minor Infrastructure	*Managed Retreat*			
Actions				
Undeveloped Areas	AV, MR3 - Implement planning controls to prevent new development and intensification of development in the Coastal foreshore reserve			
Developed Areas	PR5 - Protection by seawall		MR2 - Remove assets as their risk becomes intolerable	
Minor Infrastructure	MR1, MR2 - Remove minor infrastructure as it becomes damaged, irreparable and/or unsafe			

Management Pathway Triggers	Trigger 1	Trigger 2	Trigger 3	Trigger 4
Trigger	CHRMAP recommendation	HSD plus S1 reaches 2030 vulnerability line	HSD plus S1 reaches 2070 vulnerability line	Minor infrastructure becomes damaged or unsafe
Action	Implement planning controls and prepare emergency plans, apply notification on title	Retorfit seawall, commence dune care program	Remove damaged assets and relocate assets at risk	Remove assets
Responsibility	Shire of Gingin and State Government	Shire of Gingin	Shire of Gingin	Shire of Gingin

SE2: Seabird Township North



Timeframe	2016	2030	2070	2110
Vulnerability Rating				
Beach	Low	High	High	High
Coastal/dune vegetation	Low	Medium	High	Very High
Caravan Park (Seabird Private)	Low	Medium	Very High	Very High
Tavern	Low	Medium	Medium	High
Asset lifecycle			**Estimated end of Caravan Park lifecycle**	
Pathways				
Undeveloped Areas	*Avoid*			
Developed Areas	*Protect*		*Managed Retreat*	
Minor Infrastructure	*Managed Retreat*			
Actions				
Undeveloped Areas	AV, MR3 - Implement planning controls to prevent new development and intensification of development in the Coastal foreshore reserve			
Developed Areas	AC1, AC2, PR1 - Implement planning controls and emergency plans to accommodate coastal risk and dune care and sand management		MR2 - Remove assets as their risk becomes intolerable	
Minor Infrastructure	MR1, MR2 - Remove minor infrastructure as it becomes damaged, irreparable and/or unsafe			

Management Pathway Triggers	Trigger 1	Trigger 2	Trigger 3	Trigger 4
Trigger	CHRMAP recommendation	HSD plus S1 reaches 2030 vulnerability line	HSD plus S1 reaches 2070 vulnerability line	Minor infrastructure becomes damaged or unsafe
Action	Implement planning controls and prepare emergency plans, apply notification on title	Commence dune care program and sand management	Remove damaged assets and relocate assets at risk	Remove assets
Responsibility	Shire of Gingin and State Government	Shire of Gingin	Shire of Gingin	Shire of Gingin

LP1: Ledge Point South of Township

	Timeframe	2016	2030	2070	2110
	**Vulnerability Rating**				
	Beach	Low	Low	Low	Low
	Coastal/dune vegetation	Low	Medium	Medium	High
	Beach Carpark (unsealed)	Low	Low	Low	Medium
	Road (unsealed)	Low	Low	Low	Low
	Asset lifecycle				
	Pathways				
	Undeveloped Areas	*Avoid*			
	Developed Areas	*NA*			
	Minor Infrastructure	*Managed Retreat*			
	Actions				
	Undeveloped Areas	AV, MR3 - Implement planning controls to prevent new development and intensification of development in the Coastal foreshore reserve			
	Developed Areas	AC1, MR3 - Implement planning controls and emergency plans to accommodate coastal risk			
	Minor Infrastructure	PR1 - Dune care and sand management			MR1, MR2 - Remove minor infrastructure as it becomes damaged, irreparable and/or unsafe

Management Pathway Triggers	Trigger 1	Trigger 2	Trigger 3	Trigger 4
Trigger	CHRMAP recommendation	HSD plus S1 reaches 2030 vulnerability line	HSD plus S1 reaches 2070 vulnerability line	Minor infrastructure becomes damaged or unsafe
Action	Implement planning controls and prepare emergency plans, apply notification on title	Commence dune care program and sand management	Commence dune care program and sand management	Remove assets
Responsibility	Shire of Gingin and State Government	Shire of Gingin	Shire of Gingin	Shire of Gingin

LP2: Ledge Point Township South of Jetty



Timeframe	2016	2030	2070	2110
Vulnerability Rating				
Beach	Medium	Medium	High	High
Foreshore recreation area	Low	Low	Medium	High
Residential	High	Very High	Very High	Very High
Roads	Low	Low	High	Very High
Asset lifecycle		**Estimated end of residential properties lifecycle**		
Pathways				
Undeveloped Areas	*Avoid*			
Developed Areas	*Protect*		*Managed Retreat*	
Minor Infrastructure	*Managed Retreat*			
Actions				
Undeveloped Areas	AV, MR3 - Implement planning controls to prevent new development and intensification of development in the Coastal foreshore reserve			
Developed Areas	PR3 - Protection by groyne		MR2 - Remove assets as their risk becomes intolerable	
Minor Infrastructure	MR1, MR2 - Remove minor infrastructure as it becomes damaged, irreparable and/or unsafe			

Management Pathway Triggers	Trigger 1	Trigger 2	Trigger 3	Trigger 4
Trigger	CHRMAP recommendation	HSD plus S1 reaches 2030 vulnerability line	HSD plus S1 reaches 2070 vulnerability line	Minor infrastructure becomes damaged or unsafe
Action	Implement planning controls and prepare emergency plans, apply notification on title	Extend groyne if feasible, commence dune care program	Remove damaged assets and relocate assets at risk	Remove assets
Responsibility	Shire of Gingin and State Government	Shire of Gingin	Shire of Gingin	Shire of Gingin

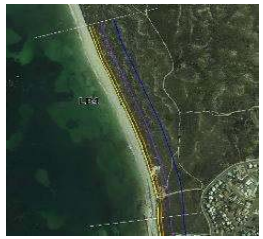
LP3: Ledge Point Township North



Timeframe	2016	2030	2070	2110
Vulnerability Rating				
Beach	Low	Low	Medium	High
Coastal/dune vegetation	Low	Medium	Medium	Very High
Carpark (De Burgh St)	Low	Low	Medium	High
Road (De Burgh St)	Low	Low	Medium	High
Holiday Village	Low	Low	High	Very High
Residential	Low	Low	Very High	Very High
Key Biscoyne Park	Low	Low	Medium	Very High
Asset lifecycle				**End of asset lifecycle**
Pathways				
Undeveloped Areas	*Avoid*			
Developed Areas	*Accommodate*		*Managed Retreat*	
Minor Infrastructure	*Managed Retreat*			
Actions				
Undeveloped Areas	AV, MR3 - Implement planning controls to prevent new development and intensification of development in the Coastal foreshore reserve			
Developed Areas	AC1, MR3 - Implement planning controls and emergency plans to accommodate coastal risk		MR2 - Remove assets as their risk becomes intolerable	
Minor Infrastructure	MR1, MR2 - Remove minor infrastructure as it becomes damaged, irreparable and/or unsafe			

Management Pathway Triggers	Trigger 1	Trigger 2	Trigger 3	Trigger 4
Trigger	CHRMAP recommendation	HSD plus S1 reaches 2030 vulnerability line	HSD plus S1 reaches 2070 vulnerability line	Minor infrastructure becomes damaged or unsafe
Action	Implement planning controls and prepare emergency plans, apply notification on title	Commence dune care program and sand management	Remove damaged assets and relocate assets at risk	Remove assets
Responsibility	Shire of Gingin and State Government	Shire of Gingin	Shire of Gingin	Shire of Gingin

LP4: Ledge Point North of Township

	Timeframe	2016	2030	2070	2110
	**Vulnerability Rating**				
	Beach	Low	Low	Low	Low
	Coastal/dune vegetation	Low	Medium	Medium	Medium
	Carpark (unsealed)	Low	Low	Low	Low
	Road (unsealed)	Low	Low	Low	Low
	Asset lifecycle				
	Pathways				
	Undeveloped Areas	*Avoid*			
	Developed Areas	*NA*			
	Minor Infrastructure	*Managed Retreat*			
	Actions				
	Undeveloped Areas	AV, MR3 - Implement planning controls to prevent new development and intensification of development in the Coastal foreshore reserve			
	Developed Areas	AC1, MR3 - Implement planning controls and emergency plans to accommodate coastal risk			
	Minor Infrastructure	PR1 - Dune care and sand management			MR1, MR2 - Remove minor infrastructure as it becomes damaged, irreparable and/or unsafe

Management Pathway Triggers	Trigger 1	Trigger 2	Trigger 3	Trigger 4
Trigger	CHRMAP recommendation	HSD plus S1 reaches 2030 vulnerability line	HSD plus S1 reaches 2070 vulnerability line	Minor infrastructure becomes damaged or unsafe
Action	Implement planning controls and prepare emergency plans, apply notification on title	Commence dune care program and sand management	Commence dune care program and sand management	Remove assets
Responsibility	Shire of Gingin and State Government	Shire of Gingin	Shire of Gingin	Shire of Gingin

LA1: Lancelin South of Twonship



Timeframe	2016	2030	2070	2110
Vulnerability Rating				
Beach	Low	Low	Low	Low
Coastal/dune vegetation	Low	Low	Medium	Medium
Carpark (Back Beach)	Low	Low	Low	Low
Caravan Park (Lancelin South End)	Medium	Medium	High	Very High
Sea Rescue	High	High	Very High	Very High
Grace Darling Park	High	High	Very High	Very High
Asset lifecycle		End of Grace Darling Park lifecycle		
Pathways				
Undeveloped Areas	*Avoid*			
Developed Areas	*Accommodate*		*Managed Retreat*	
Minor Infrastructure	*Managed Retreat*			
Actions				
Undeveloped Areas	AV, MR3 - Implement planning controls to prevent new development and intensification of development in the Coastal foreshore reserve			
Developed Areas	AC1, MR3 - Implement planning controls and emergency plans to accommodate coastal risk		MR2 - Remove assets as their risk becomes intolerable	
Minor Infrastructure	PR2 - Implement beach nourishment to accommodate risk		MR1, MR2 - Remove minor infrastructure as it becomes damaged, irreparable and/or unsafe	

Management Pathway Triggers	Trigger 1	Trigger 2	Trigger 3	Trigger 4
Trigger	CHRMAP recommendation	HSD plus S1 reaches 2030 vulnerability line	HSD plus S1 reaches 2070 vulnerability line	Minor infrastructure becomes damaged or unsafe
Action	Implement planning controls and prepare emergency plans, apply notification on title	Implement beach nourishment, commence dune care program and sand management	Remove damaged assets and relocate assets at risk	Remove assets
Responsibility	Shire of Gingin and State Government	Shire of Gingin	Shire of Gingin	Shire of Gingin

LA2: Lancelin Township South of Jetty



Timeframe	2016	2030	2070	2110
Vulnerability Rating				
Beach	Low	Medium	High	Very High
Coastal/dune vegetation	Low	Medium	High	Very High
Residential	Low	Low	High	Very High
Road (Cunliffe St)	Low	Low	Medium	High
Jetty	Low	Medium	High	High
Light Industrial	Low	Low	Medium	High
Café	Low	Low	Medium	High
Asset life cycle				**End of asset lifecycle**
Pathways				
Undeveloped Areas	*Avoid*			
Developed Areas	*Accommodate*		*Managed Retreat*	
Minor Infrastructure	*Managed Retreat*			
Actions				
Undeveloped Areas	AV, MR3 - Implement planning controls to prevent new development and intensification of development in the Coastal foreshore reserve			
Developed Areas	AC1, MR3 - Implement planning controls and emergency plans to accommodate coastal risk		MR2 - Remove assets as their risk becomes intolerable	
Minor Infrastructure	MR1, MR2 - Remove minor infrastructure as it becomes damaged, irreparable and/or unsafe			

Management Pathway Triggers	Trigger 1	Trigger 2	Trigger 3	Trigger 4
Trigger	CHRMAP recommendation	HSD plus S1 reaches 2030 vulnerability line	HSD plus S1 reaches 2070 vulnerability line	Minor infrastructure becomes damaged or unsafe
Action	Implement planning controls and prepare emergency plans, apply notification on title	Commence dune care program and sand management	Commence dune care program and sand management	Remove assets
Responsibility	Shire of Gingin and State Government	Shire of Gingin	Shire of Gingin	Shire of Gingin

LA3: Lancelin Township Jetty to Lancelin Point



Timeframe	2016	2030	2070	2110
Vulnerability Rating				
Beach	Low	Medium	High	Very High
Coastal/dune vegetation	Low	Medium	High	Very High
Road (Gingin Rd)	Low	Medium	Medium	Medium
Caravan Park (Lancelin North End)	Low	Medium	High	High
Hotel & Restaurant	Low	Medium	High	High
Park (Gingin Rd)	Low	Medium	High	High
Primary School	Low	Low	Medium	Medium
Tavern (Endeavour)	Low	Medium	High	High
Residential	Low	High	Very High	Very High
Asset lifecycle			**Estimated end of lifecycle**	
Pathways				
Undeveloped Areas	*Avoid*			
Developed Areas	*Accommodate*		*Managed Retreat*	
Minor Infrastructure	*Managed Retreat*			
Actions				
Undeveloped Areas	AV, MR3 - Implement planning controls to prevent new development and intensification of development in the Coastal foreshore reserve			
Developed Areas	AC1, MR3 - Implement planning controls and emergency plans to accommodate coastal risk		MR2 - Remove assets as their risk becomes intolerable	
Minor Infrastructure	MR1, MR2 - Remove minor infrastructure as it becomes damaged, irreparable and/or unsafe			

Management Pathway Triggers	Trigger 1	Trigger 2	Trigger 3	Trigger 4
Trigger	CHRMAP recommendation	HSD plus S1 reaches 2030 vulnerability line	HSD plus S1 reaches 2070 vulnerability line	Minor infrastructure becomes damaged or unsafe
Action	Implement planning controls and prepare emergency plans, apply notification on title	Commence dune care program and sand management	Commence dune care program and sand management	Remove assets
Responsibility	Shire of Gingin and State Government	Shire of Gingin	Shire of Gingin	Shire of Gingin

LA4: Lancelin Township North of Lancelin Point



Timeframe	2016	2030	2070	2110
Vulnerability Rating				
Beach	Low	Medium	Very High	Very High
Coastal/dune vegetation	Low	Medium	Very High	Very High
Residential	Low	High	Very High	Very High
Beach Carpark (unsealed)	Low	Low	Low	Medium
Beach Access (Lancelin Island Point)	Low	Medium	Medium	Medium
Asset lifecycle			**Estimated end of lifecycle**	
Pathways				
Undeveloped Areas	*Avoid*			
Developed Areas	*Accommodate*		*Managed Retreat*	
Minor Infrastructure	*Managed Retreat*			
Actions				
Undeveloped Areas	AV, MR3 - Implement planning controls to prevent new development and intensification of development in the Coastal foreshore reserve			
Developed Areas	AC1, MR3 - Implement planning controls and emergency plans to accommodate coastal risk		MR2 - Remove assets as their risk becomes intolerable	
Minor Infrastructure	MR1, MR2 - Remove minor infrastructure as it becomes damaged, irreparable and/or unsafe			

Management Pathway Triggers	Trigger 1	Trigger 2	Trigger 3	Trigger 4
Trigger	CHRMAP recommendation	HSD plus S1 reaches 2030 vulnerability line	HSD plus S1 reaches 2070 vulnerability line	Minor infrastructure becomes damaged or unsafe
Action	Implement planning controls and prepare emergency plans, apply notification on title	Commence dune care program and sand management	Commence dune care program and sand management	Remove assets
Responsibility	Shire of Gingin and State Government	Shire of Gingin	Shire of Gingin	Shire of Gingin

APPENDIX B

Appendix B - Coastal Inundation Study (Baird, 2020)

Gingin Coastal Inundation Study (CIS)

Lancelin, Ledge Point, Seabird and Guilderton

1 July 2020 | 13288.101.R1.Rev1

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Gingin Coastal Inundation Study (CIS)

Lancelin, Ledge Point, Seabird and Guilderton

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Executive Summary

Baird Australia (Baird) have undertaken a Coastal Inundation Study (CIS) for the Shire of Gingin which examines extreme water levels in coastal areas during severe storms and tsunami events. The study has determined design water levels that will be used to inform coastal planning in the Shire at the key coastal townsites of Lancelin, Ledge Point, Seabird and Guilderton, consistent with the guidelines of the State Coastal Planning Policy 2.6 (SPP2.6).

Baird's established and validated numerical model of the West Australian coast was adopted in the CIS to examine extreme events:

- The model was used to simulate historical cyclone cases which have impacted the study area, providing a basis for understanding magnitude of storm surge in extreme cyclone events and demonstrating model performance.
- Design (cyclonic) storm cases were developed and used to define the 20yr-ARI, 100yr-ARI and 500-year ARI inundation level for the four towns of the study area.
- Sea level rise projections based on current State policy (DoT 2010) were applied over a range of planning periods to define the final design water level recommendations for the present day (2020), 2040, 2070 and 2120.

The final design water levels at locations through the study area are summarised in Table E.1 based on the present day (2020) sea level.

Table E.1: Design water level across the four towns in the Gingin study area.

ARI (yr)	Lancelin North (m AHD)	Lancelin Mid (m AHD)	Lancelin South (m AHD)	Ledge Point North (m AHD)	Ledge Point South (m AHD)	Seabird (m AHD)	Guilderton (m AHD)
20	1.3	1.2	1.2	1.2	1.1	1.3	1.3
100	1.5	1.3	1.3	1.3	1.2	1.4	1.4
500	2.0	2.0	1.8	1.9	1.8	1.7	1.8

The TC Mangga storm which occurred in May 2020 is a recent example of the type of severe storm event that produces extreme water levels for the Gingin coast. During that event, the peak water level measured at Jurien Bay just north of the Gingin study area was 1.18m AHD which was approximately 0.75m above the normal tide level due to the storm surge associated with the event. Based on the design water levels in Table E.1 this is just below the 1 in 20-year event.

The design water levels in Table E.1 have been used to produce spatial mapping for the four towns of the study area for the present day and under future sea level rise scenarios. The mapping is presented in Appendix C, representing the risk of storm surge inundation (S4 inundation, SPP2.6). The following is noted:

- Inundation risk is highest for Lancelin, where the foredune provides a barrier that protects the lower lying inland areas from ocean-based flooding during extreme events. The stability of the foredune in severe storm events when subjected to elevated water level and large waves was assessed, to determine if there was potential for dune breaching which could lead to flooding of the inland areas.
    - For the section of coast north from Grace Darling Park, there is the potential for dune breaching of the foredune in severe events. The dune system is estimated to be able to withstand the 20yr ARI

event and the 100yr ARI event in the present day (2020). Under future sea level rise scenarios for the 2070 planning period (+0.4m) and beyond, breaching of the foredune may occur. A storm event of 500yr ARI magnitude is estimated to breach the dune system in the present day and all future planning periods.

  - For the section of coast south of Grace Darling Park, the dune system is significant and breaching of the dune would not occur in any of the extreme events, including under future sea level rise scenarios.
- For Ledge Point, Seabird and Guilderton the developed areas are not at risk of inundation, with the natural topography set well above the extreme design water levels, including under future sea level rise scenarios.
- The foreshore areas at all study locations are susceptible to the impacts of wave run-up in design storm cases, which may result in overtopping of dunes and foreshore structures.

An assessment of the hazard associated with tsunami within the study area was completed using Geoscience Australia's 2018 Australian Probabilistic Tsunami Hazard Assessment (PTHA, Geoscience Australia, 2018). Baird applied its hydrodynamic model to model a validation case of the 2006 Boxing day Tsunami which showed good agreement to measured peak water level captured at tide gauges in Geraldton and Lancelin. A 500yr ARI magnitude tsunami event for the Gingin study area was examined in the model with peak water level results shown in Table E.2. The tsunami inundation risk is comparable (within 0.1m) with the design water levels from the modelled 500yr ARI cyclone event for Lancelin and Ledge Point (refer Table E.1). At Seabird and Guilderton, the peak modelled water level for the design 500yr ARI Tsunami is 0.4m to 0.5m higher than the 500yr ARI cyclone event.

Table E.2: Tsunami event at 500yr ARI – Modelled Water Level (Datum m AHD)

Return Period	500yr ARI Modelled Tsunami – Peak Water Level			
Timeframe	Lancelin	Ledge Point	Seabird	Guilderton
2020	1.9	2.1	2.1	2.2
2040	2.0	2.2	2.2	2.3
2070	2.3	2.5	2.5	2.6
2120	2.8	3.0	3.0	3.1

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1. Introduction

1.1 Overview of Project

Baird Australia (Baird) have undertaken a Coastal Inundation Study (CIS) for the Shire of Gingin to identify potential areas subject to coastal inundation risk through coastal locations of the Shire at Lancelin, Ledge Point, Seabird and Guilderton.

The project outcomes will be used to improve the understanding of coastal inundation hazard for the Shire now and in future planning timeframes under projected sea level rise, to inform risk management and adaptation planning.

1.2 Project Brief

The purpose of the project is to clearly identify areas that are potentially subject to coastal inundation risks over the following planning timeframes for the townsites of Guilderton, Seabird, Ledge Point and Lancelin: present day (2020), 2040, 2070 and 2120.

The assessment will be used:

- For coastal adaptation planning purposes in accordance with Western Australia's State Planning Policy 2.6 (Coastal Planning Policy); and
- For the Shire to communicate the current and future inundation risks with private landowners and the broader community.

The Shire of Gingin recently completed a Coastal Hazard Risk Management and Adaption Plan (CHRMAP). However, the CHRMAP does not include an assessment of coastal inundation. In this study, the Coastal Inundation Hazard is defined for the Shire of Gingin coastal townships of Guilderton, Seabird, Ledge Point and Lancelin. The aim of the assessment is to clearly identify areas that are potentially subject to a range of coastal inundation risks over a range of planning timeframes.

The recently completed CHRMAP found stretches of the Gingin coastline and key assets are at risk of coastal erosion over a range of planning timeframes. The Coastal Inundation Hazard Assessment will need to consider erosion on the topography of each coastal town and the influence this may have on the extent of coastal inundation.

It is anticipated the Coastal Inundation Hazard Assessment will form part of an updated CHRMAP, in a future review process. This will ensure the updated CHRMAP includes adaptation options for coastal erosion and inundation.

The coastal inundation hazard has been determined for a range of future planning periods (2020, 2040, 2070, 2120) which incorporate sea level rise in accordance with SPP2.6 recommendations (WAPC2010). The inundation levels have been determined at three return periods – 20yr ARI, 100yr ARI and 500yr ARI. Detailed flood mapping at appropriate resolution in the four key areas has been produced to show inundation extents and depth in shoreline areas.

1.3 Project Location and Key Sites of Interest

The study focus is along the shoreline of the Shire of Gingin which is located approximately 70km north of Perth in Western Australia. There are four key towns of interest in this study as shown in Figure 1.1 from north to south as Lancelin, Ledge Point, Seabird and Guilderton.

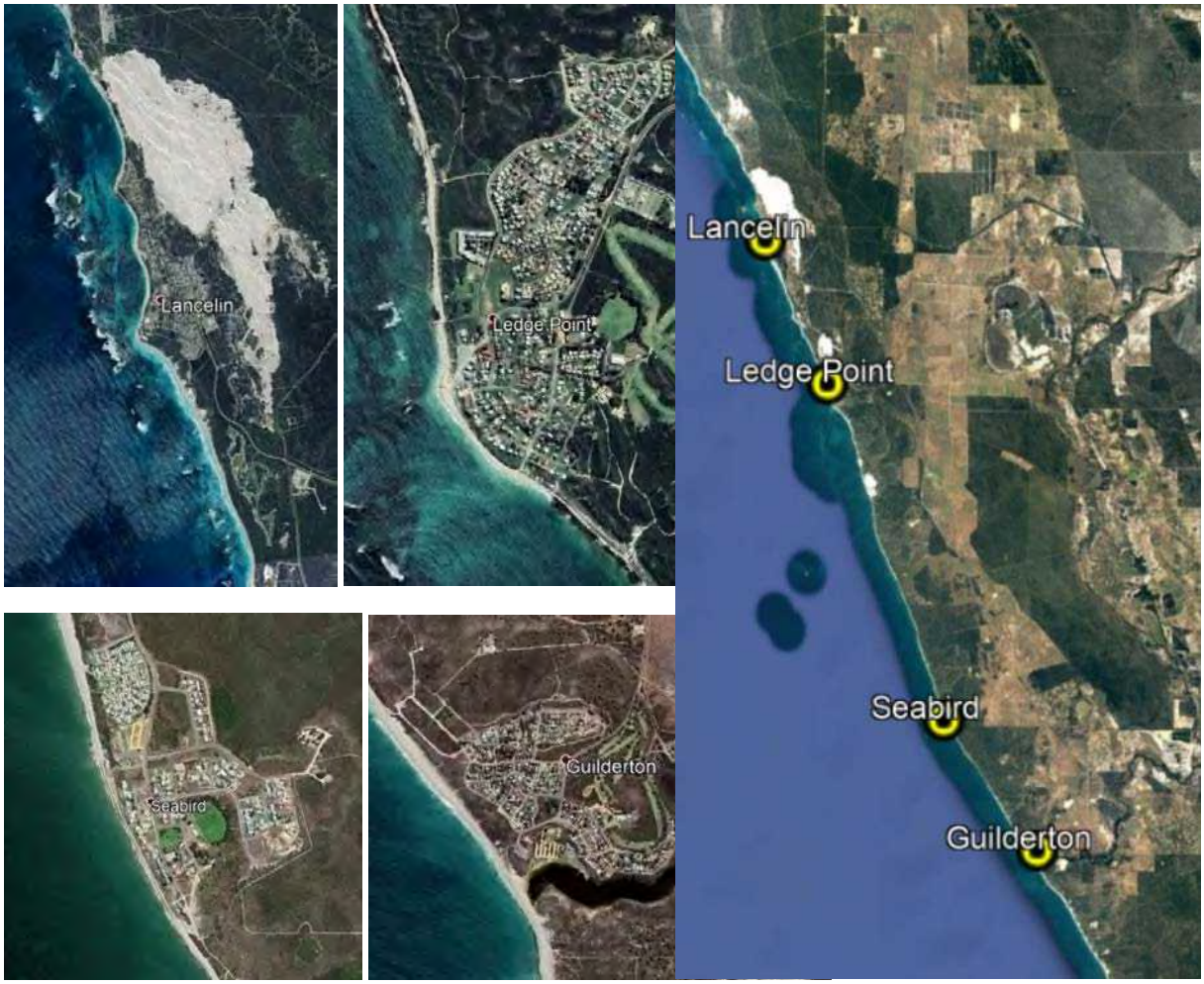


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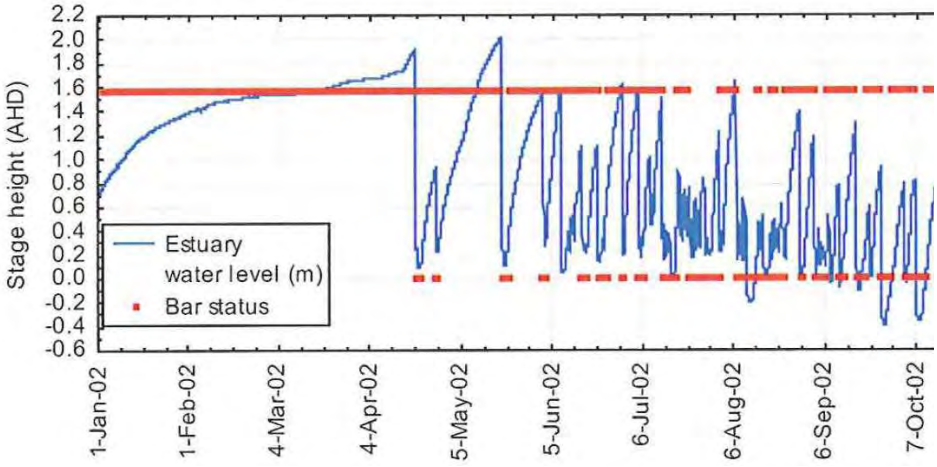
2. Background Information

There are a range of background reports and data sources that were reviewed to inform the inundation study. The literature review and background information is outlined in this section.

2.1 Literature Review

The documents that were reviewed as part of the literature review are summarised in Table 2.1. A summary of the findings from each of the literature review items and relevance to this study is provided.

Table 2.1: Literature Review Documents and Key Findings for the Current Study

Reference	Key Findings
[1] Department of Environment. (2002). Water Quality and Hydrodynamics of the Moore River Estuary and Surrounds: March – November 2002 – Final Report to the Community. Reference: 500811, 556.047 (941) MOO. Prepared by Department of Environment, Western Australia.	Recorded water levels (reproduced in Figure 2.1) in the Moore River Estuary and status of the bar blocking estuary from the ocean. Water levels in the estuary peaked at about 2m AHD during the measurement campaign from January 2002 to the start of December 2002. The stability of the bar decreased over the winter months with the bar being breached frequently and maximum water levels prior to the bar breaching tended to decrease. By the end of October, the bar became more stable and started to remain closed for longer periods of time as the river discharge decreased and the bar started to build up again. Whilst, there is no analysis of long term extreme inundation level of the estuary, the mechanism for controlling extreme river level at Guilderton namely the breaching of the bar is well captured and is considered in the joint probability assessment (Section 5.5) where extreme coastal storm tide levels as well as catchment flooding could combine. Baird contacted Department of Water and Environmental Regulation (pers comm J.Churchill-S.Rogers) to request flood studies for Guilderton. The Department indicated they have no flood studies or floodplain mapping for Guilderton, but provided a flood study for the Bidaminna area, approximately 35 kms upstream of Guilderton. Oblique photos of large flood events where the Moore River has broken the bar in 1995 and 1999 were provided (presented in Section 5.5.1 of this report).  **Figure 2.1: Water levels in the Moore River Estuary and indication of when the bar was open or closed [1].**

Reference	Key Findings
[2] MP Rogers & Associates (2018). Ledge Point Boat Harbour – Coastal Processes Assessment. R1020 Rev 2. Prepared for the Shire of Gingin.	Outlines a coastal processes study for the Ledge Point Boat Harbour located to the south of Ledge Point Township. The document provides some context on water level climate at the site, specifying that the mean sea level in the southwest of Australia rises 0.1 m during winter and fall 0.1 m during summer due to seasonal shifts in meteorological and oceanographic effects. Whilst no statistical context is provided, the document comments that storm surge can exceed 1 m above the astronomical tide level in rare storms and in winter storms, storm surge often reaches 0.4 m.
[3] MP Rogers & Associates (2019). Grace Darling Park Seawall – Technical Specification. R1275 Rev 0. Prepared for the Shire of Gingin.	Reference to the Grace Darling Park Seawall. Is a technical specification for the construction works and is not entirely relevant for the Gingin Inundation Study, however the document does contain design drawings of the seawall. According to the design drawings, the seawall had a crest level of 2.7m AHD (and toe level of -0.5 m AHD). No basis of design was provided and hence design water levels was not available.
[4] MP Rogers & Associates (2019). Grace Darling Park Seawall – Safety in Design Report. R1284 Rev 0. Prepared for the Shire of Gingin.	Reference to the Grace Darling Park Seawall. Is a Safety in Design document and does not provide any context on design criteria or assumptions.
[5] MP Rogers & Associates (2015). Shire of Gingin Boat Launching Facility Planning Study. R528 Rev 1. Prepared for the Shire of Gingin.	Report to identify a safe site for ocean boat launching within the Shire of Gingin with sites investigated at Lancelin, Ledge Point, Seabird and Guilderton. The report provides analysis of the available metocean data to present summary of the coastal environment and coastal processes at each location. This includes a detailed summary of wind, wave and current conditions for each location. The summary of astronomical tides comments the astronomical tides along the Shire of Gingin coastline are predominantly diurnal (one tidal cycle each day) and relatively limited in range. The daily range is typically about 0.5 metres during spring tides and less than 0.2 metres during neap tides. The Two Rocks tidal submergence curve from the DoT is used as a reference for water levels across the study area. Similar to document [2] there is comment the mean sea level at the Study Area rises 0.1 metre during winter and falls 0.1 metre during summer. Inter-annual variations in the Leeuwin Current can cause variations in the mean sea level of a similar magnitude. Regarding extreme water levels and storm surge it is stated extreme storms and cyclones can exceed 1 metre above the astronomical tide level. In addition to the storm surge inshore setup is discussed with MRA analysis showing the more usual winter storms often cause inshore setup of about 0.4 to 0.6 metres.

Reference	Key Findings

[6] Seashore Engineering (2018). Design Storms for Western Australian Coastal Planning: Tropical Cyclones. Document prepared for Department of Transport Seashore Engineering Report No. SE015-01-RevB

The Seashore document provides guidance on Design Storms for WA coastal regions to determine coastal hazard assessment under the Western Australian State Coastal Planning Policy SPP 2.6 (SPP2.6). The approach is intended to define erosion and inundation hazard zones associated with tropical cyclones. For the Gingin Study area, tropical cyclones are deemed the inundation design storm for calculation of the S4 inundation component of coastal hazard under SPP2.6. Baird has been provided with an updated set of cyclone tracks based on TC Ned in Ref [15].

For the Gingin study area (Area 3 for Design Storm Identification) the process of extra-tropical transition is significant, as it causes large increases to the effective radius of maximum winds as the storm system travels southward. The influence of shelf waves is noted as important for consideration. The Bureau of Meteorology track data has been used to provide an estimate of scale suitable for use with a vortex model. In the report it is noted that alternate methods based on a combination of local vortex and regional wind fields may provide a more accurate representation of the tropical cyclone wind fields through the process of extra-tropical transition.

Analysis of cyclonic water level records from tide gauges and tropical cyclone tracks associated with the highest recorded surges have identified TC Ned (March 1989) and TC Alby (April 1978) as key for the region around the study area (Area 3). For the towns of Seabird and Lancelin the design storm is based on TC Ned (1989). The cyclone track of the reference storm has been adjusted to provide the 'worst-case' path required for scenario modelling (refer Figure 2.2 and Figure 2.3).

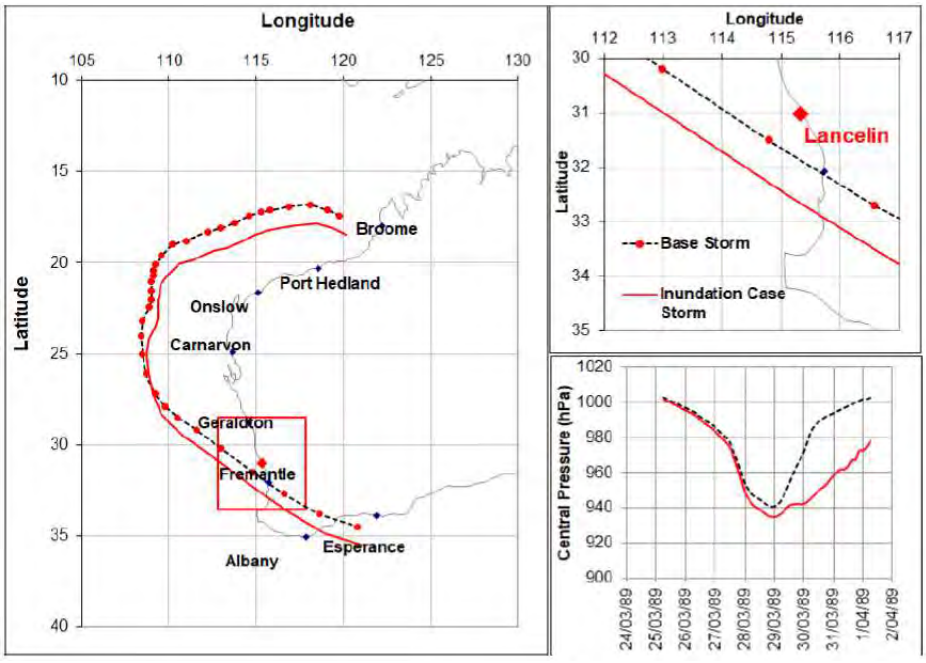


Figure 2.2: Design Storm for Lancelin developed in Seashore (2020) with track and pressure based on 'worst case' TC Ned (March 1989)

Reference	Key Findings

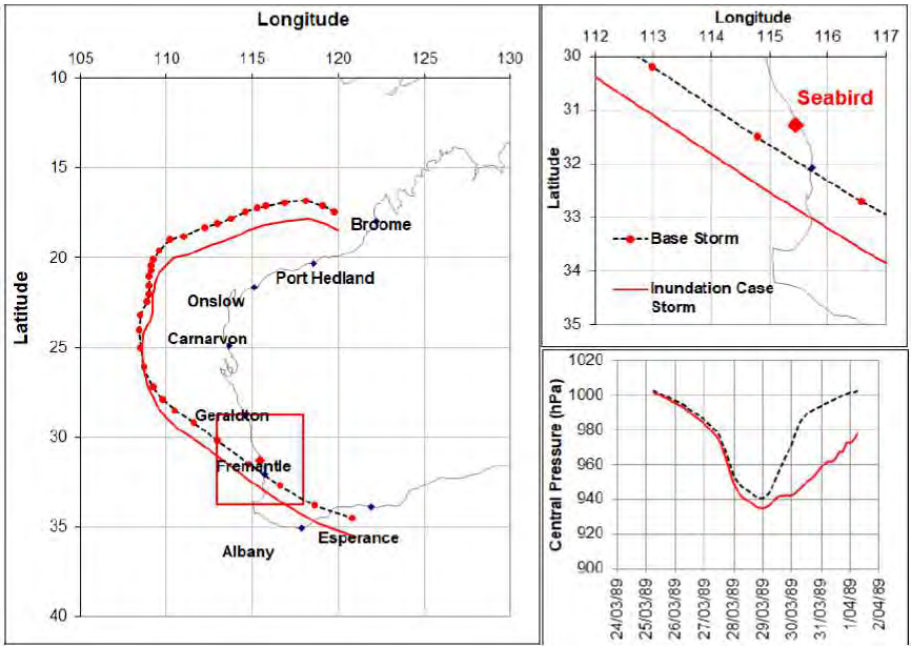


Figure 2.3: Design Storm for Seabird developed in Seashore (2020) with track and pressure based on 'worst case' TC Ned (March 1989)

[7] Department of Transport (2010). Sea Level Change in Western Australia. Application to Coastal Planning. Report 59917806 Dated 2/2/2010

The DoT document makes recommendations for appropriate sea level rise allowance to apply for future planning considerations in Western Australia. The recommended sea level rise allowances are based on the IPCC 2000 report using the upper bound projection of the IPCC AR4 case (95th percentile of the SRES scenario A1FI).

It is recommended that a vertical sea level rise of 0.9 m be adopted when considering the setback distance and elevation to allow for the impact of coastal processes over a 100-year planning timeframe for the period 2010 to 2110. For planning timeframes beyond the 2110 timeframe a vertical sea level rise of 0.01 m/year be added to 0.9 m for every year beyond 2110.

Recent discussions with the DoT and DPLH (pers comm-JChurchill-B.Bassett-F.Li-L.Roncevich) were used to clarify the appropriate sea level rise allowance beyond the 2110 planning timeframe. Based on this discussion, for a planning timeframe that starts in year 2020, the 100-year sea level rise allowance at year 2120 is 0.9m. In this study this 100-year allowance will be adopted. Interim values for sea level rise (eg at 20-year timeframe planning year to 2040 and 50-year timeframe to planning year 2070) will be determined from examination of the recommended allowance for sea level rise in coastal planning for WA graph presented in DoT 2010.

Reference	Key Findings
[8] Cardno (2019). Final Coastal Hazard Risk Management and Adaptation Plan, Prepared for Shire of Gingin. Rev0 17 June 2019.	[8] The Cardno report focuses on the impacts of coastal erosion and shoreline recession processes and presents risk management and adaptation planning advice without consideration of the inundation risk. It is noted that the Lancelin coastal zone is predominantly low lying, and coastal inundation is expected to be a major factor in future decision making and adaptation planning. The current study will inform future revisions of the CHRMAP.
[9] MP Rogers & Associates Pty Ltd. (2015) Seabird Coastal Erosion Hazard Mapping Technical Note Report to the Shire of Gingin by MP Rogers and Associates.	
[10] M P Rogers and Associates (2016a) Seabird Coastal Erosion Hazard Mapping Technical Note Report to the Shire of Gingin by MP Rogers and Associates.	The coastal erosion hazard lines were calculated by MRA over future planning timeframes 2020, 2030, 2050, 2070 and 2110. The hazard lines will be considered in the context of how the potential changes to shoreline position through the study area may influence the coastal inundation hazard in future planning periods. Of particular relevance at Lancelin where the foredune is a controlling feature that provides a natural barrier to areas on the landward side from extreme ocean storm tide level.
[11] M P Rogers and Associates (2016b) Coastal Erosion Hazard Assessment, Ledge Point, Lancelin and Cervantes. Report to the Shires of Gingin and Dandaragan by MP Rogers and Associates.	

Reference	Key Findings
	Report identified that no existing long-term water level data was available in the study area and hence Fremantle tide gauge data was used as it contained digital data back to 1959. Whilst the site is 100km south of the study area, they state that Fremantle tide data has close correlation to Jurien Bay and Geraldton and hence was considered sufficient for the study. They also state that the water level signal is strongly influenced by non-tidal forcing including surges and mean sea level variation, such that the total water level range at Fremantle from 1959 to 2016 was 2.15 m which is roughly twice the astronomic tidal range. Seasonal variation was observed by Seashore noting that high water levels mainly occurring during intense winter storms from May through to July, and low water levels between October and February. They also note that there were occasional high water levels due to meteorological events such as Tropical Cyclone Alby in 1978 (1.79 m CD), as well as due to resonant phenomena, such as shelf waves. Report also discussed the wind climate, however inundation levels are likely determined by cyclonic events and hence not too relevant to the study. The study also noted the wave transmission to the coastline was complex due to the nearshore reefs in the study area.
[12] Seashore Engineering (2017). Seabird, Ledge Point, Lancelin – Coastal Monitoring Action Plan. Document prepared for Department of Transport. Seashore Engineering Report No. SE045-01-Rev0.	Provides a summary of the influence of fluctuations in water level on coastal erosion and accretion trends, as well as providing a summary of available metocean data in the study area. The document states that due to the relatively small tidal range (0.6 m from Mean Higher High Water to Mean Lower Low Water) and complex wave attenuation due to reefs and islands, fluctuations in water level can have a significant impact on the coastline evolution. Figure 2.4 is reproduced from [12] and shows the mean sea level fluctuations at Fremantle (30-day running mean water level). This shows seasonal and inter-annual variation of up to around 30cm each since 1959, with recent periods of unusually high mean sea levels in 1999-2000 and 2011-2013 likely to have contributed to observed erosion at Seabird, Ledge Point and Lancelin. These fluctuations have been linked to the El Niño/La Niña cycle, with higher water levels occurring during the la Niña phase along with correlation to the strength of the Leeuwin Current.

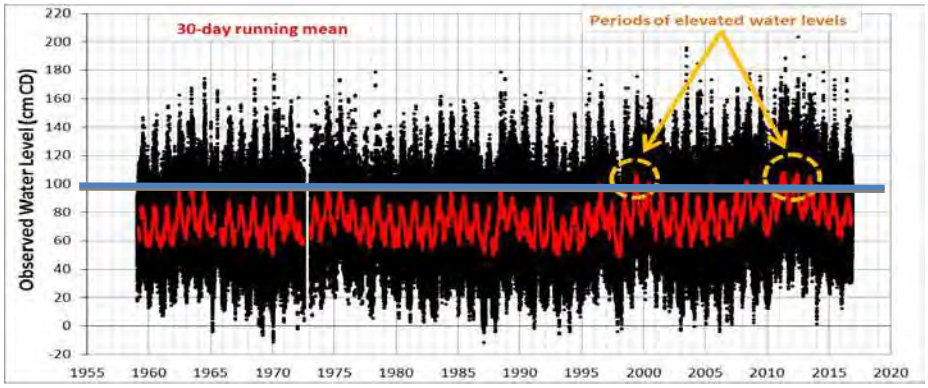


Figure 2.4: Record of observed hourly water level at Fremantle from 1959 – 2016. *Australian Height Datum (AHD) is 76cm above Chart Datum (CD) at Fremantle [12].*

Reference	Key Findings
[13] Coastal Focus (2013). Data and Information Gap Analysis For Coastal Hazard & Risk Management – Gingin Dandaragan Coast (Hill Primary Coastal Compartment). Prepared for the Northern Agricultural Catchments Council, The shires of Gingin and the Shire of Dandaragan. September 2013.	Describes the coastal processes involved in completing a coastal hazard and risk management study for the Gingin Dandaragan Coast. The document also summarises a data gap analysis for the study. The key message from the report in terms of this inundation study is that extreme storm surges in the study area are due to major storms such as extra tropical and tropical cyclones. The study identifies that the longest water level records are at Geraldton and Fremantle, however further study of extreme weather events is required with regards to water levels
[14] Damara WA Pty Ltd (2012). The coast of the Shires of Gingin and Dandaragan, Western Australia: Geology, Geomorphology and Vulnerability. Prepared for the Department of Planning. March 2012.	Provides strategic planning guidance and management strategies on appropriate land uses for coastal land in the Shire of Gingin and the Shire of Dandaragan, by assessing and understanding the coastal erosion hazards. Completed various studies, including an analysis of water level data at Geraldton (1966 – 2008) and Fremantle (1959 – 2008). The water level time series were decomposed into approximations for mean sea level (30 day running mean), tide (Doodson-x_0 filter) and surge (residual), with some overlap between the approximations. The analysis tries to understand the range of water level components contributing to the total water level. The results are reproduced in Table 2.2. Results show that non-tidal components such as storm surge have a large ratio to the astronomical tide component.

Table 2.2: Mean Sea Level, Surge and Tide Approximations for Geraldton and Fremantle [14].

Water Level Component	Geraldton (1966 – 2008)		Fremantle (1959 – 2008)
	Range	Standard Deviation	Range
Water Level (cm CD)	-28 to 180	24	-11 to 197
Mean Sea Level (cm)	36 to 97	11	49 to 107
Surge (cm)	-35 to 50	10	-38 to 50
Tide (cm)	-37 to 41	18	-35 to 39

Also discusses the atmospheric surge associated with extra-tropical storms peaking around May to July. Tropical cyclones are often combined with resonant

Reference	Key Findings
	phenomena, such as continental shelf waves. A continental shelf wave of 0.75m, generated by Tropical Cyclone Bianca, was recorded at Fremantle and Geraldton in March 2011. The document also states that the relative timing of tide, mean water level and extra-tropical surge controls the potential for high water levels which occurs in June in Fremantle and May to June in Geraldton. Whilst, they say that the timing of this high water level is generally out of phase with tropical cyclone season, they do note that high water levels occur with tropical cyclones, for example TC Glynis in 1970. States that a hydrology study to estimate 10, 25 and 100 year average recurrence interval flood levels for the Moore River at Moora (90km upstream from the mouth) was prepared by GHD in 1991 and revised by Water Studies in 2000. However, extreme water levels are not presented in the report and being so far from the river mouth would provide limited benefit to the study.
[15] Seashore Engineering (2020). Design Storms for Western Australian Coastal Planning: Revised Design Storms based on TC Ned. Doc: Revised Design Storms based on TC Ned.pdf	Provides the latest design storm information for the study area and has been used in the consideration of the design storm event (500-year ARI) in the final sections of this memo.
[16] DWER (2020). Department of Water and Environmental Regulation water data is available via:www.water.wa.gov.au	Provides the links to the measured water level data (stream gauge information) from the DWER. The data will be used to evaluate the water levels in Moore River for joint occurrence flooding consideration. The measured data from sites around the Guilderton section of the river are of limited duration (1 to 2 years). The longest record back to the 1960's at the Quinns Ford location approximately 35km upstream of Guilderton.

2.2 Coastal Inundation Processes

The following section provides a general overview of coastal inundation processes that are important for the current study.

Coastal inundation is comprised of a number of components that will vary on a range of spatial and temporal scales. These include: the astronomical tide, storm surge due to extreme wind events such as tropical cyclones, elevated water levels due to wave action, and seasonal and longer-term variations in mean sea level. These components are summarised in Figure 2.5.

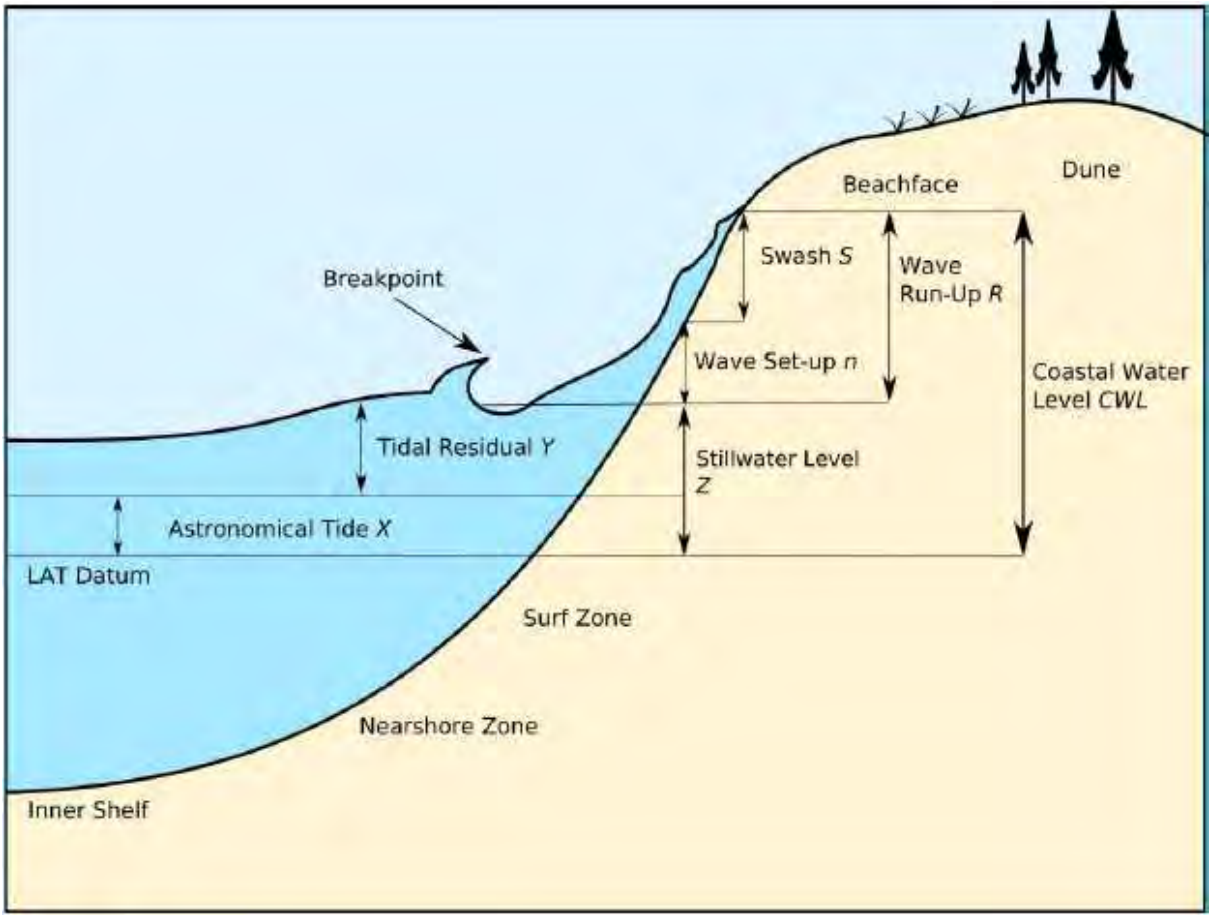


Figure 2.5: Schematic diagram illustrating components of coastal inundation

2.2.1 Tropical Cyclones

Tropical cyclones are intense rotating low-pressure systems consisting of a calm eye surrounded by strong winds rotating clockwise and radially inwards in the Southern Hemisphere. They form over tropical waters that have surface temperatures greater than 26.5 °C and can persist over oceans with lower temperatures, although the energy tends to dissipate over cooler waters and land. Other factors contributing to cyclogenesis include low vertical wind shear, atmospheric instability, high humidity and a pre-existing atmospheric disturbance. A cyclone's intensity is categorised based on the severity of its winds.

Tropical cyclones are divided by the Bureau of Meteorology (BoM) into five categories, ranging from Category 1 (minor) to Category 5 (extreme) as summarised in Table 2.3. The intensification of tropical cyclones is limited by energy loss through friction and the maximum temperature of sea water.

Table 2.3: Australian tropical cyclone category scale used by the Bureau of Meteorology

Category	Maximum Wind Gust (km/h)	Potential Damage
1	< 125	Minor
2	125-170	Moderate
3	170-225	Major
4	225-280	Devastating
5	> 280	Extreme

The cyclone wind field is typically almost axisymmetric, being low at the eye, peaking at the radius to maximum winds which is typically located in the eyewall of the cyclone, then decaying more gradually further away from the eye. This characteristic makes the simulation of cyclonic wind fields amenable to empirical methods in tropical areas in the north of Australia, and a parametric vortex model can be applied in numerical models to simulate the cyclone wind field characteristics (eg Holland 2010).

However, at the latitude of southern Western Australia where the Gingin area is located, the axisymmetric characteristics of the wind field tend to breakdown and parametric methods to define the cyclone wind field which work well in tropical regions become unreliable.

2.2.2 Ex-tropical Cyclones

A transitioning tropical cyclone which is no longer subject to convective energy forcing as occurs in warmer, tropical waters can interact with a significant southerly cold front coming up from the southern Indian Ocean which can increase the intensity and scale of the storm system. In these situations, as occurred with TC Alby in April 1978, the system transitions into an extra-tropical cyclone where the scale and fetch of the wind-field which generated a large storm surge and extreme waves on the coastal shelf is not well described by a parametric vortex model.

A significant gap in the physics for a transitioning cyclone is noted for surface wind speed as a result of the forward speed asymmetry. In the case of a transitioning storm the fast translation speed of the storm when it is offshore is a challenge to recreate in a parametric model. There are a range of parametric and boundary layer cyclone wind and pressure models that compute forward speed wind asymmetry to a reasonable degree of accuracy. For example, Baird's *Cycwind* model which computes tropical cyclone winds using the Holland (2010) parametric vortex model and solves forward speed asymmetry using the McConochie (2004) model.

Hybrid storms that are comprised of a transitioning tropical cyclone interacting with a frontal system are not well described with parametric models and the phenomena of forward track speed causing enhanced wind speeds in the forward right quadrant (southern hemisphere, forward left in northern hemisphere) is not consistently observed in hybrid storms. A large research effort on transitioning cyclones (typhoons) and hybrid storms has been undertaken in Japan due to the frequency and severity of transitioning and hybrid storms that impact on Japan each typhoon season. Some recent literature of note identified the following regarding the wind field structure of storms during and after extra-tropical transition in the northwest Pacific:

- Loridan *et al* (2013) noted that for 67% of events storms in a 31-year reanalysis data set that underwent extra-tropical transition did not exhibit forward left quadrant wind asymmetry that was consistently observed for storms when they were in their tropical cyclone phase.
- Evan *et al* (2007) examined storm event forecasting for typhoons (cyclones) that underwent extratropical transition. Whilst definitive conclusions lack statistical confidence, the results of that study

supported the hypothesis that inserting a synthetic vortex with forward speed asymmetry can improve the tropical phase structure forecasts. The accuracy of the forecast once extra-tropical transition commenced was degraded as the synthetic vortex model did not generate the wind field characteristics that were observed with the transitioning storm.

Bieli *et al* (2019a and 2019b) completed a global review of cyclones that underwent extratropical transition and compared re-analysis data sets (JRA-55 and ECMWF interim reanalysis) with best track storm data during the extra-tropical transition phase. The JRA-55 re-analysis data set consistently had the best validation metrics compared to the best track storm data. Further details on the track characteristics of historical storms that exhibited extra-tropical transition offshore of southwest Western Australia is presented in Section 2.2.2.1.

The Australian cyclone season extends from November through to April with an average of 10 cyclones per year, although not all make landfall. The extreme winds and intense low pressure associated with tropical cyclones produce storm surge at the coastline. On the west coast of Australia, the onshore winds occur to the north of the location of the cyclone's landfall. The highest surge tends to occur near the radius of maximum winds, or where the strongest winds of the cyclone occur, which is typically 10 to 50 km northeast of the cyclone eye. These systems are frequently associated with heavy rainfall that can cause significant flooding. The Australian cyclone region generally has a low frequency of extra-tropical transition compared to other basins including the northwest Pacific and North Atlantic basins.

2.2.2.1 Track Characteristics of Storms Exhibiting Extra-Tropical Transition

As noted in the previous section, extra-tropical transition is an important process in the context of the design inundation events presented in Seashore Engineering (2020) which will be considered in this study for the Gingin region. A tropical cyclone which undergoes extra-tropical transition, for example Tropical Cyclone Alby which occurred in 1978 resulting in significant coastal inundation in the Busselton region or Tropical Cyclone Ned in 1989, occur infrequently but is likely to be the result of a southwards tracking tropical cyclone intersecting with an approach cold front offshore of southwest Western Australia.

Hetzel and Pattiaratchi (2014) provides a summary of extra tropical cyclone transitions in the contest of the Western Australia coastline and a discussion of notable events between 1970 and 2014. Whilst TC Alby is the notable event in the last 50 to 100 years to impact on southwest Western Australia, between 1970 and 2014 Hetzel and Pattiaratchi (2014) identify a total of 8 tropical cyclones impacting along the Western Australian coastline which showed evidence of extra-tropical transition, 5 of which track south of -28^{o}S latitude.

Table 2.4 presents a summary of the 5 tropical cyclones identified in Hetzel and Pattiaratchi (2014) which had characteristics of extra-tropical transition offshore of southwest Western Australia. Since 2014, no other notable events have been identified. Table 2.4 clearly indicates that TC Alby is unique and extreme with respect to intensity between the Tropic of Capricorn and -34^{o}S, and storm scale as defined by the radius of gale force winds. The extent of gale force winds for TC Alby, approximately 500 km in the northeast quadrant from the storm eye, is significantly larger than the other 4 events where the radius to gales near -34^{o}S is more typical of frontal storm systems. As noted in Table 2.4 and Table 5.2, there is limited scale and intensity data for TC Ned during the period it was experiencing extra tropical transition.

Hetzel and Pattiaratchi (2014) summarise some observations that correlate with storms that undergo extra tropical transition offshore of the Western Australia coastline. A key observation is that these storms are most likely to occur late in the cyclone season, in March and April, when cold fronts are more likely to track from the west towards the southwestern Western Australia coastline. This important joint occurrence requirement (southwards tracking tropical cyclone interacting with large scale frontal system) is likely to significantly reduce the likelihood of extra-tropical cyclone transition, compared to a tropical cyclone decaying in intensity and scale over the cooler water south of the Tropic of Capricorn.

Table 2.4: Tropical Cyclones which Tracked South (to -34ºS) which Exhibited Extra-Tropical Transition Characteristics by Hetzel and Pattiaratchi (2014).

Event	Tropic of Capricorn -23.43ºS	Mid Latitude band -28 ºS	Port Geographe -34 ºS		Data Source for Radius to Gales
	Cent. Pres (hPa)	Cent. Pres (hPa)	Cent. Pres (hPa)	Radius Gales (R34, km)	
TC Vida	982	986	991	140	BoM event report, estimated from ship observations.
TC Alby	938	955	955	500	JRA-55 hindcast
TC Idylle	980	990	990	300	BoM event report, estimated from ship observations. Well offshore in Indian Ocean. Force 10 winds @ 190 km from eye.
TC Ned	984	998	998	N/A	
TC Vincent	966	978	991	205	BoM event report, best track analysis.

2.2.3 Astronomical Tide

The astronomical tide is the periodic rise and fall of the sea surface caused by the combination of the gravitational force exerted by the moon and the Sun upon the Earth and the centrifugal force due to rotations of the Earth and moon, and the Earth and the Sun around their common centre of gravity.

Tides are subject to spatial variability due to hydrodynamic, hydrographic and topographic influences. In the study area, tides are typically diurnal (1 high water and 1 low water per day) and the tide range is typically small as described in Section 3.1.1.

2.2.4 Storm Surge

Storm surge is a long-gravity wave with a period of hours to days resulting in the elevation or depression of the sea surface which develops in response to storm activity. Storm surge is generated by two main processes: the inverse barometric effect and the wind set-up against the coastline. There are a range of weather systems capable of generating storm surge around Australia, including tropical cyclones, east coast lows, mid-latitude lows, and cold fronts. Typically, the most important component of the storm surge is the wind set-up component, particularly when the storm event crosses the coast where cross-shore wind set-up is in the order of metres whereas the inverse barometric set-up is in the order of 0.5 m or less for southwest Western Australia.

A conceptual diagram of storm surge development is presented in Figure 2.6. The most severe storm surges are generated by severe tropical cyclones in areas with broad and shallow continental shelves, especially when coinciding with high tide.

The term storm water level refers to the absolute water level resulting from the combination of storm surge and the astronomical tide, referred to a vertical datum such as Lowest Astronomical Tide (LAT) or Australian Height Datum (AHD).

The coastline of Western Australia is vulnerable to the occurrence of storm surge; however for southwest Western Australia (between Geraldton and Bunbury) storm surge is not always the dominate component in coastal water levels and wave processes, including setup inshore of an outer reef, can dominate the residual water level.

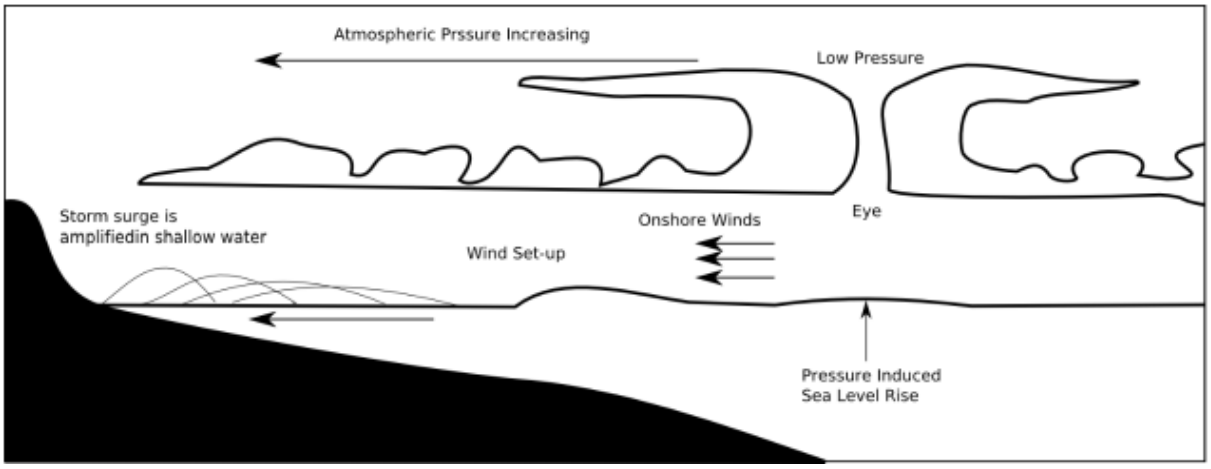


Figure 2.6: Conceptual diagram showing the development of storm surge due to barometric set-up and wind set-up in a tropical cyclone.

The inverse barometric effect is a vertical force exerted on the ocean surface, caused as low pressure creates a local rise in sea level. Approximately one hectapascal (hPa) decrease in air pressure leads to a one-centimetre increase in sea level, providing that low pressure persists for a sufficient length of time. This effect is for a static storm system, and can be enhanced for a moving system, especially if it is moving at a speed close to that of a shallow water wave, forming travelling resonance (Dean and Dalrymple 2004). The inverse barometric set-up is independent of water depth and is the main contributor of tidal residual for offshore non-continental waters. For storm tide at the coastline induced by tropical cyclones, the elevated water level due to the inverse barometric effect is secondary to the wind set-up.

Wind set-up results from strong onshore winds pushing surface waters against the coastline. Wind stress occurs parallel to the ocean surface as energy and momentum is transferred to the water. Wind stress, or drag, is proportional to the square of wind speed. The effect of wind set-up is not instantaneous and is acted upon by the Coriolis force as the Earth rotates. The rate at which the wind increases in speed also affects storm surge elevation, with rapid wind speed acceleration leading to larger surge maximum.

Theoretically, the wind set-up in the one-dimensional case is inversely proportional to depth. As such, wider and shallower continental shelf waters are subject to higher wind set-up than locations with a steeper continental shelf. Coastal topographies such as shallow bays and funnel shaped estuaries may amplify the storm surge level.

Storm surge development is complex and its height is dependent on a number of factors for any given cyclone event and location. Even for a cyclone of a given category, the storm surge height can vary dramatically depending on the location of impact and the cyclone's specific characteristics:

- Cyclone intensity: A more intense cyclone has stronger winds and lower atmospheric pressure which generates a larger storm surge and also larger waves.

- Cyclone scale: The extent of a cyclone's wind field influences the height of its storm surge. A cyclone with a large wind field will create a greater surge as the storm is forcing on a larger area of ocean water. Additionally, a larger storm will affect a larger given area of coastline for a longer period of time.
- Translational speed: The forward speed of the cyclone, being the rate at which it moves over time, also affects the height of the storm surge. A cyclone moving forward quickly has higher wind speeds than one moving more slowly and can generate a larger surge on the open coast. However, a slower storm may impact a given location for longer, leading to larger surge in bays and estuaries.
- Angle of approach: A cyclone will produce a larger surge in a given location when it approaches the coast head-on, while a cyclone that approaches the coast at an oblique angle or tracking parallel to the coast will result in a lower surge as the surge is highly sensitive to the wind direction. However, as the coastline changes orientation and has complex bays and inlets, the surge may develop more in some areas than others.
- Bathymetry: The depth and slope of the ocean floor (offshore bathymetry) influences the storm surge development. For example, an area with a wide, shallow coastal shelf, would experience greater surge with relatively smaller waves. Conversely, a coastline with a narrow, steep shelf will experience lower surge but much higher waves.
- Coastline topography and orientation: Variations in local coastline features, such as open or narrow estuaries and bays, also influence storm surge compared to an open coastline. The shallow waters of bays amplify the surge as the friction of the shallow seabed slows the water down, allowing it to pile up. Storm surge can be further amplified in open estuaries that become narrow.

Given the complexity of storm surge development, its behaviour is best modelled using hydrodynamic modelling techniques. Modelled surface wind and atmospheric pressure fields are the forcing mechanisms required for hydrodynamic simulation of storm surge.

2.2.5 Wave Action – Setup and Runup

The strong winds in a tropical cyclone can generate extreme wave conditions. When impacting the coastline, these waves contribute to the total water level through wave run-up.

Wave runup and setup is the maximum vertical extent of wave uprush on a beach. The wave runup is superimposed on setup (refer Figure 2.5). Wave set-up is the super-elevation of the time-averaged water level landward of the initial wave breaking point. It is caused by the cross-shore gradient in wave radiation stresses which result from wave breaking (Longuet-Higgins and Stewart 1963 and 1964). Swash is the motion of the water line up and down the beach face due to wave uprush (Nielsen and Hanslow 1991). The impact of waves on a given coastline depends on its local setting, including the exposure along the fetch of the cyclonic winds and local bathymetry, and effect of islands.

For southwest Western Australia, wave action can be a particularly significant component of coastal water levels due to the complex bathymetry, including outer reef features, and the large waves that can be generated from severe frontal system and extra-tropical cyclones.

Wave run-up increases with the increasing wave height, wave period and beach slope. Waves that occur during cyclones can reach areas not usually reached and can carry immense power that also lead to coastal erosion and breaching of dunes. A 2% exceedance value for wave runup is commonly used in coastal engineering applications (Holman 1986), which is calculated based on the cumulative probability density function of the run-up elevations.

It should also be noted that that the elevated water levels caused by wave set-up will not propagate far inland after overtopping frontal dunes flowing over low-lying areas or proceeding through inlets (Hardy et al. 2004).

The dynamics of wave set-up at river entrances is different to that observed on the open beach. The physics of the river entrance hydrodynamics, particularly with regard to wave set-up, is extremely complex

and further complicated by the influence of significant freshwater discharges and the behaviour of storm tide propagation through the entrance during extreme conditions.

2.2.6 Overland Inundation

Coastal inundation occurs when storm surge leads to an ocean water level that is higher than the general tide range at a location. This causes flooding of land areas that are usually elevated above the influence of the ocean. The elevation of ocean water levels during extreme events is caused by the combination of the processes discussed in this section. At the local scale, the elevation reached by the storm tide inundating the land can be amplified over its nearshore level by the, 'local' wind set-up. This is the same phenomenon as the wind set-up discussed above occurring on a localised scale as the intense cyclonic wind forcing continues to act on the water surface in increasingly shallow water, which can force water up a slope where the wind stress exceeds the gravitational force down the slope and the bottom friction losses. This phenomenon is site specific and the balance of the friction losses and the wind stress will be controlled by local conditions. In numerical modelling, this will be somewhat a function of the spatial resolution of the model mesh or grid as the land surface is discretised and the slope of the land is not smooth but consists of steps.

Broadly, there are three 'modes' by which storm tide inundates the land:

1. The storm tide level intersects the beach face and water piles up against beach face. If onshore winds are present when the storm tide impacts the shoreline, 'local' wind set-up may amplify the resultant onshore storm tide levels.
2. The storm tide level exceeds the elevation of beach face / dune crest and continues to propagate overland. The resultant storm tide level may be amplified from its nearshore level due to 'local' wind set-up as the fetch length increases.
3. The storm tide propagates through waterway entrances and combines with rainfall discharges. The 'local' wind set-up may also act on the water surface along the fetch of the estuary, and in theory, potentially increasing the storm tide level relative to the open coast. Overland flow from waterways would then inundate low lying areas.

2.2.7 Variations in Mean Sea Level

Further, the background sea level can be affected by other phenomenon such as seasonal fluctuations related to El Nino/La Nina cycles, relative position of ocean currents and eddies to the shoreline, coastally trapped waves and persistent monsoon winds. Church et al. (2004b) identify that the north-western and western Australian coasts have the strongest interannual variations in mean sea level due to the ENSO (El Nino Southern Oscillation) cycle. Such effects will be investigated in this study as non-cyclonic influences on mean sea level.

2.2.8 Catchment Rainfall / Runoff and Overland Flow

Catchment rainfall and runoff has not been addressed in this study. However, a discussion of water levels and available flood information for the Moore River is presented in Section 2.1 and the potential impacts of riverine flooding in conjunction with elevated coastal water levels for Guilderton is discussed in Section 5.5.

2.2.9 Tsunami

Tsunami are long period waves that may be generated by earthquakes, volcanic activity, underwater landslides and possibly meteors landing in the sea. They have much greater destructive force than storm waves due to their long wavelength and hence greater power. Tsunami do not break at the shoreline, instead propagating inland as a bore with significantly more wave power than storm waves.

Potential tsunami inundation impacts are presented in Section 8.

2.3 Water Level Components not Considered in this Study

The coastal inundation risk posed by the following processes is not considered within the context of this report:

- Coastally trapped waves; and
- Stormwater run-off and localised flash flooding.

Coastal water levels can also vary due to coastally trapped waves or shelf waves. They are low amplitude, long period waves that may be initiated by atmospheric disturbances associated with storms of intense frontal systems remote to the site affected. These are driven by differences in density, and result in the movement in the interior of the ocean with a small surface signal. For example, coastally trapped waves that affect the NSW coastline propagate northwards from Bass Strait and can generate variations in ocean level of up to 0.2 m with periods of up to 10 days (Freeland et al. 1986, Buchwald & Kachoyan 1987). Shelf waves are also known to propagate from the North West Shelf down the Western Australian coastline, where the coastally trapped wave can propagate along the coast and impact water levels thousands of kilometres away from the event (Pattiaratchi et al, 2016).

The 2016 report on continental shelf waves in Western Australia undertaken by the University of Western Australia in 2016 (Pattiaratchi et al, 2016) determined that the cyclones path, speed and category all impact the generation and propagation of the continental shelf wave. Key findings from Pattiaratchi *et al* (2016) on the regional scale modelled events were;

- Model simulations were undertaken of 70 synthetic category 5 events with various paths and speed;
- The greater the cyclone category the higher the amplitude of the generated shelf wave;
- Coast parallel cyclones generated the largest shelf waves along the Western Australia coastline, including southwest WA; however, shelf wave amplitude was largest when the forward track speed of a cyclone was between 7.6 and 10 m/s and the shelf wave was a 'forced' wave propagating at a velocity similar to the cyclone track. When cyclone track speed was above 10 m/s the amplitude of shelf waves decreased significantly, and the shelf wave along the coast trailed behind the storm track.

Pattiaratchi *et al* (2016) demonstrated some model skill for hindcasting shelf waves along the Western Australia coastline using a shelf scale hydrodynamic model with wind and pressure forcing. The most relevant historical event analysed in Pattiaratchi *et al* (2016) that generated a distinct shelf wave south of Exmouth was Tropical Cyclone Bianca. The track and intensity of TC Bianca is presented in Figure 2.7. The track followed a predominantly coast-parallel track between Broome and Geraldton before weakening and dissipating below tropical low strength approximately 300 km offshore of the coast, just north of Perth. Figure 2.8 presents the analysis of tide gauge data as presented in Pattiaratchi *et al* (2016) for TC Bianca. A low water trough from the shelf wave is initially observed along the coast (see red line) before a peak shelf wave height is observed 24 to 48 hours later. TC Bianca maintained a steady track speed between 5 to 7 m/s from its formation offshore of Broome until it dissipated offshore of Perth. At the tide gauges south of Carnarvon where a distinct propagating shelf wave was observed (see Figure 2.8), the peak height of the shelf wave was observed after TC Bianca had tracked south of the site. At Fremantle, the peak amplitude of the shelf wave was approximately 12-hours after the storm had dissipated below tropical strength.

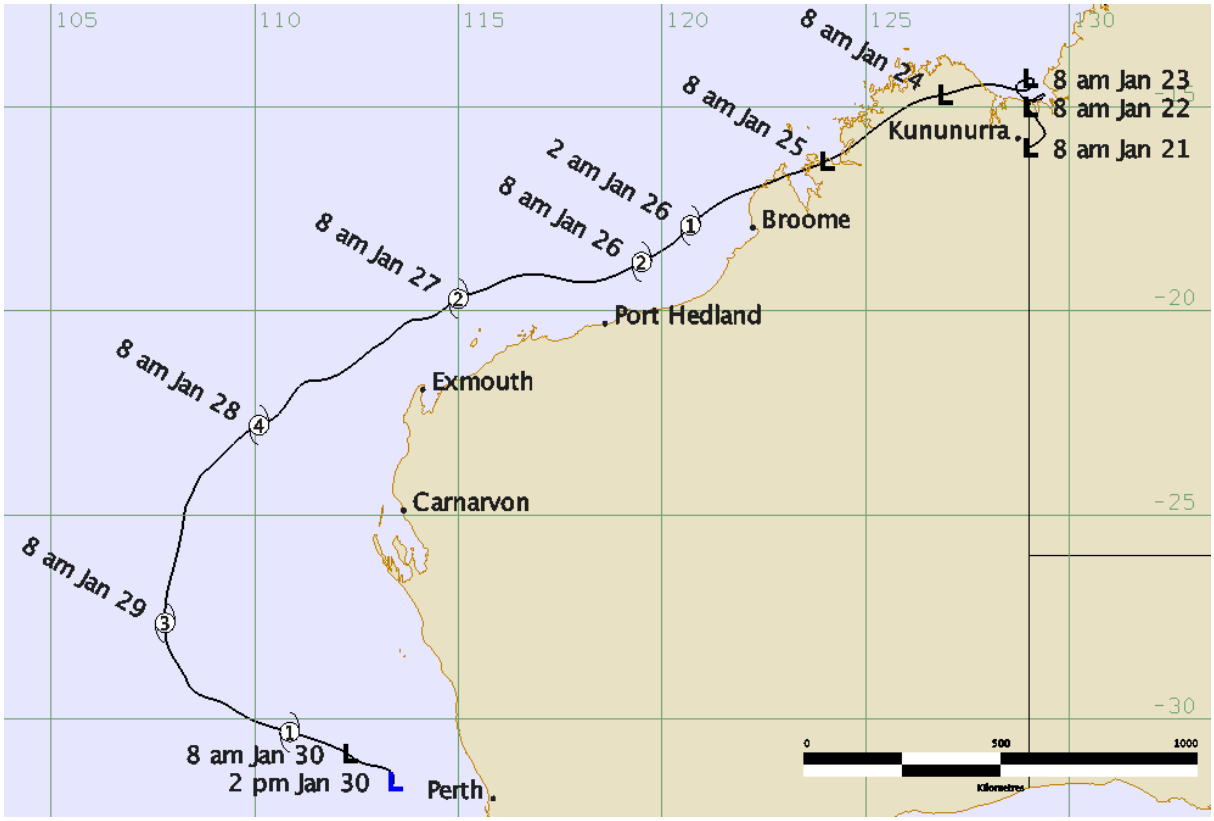


Figure 2.7: Track and Intensity of Tropical Cyclone Bianca (BoM, 2011).

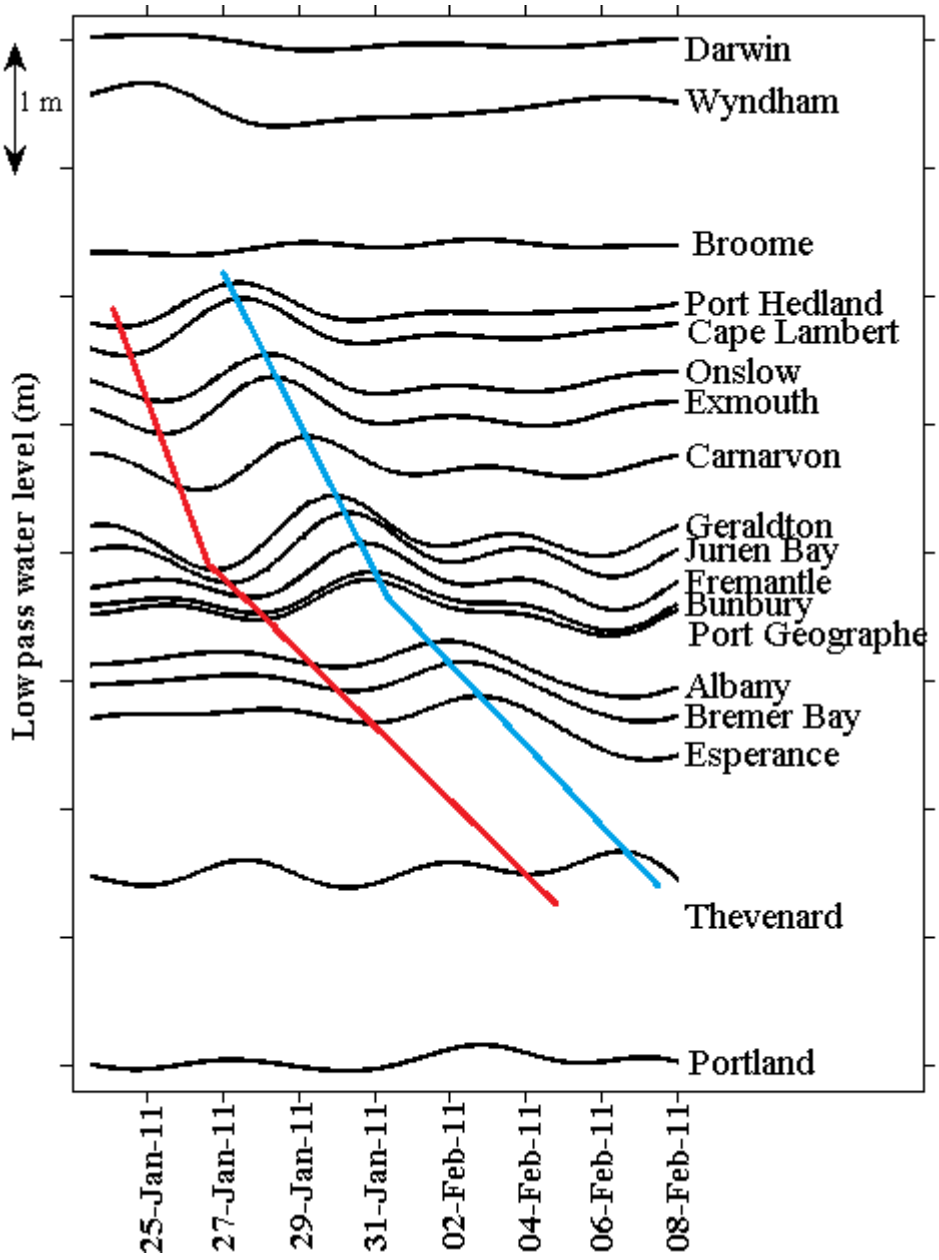


Figure 2.8: Continental Shelf Wave Evident in Measured Tide Gauge data for the 2011 TC Bianca Event showing the Low Water (red) Preceding the Highest Amplitude in Wave Height (blue) Travelling South down the WA Coast (Pattiaratchi et al, 2016)

Shelf waves generated from transitioning tropical cyclones offshore of the southwest Western Australian coastline have not be investigated in the same detail as shelf waves from tropical cyclones. For the design coastal inundation event modelled in this study that is based on Tropical Cyclone Ned, the effect of a continental shelf wave on the peak coastal water level in the Gingin study area has been assessed as small compared to the potential variability in storm surge as a result of wind speed, storm track and storm scale for a latitude of -30˚S and further south. The basis for this assessment is:

- TC Ned had a very fast forward track speed which was above 15 m/s south of -30º latitude and Pattiaratchi *et al* (2016) identified that cyclone track speeds greater than 10 m/s had reduced shelf wave amplitudes;

- Any significant shelf wave that may be observed in the Gingin study area would occur after the peak storm surge from direct wind stress and pressure forcing as the propagation speed of the storm track is significantly greater than the propagation speed of any shelf wave.

It should be noted that as discussed in Section 5.4, based on analysis of measured water levels in the study area (see Section 2.1), a positive water level residual of 0.30 m has been included in the design inundation event simulations to account for non-cyclonic positive water level residual and the potential impact of a shelf wave acting in addition to the peak storm surge during the design events. The +0.3m is included as a fixed baseline to the water level in the simulations with further discussion in Section 6.

3. Data Sources

A summary of the survey data and assumptions applied in the modelling and analysis for the CIS is provided in this section.

3.1 Ocean Levels and Datum

3.1.1 Tidal Planes

A summary of the tidal planes through the study area are presented in Table 3.1 based on tidal submergence curve information provided by the DoT for Jurien Bay, Lancelin and Two Rocks Marina.

Table 3.1: Tidal Planes (based on DoT submergence curves).

Tidal Level	Jurien Bay[1] (m CD)	Jurien Bay (m AHD)	Lancelin[2] (m CD)	Lancelin (m AHD)	Two Rocks Marina[3] (m CD)	Two Rocks Marina (m AHD)
Highest Astronomical Tide (HAT)	1.41	0.53	1.39	0.41	1.39	0.52
Mean High High Water (MHHW)	1.14	0.26	1.15	0.17	1.14	0.27
Mean Low High Water (MLHW)	1.04	0.16	1.05	0.07	1.04	0.17
Australian Height datum (AHD)	0.88	0	0.98	0	0.87	0
Mean Sea Level (MSL)	0.80	-0.08	0.81	-0.17	0.80	-0.07
Mean High Low Water (MLLW)	0.57	-0.31	0.58	-0.40	0.56	-0.31
Mean Low Low Water (MLLW)	0.46	-0.42	0.48	-0.50	0.46	-0.41
Lowest Astronomical Tide (LAT)	0.24	-0.64	0.24	-0.74	0.24	-0.63

Notes:

1. Compilation 31/10/2016. Datum: Jurien, Lowest Low Tide 1985. 2.136 m below benchmark HLR 117, [formerly titled JUR 2001]. 0.88 m below AHD (2014).
2. Datum: Lancelin, Lowest Low Tide 1976. 2.512 m below benchmark PWD WA, A 420. 0.98 m below AHD (2013).
3. Compilation 21/3/2018, Datum: Two Rocks Lowest Low Tide 1976. 5.468m below benchmark PWD WA A 431. 0.87m below Australian Height Datum (AHD).

The datum conversion to AHD for the Lancelin location was verified with DoT to confirm the conversion from MSL to AHD. The conversion looks inconsistent with the Jurien Bay and Two Rocks locations (MSL to AHD conversion is -0.17m at Lancelin vs -0.08m and -0.07m at Jurien Bay and Two Rocks respectively). The Lancelin AHD datum has been confirmed as correct with tides at DoT. The anomaly of the Lancelin

AHD is attributed to establishment of AHD between the primary tide stations of Geraldton and Fremantle Stations (Lowry 2020).

The tide level adopted in the design cyclone model simulations is MHHW (refer Section 5.4).

3.1.2 Sea Level Rise

Based on the recommendations from DoT 2010, the sea level rise allowance that will be applied to design water levels over the 100-year planning period for this study are summarised in Table 3.2.

Table 3.2: Sea Level Rise Allowance in Future Planning Periods

Planning Year	Sea Level Rise Allowance
2020	0m
2040	0.10 m
2070	0.35 m
2120	0.90 m

3.2 Bathymetric and Survey Data

Table 3.3 summarises the bathymetry and landside survey data available for this study. The key survey and bathymetric sources are shown in Figure 3.1 and Figure 3.2.

Table 3.3: Summary of Bathymetry Data relevant to the study

Description	Type	Date	Comments	Reference
Horrocks to Hillarys and Houtman Abrolhos LiDAR Bathymetric Survey	LiDAR Bathymetric Survey	2016	Highest priority – used to define all nearshore areas from Wedge Island to Yanchep (refer Figure 3.1 Areas named LA,LP,SE,TR)	DoT
Composite Surfaces - Lancelin	Multibeam-LiDAR Laser	Unknown	Used to fill gaps in LiDAR Bathymetric Survey	DoT
Western Australia Two Rocks to Cape Naturaliste Bathymetry and Seabed Survey	Multibeam Bathymetric Survey	2009	Used to define bathymetry in coastal regions from Two Rocks to Cape Naturaliste in the model systems	DoT
AusENC	Soundings and Contours State-wide	2016	Digital Version of Navigational Charts used for offshore areas	Australian Hydrographic Office

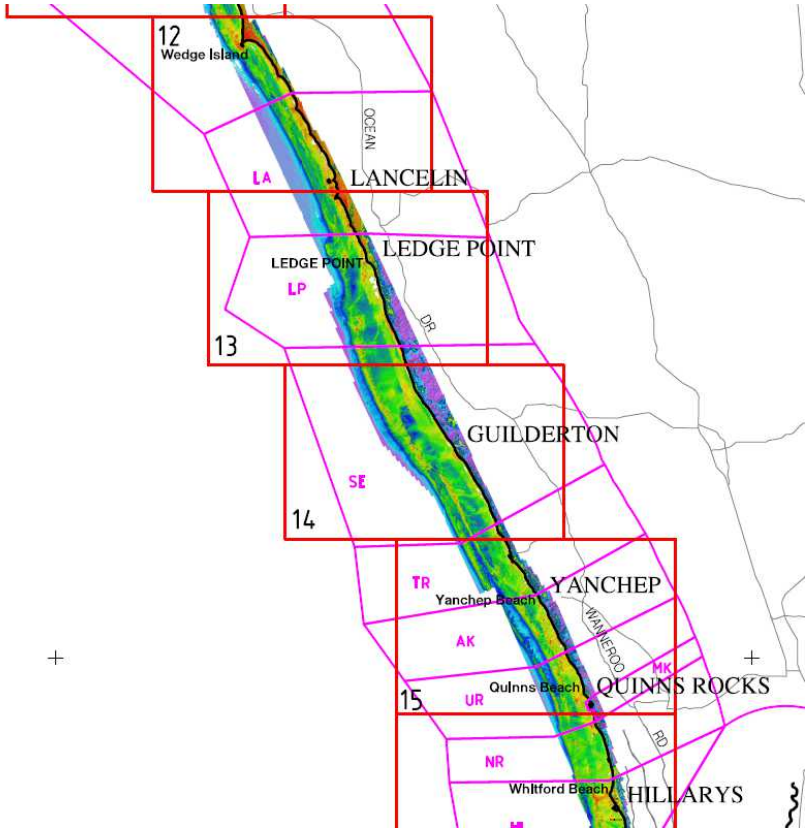


Figure 3.1: Locality of key LiDAR Bathymetric survey data. LiDAR data was made available for blocks; LA, LP, SE and TR (DoT 2016).

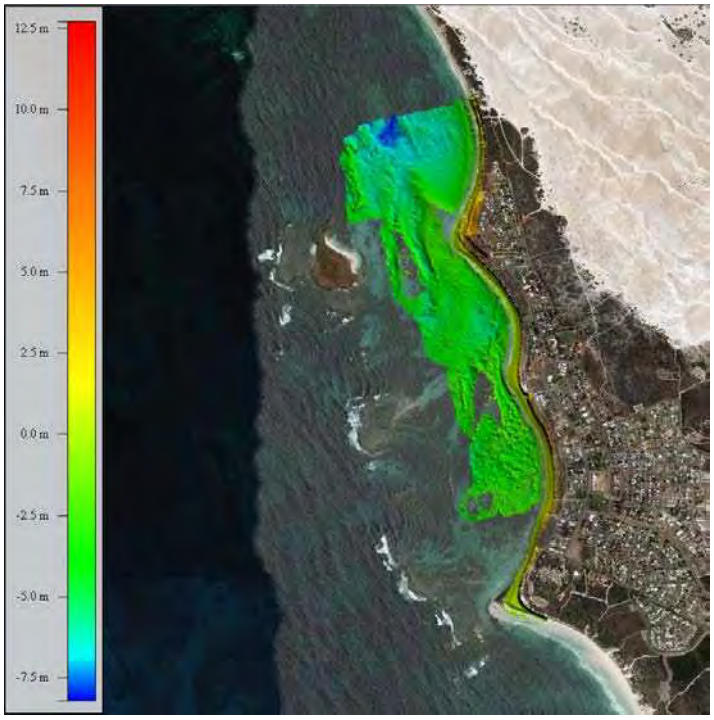


Figure 3.2: Lancelin Composite 32bit survey data.

3.3 Metocean Data

The metocean data available for the coastal inundation study is summarised in Table 3.4. The locality of the metocean data collection sites are shown in Figure 3.3 and Figure 3.4.

Table 3.4: Summary of Metocean data for use in the study.

Site	Lon.	Lat.	Param.	Start	End	Comment	Ref.
Fremantle (Fishing Boat Harbour)	115.748056	-32.065556	Water Level	1986	Present		DoT
Hillary's	115.738578	-31.825535	Water Level	1991	2003		DoT
Jurien Bay	115.042778	-30.287222	Water Level	1991	Present		DoT
Lancelin	115.316667	-31.016667	Water Level	22/6/1993 1/1/2003	29/7/1997 19/7/2012		DoT
Two Rocks Marina	115.568055	-31.494444	Water Level	01/02/2013	11/05/2016		DoT
Ledge Point (Location 4)	115.380917	-31.127144	Water Level, Currents, Waves, Temp.	31/01/2003	2/04/2003	AWAC	DoT
				9/04/2003	1/07/2003	AWAC	
				7/08/2003	2/10/2003	AWAC	
				7/11/2003	13/02/2004	AWAC	
				25/02/2004	19/05/2004	AWAC	
				15/06/2004	16/09/2004	AWAC	
Ledge Point (Location 5)	115.366388	-31.099444		7/08/2003	2/10/2003	AWAC	
				7/11/2003	13/02/2004	AWAC	
				25/02/2004	19/05/2004	AWAC	
				15/06/2004	16/09/2004	AWAC	
Ledge Point (Study)	115.373717	-31.115567		03/04/2017	25/07/2017	AWAC	
				25/07/2017	11/12/2017	AWAC	
				11/12/2017	16/05/2018	AWAC	
Jurien Bay South	115.022883	-30.295517	Water Level, Currents,	29/05/2014	1/10/2014	AWAC	DoT
				1/10/2014	26/02/2015	AWAC	
				26/02/2015	24/07/2015	AWAC	

Site	Lon.	Lat.	Param.	Start	End	Comment	Ref.
			Waves, Temp.	24/07/2015	29/10/2015	AWAC	
				29/10/2015	20/01/2016	AWAC	
				20/01/2016	27/05/2016	AWAC	
				27/05/2016	15/12/2016	AWAC	
				15/12/2016	4/04/2017	AWAC	
				4/04/2017	10/08/2017	AWAC	
				10/08/2017	5/10/2017	AWAC	
Sea Bird	115.434094	-31.244628	Water Level, Currents, Waves, Temp.	30/01/2003	03/04/2003	AWAC	DoT
				08/04/2003	08/07/2006	AWAC	
Two Rocks	115.568055	-31.494444	Water Level, Currents, Waves, Temp.	1/02/2013	12/04/2013	AWAC	DoT
				11/04/2013	5/08/2013	AWAC	
				2/08/2013	21/11/2013	AWAC	
				21/11/2013	27/02/2014	AWAC	
				26/02/2014	6/06/2014	AWAC	
				5/06/2014	15/09/2014	AWAC	
				12/09/2014	5/12/2014	AWAC	
				5/12/2014	15/06/2015	AWAC	
				15/06/2015	9/10/2015	AWAC	
				9/10/2015	4/02/2016	AWAC	
				4/02/2016	11/05/2016	AWAC	
Two Rocks (Marina 3)	115.581367	-31.496033	Water Level, Currents, Waves, Temp.	6/12/2016	28/03/2017	AWAC	DoT
				28/03/2017	20/06/2017	AWAC	
				23/06/2017	14/09/2017	AWAC	
Two Rocks (Breakwater West)	115.576139	-31.487972	Water Level, Currents, Waves, Temp.	6/12/2016	28/03/2017	AWAC	DoT
				28/03/2017	20/06/2017	AWAC	
				20/06/2017	14/09/2017	AWAC	
				14/09/2017	30/11/2017	AWAC	

Site	Lon.	Lat.	Param.	Start	End	Comment	Ref.
Ledge Point LDG45	-31.1347222	115.31444	Wave Param.	5/6/2002	18/10/2004	Non-Dir WRB	DoT
Guilderton Offshore (33m)	115.427778	-31.404722	Wave Param.	11/04/1988	10/02/1989	Non-Dir WRB	DoT
Guilderton Inshore (10m)	115.4819	-31.3597	Wave Param.	Apr/1988	Jul/1989	Non-Dir WRB	DoT
Jurien Bay	115.0336111	-30.292222	Wave Param.	02/01/1998	23/10/2009	Non-Dir WRB	DoT
Jurien Bay	115.0336111	-30.292222	Wave Param.	27/10/2009	31/12/2018	Dir. WRB	DoT

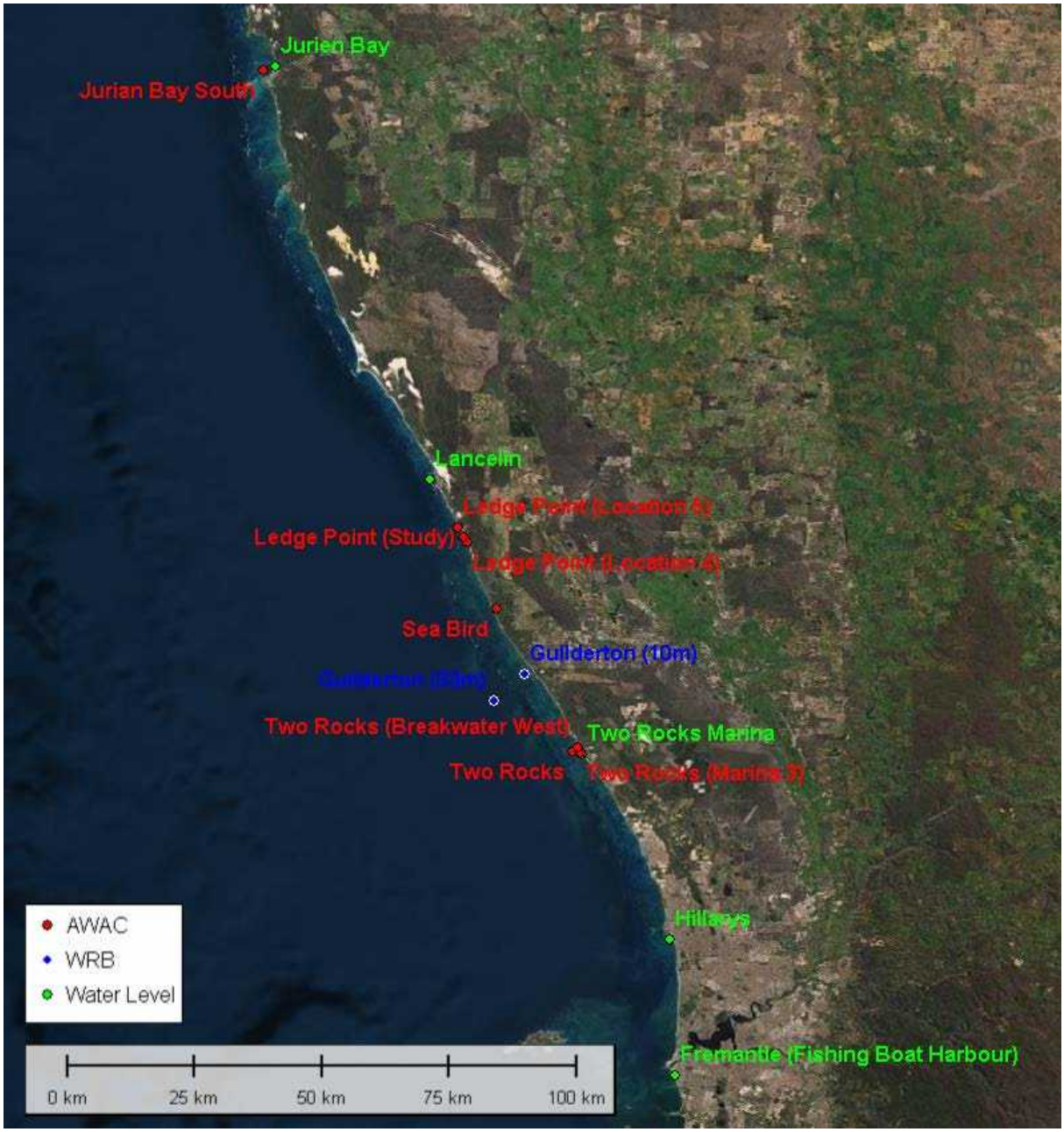


Figure 3.3: Summary of Metocean Data Collection Sites.



Figure 3.4: Summary of Metocean Data Collection Sites Near the Study Area.

3.4 Wind Data

Historical wind data was sourced from the Bureau of Meteorology (BoM) locations around the Gingin study area including Lancelin (station 9114) and Jurien Bay (station 9131).

Wind and pressure data was accessed from the Japanese Reanalysis atmospheric model (JRA-55). Spatial 3-hourly and 6-hourly U and V wind speed components and atmospheric pressure were extracted for the hindcast cyclone events at a 0.56-degree resolution.

4. Numerical Model System

4.1 Model Overview

Baird's established and validated numerical model of the West Australian coast was used as a baseline for this study. This hydrodynamic model system has been applied for a number of similar studies in Western Australia and was developed by Baird using the Deltares numerical model *Delft3D Flexible Mesh Suite* (Delft-FM). The Delft-FM modelling suite has been developed to offer a fully integrated modelling framework for a multi-disciplinary approach in coastal, river and estuarine areas (Deltares 2020). It can carry out simulations of flows, sediment transport, waves, water quality and morphological changes and has been applied in similar studies by Baird to determine waves, water levels and currents in extreme cyclonic conditions. The numerical model applied in this study is comprised of a dynamically coupled hydrodynamic model and wave model driven by a wind model outlined in the sections to follow.

4.2 Wind Model

The wind model adopted in this study is Baird's *Cycwind* model system that adopts a Holland (2010) spatial cyclone vortex model. The cyclone wind field has adopted track parameters from the BoM's best track database (BoM, 2019) with adjustment of the Radius to Gales (R34) and Radius to Outer Closed Isobar (ROCI) parameters to better describe the windfield along the coastal waters of southwestern WA as the system track south. The design cyclone tracks for the Gingin study area presented in Seashore Engineering (2020) are based on the TC Ned track, but experiencing a stronger extra-tropical transition. The scale and fetch of the windfield for a storm undergoing extra-tropical transition is not well described by a parametric vortex model (i.e. Holland, 2010), even when scale parameters (R34, ROCI) are including in the parameterisation. As discussed in Section 2.2.1, extratropical transition adds significant complexity to the spatial characteristics of the storm wind field.

A significant gap in the physics for a transitioning cyclone like TC Ned (a key cyclone for the Gingin study area) is that the impact on surface wind speed as a result of forward speed asymmetry due to the fast translation speed and relatively large scale of storm winds of the storm when it is offshore of the Gingin study area is not well defined. Loridan *et al* (2013) noted that the majority of transitioning tropical cyclones did not exhibit forward speed wind asymmetry. However, the specification of the design cyclone track parameters in Seashore Engineering (2018) lends to the application of a parametric vortex model to model the windfield, even for southwestern Western Australia.

For the Seashore Engineering (2020) design cyclone tracks for Gingin region (Lancelin and Seabird storms), forward speed asymmetry was not included in the modelled wind field due to the scale and speed of the storm being beyond the conditions which tropical cyclone forward speed asymmetry models (including the McConochie (2004) that are adopted in *Cycwind* . For the Gingin area the TC Alby event is particularly difficult to model, with parametric cyclone vortex models not well suited at describing the spatial characteristics of the wind field of an extra-tropical cyclone. For hindcasting TC Alby and TC Ned, JRA-55 hindcast winds were also applied to the storm surge model and generally improved the agreement between modelled and measured water levels and this is consistent with a recently completed CIS completed for a site at Busselton (Baird, 2020a). However, it should be noted that the grid resolution of the JRA-55 (≈50 km) was not sufficient to represent the intensification of TC Ned which occurred as it approved the coastline near the Gingin study area.

4.3 Hydrodynamic Model

The Delft-FM model extent covers the entire west coast of Western Australia from Northwest Cape to Cape Leeuwin as shown in in Figure 4.1. There is varying model resolution, highest along the coastline areas. The model grid was refined spatially from Lancelin to Guilderton and customised for this study. Spatial

resolution as fine as 15m was used around Lancelin, Ledge Point, Seabird and Guilderton, with resolutions ranging from 15m to 150m between the towns. The model extent and resolution at the four towns are shown in Figure 4.1.

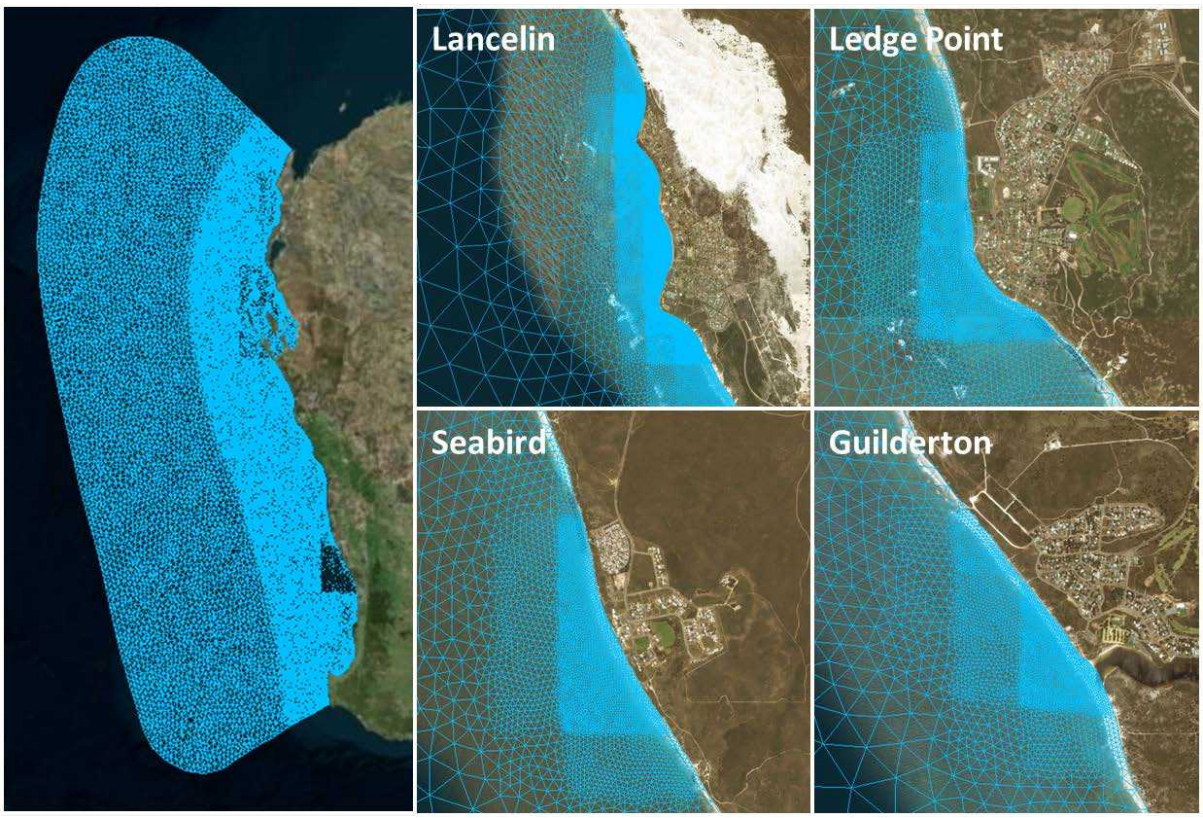


Figure 4.1: Hydrodynamic model grid extent and resolution at Lancelin, Ledge Point, Seabird and Guilderton. The spatial grid resolution increases in the nearshore areas to approximately 15m

It is noted for Guilderton that the Moore River is not included in the model grid extent shown in Figure 4.1. It is expected that coastal inundation levels nearshore at Guilderton in extreme events will dominate over catchment based flooding and these will transfer inside the Moore River at Guilderton in extreme events (further discussed in Section 5.5).

The nearshore seabed areas along the Gingin study region have been defined in the model incorporating the high-resolution bathymetry sets outlined in Table 3.3. Offshore bathymetry has been defined using hydrographic chart data and bathymetric models (Figure 4.2).

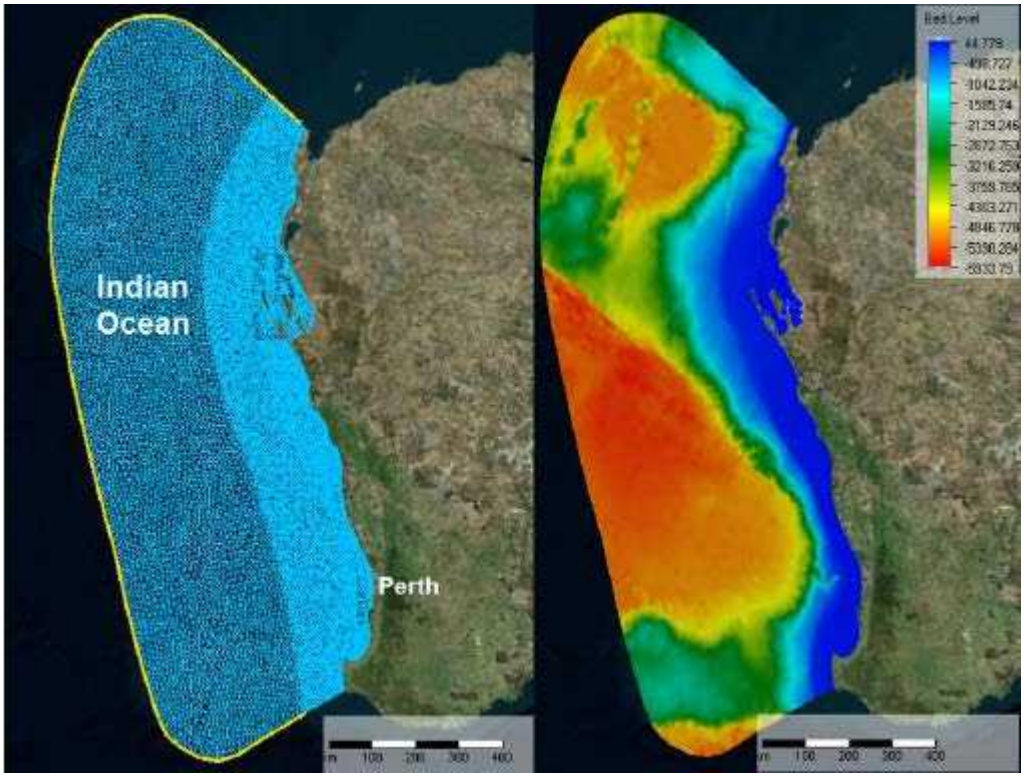


Figure 4.2: Model Bathymetry

4.4 Wave Model

The wave model adopted for the simulation of wave conditions in this study is the industry standard SWAN wave model (Simulating Waves Near Shore) developed at Delft University of Technology in the Netherlands. SWAN is a third generation spectral wave model which computes wave propagation, wave generation by wind, non-linear wave-wave interactions and dissipation, for a given bottom topography, wind field, water level and current field (Deltares 2019).

The SWAN model accounts for (refractive) propagation due to current and depth and represents the processes of wave generation by wind, dissipation due to whitecapping, bottom friction and depth-induced wave breaking and non-linear wave-wave interactions (both quadruplets and triads) explicitly with state-of-the-art formulations. Wave blocking by currents is also explicitly represented in the model (Deltares 2019).

A coupled SWAN model was established across the same extent as the hydrodynamic model, comprised of five nested grids which increase in resolution approaching the Gingin Study area at 5km, 1km, 500m, 100m and 50m resolutions. The positions of the grids are displayed in Figure 4.3 and Figure 4.4.

The bed roughness applied in the model is based on a standard Chezy formulation (U =65 and V =65). The nearshore reef systems along the coast are described in the wave model system in terms of bathymetric changes but specific roughness for the features has not been included in the model settings.

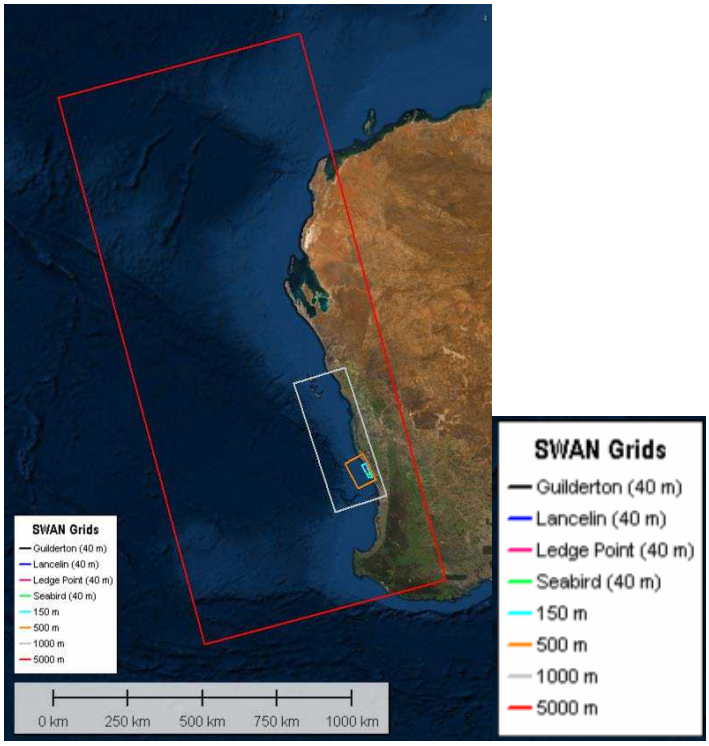


Figure 4.3:: SWAN Model Grid extending across entire D-FM Model Domain (5000m grid size)

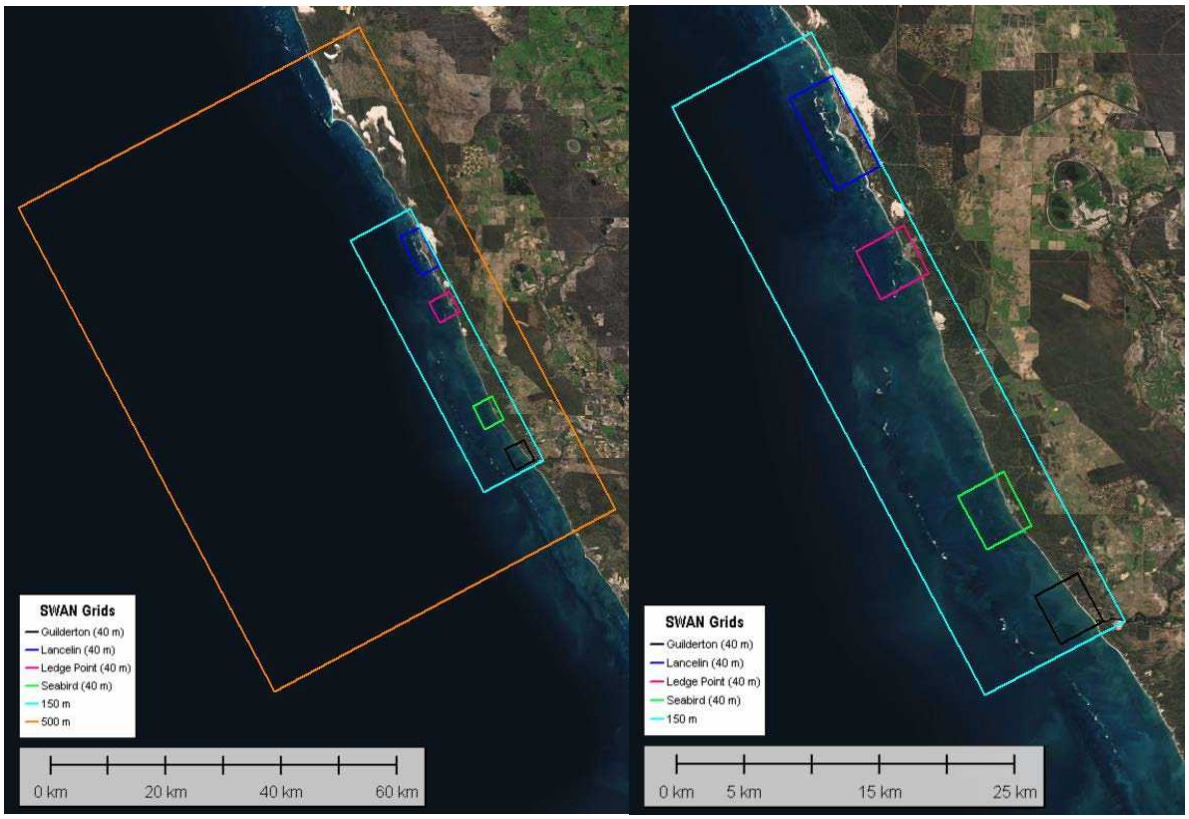


Figure 4.4: Nested SWAN model grids showing Lancelin, Ledge Point, Seabird, and Guilderton.

4.5 Coupled Model approach

The Deltares model system allows for coupling of the wave conditions and hydrodynamics through the duration of a cyclone simulation. The modelling approach is termed FLOW-WAVE-FLOW with the water levels in the model evaluated in the hydrodynamic model (FLOW) and the wave conditions separately evaluated in the waves module (WAVE). Typically, the FLOW-WAVE-FLOW is run with a Delft3D structured or unstructured grid, in this case we have used the Delft-FM (flexible mesh) model for hydrodynamics.

The key processes affecting water level including radiation stresses are passed across and updated in the hydrodynamic model during the simulation. The coupled process runs continuously through the cyclone event to update and interchange wave and water level information. The effect of waves on current (via forcing, enhanced turbulence and enhanced bed shear stress) and the effect of flow on waves (via set-up, current refraction and enhanced bottom friction) are accounted for within this coupled modelling approach (Deltares, 2015).

Spatial wind and pressure fields active over the model domains influence the wind growth of waves and wind/pressure setup of the water level in the hydrodynamics. Spatial wind and pressure fields were updated every 6 hours in the cyclone simulations, and the input forcing the coupling interval of hydrodynamics and waves was set to between 30 minutes (production Cases) and 120 minutes (validation cases).

4.6 Hydrodynamic Model Validation to Tides

For the Gingin study area, the hydrodynamic model was validated against predicted water levels at key locations across the study area based on a one-year simulation of tides (2011). The model validation is shown in Figure 4.5 and shows excellent agreement with time series and validation statistics for modelled and predicted tides from the model at Hillary's, Jurien Bay, Lancelin and Two Rocks Marina. The validation metrics are excellent with little bias and RMS error of about 0.01-0.02 m. The model validation provides confidence the hydrodynamic model can be applied as a basis for the study in the phases to follow.

The validated tide model was applied to examine some key extreme events in the historical record in the next section with the inclusion of wind and pressure in the model simulations. The model performance in reproducing storm surge in extreme events is presented by comparing model performance against measured data where available.

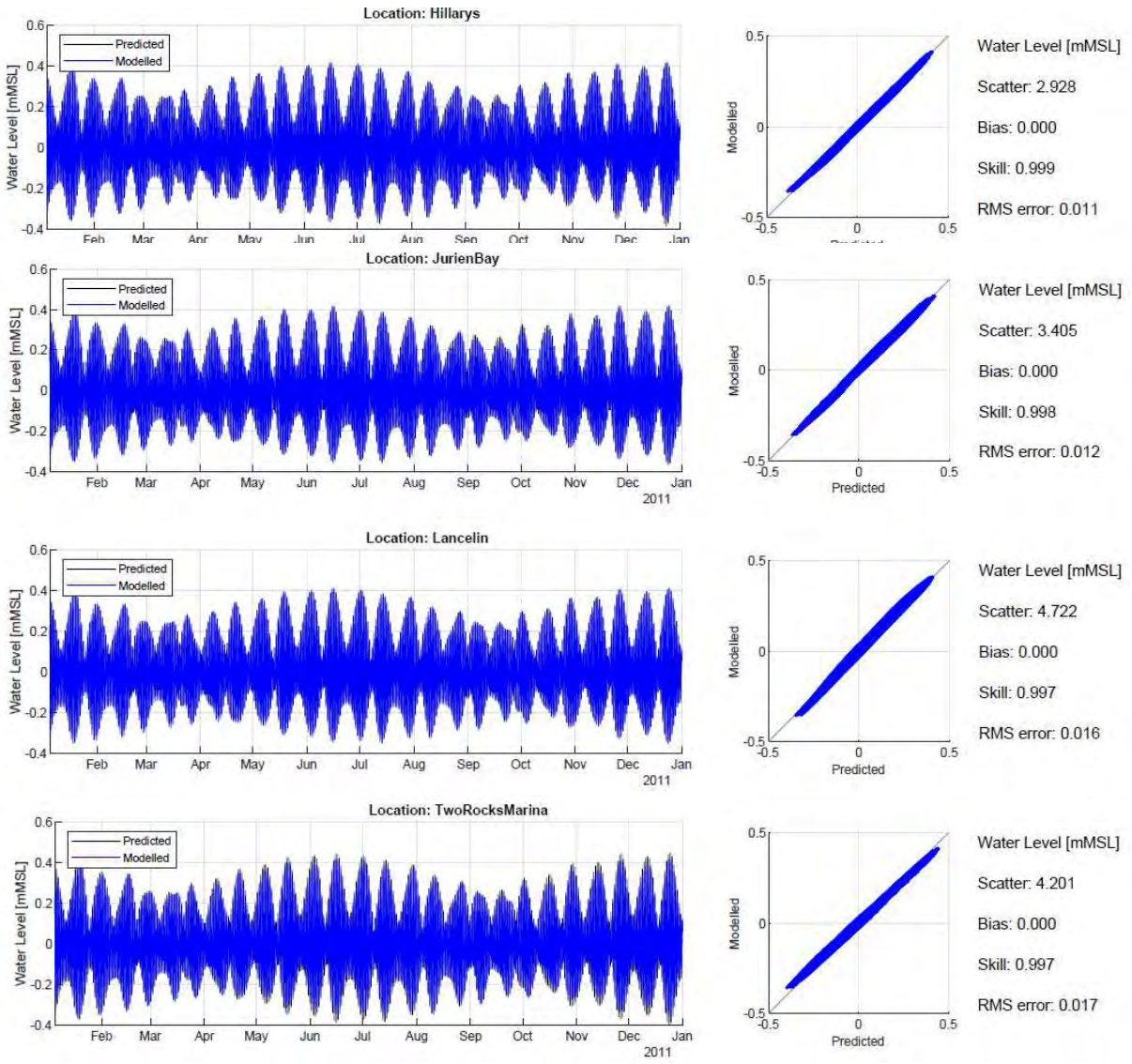


Figure 4.5: Hydrodynamic model validation showing comparison of modelled water level and predicted water level at locations around the study area - Hillary's, Jurien Bay, Lancelin and Two Rocks Marina. Validation Metrics show excellent agreement between modelled and predicted water level at all locations

4.7 Tropical Cyclone Validation Events

The setup and validation of Baird's cyclone storm surge and tide models for the whole of Australia, including Western Australia, is specifically addressed in the following references:

- Burston et al (2015) and Burston et al (2017): Description and validation of Baird's Monte Carlo cyclone track model system and large-scale, high resolution tide and storm surge models.
- Churchill et al (2017): Detailed model validation completed for historical events impacting on Dampier and Karratha resulting in revised wind drag coefficients for wind speeds less than 20 m/s.
- Taylor et al (2018): Summary of the overall Australia wide model including tide and surge model validation Australia-wide.

For this project, the southern Western Australia model presented in has been adopted, with the wind drag coefficients recommended in Churchill (2017). The model has been calibrated with a large number of cyclone events across Western Australia as documented in Churchill et al (2017), Burston et al (2017) and Taylor et al (2018). The modelling of extreme events undergoing extra-tropical transition through the south of the State and application of the model to derive 500yr ARI inundation levels under SPP2.6 requirements was examined in detail for the Busselton location by Baird in 2019-2020.

For the Gingin study area, the model validation for extreme storm cases has been undertaken for four key cyclone events that tracked south and impacted the region. A summary of the historical tropical cyclones follows:

- **TC Alby (27 March – 4 April 1978):** TC Alby formed off the Pilbara coast with an estimated minimum central pressure of 930 mb. During Tuesday 4 April TC Alby accelerated towards the lower west coast as it slowly weakened to an extra-tropical depression. As it passed to the southwest of the continent it caused strong to storm force winds over a large area of the southwest of Western Australia.
- **TC Ned (25 March – 1 April 1989):** TC Ned developed on 26 March well north of the Pilbara coast. Ned intensified reaching category 4 intensity early on 29 March to the west northwest of Exmouth. Ned then weakened owing to increasing wind shear as it moved southwards. A strong mid-latitude trough approaching from the southwest accelerated the remains of Ned to the southeast crossing near Perth on the morning of 1 April. Strong winds were reported at Rottnest Island and in the Rockingham area, and caused power disruptions and isolated roof damage.
- **TC Bianca (21 January – 30 January 2011):** TC Bianca formed offshore of Broome and tracked west-southwest, parallel to the Pilbara coastline. The system intensified, reaching Category 3 intensity at 2 pm AWST 27 January. Bianca then moved southwest and reached a peak intensity of Category 4 at 8 am AWST 28 January. Bianca began to weaken by 2 am AWST 29 January as it moved south over cooler sea surface temperatures and experienced increased wind shear. The system eventually dissipated over open water to the west of Perth, never crossing the Western Australian coastline.
- **TC Iggy (23 January – 3 February 2012):** TC Iggy remained offshore for the majority of its track, weakening to a low pressure system before crossing the coast between Geraldton and Jurien Bay on the 3rd of February 2012. A pronounced tidal surge was recorded at most towns from Onslow to Perth as *Iggy* moved south along the west coast. The peak was 80 cm recorded at Geraldton and 70 cm at Fremantle on 2 February with no apparent damage reported from any locations

It is noted that TC Mangga which occurred in May 2020 occurred at the conclusion of this study and was not analysed in detail as one of the historical storms. A summary of the storm is presented in Section 4.1.5.

Cyclone tracks have been extracted from the Bureau of Metrology's Best Track database and the Japanese 55-year Reanalysis (JRA-55) data. Cyclone tracks are shown in Figure 4.6.

For each of the validation cases, the hydrodynamic model simulations include the general tides (predicted tide) with environmental forcing based on the cyclone track pressure and wind field, along with wave stresses (and consequently wave setup) from a coupled wave model. The modelled water levels through the event are compared against available measured data where this was available in the historical record. The storm surge residual is calculated as the difference between the predicted tide and the actual water level during the event. With the exception of TC Alby, the historical cyclone events presented for model validation have relatively low storm intensity when tracking close to the study area compared to the design events presented in Section 5. A brief discussion of the validation events follows.

The detailed validation cases are presented in Appendix B at the model datum of mean sea level (MSL). For reference, the adjustment to Australian height datum (mAHD) is as follows:

- Fremantle: AHD = MSL - 0.01m
- Jurien Bay: AHD = MSL - 0.08m
- Two Rocks Marina: AHD = MSL - 0.07m

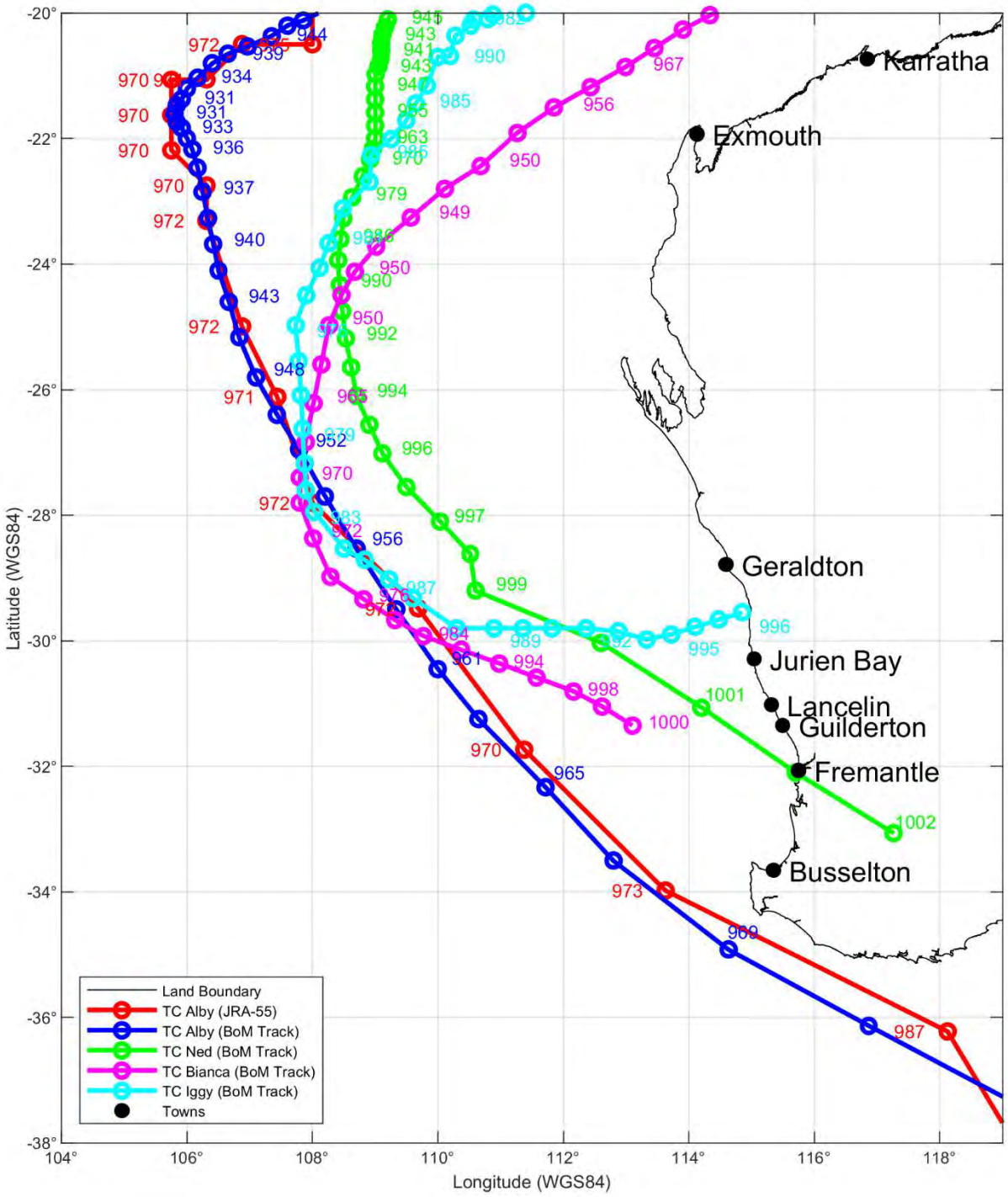


Figure 4.6: Cyclone tracks with central pressure (hPa).

4.7.1 TC Alby (Apr 1978) Model Validation

Measured data was available from Fremantle location only during TC Alby. The model results and validation metrics are presented against the predicted tide at locations across the study area and for Fremantle in Appendix B.1. Whilst TC Alby did not track close to the study area, by the time it reached southern WA, it was a very large-scale storm and storm surge along the southern WA coastline including the study area was significant. Model results indicate a storm surge of approximately 0.5 to 0.7 m across the study site, with larger surge towards the south, which was closer the cyclone track.

Bureau of Meteorology summary reporting of TC Alby (BoM Tropical Cyclone Summary) indicates that as TC Alby tracked down the WA coast there were significant storm surges for the area between Lancelin and Cape Naturaliste. For Fremantle the measured peak water level of approximately 1m above mean sea level (1.8m CD) compares very closely with the modelled (coupled) result in the upper plot of Figure 4.7. The water level residual of 0.8m shown in the lower plot is very closely matched by the model case.

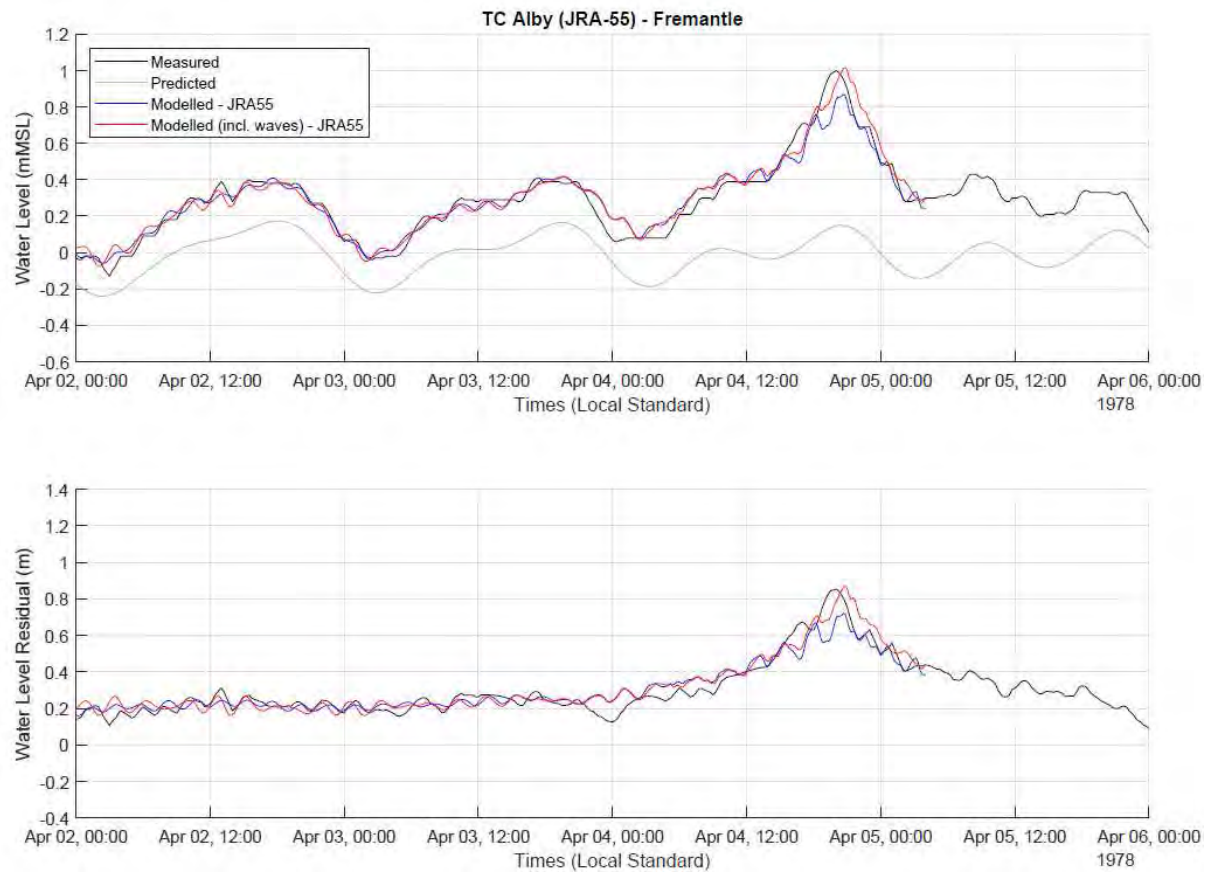


Figure 4.7: Modelled and predicted water level (upper) and water level residual (lower) at Fremantle for TC Alby. Based on JRA-55 data. Datum of Mean Sea Level is 0.01m below AHD.

4.7.2 TC Ned (Mar 1989) Model Validation

For TC Ned, measured data was available at the Fremantle tide gauge. The model results and validation metrics are presented against the predicted tide at locations across the study area and for Fremantle in Appendix B.2.

Since TC Ned had weakened in strength as it reached the southern WA coastline, the parametric cyclone wind field model applied in the simulation of the event was not applicable due to the low intensity of the event. Instead the model was forced with JRA-55 and CFSR wind datasets.

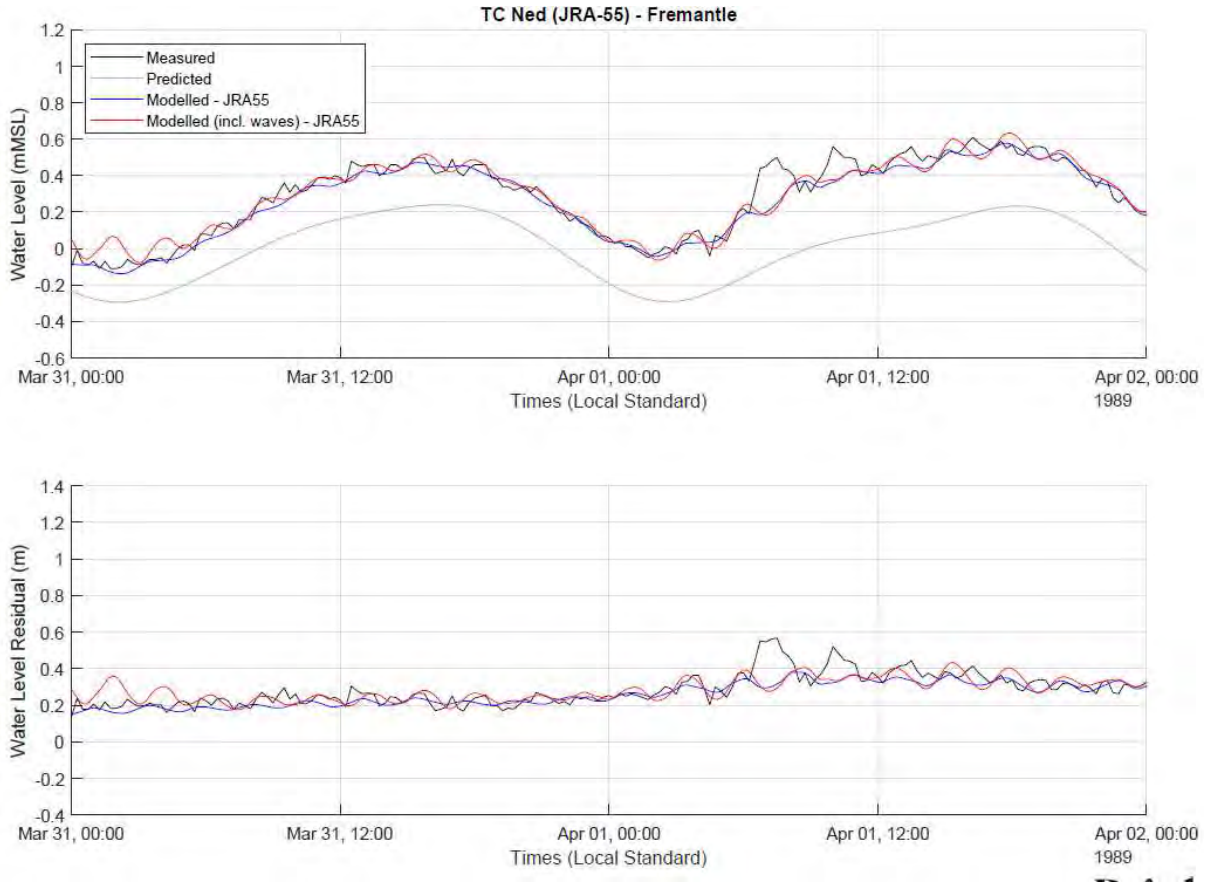


Figure 4.8: Modelled and predicted water level (upper) and water level residual (lower) at Fremantle for TC Ned. Based on JRA-55 data. Datum of Mean Sea Level is 0.01m below AHD.

Based on the model outcomes for the TC Ned case, it is concluded that for low intensity, weakening cyclone events the parametric model is not suited to reproducing a suitable windfield.for the cyclone simulations in the model. However, for the design cyclone cases that will be recommended for application in this study (eg 100yr ARI and 500yr ARI event), the cyclone wind field model will be suitable as these will be a more intense cyclone that can be described by a parametric wind model.

4.7.3 TC Bianca (2011) Model Validation

For TC Bianca water level measurements were available at Fremantle, Lancelin and Jurien Bay. The model results and validation metrics are presented against the predicted tide at locations across the study area and for Fremantle in Appendix B.3.

Similar to TC Ned, TC Bianca had weakened by the time it reached the southern WA coastline and hence the parametric cyclone wind field model is not suited to reproducing a suitable windfield.for the cyclone, so the modelled winds were derived from the high resolution CFSR dataset. The model comparisons of the peak storm surge from the model vs measured data at Fremantle, Lancelin and Jurien Bay showed the model was underpredicting the peak storm surge by approximately 0.3m. For this case the winds are taken solely from CFSR and its likely the wind and pressure in the CFSR dataset for TC Bianca are not a good

representation of the actual event. CFSR has known limitations in the nearshore region due to the land sea interface and this is likely affecting the wind and pressure inputs for TC Bianca.

4.7.4 TC Iggy (Feb 2012) Model Validation

For TC Iggy water level measurements were available at Lancelin, Fremantle and Jurien Bay. The model results and validation metrics are presented against the predicted tide at locations across the study area and for Fremantle in Appendix B.4.

TC Iggy also had weakened by the time it reached the southern WA coastline and hence the cyclone wind field model is not suitable for application in the model, so the modelled winds were derived from the high resolution CFSR dataset.

Measured water levels at Lancelin are compared to modelled water levels in Figure 4.9. Comparisons to the measured data show a close agreement through the peak of the storm surge of approximately 0.6 m at Lancelin.

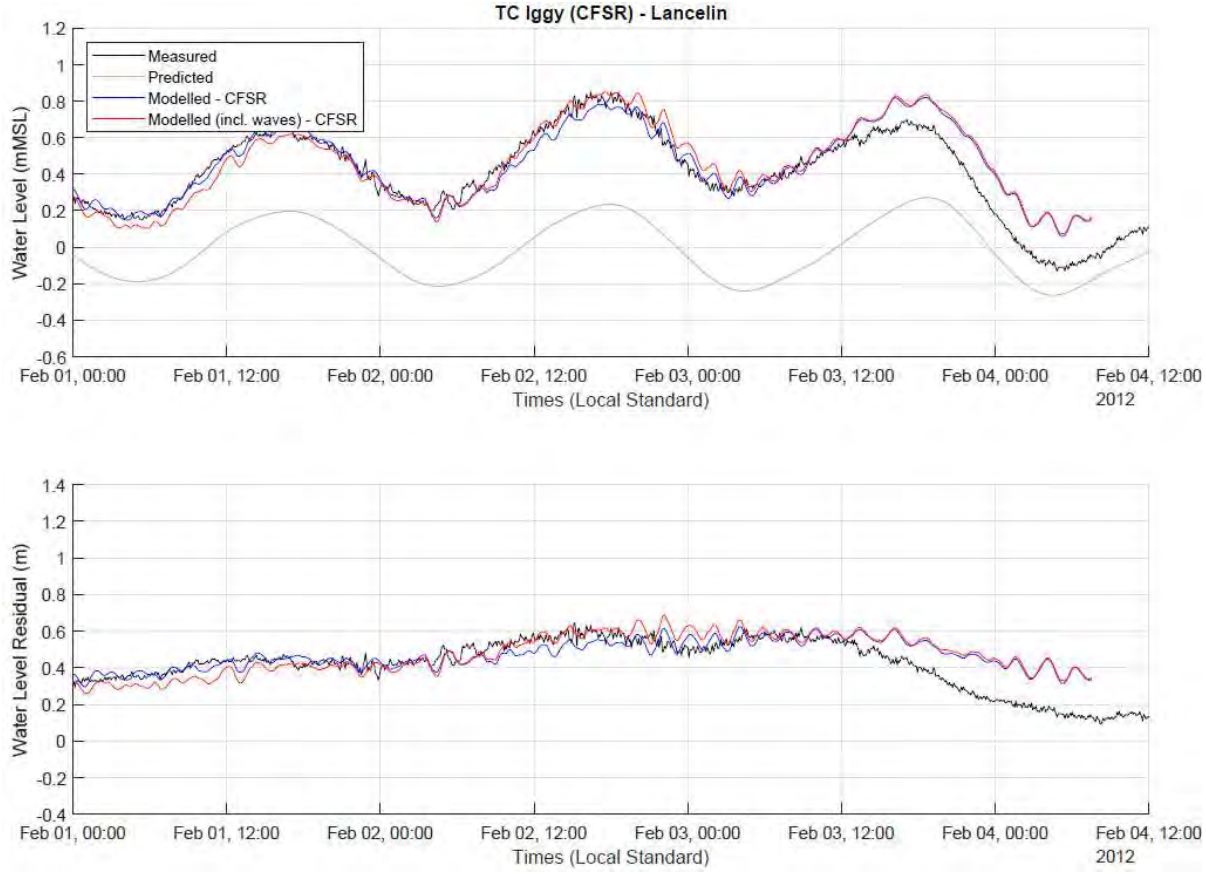


Figure 4.9: Modelled and predicted water level (upper) and water level residual (lower) at Lancelin for TC Iggy 2012. Based on CFSR data. Datum of Mean Sea Level is 0.07m below AHD.

4.7.5 TC Mangga (May 2020) Overview

The TC Mangga storm which occurred in May 2020 was an ex-tropical cyclone that tracked south and interacted with a frontal system in the southern Indian Ocean to produce extreme winds, waves and water levels for the entire west coast of western Australia.

The satellite image for the event is presented in Figure 4.10 and shows the extent of the storm across the Western coast of Australia.

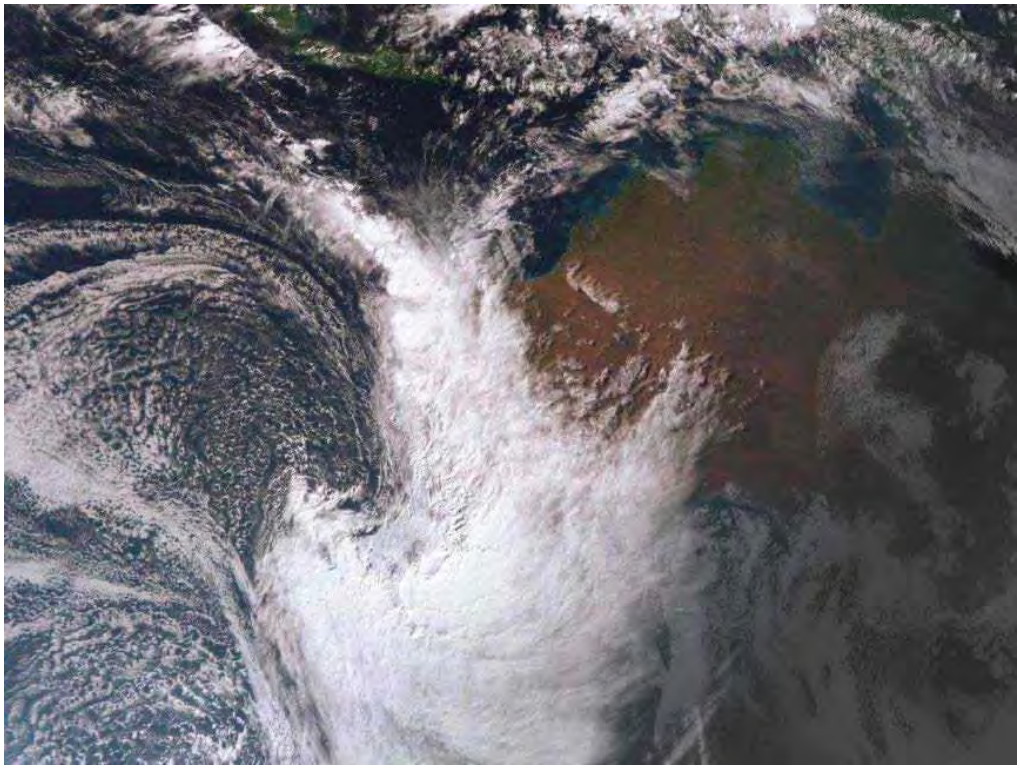


Figure 4.10: TC Mangga satellite image (ABC 2020, sourced from BOM)

For the section of coast through the study area of Gingin, the water levels through the event were captured by the DoT tide gauges at Jurien Bay to the north and Two Rocks to the south.

- The peak water level measured at Jurien Bay just north of the Gingin study area was at 10.30am on 25th May 2020 as 1.18m AHD (2.06m CD). This is the highest water level ever recorded at Jurien Bay over the approximate 30-year period the tide gauges have been active. At the time of the peak water level there was a residual of approximately +0.75m above the predicted astronomical tide level (i.e. the increase in the measured tide level above the normal astronomical tide level). The peak residual (surge) occurred a few hours earlier and was approximately +0.84m (DoT 2020a); and
- At Two Rocks to the south of the study area the tide gauge did not capture the peak of the event due to instrument failure, however the tide gauge showed that in the lead up to the peak that there was a residual of approximately +0.7m (DoT 2020b).

The analysis of the measured water level data through the event at Jurien Bay is shown in Figure 4.11 (DoT 2020a). The DoT real time system data from Two Rocks is shown in Figure 4.12 (DoT 2020b).

The measured wave conditions from the DoT real time system offshore of Jurien Bay at the peak of the storm showed wave heights around 7.5m with a mean wave period of approximately 11s (H_s=7.5m, T_m=11s). The peak significant wave height through the event of 8.2m was measured at 1:56pm on 25 May 2020 (DoT2020a). This is the highest significant wave height on record at Jurien Bay.

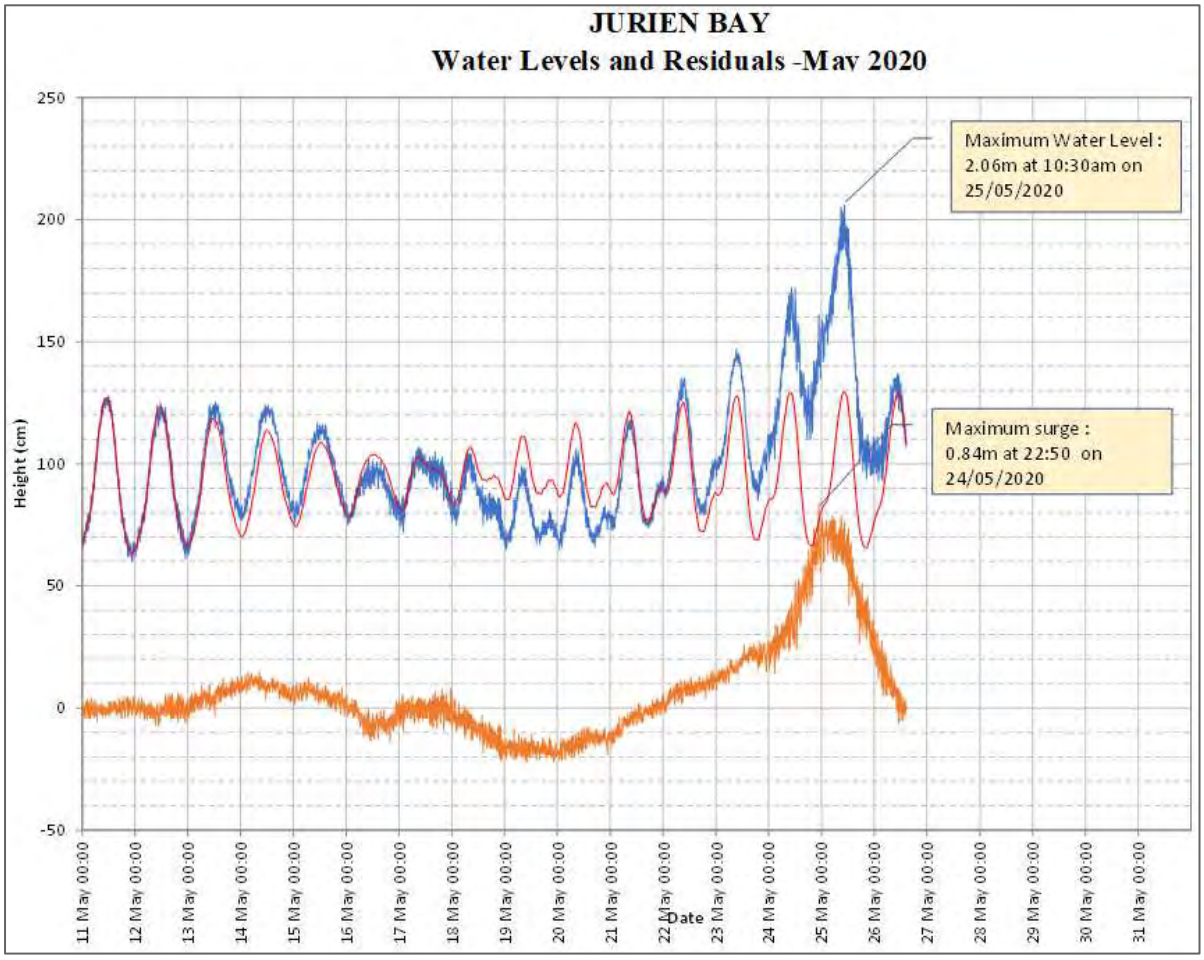


Figure 4.11: Analysis of the Jurien Bay tide gauge data through peak of TC Mangga in May 2020 showing the measured water level, predicted water level and residual (DoT 2020a).

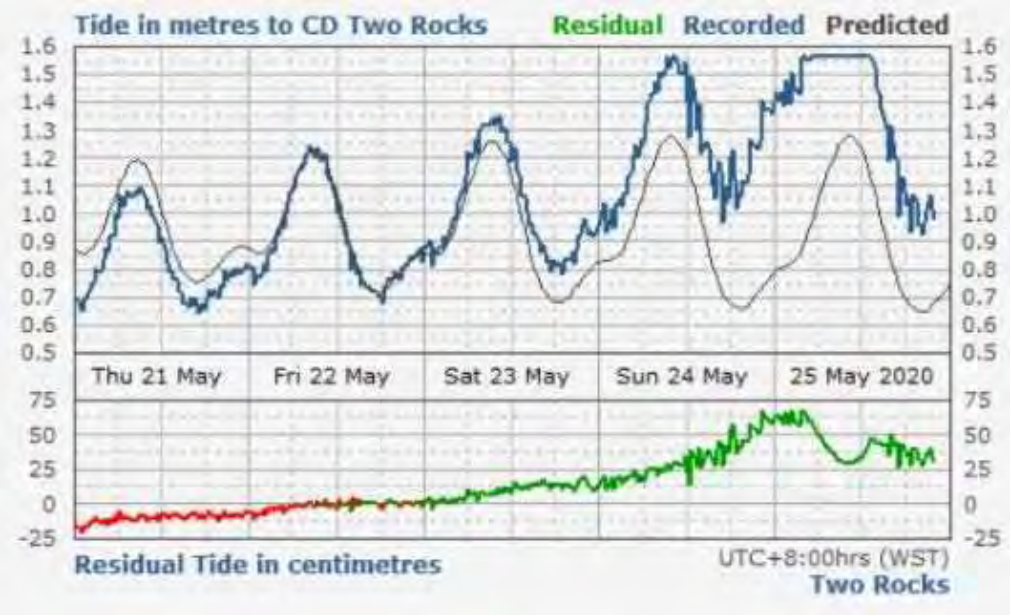


Figure 4.12: Measured tide gauge data at Two Rocks through TC Mangga in May 2020 (DoT 2020b).

For the study area, the TC Mangga event impacted the shorelines through Gingin bringing elevated water levels and large waves. High water levels and localised erosion occurred through Lancelin with images from Grace Darling Park shown in Figure 4.13. Elevated water levels along the Lancelin shoreline are shown in Figure 4.14 for locations at the jetty and Edward Island Point track.

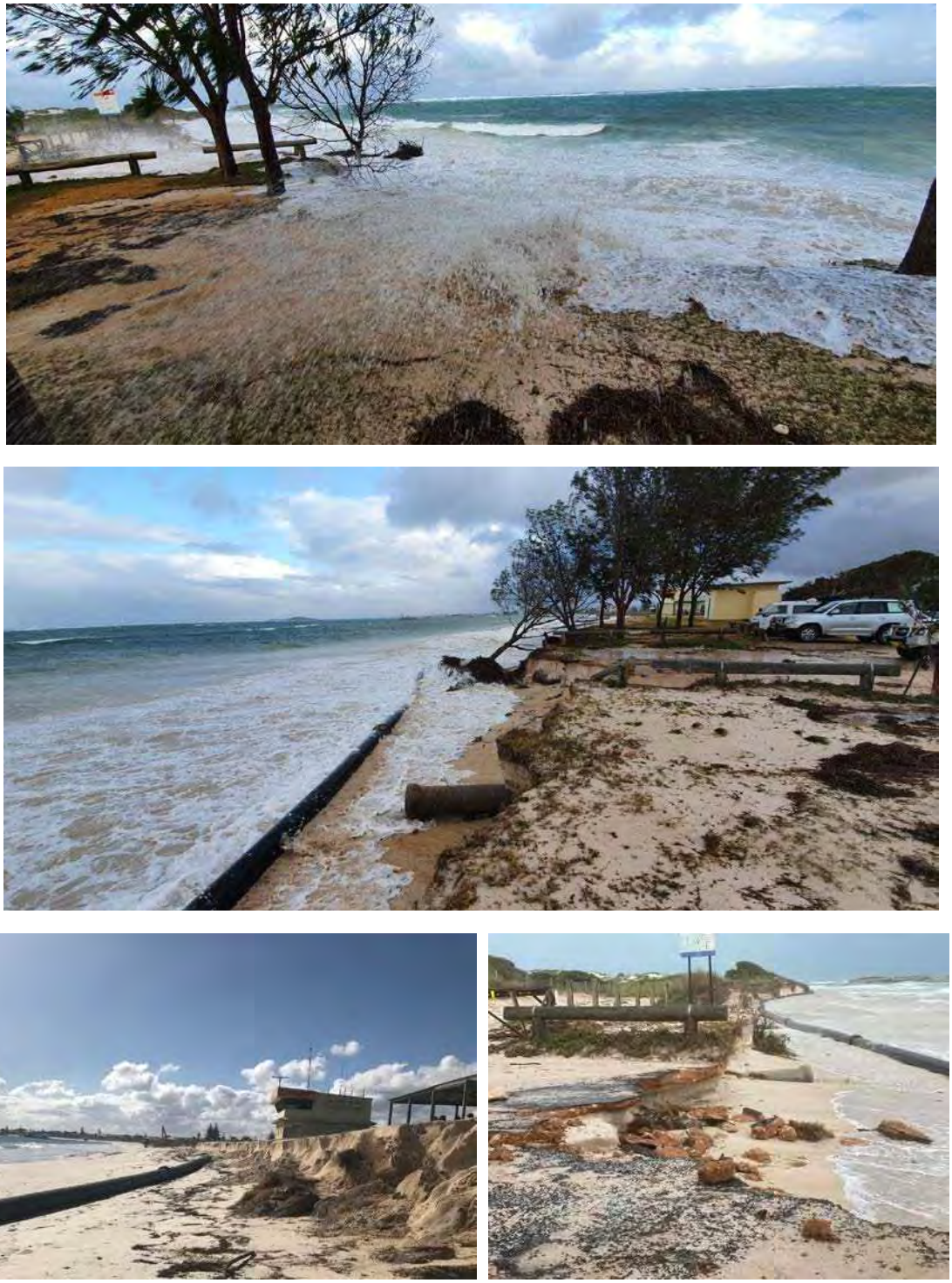


Figure 4.13: Upper image and middle Image: Grace Darling Park, elevated water levels through peak of storm, 25 May 2020. Lower image: post storm showing erosion scarp at Grace Darling Park and Edward Island Track. Images provided by Shire of Gingin and Lancelin Facebook Site

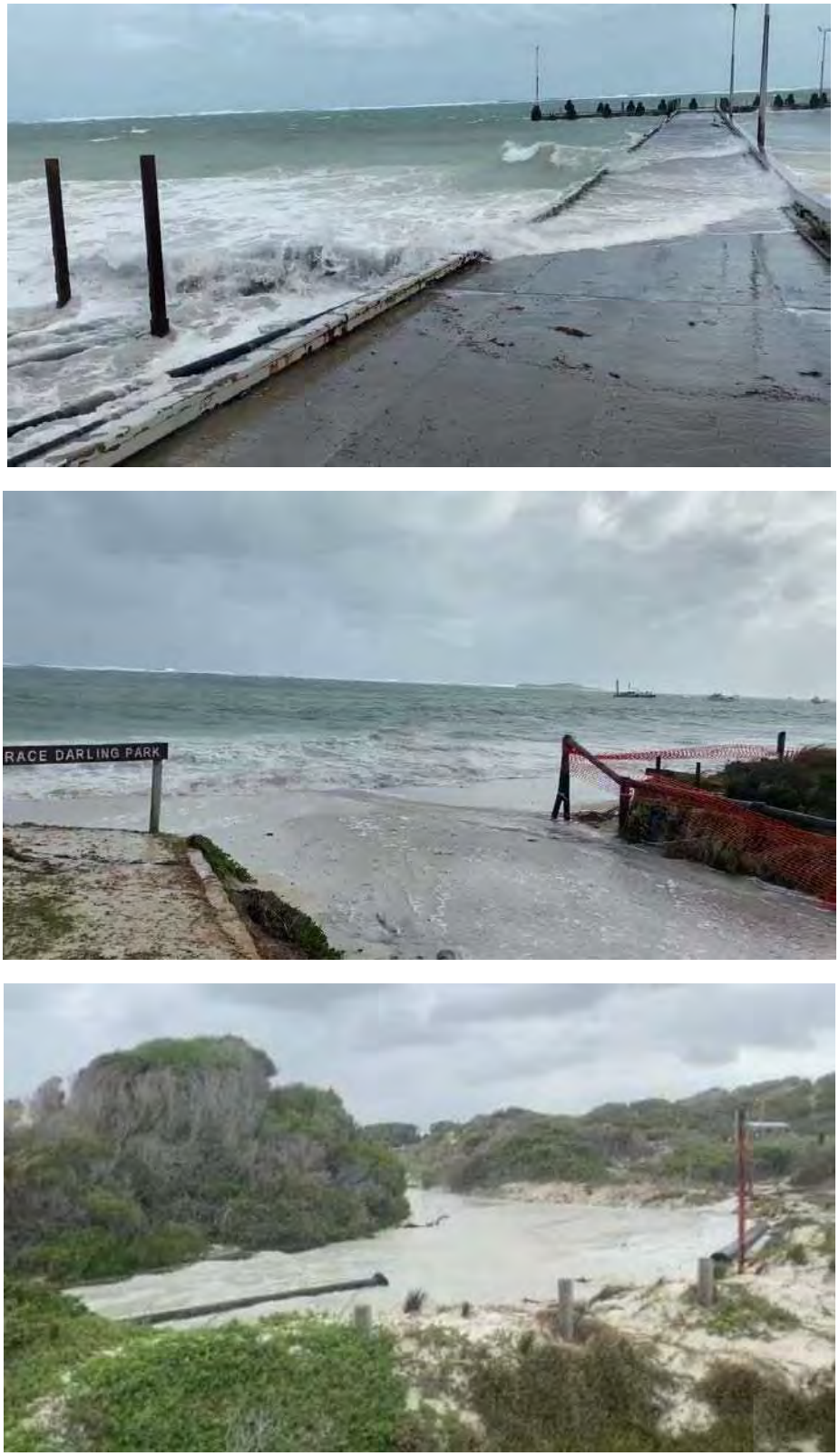


Figure 4.14: Images from Lancelin during TC Mangga storm showing elevated water levels at the jetty (upper image), Hopkins Street Track (centre Image) and Edward Island Track (Lower Image). Source. Images provided by Shire of Gingin and Lancelin Facebook Site

5. Design Event Selection

In developing a 'design' storm for coastal inundation along the Gingin study sites consideration of the following three datasets has been undertaken:

1. DoT design storm reference based on TC Ned (Seashore Engineering, 2020);
2. Baird's 10,000 yr cyclone track data set (Taylor et al, 2018); and
3. Hybrid storm event based on data from the JRA-55 model

5.1 Department of Transport Design Storm Events

Figure 2.2 and Figure 2.3 present the design storm tracks for a 500-yr ARI inundation event (based on historical event TC Ned) prepared for the DoT and presented in Seashore Engineering (2020). Appendix A.1 presents the track parameters for those events as defined in Seashore Engineering (2020). Both of those storm events have been modelled with the coupled hydrodynamic and wave model presented in the previous sections.

Seashore Engineering (2020), nor earlier documents including Seashore Engineering (2018) describe the specific derivation of the design cyclone tracks for the 500-year inundation track from the original TC Ned track. Table 5.2 presents a summary of the TC Ned track data available from the Bureau of Meteorology, the 500yr ARI DoT inundation track data presented in Appendix A, and the 500yr ARI event from the Baird Monte Carlo data base (see Section 5.2). It is noted that approaching the coast between the Gingin study area and the Perth northern suburbs, TC Ned experienced extra-tropical transition and intensified compared to early track positions further north. The assumed extra-tropical transition in the 500yr ARI event tracks are critical to the intensity and scale of those design events.

5.2 Baird Monte Carlo Cyclone Track Model

Baird's Monte Carlo data set (Taylor et al, 2018) for Australia representing a 10,000-year climatology of cyclone tracks has been analysed to identify synthetic storm events that generate storm surges with return periods between 100 and 500 years ARI.

Baird's Monte Carlo cyclone track model extend the historical record with simulated events using a stochastic-based modelling approach. Such approaches have been applied in the USA and Australian context for several years, e.g., Vickery et al (2000a, 2000b; James and Mason 1999).

Baird Australia's Monte Carlo cyclone track model covering the Australian cyclone region (90 °E to 160 °E, 10 °S to 40 °S) is based on the Bureau of Meteorology historical best track database using cyclone tracks recorded in the post-satellite era (1960/61 to 2014/15 seasons). The operation and validation of this model has been presented in Burston et al (2015) and Taylor et al (2018). The validation shows good agreement between the Monte Carlo model and the historical climatology over the northeast Indian Ocean (Figure 5.1).

Further, the incidence of tropical cyclone landfall along Western Australia coastline in the Monte Carlo model verifies well against the historical climatology. In the context of this study, the study area is near the boundary of Sectors 5 and 6 in Figure 5.2. The modelled landfall crossing in Sector 5 agrees well with the historical best track data set whilst for Sector 6 the median modelled landfall frequency is lower than the historical data set but the historical data landfall is within the 95% confidence interval model.

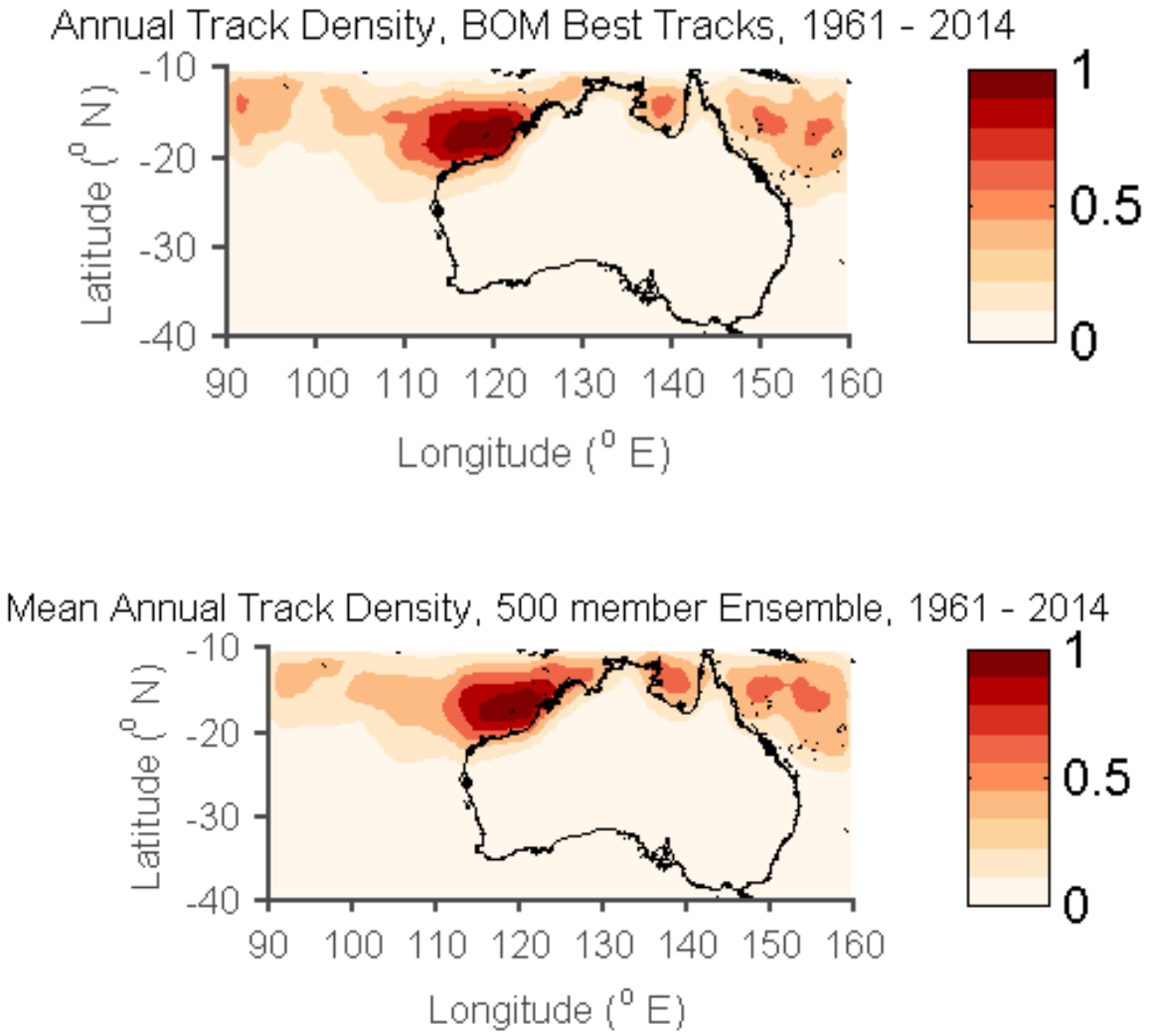


Figure 5.1: Comparison of (upper) measured and (lower) mean modelled track density of tropical cyclones in the Australian region.

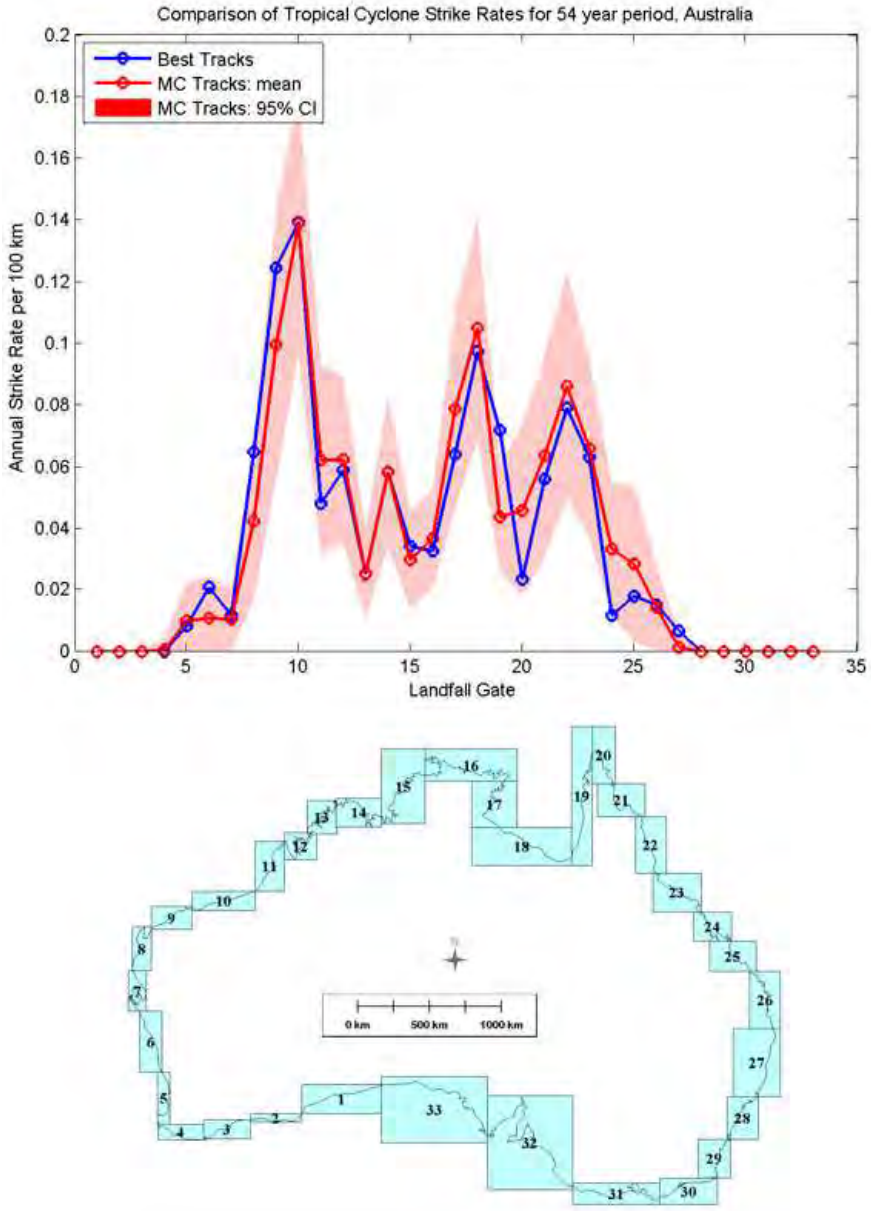


Figure 5.2: (Upper) Comparison of landfall incidence along the Australian coastline: measured (blue) BOM best track dataset: 1960/61 – 2014/2015 and modelled (red) 500-member ensemble of the Monte Carlo track model for a corresponding time period. (Lower) Coastal crossing 'gates'.

Focusing on the largest storm surge events in the study area, the Monte Carlo data set had a higher frequency of coast 'parallel' cyclones that generated large storm surges between Guilderton and Lancelin. A design cyclone track was selected based on modelled storm surge at the four focus areas of this study (Lancelin, Ledge Point, Seabird and Guilderton) and examining the track parameters for all events within 150 km of the coastline in the study area. This criterion identified approximately 400 unique storm tracks over a 10,000 year period representing a frequency of a cyclone event every 25-years on average with an intensity of Category 1 or higher. It should be noted, the event frequency in the Monte Carlo data set was not used to directly assign design cyclone tracks. To select a representative design cyclone event, the Monte Carlo data set was analysed in three steps:

1. The step first involved reviewing the cyclone tracks of the top 20 storm surge events in the data base as presented in Figure 5.3. The track analysis indicated that coast parallel tracks dominated the top 20 events in the database (≈67% of tracks) and that there was a particular event which had a coast parallel track that was positioned off the coastline to result in the maximum wind speeds being generated near the coastline along the length of the Gingin study area. This event (MC ID 67197, see red line Figure 5.3) had a return period of between 500 and 1000 years ARI based on the Monte Carlo data set with a central pressure near Lancelin of 958 hPa. The scale parameters of the storm included a Radius to Maximum Wind (RMW) of 33 km, and a radius to gales (R34) of ≈200 km.

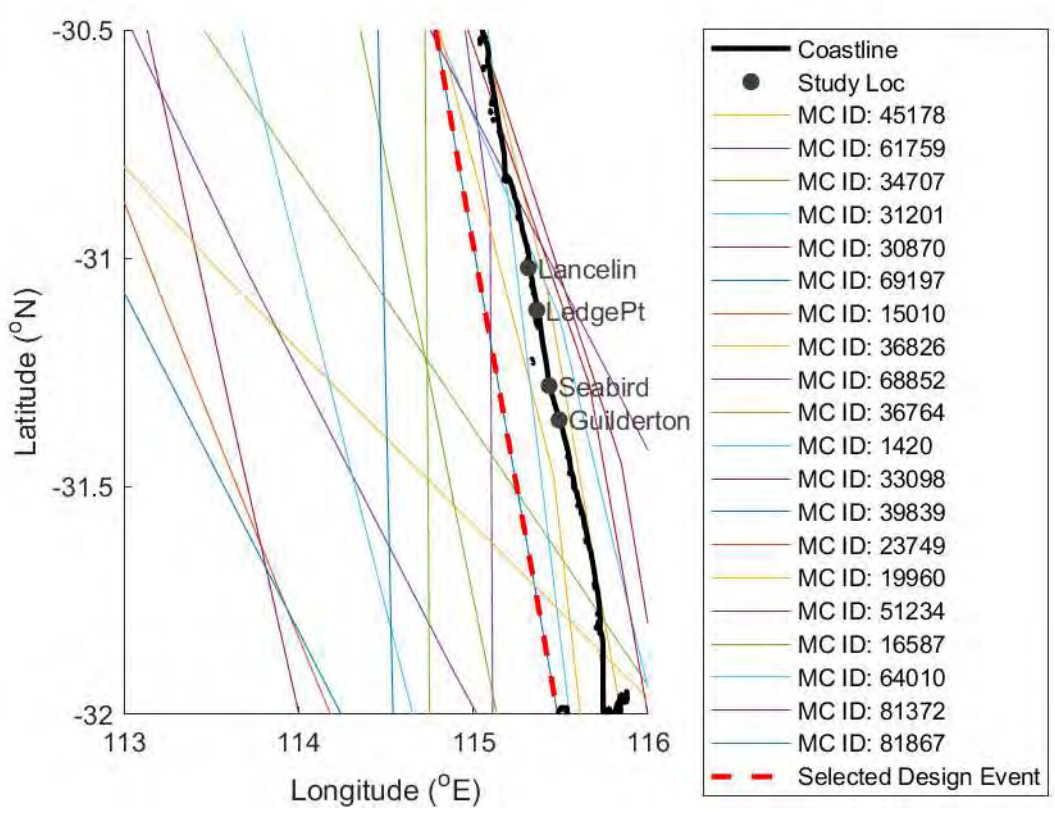


Figure 5.3: Top 20 Monte Carlo (Taylor et al, 2018) storm surge events for the Gingin study area with the selected design event (red dashed line)

2. The second step in the cyclone selection was to analyse the central pressure distribution for all Monte Carlo cyclones within 150 km of the study area and complete an Extreme Value Analysis for relatively frequent (20 to 50 yrs ARI) and extreme events (>= 100 yrs ARI) and compare the Monte Carlo data set with the post-satellite era Bureau of Meteorology track data (1970 to 2019). The post-satellite era Bureau of Meteorology track data had limited track events within 150 km of the study area, and as a result the analysis region for historical data was expanded to within 250 km.
3. The third step was to select scale parameters for the design Monte Carlo track including Radius to Maximum Winds (RMW), radius to gales (R34) and Radius to Outer Closed Isobar (ROCI). The Monte Carlo data set was analysed for all events within 150 km of the study area and 75th=percentile (25% probability of exceedance values were selected for all scale parameters based on events that were of similar central to the specific design event. The scale parameters for the design cyclones is presented in Table 5.2.

The design track selected is MC69197 shown in Figure 5.4 and this was adopted for the 20, 100 and 500-years ARI events.

Table 5.1: Comparison of historical (BoM Best Track) and Monte Carlo cyclone minimum central pressure near the study area (bold values indicate central pressure adopted for design events – see Table 5.2)

ARI (yr)	BoM Best Track (1970-2019): 250 km of study area (n=12)	Monte Carlo Data Set (10000 yr): 150 km of study area
10	995	1000
20	992	**994**
50	987	990
100	985	**985**
500	`N/A	**967**

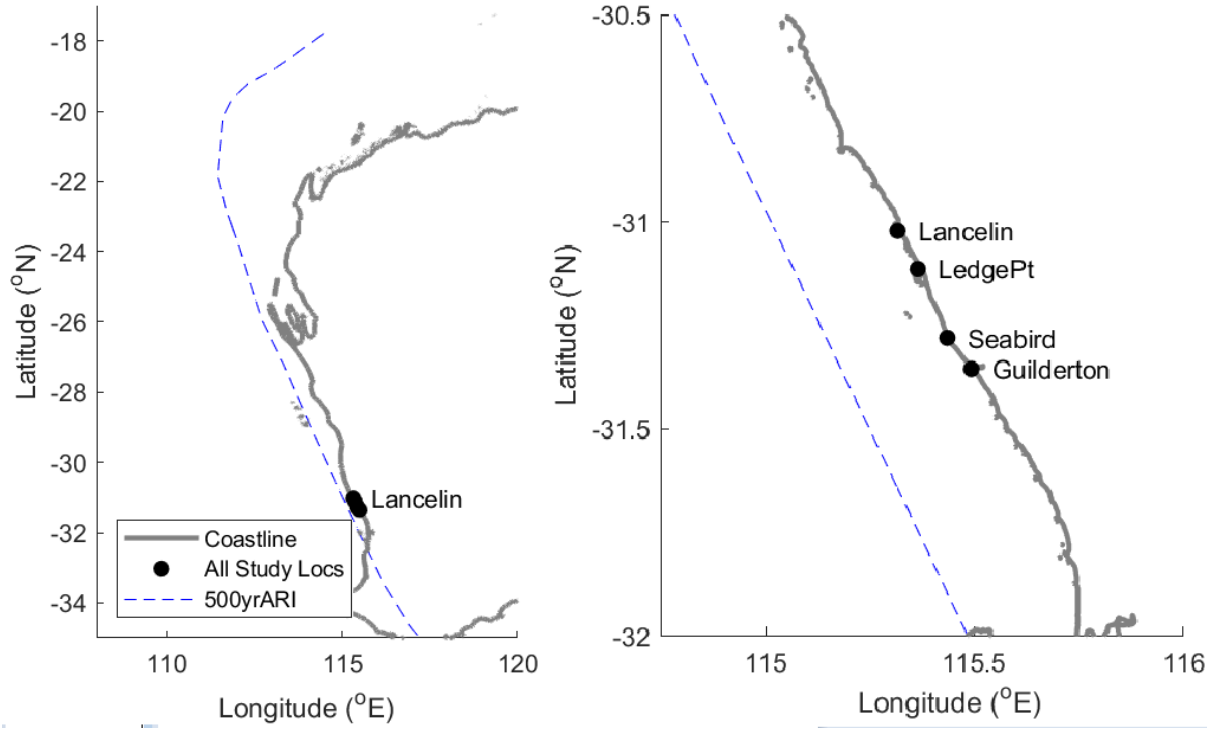


Figure 5.4: Baird MC Database – 500-yr ARI Inundation Event (MC69197)

The intensity and track parameters of the synthetic cyclone track (MC69197) are presented in Table 5.2. For reference the DoT design track based on a 'Worst Case' TC Ned is also presented (Seashore 2020). There is good agreement for the 500-year ARI event between the Baird synthetic event, and the DoT design inundation track for central present and peak wind speed, excluding forward speed asymmetry. Baird synthetic event is a relatively tight radius cyclone which has a storm scale that it is appropriate to include forward speed asymmetry in the calculation of Maximum Sustained Wind.

In Table 5.2, the Baird MC event (69197) has a MSW which includes forward speed asymmetry based on the McConochie (2004) model whereas the DoT design inundation track does not add forward speed asymmetry based on Loridan *et al* (2013) which estimated that 67% of transitioning tropical cyclones did

not exhibit a forward speed asymmetry as normally defined for a tropical cyclone (i.e. forward right quadrant for southern hemisphere – see Section 2.2.1)

The DoT track has a very large radius to maximum winds whereas the Baird track has the eye passing close to all the study locations (see Figure 5.4).

Table 5.2: Summary of design cyclone intensity and scale parameters – Baird MC and Seashore Engineering (2020) track.

ARI (yr)	Reference Event	CP (hPa)[c]	MSW (m/s)[c]	Fwd. Spd. (m/s)[c]	RMW (km)[c]	R34 (km)[c]	ROCI (km)[c]	Min. Dist. Study Site (km)[c]
20	69197	994	31.6[a]	13.6	44.7	140	350	28
100	69197	985	38.6[a]	13.6	44.2	155	400	28
500	69197	968	46.6[a]	13.6	43.9	198	500	28
500	Seashore 'Worst Case' TC Ned	972.8	36.7[b]	20.0	180	630	N/A	180
-	TC Ned	1001[d]	23.2[b, d]	20.0[d]	N/A[d]	N/A[d]	500[d]	≈70[d]

a. Including forward speed asymmetry.

b. Forward speed asymmetry not added to event undergoing extra tropical transition.

c. Abbreviations: CP = Central Pressure, MSW = Maximum Sustained Wind speed, Fwd Spd. = Forward Track speed, RMW = Radius to Maximum Wind speed (from eye location), R34 = Radius to Gale Force wind speed (from eye location), ROCI = Radius to Outer Closed Isobar (from eye location).

d. Tropical Cyclone Database (BoM, 2019). Reference at time 21:00 31/03/1989 UTC. Position: Longitude 114.8, Latitude -31.5. Noted as event undergoing extratropical transition and developing intensity from earlier track positions.

5.2.1 Consideration of TC Alby as a Design Event

Consideration has been given to modelling a shifted TC Alby as a potential design event. The historical track of TC Alby is presented in Figure 5.5. TC Alby tracked approximately 480 km west of the study area and had a central pressure at a latitude of -31ºS of 963 hPa. This resulted in a maximum sustained wind speed of approximately 43 m/s. TC Alby was undergoing extra-tropical transition at the time it tracked offshore of the study area. TC Alby was able to maintain its intensity as it tracked south of the tropics in part due to its offshore track. The design cyclones presented in Seashore Engineering (2020) have cyclones losing intensity events track closer to the coastline.

Based on Baird's previous modelling of TC Alby, it is not considered to be a realistic event to track shift close to the study site without also assuming a significant reduction in cyclone intensity. The 'Worst Case' TC Ned is also presented (Seashore 2020) as presented in Figure 2.2 and Figure 2.3 are more appropriate for the study area. However, as noted in Sections 2.2.2.1 and 4.2, a parametric wind field model is not well suited to modelling the spatial wind field for a transitioning tropical cyclone event but the data that is provided in Seashore Engineering (2020) requires a parametric wind model to be adopted.

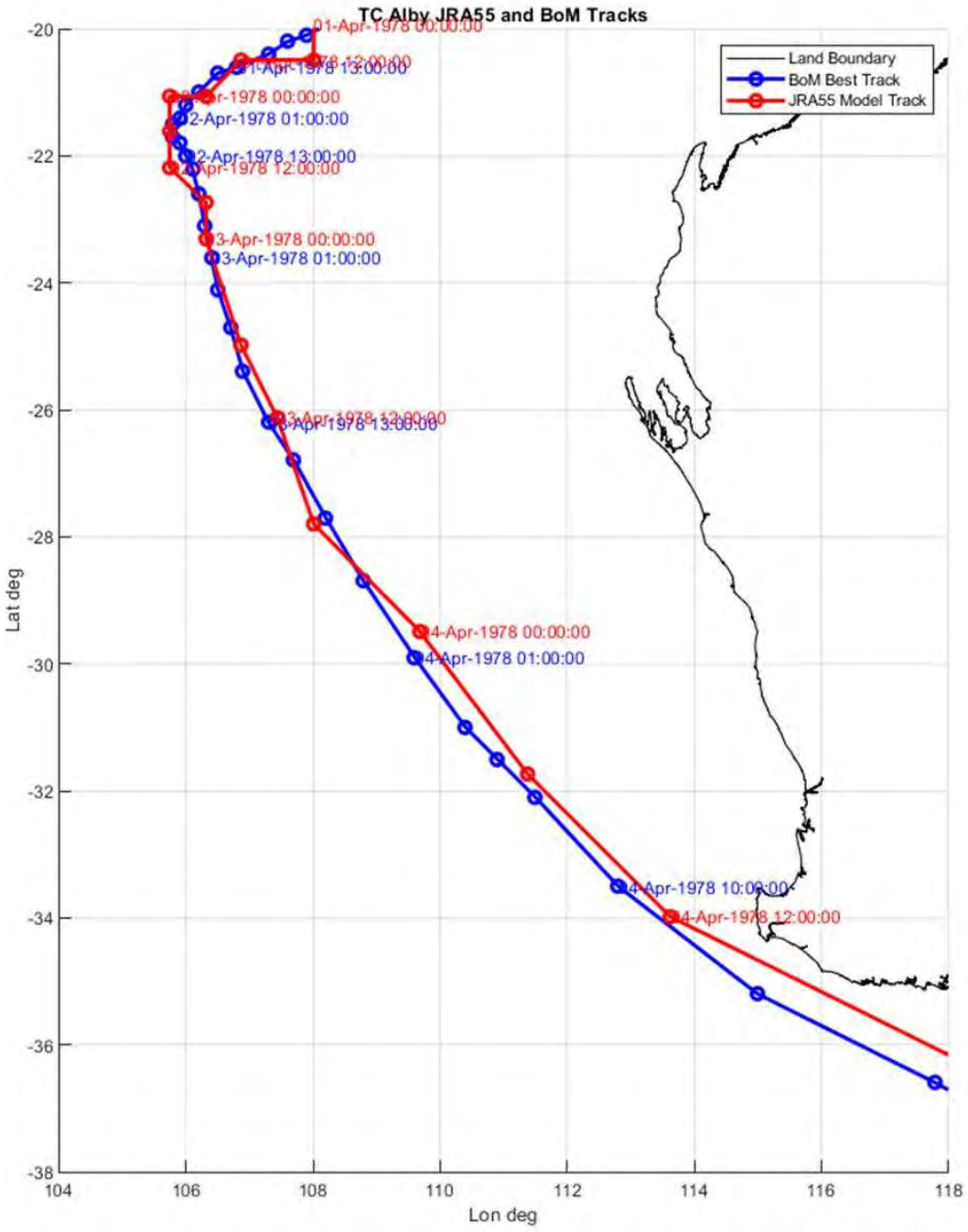


Figure 5.5: Comparisons of the TC Alby historical BoM track and the synthetic JRA-55 track

5.3 Final Recommendations for Design Events

Baird recommended the four events presented in Table 5.2 for the Gingin study area be modelled to define the design water level for the 20-year ARI, 100-year ARI and 500-year ARI. It was determined the 500-year ARI event which generates the largest total water level from the Baird (MC69197) and DoT Design Track (Seashore 2020) would be adopted as the 500-year ARI design water level for the study area. The DoT Design Track generated the largest storm surge from those two scenarios.

The events were simulated for present day and future periods across the 100-year planning period adopting sea level rise projections based on DoT recommendations:

- Current (year 2020);
- 2040 with +0.10m sea level rise allowance;
- 2070 with +0.35m sea level rise allowance; and
- 2120 with +0.90m sea level rise allowance.

In total 12 scenarios were established for design water levels across the study site for the present day and future planning periods (3 design cases, 4 ocean levels).

5.4 Concurrent Tide and Non-cyclonic Water Level in Design Events

For the design event simulations, Baird adopted the following tide and residual water level allowances in the design event modelling:

- Tide concurrent with peak surge: MHHW (see Table 3.1); and
- Residual water level (added to MSL): +0.3 m based on Figure 2.4 and Table 2.2.

5.5 Guilderton – Joint Occurrence of Ocean Inundation and catchment Flooding from the Moore River

5.5.1 Moore river Peak Level at Guilderton

Based on the literature review (DoE 2002) and Baird's analysis of the water levels in the lower Moore River, the river level around Guilderton peaks in the early autumn (April, May). River levels reached their highest point in May in the DoE 2002 study, with the bar breached for the first time in April and then breached more frequently through the winter period at lower levels. It is possible that under future sea level rise scenarios the stability of the bar may be affected, however this has not been investigated in the current study.

The breaching of the bar provides a control mechanism for limiting flood inundation at Guilderton from the Moore River during extreme catchment-based runoff. The measured data from DoE (2002) showed a peak level of approximately 2.0 m AHD prior to the breaching of the bar, with lower peaks thereafter. This control mechanism at the bar safeguards Guilderton from this type of flooding event. Photos supplied by The DWER for a major flooding event breaching the bar in 1995 are shown in Figure 5.6.



Figure 5.6: Moore River Mouth Guilderton - Large Flood Event in 1995 (DWER)

5.5.2 Joint Occurrence of Moore River Catchment Based Flood and Ocean Flooding

Joint occurrence of catchment peak water level from Moore River and ocean peak water level in cyclone events is not expected to be a critical consideration for peak inundation levels in Guilderton. It is expected that the upstream size of the Moore River catchment will delay the timing of peak catchment-based flows to Guilderton during extreme events.

Of greater relevance, the natural land levels around Moore River at Guilderton rise sharply as shown in Figure 5.7. Development is set well above the river, with house development at a minimum of 5 m AHD but generally at levels higher than 10 m AHD. This level is well above any potential inundation threat from the

river or ocean even under sea level rise projections. The lowest section of the riverbank where infrastructure is located is around the Caravan Park and car park, which are located at between 3 m AHD and 5 m AHD as shown in Figure 5.7. This elevation level is above the extreme ocean levels in historical cyclone cases (Appendix B) and the peak water levels of the Moore River in the measured data (DoE 2002) however may be within the extreme flood range for the Moore River.



Figure 5.7: Guilderton Elevation Levels around Moore River based on LiDAR (2016)

6. Design Water Levels

6.1 Analysis of Measured Data – Extreme Value Analysis

The measured water level from the tide gauges at Jurien Bay and Lancelin were analysed using standard extreme value analysis (EVA) methods to extrapolate the expected design water levels for return periods of 2, 5, 10, 20, 50, 100, 200 and 500 years with a 95% confidence interval. The EVA provides a reference against the modelled outcomes for the extreme design cyclone cases.

For Jurien Bay and Lancelin the water level records were filtered with a 72-hour period, and a threshold of 0.88m to 0.77m respectively to obtain ~20 peak events over the 20 to 30 year data record period. Extreme design values were obtained using three extreme distributions; Weibull, Gumble and Generalised EVA.

Results are summarised in Table 6.1 for Jurien Bay and Table 6.2 for Lancelin. It is noted that EVA extrapolation above the 50yr ARI return period is provided for reference but should be treated with caution due to the limited duration of the measured data record.

Table 6.1: Extreme Value Analysis on Jurien Bay Measured Water level Data Record (1991 - 2020)

Return Period ARI	Design WL (m AHD)	Lower Bound (m AHD)	Upper Bound (m AHD)
2	0.82	0.79	0.84
5	0.88	0.82	0.93
10	0.92	0.84	1.00
20	0.97	0.86	1.09
50	1.04	0.88	1.21
100[1]	1.10	0.89	1.31
200[1]	1.15	0.90	1.41
500[1]	1.23	0.91	1.55

Note 1. ARI provided for reference but should be treated with caution due to the 30-year duration of measured data record.

Table 6.2: Extreme Value Analysis on Lancelin Measured Water level Data Record (1993-1997, 2003-2012)

Return Period ARI	Design WL (m AHD)	Lower Bound (m AHD)	Upper Bound (m AHD)
2	0.67	0.65	0.69
5	0.77	0.73	0.82
10	0.84	0.75	0.94
20	0.92	0.77	1.06
50	1.01	0.77	1.24
100[1]	1.07	0.77	1.38
200[1]	1.14	0.76	1.52
500[1]	1.23	0.74	1.72

Note 1. ARI provided for reference but should be treated with caution due to the limited duration of the measured data

6.2 Design Cyclone Model Outcomes

The recommended design cases were assessed in the model system with the peak water levels from the model cases summarised in Table 6.3 for the four towns of the study area. It is noted:

- The peak water levels are generally consistent across the four towns with up to 0.2m variation at each respective ARI;
- For the synthetic track cases at 20yr ARI, 100yr ARI and 500yr ARI Lancelin shows the highest water levels comparatively and Ledge Point the lowest.
- For the Seashore design 500yr ARI case, Lancelin shows the highest water levels comparatively and Seabird the lowest;
- The modelled 20yr ARI water level for Lancelin in Table 6.3 is slightly above the 95% confidence level of the EVA results at Lancelin in Table 6.2 calculated from the 13 years of measured data; and
- A comparison of the peak water levels from the 500yr ARI synthetic track MC 69197 and the DoT design 500yr ARI track (Seashore 2020) shows the DoT design 500yr ARI case produces a higher peak water level. As stated in Section 5.3, the adopted design case for the 500yr ARI event is based on the most severe of these two approaches.

Table 6.3: Summary of design cyclone outcomes. Peak modelled water level across the four towns in the Gingin study area.

ARI (yr)	Reference Event	Lancelin (m AHD)	Ledge Point (m AHD)	Seabird (m AHD)	Guilderton (m AHD)
20	69197	1.3	1.2	1.3	1.3
100	69197	1.5	1.3	1.4	1.4
500	69197	1.8	1.6	1.7	1.7
500	Seashore ‘Worst Case’ TC Ned	2.0	1.9	1.7	1.8

6.3 Nearshore Wave Setup

The effect of wave action on nearshore water levels has been included in the numerical modelling. Wave setup is generated within the coupled Delft-FM model as a result of radiation stress gradients from the wave field being added to the hydrodynamic model. However, Delft-FM does not represent the shoreline wave setup at fine detail and for lower period wave conditions the modelled wave setup from Delft-FM model will underestimate the total wave setup observed at the shoreline. Baird (2020a) identified that the radiation stress model in Delft-FM may overestimate nearshore wave setup for very long period storm swell conditions (i.e. $T_p \approx 15s$) as was observed in TC Alby at Busselton (see Baird, 2020) and for the large scale storm event in the DoT design track (Seashore 2020) adopted in this study. assessment as follows:

- For the cases assessed using the synthetic design cyclone track (MC69197) additional shoreline wave setup was added to the modelled water levels through the peak of the respective events as the nearshore wave periods were in the range of 7 to 10 s (T_p). Additional wave setup was estimated using the Nielsen and Hanslow (1991) wave setup distributions with inputs from the modelled cases (Hs, Tp) and beach slope; and
- For the adopted 500yr ARI design water level based on the DoT design track (Seashore 2020) the scale and intensity of the event in the model resulted in very long period nearshore waves ($T_p \approx 17s$) and the Delft-FM modelled wave setup was assessed as suitably conservative and no additional shoreline wave setup was added.

It is noted that the Nielsen and Hanslow (1991) wave setup model is most applicable for an open coast sandy beach and does not account for the full complexity of the wave setup on a shoreline with complex nearshore bathymetry, including outer reefs and rock outcrops as occurs in the study area. However, it is important to note that in the approach adopted in this study, Delft3-FM model provides a wave setup solution for the water level inside the outer breakpoint (i.e. inside the outer reef) and that the Nielsen and Hanslow (1991) wave setup models applied to the synthetic design cyclone track to provide a solution to the additional setup that occurs close to the shoreline from the final shoreline wave breaking. Baird has obtained reasonable comparisons of Nielsen and Hanslow (1991) wave setup and run-up model based on post-event survey and shoreline inspection data at a number sites including Port Hedland Spoilbank (TC Veronica March 2019, Baird Australia 2020), Collaroy-Narrabeen (June 2016, Burston et al 2016) and Busselton (TC Alby April 1978, Baird Australia 2020b).

6.4 Climate Change and Impacts on Cyclone Intensity and Frequency

The frequency of storms with tropical cyclone strength winds offshore of Gingin is very low and as a result there is considerable uncertainty in the long-term cyclone climatology of the region. For a storm like TC Alby or TC Ned whose intensity and storm scale was influenced by the combination of a rapidly moving cold front interacting with a transitioning tropical cyclone is an example of two discrete storm systems, each with a relatively low probability of occurrence occurring at the same time resulting in this being a rare combination of storm conditions.

In addition to uncertainty in historical climatology, climate change may alter cyclone climatology. There are no definitive projections of the impacts of climate change on the cyclone climatology of the Gingin region. The latest consensus literature, for example Knutson et al (2019) state medium to high confidence in the following changes to global cyclone climatology due to climate change:-

- Increase in precipitation with a median increase of 14%;
- Increase in global average event intensity with average peak intensity increasing ≈ 5%;
- An increase in proportion of events that reach severe intensity (CAT 4 and 5).

Knutson et al (2019) reports low confidence in the following:

- Increase in poleward extent of tropical cyclone events;
- An overall decrease in cyclone frequency; and

- An increase in overall number of severe cyclone events (CAT 4 and 5).

Continuing sea level rise is the most definitive climate change impact on coastal inundation along the Gingin study area. There is a high degree of confidence that sea levels will continue to rise in the future, likely at an increasing rate. In accordance with SPP2.6, sea level rise for future planning horizons is included for coastal inundation level in future planning periods but no changes in cyclone climatology have been considered. Sea level rise projections are summarised in Table 3.2.

6.5 Final Design Water Levels

The final design water levels represent the peak water level during the respective cyclone events and include near shore wave setup. Based on the model outcomes, the peak level is experienced for a period of 2 hours or less.

The final design levels have been adjusted to Australian Height Datum (AHD) based on the conversion of model results (the model datum is in mean sea level). It is noted that a common adjustment of MSL to AHD of -0.07m has been applied for the whole Gingin study area based on the Two Rocks Marina data presented in Table 3.1 to overcome the conversion anomaly at Lancelin (refer end Section 3.1.1). This represents a conservative approach.

The final design water levels are shown in Table 6.4 for Lancelin. Water level is presented for 3 locations along the Lancelin shoreline – north, mid and south. The northern shoreline is more exposed to the design storms and modelled peak water levels are generally higher. The applicable shoreline sections are shown in Figure 6.1.

Table 6.4: Lancelin Final Design Water Levels (Datum m AHD)

Return Period	20yr ARI			100yr ARI			500yr ARI		
Timeframe	North	Mid	South	North	Mid	South	North	Mid	South
2020	1.3	1.2	1.2	1.5	1.3	1.3	2.0	2.0	1.8
2040	1.4	1.3	1.3	1.6	1.4	1.4	2.1	2.1	1.9
2070	1.7	1.5	1.5	1.9	1.7	1.6	2.3	2.3	2.2
2120	2.2	2.1	2.1	2.4	2.2	2.2	2.9	2.9	2.7

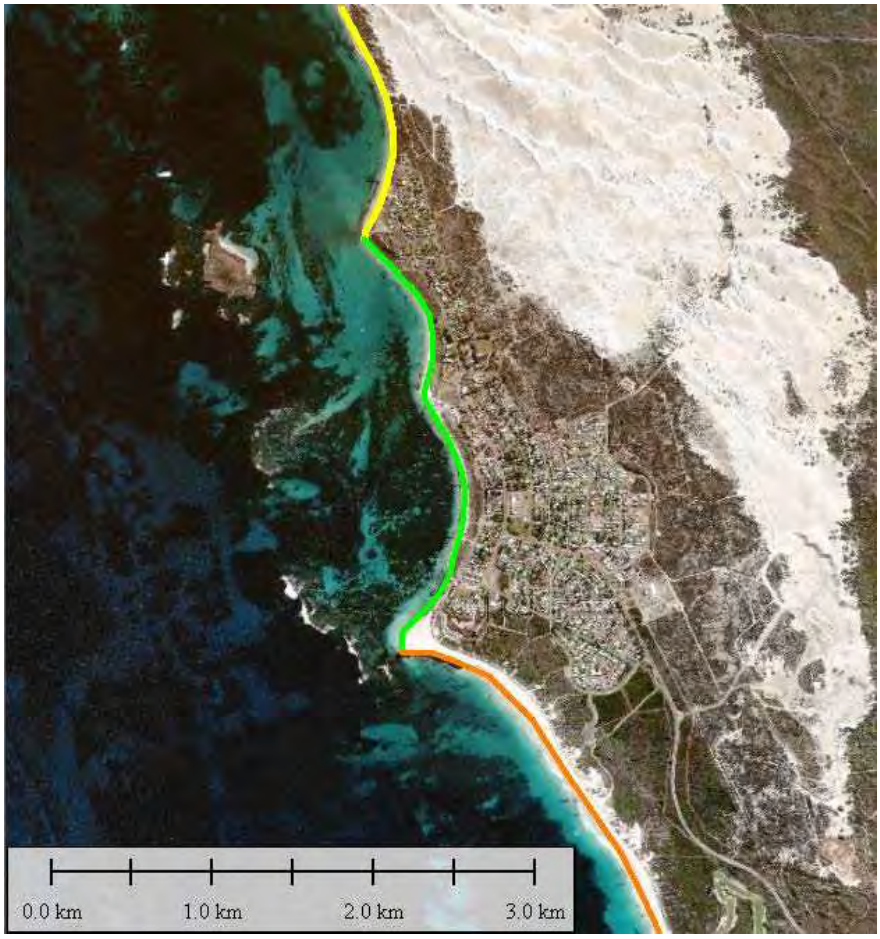


Figure 6.1: Lancelin Shoreline Sections for Design Water Level. North (Yellow), Mid (Green) and South (Orange)

The final design water levels are shown in Table 6.5 for Ledge Point. Water level is presented for 2 shoreline sections - north and south. The applicable shoreline sections are shown in Figure 6.2.

Table 6.5: Ledge Point Final Design Water Levels (Datum m AHD)

Return Period	20yr ARI		100yr ARI		500yrARI	
Timeframe	North	South	North	South	North	South
2020	1.2	1.1	1.3	1.2	1.9	1.8
2040	1.3	1.2	1.4	1.3	2.0	1.9
2070	1.5	1.5	1.7	1.6	2.2	2.1
2120	2.1	2.0	2.2	2.1	2.8	2.7



Figure 6.2: Ledge Point Shoreline Sections for Design Water Level. North (Yellow) and South (Orange)

The final design water levels are shown in Table 6.6 for Seabird and Table 6.7 for Guilderton. Modelled water level is generally consistent along the shoreline in these two locations in the design cyclone events.

Table 6.6: Seabird Final Design Water Levels (Datum mAHD)

Return Period	20yr ARI	100yr ARI	500yr ARI
2020	1.3	1.4	1.7
2040	1.4	1.5	1.8
2070	1.7	1.8	2.0
2120	2.2	2.3	2.6

Table 6.7: Guilderton Final Design Water Levels (Datum mAHD)

Return Period	20yr ARI	100yr ARI	500yr ARI
2020	1.3	1.4	1.8
2040	1.4	1.5	1.9
2070	1.7	1.8	2.1
2120	2.2	2.3	2.7

6.6 Guilderton Inundation Level Based on Influence of Catchment based flooding from Moore River

It is noted that that the design water levels from ocean based extreme events for Guilderton in Table 6.7 at all return periods for the present to 2070 are lower than the peak river level from lower Moore River reported in the measured data (DoE 2002). Based on the reported data from the lower Moore River the river level will reach approximately 2.0m AHD at Guilderton before the bar breaks (DoE 2002).

For the design case reported in Table 6.7 at planning year 2120 with 0.9m sea level rise, the design water level at the 500yr ARI is 2.7m AHD and in this scenario it is assumed the bar would be breached and the offshore water level transferred into the lower Moore River to Guilderton through the peak of the event.

7. Inundation Mapping

The design water levels presented in the previous section have been used to produce spatial mapping of the coastal inundation extents for the four towns of the study area. This mapping represents the S4 inundation component under State Coastal Planning Policy SPP2.6.

The inundation mapping is presented in Appendix C, incorporating the following:

1. The inundation depth in the maps has been derived from a 'bathtub mapping' approach which applies the peak ocean level determined from the design cases at each of the towns (Table 6.4 to Table 6.7) over the high resolution LiDAR data.
2. Hydro-connectivity between inland flooded areas and the ocean has been established to ensure isolated pockets of inundation at low points inland are not shown in the map.
3. The requirement of SPP2.6 to assess the peak still water level in the design events against the dune profile areas to identify where potential dune breaching occurs in extreme events has been incorporated in the mapping approach.
4. The projected coastal erosion of the topography of each coastal town in future planning periods (coastal setback lines) and the influence on the extent of coastal inundation is considered

The above coastal processes and techniques that have been applied in the development of the spatial mapping are outlined in detail in this section.

7.1 Flood Map Layout Format

To allow for appropriate resolution in the mapping the flood mapping series in Appendix C.1 has been presented in a 3-map layout for Lancelin (Figure 7.1), 2-map layout for Seabird and Ledge Point and for Guilderton is shown on one map as presented in Appendices C.2, C.3 and C.4 respectively.

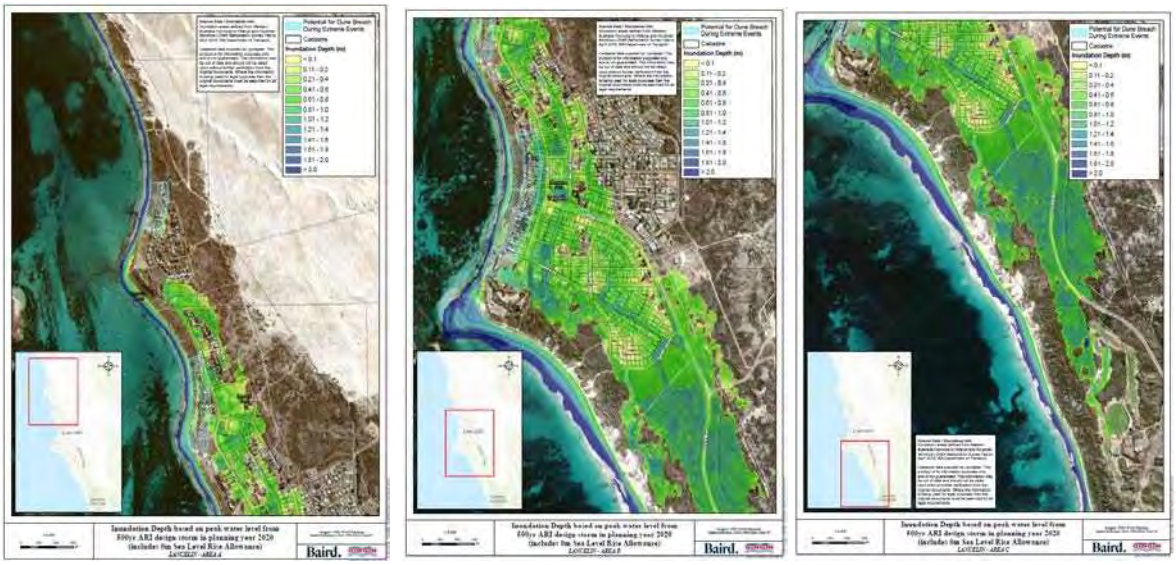


Figure 7.1: Example Map Series for Lancelin. 500yr ARI case at planning year 2020. Left to right the maps show the north, central and southern region of the Lancelin area (Full mapping is in Appendix C).

Flood depth is shown on the mapping sets in increments of 0.1m. The cadastre information from Landgate has been overlaid to provide reference to development areas and individual land parcels.

Inundation risk is highest for Lancelin, where the foredune provides a barrier that protects the lower lying inland areas from ocean-based flooding during extreme events. The stability of the foredune in severe storm events when subjected to elevated water level and large waves was assessed, to determine if there was potential for dune breaching which could lead to flooding of the inland areas (Section 7.2).

The mapping is presented for Lancelin for the three ARI design events (20yr, 100yr and 500yr) at 4 planning periods (2020, 2040, 2070, 2120). Inundation of inland areas occurs from planning year 2070 for the 20yr ARI and 100yr ARI event and from planning year 2020 for the 500yr ARI event (discussed in more detail in next section).

For Ledge Point, Seabird and Guilderton only the 500yr ARI case in the planning year 2120 is presented in Appendix C mapping. For these locations, the peak water level in the design events is contained in the foreshore areas, even under sea level rise scenarios.

7.2 Dune Stability Analysis

For the Lancelin shoreline where a foredune area protects the lower lying areas landward (Figure 7.2), the stability of the dune under elevated water levels and extreme waves is a key consideration. The foredune elevation ranges from 2m AHD to as high as 10m AHD offering natural protection to the low-lying inland areas which are at 1.0m AHD to 1.5m AHD.

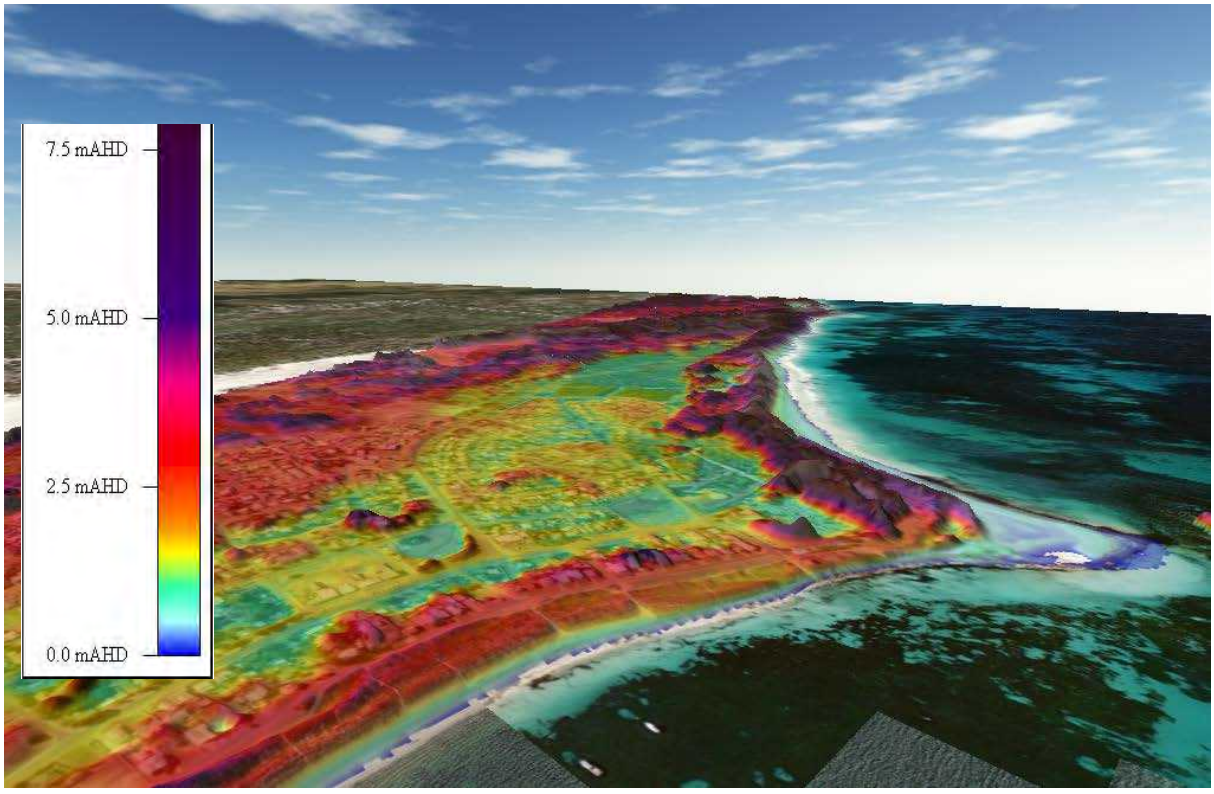


Figure 7.2: View looking south over Lancelin showing height of foredune in relation to areas landward (LiDAR imagery 3D render). The foredune elevation ranges from 2m AHD to 10m AHD offering natural protection to the low-lying inland areas which are at 1.0m AHD to 1.5m AHD.

7.2.1 Dune Stability under SPP2.6

An important consideration for the determination of inundation areas (S4 component) under the guidelines of SPP2.6, relates to the ability of the barrier dune to be maintained in extreme events under the combined

process of elevated water levels and large waves. Where a continuous barrier dune is present in the shoreline areas, the capacity of the dune to provide protection from inundation should be assessed based on the cross-sectional area of the dune above the reference datum taken as the expected peak steady water level in the design storm.

A cross sectional area less than 100 m^2/m above the reference datum is assumed to be completely removed during storm activity. Under such conditions the storm inundation extent (S4) is calculated assuming the dune is removed, and the dune breach can convey flows inland. If the cross-sectional area is greater than the 100 m^2/m above the reference datum, the general dune structure is maintained through the storm event and provide a barrier against flooding for inland areas.

7.2.2 Dune Stability – Lancelin Transect Analysis

For Lancelin, the design water levels in Table 6.4 are adopted as the likely peak steady water level in each respective design event. The levels were assessed against the elevation of the foredune area to determine if the dune will be maintained in the respective design events or would be breached consistent with the approach outlined in SPP2.6 (Section 7.2.1).

To assess the dune stability, elevation profiles located at 20m to 50m intervals along the lowest lying sections of the Lancelin coast were assessed in detail using the LiDAR data. The locations for the detailed analysis are indicated in Figure 7.3. Areas outside of these transect regions are sections where there is extensive height and / or volume in the natural dune system that will not be breached in the design events.



Figure 7.3: Lancelin – Analysis transects along the coast to examine dune system capacity to be maintained in extreme events.

The analysis has been applied in the 12 design cases for Lancelin (4 planning periods, 3 return periods) to determine where dune breach may occur and result in flow paths for inland flooding. The analysis showed the dune system will not breach until the design water level reaches or exceeds 1.5m AHD in the lower two sections of transects, whilst the level of 2.0m and above would breach the northern section.

The key design events where breaching occurs is summarised in Table 7.1. In summary:

- dune breach would commence at the 2070 timeframe under assumed sea level rise for the mid-sections and at 2120 for the north section at design storms equivalent to the 20yr ARI and 100yr ARI; and
- Under the 500yr ARI water level dune breach occurs in all scenarios (present day and all future time periods).

Table 7.1: Lancelin Dune Breach Summary

	20yr ARI		100yr ARI		500yr ARI	
Timeframe	North	Mid	North	Mid	North	Mid
2020	No	No	No	No	Breach	Breach
2040	No	No	No	No	Breach	Breach
2070	No	Breach	No	Breach	Breach	Breach
2120	Breach	Breach	Breach	Breach	Breach	Breach

The breaching of the dune at the critical water levels in Table 7.1 has been incorporated into the mapping cases in Appendix C.1 with the key dune breach areas marked on the map (refer example in Figure 7.10). In summary:

- The stability of the foredune in severe storm events when subjected to elevated water level and large waves was assessed, to determine if there was potential for dune breaching which could lead to flooding of the inland areas.
    - For the section of coast north from Grace Darling Park, there is the potential for dune breaching of the foredune in severe events. The dune system is estimated to be able to withstand the 20yr ARI event and the 100yr ARI event in the present day (2020). Under future sea level rise scenarios for the 2070 planning period (+0.4m) and beyond, breaching of the foredune may occur. A storm event of 500yr ARI magnitude is estimated to breach the dune system in the present day and all future planning periods.
    - For the section of coast south of Grace Darling Park, the dune system is significant and breaching of the dune would not occur in any of the extreme events, including under future sea level rise scenarios.
- For Ledge Point, Seabird and Guilderton the developed areas are not at risk of inundation, with the natural topography set well above the extreme design water levels, including under future sea level rise scenarios.

7.3 Wave Runup

7.3.1 Wave Runup Calculations for Lancelin

The process of wave runup is discussed in Section 2.2.5. Wave runup and setup is the maximum vertical extent of wave uprush on a beach which increases with increasing wave height, wave period and beach slope. Waves that occur during cyclones can reach areas not usually reached and can carry immense power that also lead to coastal erosion and breaching of dunes.

The wave runup levels at the shoreline for Lancelin have been calculated from the design extreme model cases based on the Nielsen and Hanslow (1991) method with inputs from the modelled cases (Hs, Tp). The processes are shown in Figure 7.4 with the Lancelin shoreline analysis adopting a beach slope of 1:5 which is representative of a shoreline profile as it develops toward an eroded beach scarp at which point property and structures may then limit the landward movement of the shoreline.

Baird has obtained reasonable comparisons of Nielsen and Hanslow (1991) wave setup and run-up model based on post-event survey and shoreline inspection data at a number sites including Port Hedland Spoilbank (TC Veronica March 2019, Baird Australia 2020), Collaroy-Narrabeen (June 2016, Burston et al 2016) and Busselton (TC Alby April 1978, Baird Australia 2020b). In particular, following the June 2016 storm that impacted on Collaroy-Narrabeen (NSW), the Nielsen and Hanslow (1991) had good agreement with surveyed wave run-up levels behind a steep dune scarp.

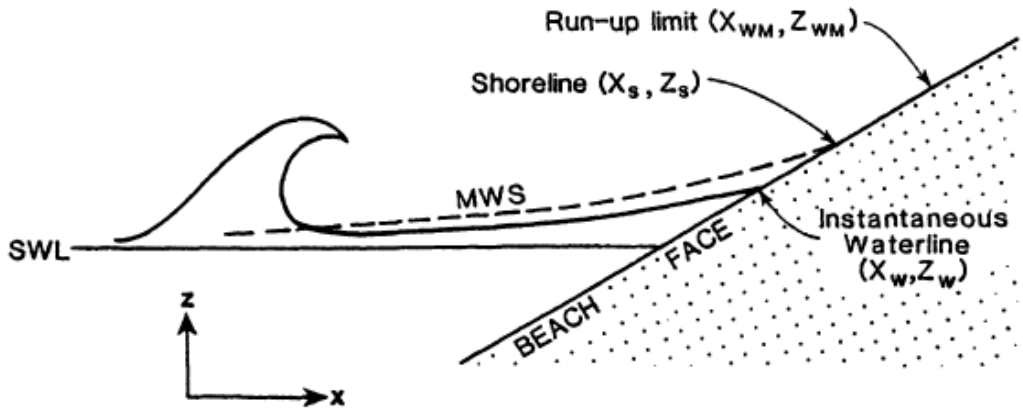


Figure 7.4: Figure showing shoreline processes of wave runup and setup under extreme wave conditions - still water level (SWL), mean water surface (MWS) and runup limit (Nielson and Hanslow 1991)

Calculated wave runup levels for Lancelin are summarised in Table 7.2 for the design cases. The wave runup levels are notably higher for the 500yr ARI case compared with the lower ARI events due to the modelled wave period for this case which had a peak period of 17s at the peak of the storm (T_p=17s).

Table 7.2: Lancelin Wave Runup Level (Datum m AHD)

Return Period	20yr ARI			100yr ARI			500yr ARI		
Timeframe	North	Mid	South	North	Mid	South	North	Mid	South
2020	2.8	2.5	3.1	3.3	3.2	3.6	7.5	6.4	7.2
2040	2.9	2.6	3.2	3.4	3.3	3.7	7.6	6.5	7.3
2070	3.2	2.8	3.5	3.7	3.5	3.9	7.8	6.7	7.6
2120	3.7	3.4	4.0	4.2	4.1	4.5	8.4	7.3	8.1

7.3.2 Calculated Wave Runup Level for Ledge Point, Seabird and Guilderton

For the three towns south of Lancelin, the natural land elevation rises steeply from the foreshore area. The crest of the foredune is at a natural elevation level well above the design water levels in the extreme events. The elevation is shown for Seabird and Ledge Point in Figure 7.5 and for Guilderton in Figure 5.7.

At these towns, the risk of inundation is not like Lancelin where a foredune protects lower lying inland areas. Even for the most extreme 500yr ARI design case in the planning year 2120 with 0.9m sea level rise the peak water level is contained within the foreshore areas. The top of the foredune where development is seen in the foreshore areas based on the LiDAR data is at:

- Approximately 6m AHD at Ledge Point;
- Approximately 8m AHD at Seabird; and
- >20m AHD at Guilderton.

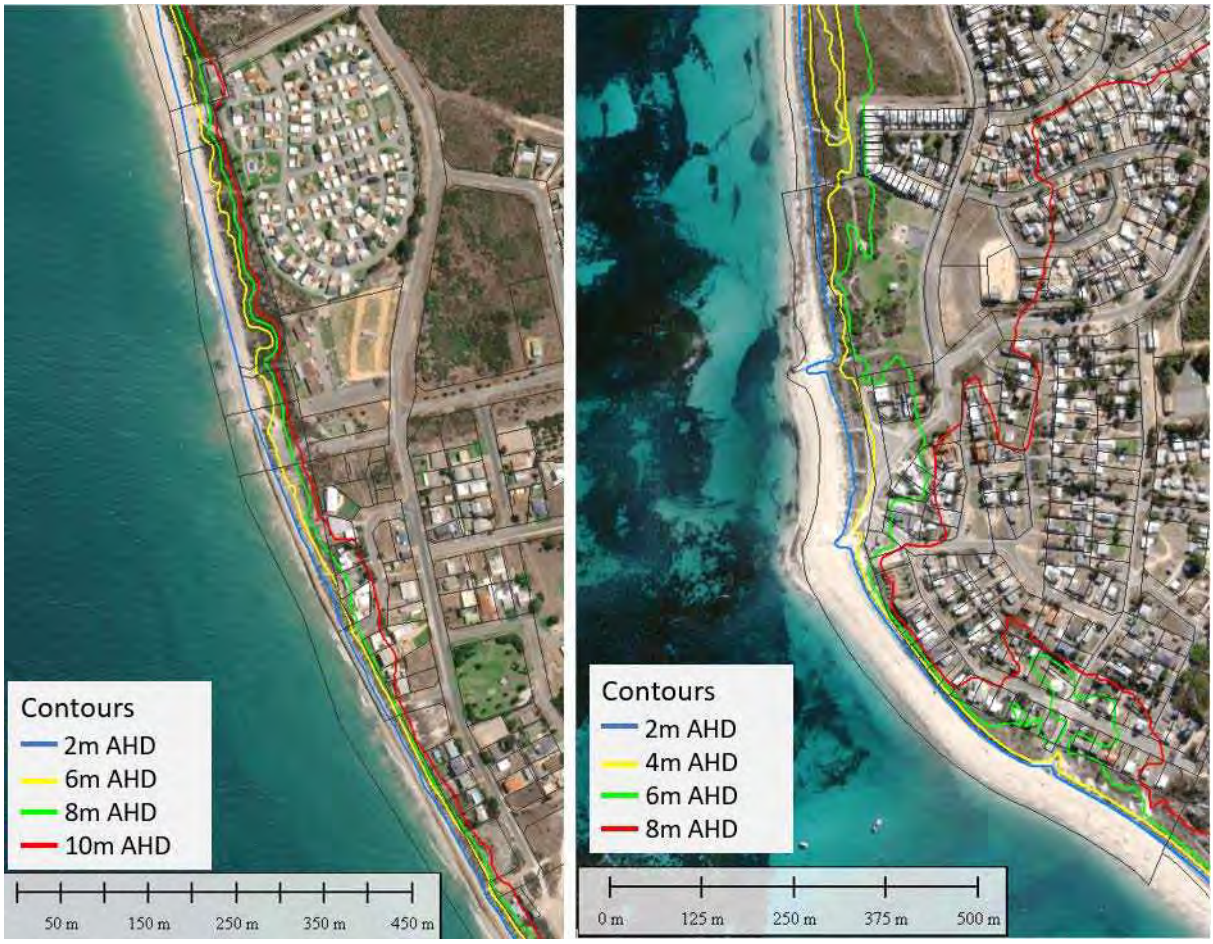


Figure 7.5: Elevation contours adjacent the foredune for the towns of Seabird (left) and Ledge Point (right) calculated based on 2016 LiDAR (DoT 2016). The contours show the natural land elevation rises steeply from the foreshore.

The wave runup calculations for Ledge Point, Seabird and Guilderton are summarised in Table 7.3, Table 7.4 and Table 7.5 respectively. The wave runup level gives an indication of the level at which wave processes during extreme events could impact the developed areas adjacent the foredune due to wave action through wave runup, over wash and sea spray.

For Ledge Point the wave runup level when compared against the LiDAR data indicates there would be some minor influence from wave runup process to the development in the foreshore areas in the south under an extreme 500yr ARI event in future planning periods (potential over wash, sea spray). At Seabird and Guilderton the foredune would be at a level to contain projected wave runup influence.

Table 7.3: Ledge Point Wave Runup Level (Datum m AHD)

Return Period	20yr ARI		100yr ARI		500yrARI	
Timeframe	North	South	North	South	North	South
2020	2.8	2.7	3.2	3.1	7.1	6.7
2040	2.9	2.8	3.3	3.2	7.2	6.8
2070	3.2	3.0	3.6	3.4	7.5	7.1
2120	3.7	3.6	4.1	4.0	8.0	7.6

Table 7.4: Seabird Wave Runup Level (Datum m AHD)

Return Period	20yr ARI	100yr ARI	500yr ARI
2020	2.6	3.0	6.9
2040	2.7	3.1	7.0
2070	3.0	3.3	7.3
2120	3.5	3.9	7.8

Table 7.5: Guilderton Wave Runup Level (Datum m AHD)

Return Period	20yr ARI	100yr ARI	500yr ARI
2020	3.0	3.3	7.7
2040	3.1	3.4	7.8
2070	3.4	3.6	8.1
2120	3.9	4.2	8.6

7.4 Coastal Processes Setback Lines

The coastal processes allowances (setback lines) for the towns of Lancelin, Ledge Point and Seabird have been calculated for the Shire (as reported in MRA 2015b, MRA 2016a and MRA 2016b). The Gingin CHRMAP report has adopted the coastal setback lines for assessment of coastal hazard risk from erosion in future planning periods. The coastal processes lines (setback lines) represent the horizontal distance from the foreshore area over which coastal processes may be active.

To incorporate the projected setback lines and the way in which they influence the extent of coastal inundation in this current study Baird have plotted the lines for the three towns in Figure 7.6, Figure 7.7 and Figure 7.8. It is important to note that the lines do not represent the shoreline position in future planning periods, rather the area over which the coastal processes have been calculated to potentially act based on the guidelines of SPP2.6. The setback distance represents the combined allowance impacts from erosion under a severe storm (S1), historical rate of shoreline change (S2) and an allowance based on sea level rise (S3). An uncertainty allowance of 0.2m a year is also included in the calculations. In many cases the

S3 component is dominant in the setback representing up to 90m of the setback allowance over the 100-years planning period.

For Lancelin, the coastal processes in future planning periods is incorporated into the method by which the dune stability calculation is undertaken (refer Section 7.2.2). The impact of sea level rise over time is included in the still water level that underpins the analysis. The inundation mapping presented for Lancelin in Appendix C reflects the effect of sea level rise on dune capacity but it is noted that it does not recognise potential for changes to the dune features as a result of landward shift of the coastal processes' setback line in future planning periods. There is considerable uncertainty over how the future shoreline evolution will occur over the 50year and 100-year planning period and a more detailed CHRMAP based approach that can include the consideration of the landform and potential adaptation approaches to provide resilience against erosion in future planning periods should be undertaken.

For the town of Ledge Point the setback lines in Figure 7.7 show a landward progression of approximately 100m between the 2030 and 2110 period. The majority of this 100m horizontal distance is composed of the allowance for sea level rise over the period (S3 component) and uncertainty allowance. The projected coastal erosion setback lines have not been considered in the presentation of the design water level in the inundation plots in Appendix C. There is considerable uncertainty over how the sea level rise would affect this section of coast and impact the process of erosion over the 50-year and 100-year planning period. To assume the coast moves back to the position of the setback line in each respective planning period due to erosion is considered unlikely and of limited value in presenting impacts for this inundation study. The consideration of likely and unlikely scenarios for erosion of the shoreline and hence future inundation could be further considered in a CHRMAP based approach that can include the consideration of the landform changes and potential adaptation approaches to provide resilience against erosion in future planning periods.

For the town of Seabird the setback lines in Figure 7.8 show similar landward progression to the Ledge Point case. The northern section of the map shows there is approximately 140m movement of the coastal processes setback line between the 2030 and 2110 period whilst in the south the distance is approximately 10m horizontal distance over this 80-year period in recognition of the presence of rock in the foreshore. As for Ledge Point, the projected coastal erosion setback lines have not been taken into account in the presentation of the design water level in the inundation plots in Appendix C. There is considerable uncertainty over how the future shoreline evolution will occur over the 50year and 100-year planning period and a more detailed CHRMAP based approach that can include the consideration of the landform and potential adaptation approaches to provide resilience against erosion in future planning periods should be undertaken. Additionally the Seabird seawall would need to be included in this analysis of shoreline stability in future planning periods as it is not included in the setback line calculations that are shown in Figure 7.8.

Finally, for Guilderton the setback lines have not been calculated in previous studies for the Shire. The scale and extent of the foredune would be expected to provide sufficient area over which coastal processes could be contained in the 100years planning period and have no effect on the overall inundation areas presented in Appendix C.



Figure 7.6: Coastal Processes Allowance for Lancelin for the planning years 2030, 2070 and 2110 (based on MRA 2016b)

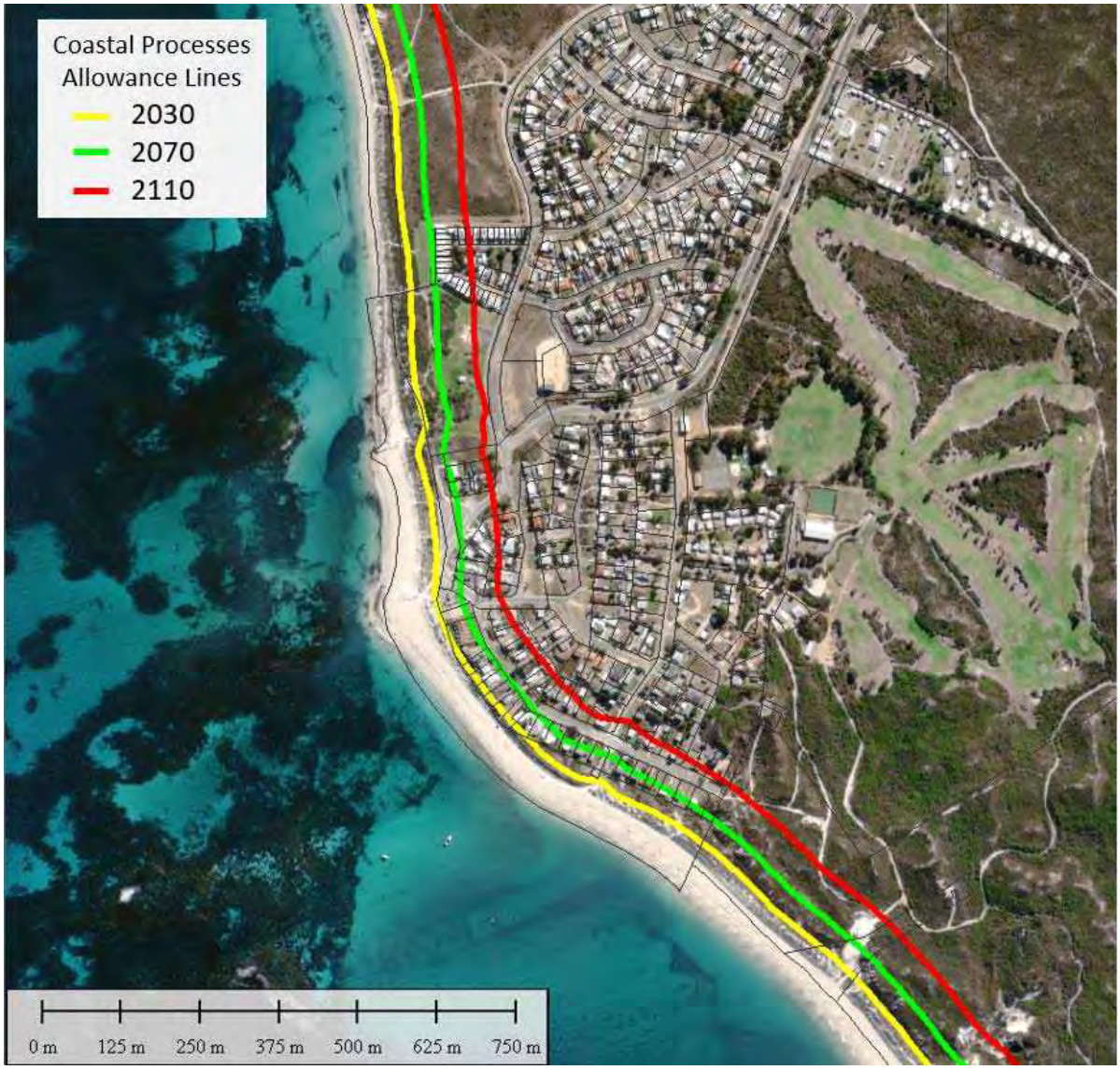


Figure 7.7: Coastal Processes Allowance for Ledge Point for the planning years 2030, 2070 and 2110 (based on MRA 2016b)

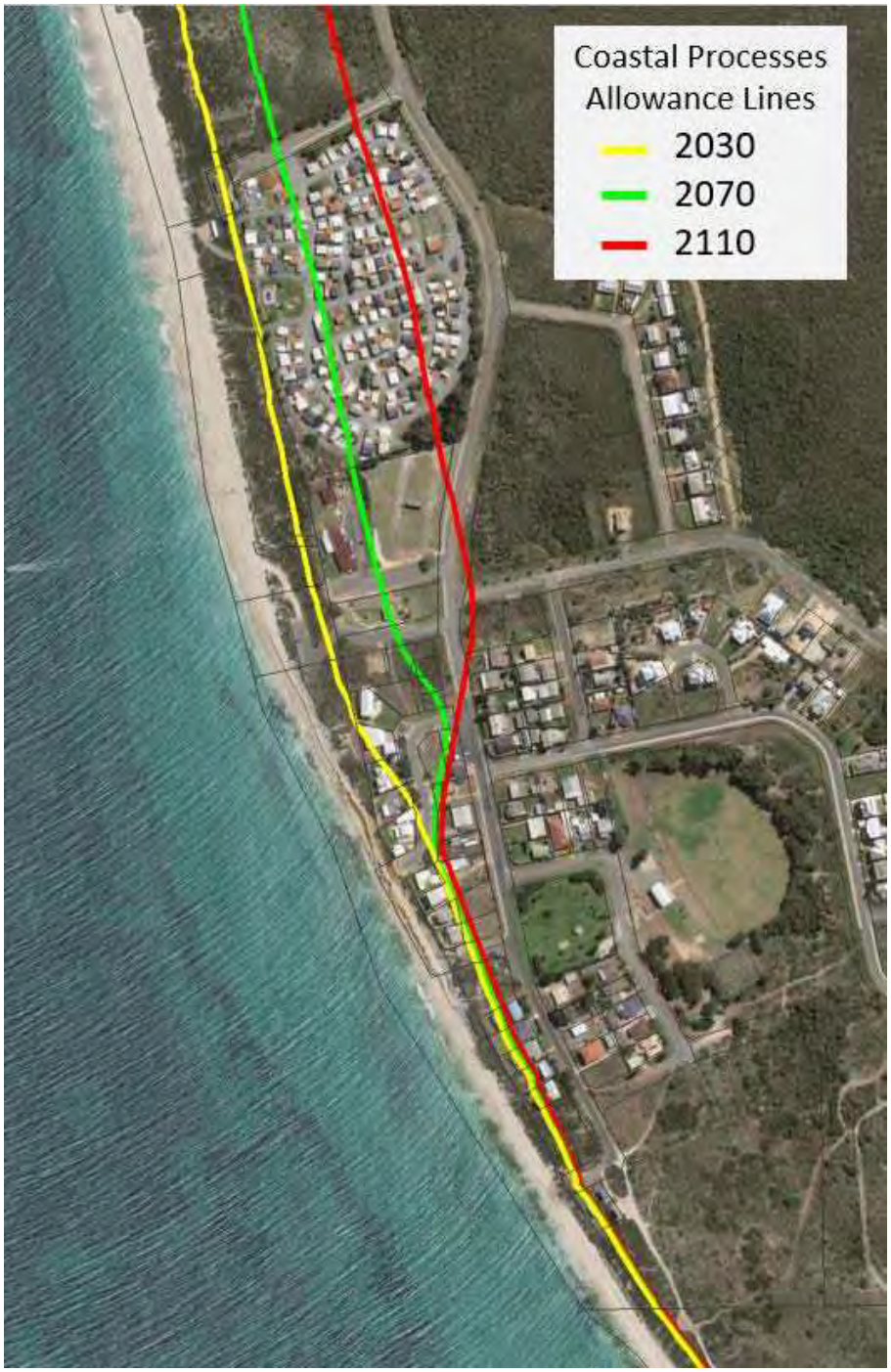


Figure 7.8: Coastal Processes Allowance for Seabird for the planning years 2030, 2070 and 2110 (based on MRA 2015b)

7.5 Bathtub Mapping Approach

The mapping of inundation areas for the design cases in Appendix C is shown as flood depth. The depth has been determined by applying the final design water levels from Section 6.5 to the land surface which is defined by high resolution LiDAR captured in 2016 (DoT 2016).

It is noted that finished floor levels of properties in the coastal areas are not considered in the inundation mapping. The accuracy of the inundation mapping in Appendix C is considered applicable at the coastal compartment scale that CHRMAP adopts (refer Figure 7.9). It is recommended that the flood assessment be refined for detailed site-specific adaptation assessments and planning policy requirements that will follow the CHRMAP study.

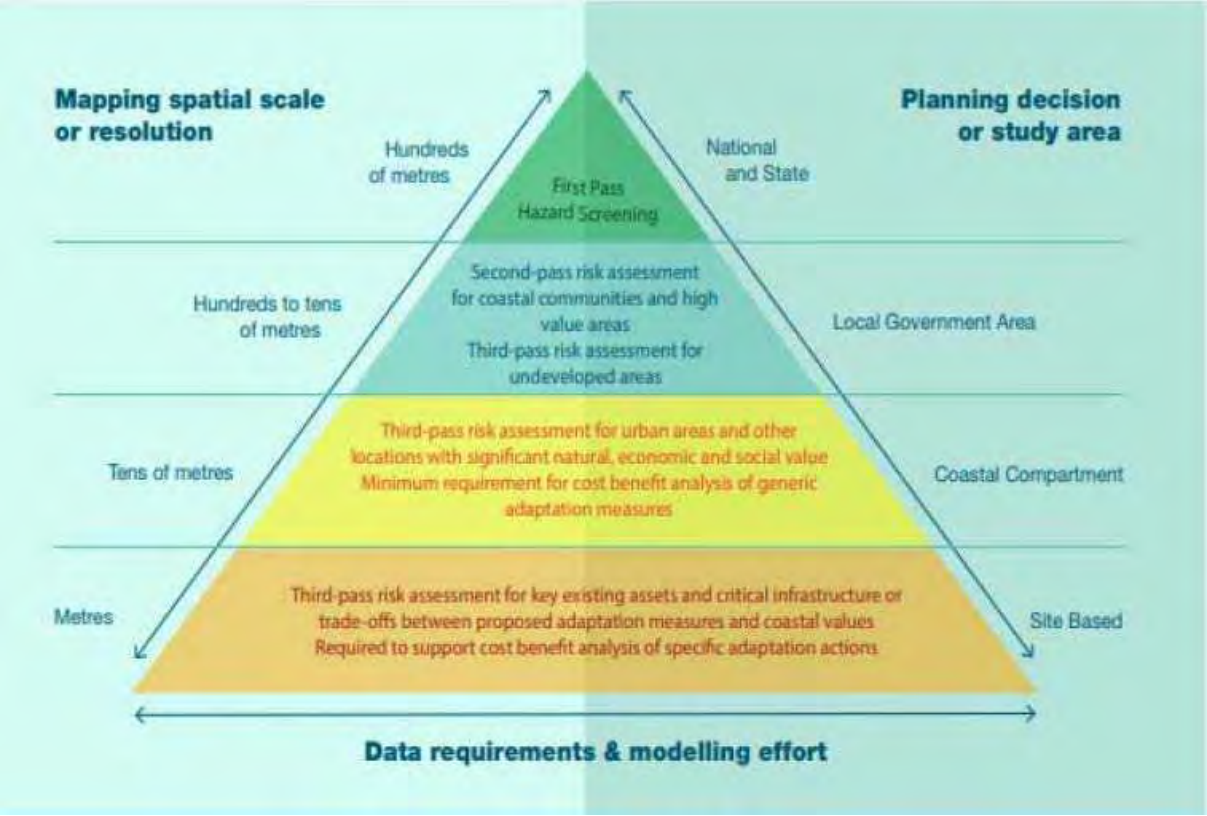


Figure 7.9: Coastal hazard mapping scale and level of data and modelling effort (Barnes 2017 adapted from Eliot 2013)

7.6 Hydro-connectivity

To improve the spatial mapping from a simple 'bathtub' flooding approach, all inundated areas have been incorporated a 'hydro-connectivity' algorithm. Hydro-connectivity ensures that the flooded areas inland connect to the offshore ocean region. This mechanism overcomes the limitation of the bathtub method where isolated inland pockets of inundation will occur, and this provided a more robust product when presenting results to the community and later developing adaptation approaches for the inland areas which would incorrectly show as flooded under the bathtub approach.

For the shoreline areas of Lancelin where dune stability may be compromised under peak storm levels and wave runup as outlined in Section 7.2 a note on the inundation mapping has been added to indicate

'Potential for Dune Breach During Extreme Events'. This ensures the mapping shows a connection point from the ocean to flooded areas inland in circumstances where the dune is considered to have been breached under the conditions specified in SPP2.6. an example is shown in Figure 7.10.



Figure 7.10: Example of dune breach area indicated on Lancelin Mapping (excerpt from 100yr ARI design storm in planning year 2070. Refer Appendix C.1)

8. Tsunami Modelling

To assess and quantify the hazard associated with tsunami within the study area, Baird has utilised Geoscience Australia's 2018 Australian Probabilistic Tsunami Hazard Assessment (PTHA, Geoscience Australia, 2018). The PTHA models the frequency with which tsunamis of any given size occur around the entire Australian coast, due to subduction earthquakes in the Indian and Pacific Oceans. Tsunami generated from sources other than subduction zones are not included in the hazard assessment. The focus on subduction zones in the southeast Indian and Pacific Oceans is justified because these are known to have produced major historical tsunami and are considered the most likely source of future events (BoM, 2010).

One such event that was observed to impact on the West Australian coast was the 2004 Sumatra–Andaman (Boxing Day) event. This event was not available from the PTHA database and there exist a number of hypothesised rupture inversions that describe the fault displacement for the event, however these are not well validated (pers. Comm. G Davies, Geoscience Australia). The challenge with the 2004 Boxing Day event is that there were no DART (Deep-ocean Assessment and Reporting of Tsunamis) buoys deployed at that time to measure the event in deep water, thus inference of the correct fault rupture characteristics cannot be accurately made.

To overcome this, Baird has collaborated with Geoscience Australia who have identified a set of 'most probable' rupture inversions and modelled each specifically for this study and provided timeseries data at the 3000m water depth contour to allow coupling with Baird's Delft-FM hydrodynamic model of the study area. Coupling the Geoscience Australia model with the Delft-FM hydrodynamic model of the coastal shelf needs to occur in deepwater where friction is not a significant influence on the tsunami propagation. This is because the Geoscience Australia model (also used for PTHA event simulations) does not include friction and is relatively coarse resolution (1-arcmin), thereby making it unsuitable for describing tsunami propagation over the shelf and into shallow water.

The Delft-FM model was run for 72hours from the earthquake rupture time, allowing a suitable simulation duration for any late arrival or nearshore resonance to be captured in the model, should they occur. The resulting nearshore tsunami signal has been compared to available tide gauge data at Lancelin, Jurien Bay and Geraldton, to benchmark the performance of the 2004 event hindcast. Figure 8.1 provides timeseries comparisons for the best performing inversion provided by Geoscience Australia against the Lancelin tide gauge with peak residual water levels summarised in Table 8.1 at locations where measured data was available at Geraldton, Jurien Bay and Lancelin.

Table 8.1: Peak Residual Water Level during the 2004 Boxing Day Tsunami

	Lancelin	Jurien Bay	Geraldton
Measured Tides (peak residual water level)	0.46	0.63	1.33
Modelled Tsunami (peak water level)	0.54	1.10	1.31

The comparison presented herein demonstrate close agreement at Geraldton and Lancelin in terms of peak water level and frequency of the largest waves during the event. The model result at Jurien Bay overestimates compared to the measured data, and the source of this is thought to be due to the bathymetric schematisation of the coastline at that site in the model, which is located within an enclosed marina location (given the close comparisons at other sites).

It is noted that no further calibration or validation has been completed for tsunami at this study site. As demonstrated at Geraldton by Geoscience Australia (2010) numerical model validation of tsunami is extremely difficult and highly dependent on the correct description of the initial rupture dimension at the tsunami source. Such a study would require considerable effort outside the scope of this study. However, the comparisons presented herein provide a degree of confidence that if the inversion rupture is well described, the Delft-FM hydrodynamic model applied in this study reasonably replicates the nearshore propagation and inshore response of the tsunami.

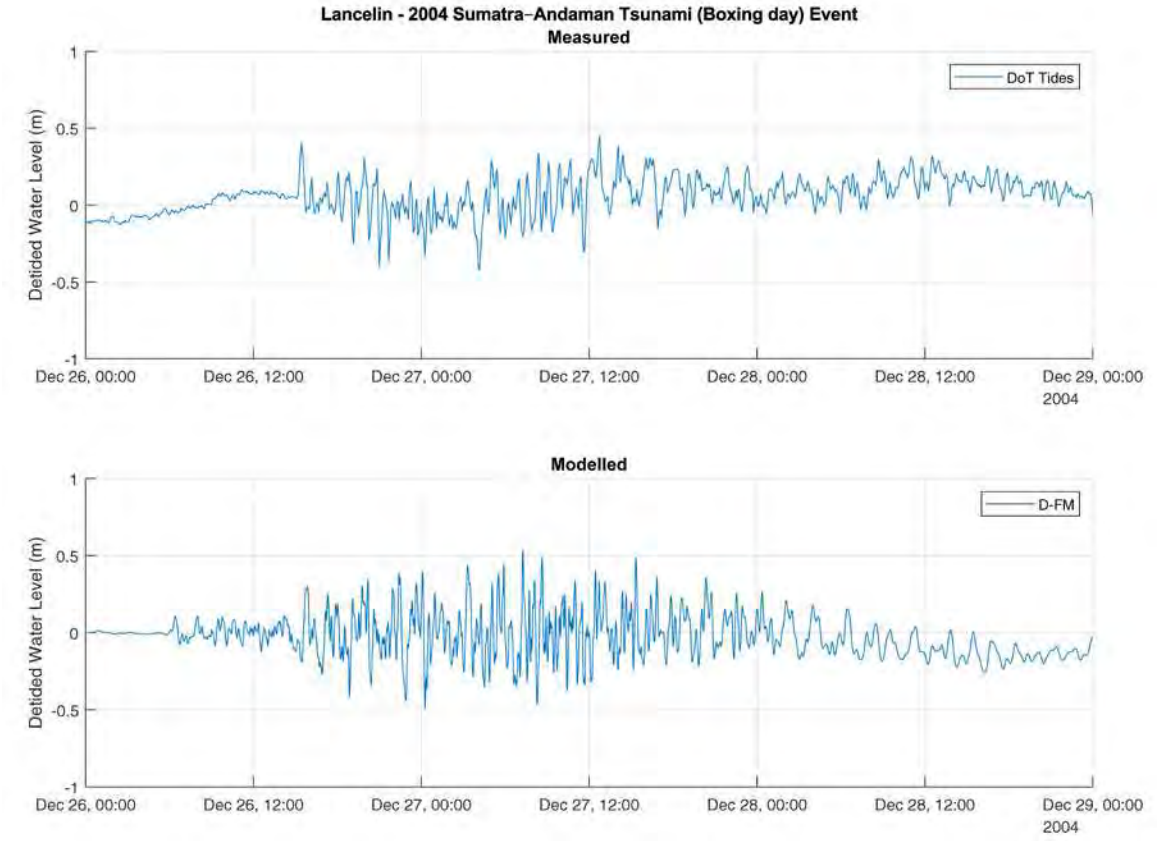


Figure 8.1: Comparison of Measured and Modelled Water Level residuals during the Boxing Day Tsunami (26th December 2004).

To define the 500-years ARI tsunami event for the study area, the publicly accessible PTHA database, consisting of modelled output from hundreds of thousands earthquake-tsunami scenarios around Australia, was interrogated to derive deepwater boundary conditions for the hydrodynamic model of the study area. The PTHA allows for the determination of average recurrence interval (ARI) levels in deep water and the identification of specific events that contribute to each ARI. From the available events at the 500 years ARI level offshore of the site, a 9.3 Mw (Mw - seismic magnitude scale) event from the Sunda arc was identified as being the most probable contributor at that hazard level. As done for the Boxing Day tsunami, water level timeseries form the PTHA model were extracted in deepwater (3000m depth contour) and applied directly to the Delft-FM model boundary.

The peak modelled water level results from the 500-years ARI tsunami event is summarised for the four towns in Table 8.2.

Table 8.2: Tsunami event at 500yr ARI – Modelled Water Level (Datum m AHD)

Return Period	500yr ARI Modelled Tsunami – Peak Water Level			
Timeframe	Lancelin	Ledge Point	Seabird	Guilderton
2020	1.9	2.1	2.1	2.2
2040	2.0	2.2	2.2	2.3
2070	2.3	2.5	2.5	2.6
2120	2.8	3.0	3.0	3.1

The results in Table 8.2 show the peak water level is comparable (within 0.1m) with the design water levels from the modelled 500yr ARI cyclone event for the Lancelin and Ledge Point locations (refer Table 6.4 and Table 6.5). At Seabird and Guilderton the peak modelled water level for the design 500yr ARI Tsunami is 0.4m to 0.5m higher than the 500yr ARI cyclone event (refer Table 6.6 and Table 6.7). Given the natural elevation of the shoreline areas at Seabird and Guilderton this additional 0.4m to 0.5m level can be accommodated in the foreshore areas. In conclusion the inundation risk to Lancelin, Ledge Point, Seabird and Guilderton from the 500yr ARI Tsunami is considered equivalent to the 500yr ARI cyclone case.

The peak water level from the 500yr ARI Tsunami event is significantly higher than for the Boxing Day Tsunami case. This is explained by the nature of the Boxing day event in which the orientation of the fault rupture was directed at Africa, whilst for the design event adopted for the Gingin coast the orientation of the fault rupture is specifically directed offshore of the Western Australia's coast.

9. Conclusion

Baird Australia (Baird) have undertaken a Coastal Inundation Study (CIS) for the Shire of Gingin to identify potential areas subject to coastal inundation risk which will inform future planning of coastal areas. The study focus is along the coastal region of the Shire of Gingin which is located approximately 70km north of Perth in Western Australia. There are four key towns of interest in this study at Lancelin, Ledge Point, Seabird and Guilderton.

A literature review and data gathering exercise is summarised in Section 2 along with a detailed explanation of the key coastal inundation processes important for the study. Measured data sources are outlined in Section 3 that have been utilised in the study delivery.

The hydrodynamic model system is presented in Section 4. Baird's established and validated numerical model of the West Australian coast was used as a baseline for this study. This hydrodynamic model system has been applied for a number of similar studies in Western Australia and was developed by Baird using the Deltares numerical model *Delft3D Flexible Mesh Suite* (Delft-FM). The Delft-FM modelling suite has been developed to offer a fully integrated modelling framework for a multi-disciplinary approach in coastal, river and estuarine areas (Deltares 2020) and has been applied in similar studies by Baird to determine waves, water levels and currents in extreme cyclonic conditions. The numerical model applied in this study is comprised of a dynamically coupled hydrodynamic model and wave model driven by a wind model developed by Baird (*Cycwind*). Model validation against predicted tides was shown to have excellent agreement at port locations through the study region. The model was used to simulate four key historical cyclone cases with comparison to available measured data and predicted tides, providing a basis for understanding magnitude of storm surge in extreme cyclone events and demonstrating model performance within the limitations of the hindcast wind fields for some historical events. The design storm for the Gingin coast is an ex-tropical cyclone which transitions south and interacts with frontal systems coming through the southern Indian Ocean, that increases the intensity and scale of the storm system. These events are rare in the historical record and occur typically in the latter part of the cyclone season (February to May). The four historical events that were simulated were TC Alby (1978), TC Ned (1989), TC Bianca (2011) and TC Iggy (2012). The TC Mangga event occurred in May 2020 at the conclusion of the study and a discussion is presented in Section 0.

In developing a 'design' storm for coastal inundation along the Gingin study sites consideration was given to the DoT design storm based on TC Ned (Seashore Engineering, 2020), a synthetic track from Baird's 10,000 yr cyclone track data set (Taylor et al, 2018) and a hybrid storm event based on data from the JRA-55 model. The process is outlined in Section 5 with the outcome that design cases at the 20yr-ARI and 100yr-ARI were defined by the Baird track (MC69197) and the DoT Design Track (Seashore 2020) was adopted as the 500-year ARI design case as it generated the largest storm surge when compared to the Baird Track (approximately 0.2 m higher water levels). Approaching the coast between the Gingin study area and the Perth northern suburbs, TC Ned experienced extra-tropical transition and intensified compared to early track positions further north. The assumed extra-tropical transition in the 500yr ARI event tracks are critical to the intensity and scale of the Seashore design event.

The events were simulated for present day and future periods across the 100-year planning period adopting sea level rise projections based on DoT recommendations. The final water levels are summarised in Table 9.1. The final design water levels represent the peak water level during the respective cyclone events and include near shore wave setup. Based on the model outcomes, the peak level is experienced for a period of 2 hours or less.

Wave runup levels were calculated for the study area and are summarised in Section 7. The wave runup levels have been calculated from the design extreme model cases based on the Nielsen and Hanslow (1991) method with inputs from the modelled cases (Hs, Tp).

Table 9.1: Summary of design cyclone outcomes. Peak modelled water level across the four towns in the Gingin study area.

ARI (yr)	Reference Event	Lancelin (m AHD)	Ledge Point (m AHD)	Seabird (m AHD)	Guilderton (m AHD)
20	69197	1.3	1.2	1.3	1.3
100	69197	1.5	1.3	1.4	1.4
500	DoT Design (Seashore 2020)	2.0	1.9	1.7	1.8

The design water levels were used to produce spatial mapping of the coastal inundation extents for the four towns of the study area. This mapping represents the S4 inundation component under State Coastal Planning Policy SPP2.6. The inundation mapping process is outlined in Section 7 with final mapping presented in Appendix C.

The inundation mapping uses a 'bathtub mapping' approach which applies the peak ocean level determined from the design cases at each of the towns (Table 9.1) over the high resolution LiDAR data (DoT 2016). The mapping approach includes consideration of hydro-connectivity between inland flooded areas and the ocean. The requirement of SPP2.6 to examine dune stability at Lancelin to identify where potential dune breaching occurs in extreme events has been incorporated. Discussion of the influence of coastal erosion processes on the inundation extents calculated at each coastal town in future planning periods is included in Section 7.

- Inundation risk is highest for Lancelin, where the foredune provides a barrier that protects the lower lying inland areas from ocean-based flooding during extreme events.
    - For the section of coast north from Grace Darling Park, there is the potential for dune breaching of the foredune in severe events. The dune system is estimated to be able to withstand the 20yr ARI event and the 100yr ARI event in the present day (2020). Under future sea level rise scenarios for the 2070 planning period (+0.4m) and beyond, breaching of the foredune may occur. A storm event of 500yr ARI magnitude is estimated to breach the dune system in the present day and all future planning periods.
    - For the section of coast south of Grace Darling Park, the dune system is significant and breaching of the dune would not occur in any of the extreme events, including under future sea level rise scenarios.
- For Ledge Point, Seabird and Guilderton the developed areas are not at risk of inundation, with the natural topography set well above the extreme design water levels, including under future sea level rise scenarios.
- The foreshore areas at all study locations are susceptible to the impacts of wave run-up in design storm cases, which may result in overtopping of dunes and foreshore structures.

In Section 8 assessment of the hazard associated with tsunami within the study area is presented using Geoscience Australia's 2018 Australian Probabilistic Tsunami Hazard Assessment (PTHA, Geoscience Australia, 2018). Baird applied its hydrodynamic model to model a validation case of the 2006 Boxing day Tsunami, with the model showing good agreement to measured peak water level during the event captured at tide gauges in Geraldton and Lancelin. A 500 yr ARI tsunami event for the Gingin study area was examined in the model with peak water level results summarised for the four towns in Table 9.2. The results show the peak water level from tsunami is comparable (within 0.1m) with the design water levels from the modelled 500yr ARI cyclone event for the Lancelin and Ledge Point locations and for Seabird and Guilderton the peak modelled water level for the design 500yr ARI Tsunami is 0.4m to 0.5m higher than the 500yr ARI cyclone event.

Table 9.2: Tsunami event at 500yr ARI – Modelled Water Level (Datum m AHD)

Return Period	500yr ARI Modelled Tsunami – Peak Water Level			
Timeframe	Lancelin	Ledge Point	Seabird	Guilderton
2020	1.9	2.1	2.1	2.2
2040	2.0	2.2	2.2	2.3
2070	2.3	2.5	2.5	2.6
2120	2.8	3.0	3.0	3.1

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Appendix A

Department of Transport Storm Tracks for 500yr ARI Design Inundation Events

A.1 Seashore Engineering (2020) Design Cyclone Tracks based on TC Ned

Table A.1: Design Track for Lancelin

Lancelin	Longitude	115.3273			Latitude	31.01469		
	Original Storm TC Ned (Mar 1988)				500-yr ARI storm Rmax 200 km			
Date / Time	Long	Lat	CP	Rmax	Long	Lat	CP	Rmax
3/25/1989 6:00	119.8	17.4	1003		120.2	18.4	1002.1	54
3/25/1989 12:00	119.1	17.1	1001		119.5	18.1	1000.0	54
3/25/1989 18:00	118.1	16.8	999		118.5	17.8	997.8	54
3/26/1989 0:00	116.9	16.9	997		117.3	17.9	995.6	54
3/26/1989 6:00	115.8	17.1	995		116.2	18.1	993.4	54
3/26/1989 12:00	115.3	17.2	992		115.7	18.2	990.2	54
3/26/1989 18:00	114.6	17.4	989		115.0	18.4	986.9	54
3/27/1989 0:00	113.8	17.8	986		114.2	18.8	983.7	54
3/27/1989 6:00	113	18.1	982		113.4	19.1	979.3	54
3/27/1989 12:00	112.2	18.3	977		112.6	19.3	973.9	54
3/27/1989 18:00	111	18.8	967		111.4	19.8	963.0	54
3/28/1989 0:00	110.2	19	954		110.6	20.0	948.9	54
3/28/1989 6:00	109.6	19.6	948		110.0	20.6	942.4	54
3/28/1989 12:00	109.2	20.1	945		109.6	21.1	939.1	54
3/28/1989 18:00	109.1	20.4	942		109.5	21.4	935.9	54
3/29/1989 0:00	109.1	20.7	941		109.5	21.7	934.8	54
3/29/1989 6:00	109	21	945		109.4	22.0	937.0	54
3/29/1989 12:00	109	21.5	954		109.4	22.5	941.3	54
3/29/1989 18:00	109	22	964		109.4	23.0	942.4	54
3/30/1989 0:00	108.9	22.4	972		109.3	23.4	942.4	54
3/30/1989 6:00	108.5	23.2	984		108.9	24.2	945.7	54
3/30/1989 12:00	108.4	24	989		108.8	25.0	950.0	61
3/30/1989 18:00	108.5	25	992		108.9	26.0	953.3	68
3/31/1989 0:00	108.7	26.1	994		109.1	27.1	958.7	75
3/31/1989 6:00	109.2	27.2	996		109.6	28.2	961.9	90
3/31/1989 9:00	109.8	27.9	997		110.2	28.9	961.9	100
3/31/1989 12:00	110.5	28.5	998		110.9	29.5	964.1	110
3/31/1989 15:00	110.6	29.2	999		112.0	30.2	967.4	120
3/31/1989 18:00	113	30.2	1000		113.4	31.2	967.4	140
3/31/1989 21:00	114.8	31.5	1001		115.2	32.5	972.8	180
4/1/1989 0:00	116.6	32.7	1002		117.0	33.7	972.8	230
4/1/1989 3:00	118.6	33.8	1002		119.0	34.8	975.0	250
4/1/1989 6:00	120.8	34.5	1003		121.2	35.5	978.2	270

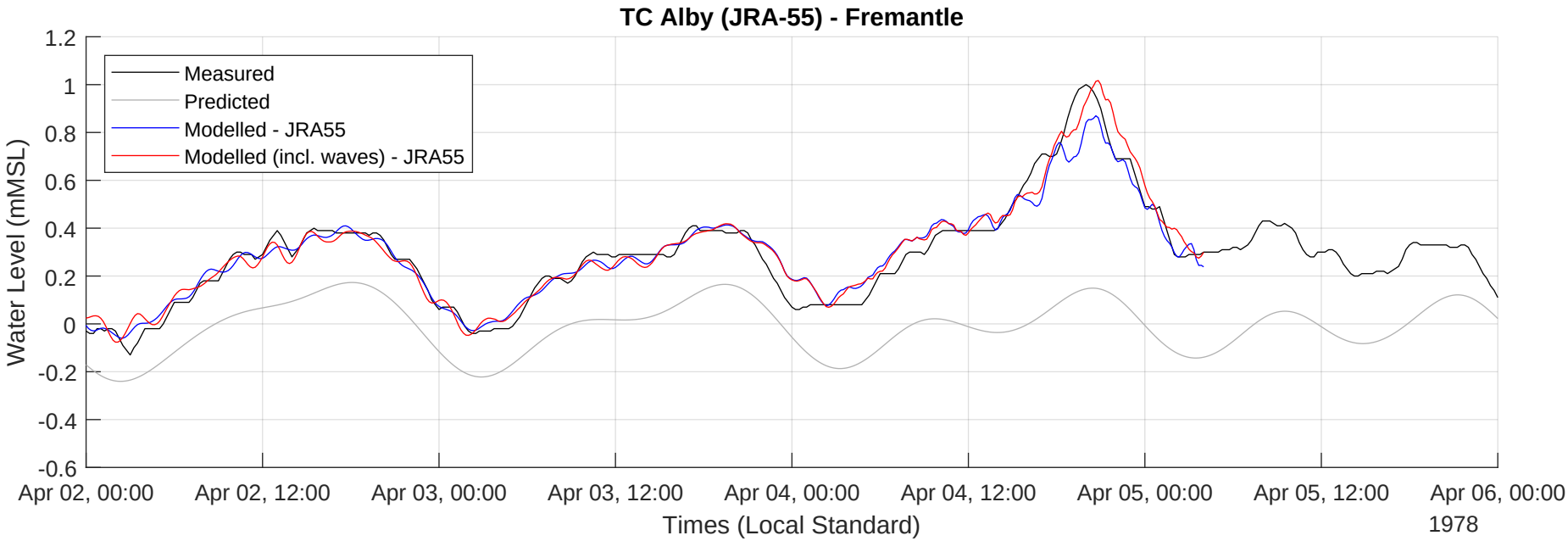
Table A.2: Design Track for Seabird

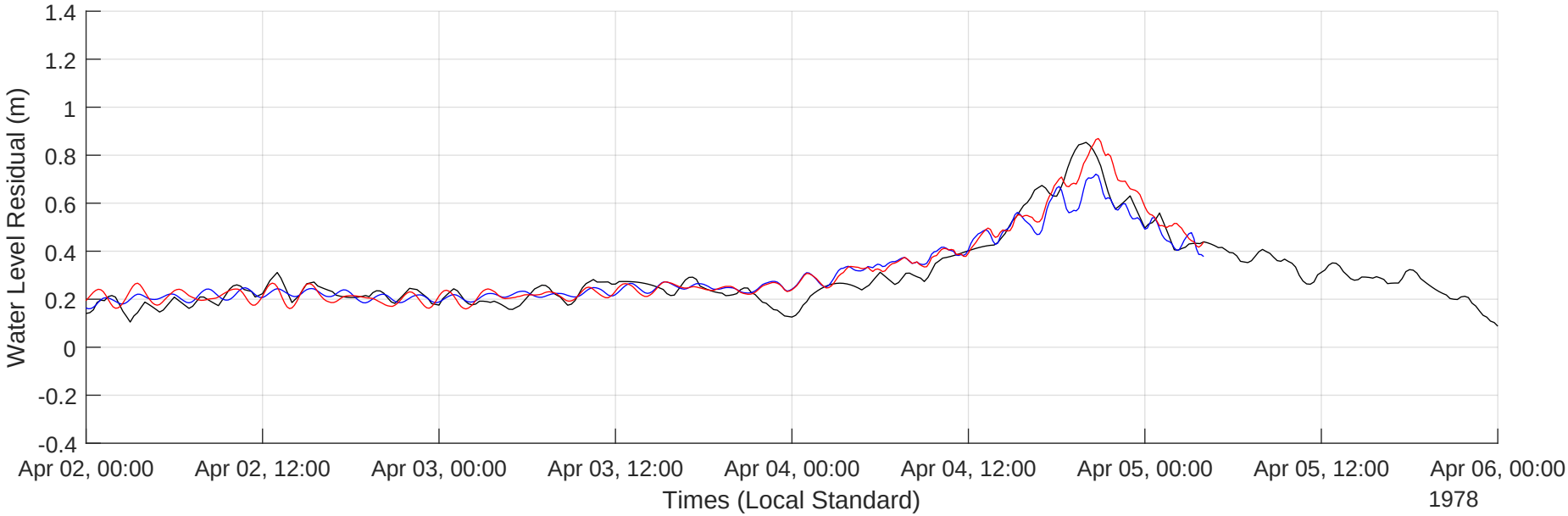
Seabird	Longitude	115.4464			Latitude	31.27694		
	Original Storm TC Ned (Mar 1988)				500-yr ARI storm			
Date / Time	Long	Lat	CP	Rmax	Long	Lat	CP	Rmax
3/25/1989 6:00	119.8	17.4	1003		120.0	18.4	1002.1	54
3/25/1989 12:00	119.1	17.1	1001		119.3	18.1	1000.0	54
3/25/1989 18:00	118.1	16.8	999		118.3	17.8	997.8	54
3/26/1989 0:00	116.9	16.9	997		117.1	17.9	995.6	54
3/26/1989 6:00	115.8	17.1	995		116.0	18.1	993.4	54
3/26/1989 12:00	115.3	17.2	992		115.5	18.2	990.2	54
3/26/1989 18:00	114.6	17.4	989		114.8	18.4	986.9	54
3/27/1989 0:00	113.8	17.8	986		114.0	18.8	983.7	54
3/27/1989 6:00	113	18.1	982		113.2	19.1	979.3	54
3/27/1989 12:00	112.2	18.3	977		112.4	19.3	973.9	54
3/27/1989 18:00	111	18.8	967		111.2	19.8	963.0	54
3/28/1989 0:00	110.2	19	954		110.4	20.0	948.9	54
3/28/1989 6:00	109.6	19.6	948		109.8	20.6	942.4	54
3/28/1989 12:00	109.2	20.1	945		109.4	21.1	939.1	54
3/28/1989 18:00	109.1	20.4	942		109.3	21.4	935.9	54
3/29/1989 0:00	109.1	20.7	941		109.3	21.7	934.8	54
3/29/1989 6:00	109	21	945		109.2	22.0	937.0	54
3/29/1989 12:00	109	21.5	954		109.2	22.5	941.3	54
3/29/1989 18:00	109	22	964		109.2	23.0	942.4	54
3/30/1989 0:00	108.9	22.4	972		109.1	23.4	942.4	54
3/30/1989 6:00	108.5	23.2	984		108.7	24.2	945.7	54
3/30/1989 12:00	108.4	24	989		108.6	25.0	950.0	61
3/30/1989 18:00	108.5	25	992		108.7	26.0	953.3	68
3/31/1989 0:00	108.7	26.1	994		108.9	27.1	958.7	75
3/31/1989 6:00	109.2	27.2	996		109.4	28.2	961.9	90
3/31/1989 9:00	109.8	27.9	997		110.0	28.9	961.9	100
3/31/1989 12:00	110.5	28.5	998		110.7	29.5	964.1	110
3/31/1989 15:00	110.6	29.2	999		111.8	30.2	967.4	120
3/31/1989 18:00	113	30.2	1000		113.2	31.2	967.4	140
3/31/1989 21:00	114.8	31.5	1001		115.0	32.5	972.8	180
4/1/1989 0:00	116.6	32.7	1002		116.8	33.7	972.8	230
4/1/1989 3:00	118.6	33.8	1002		118.8	34.8	975.0	250
4/1/1989 6:00	120.8	34.5	1003		121.0	35.5	978.2	270

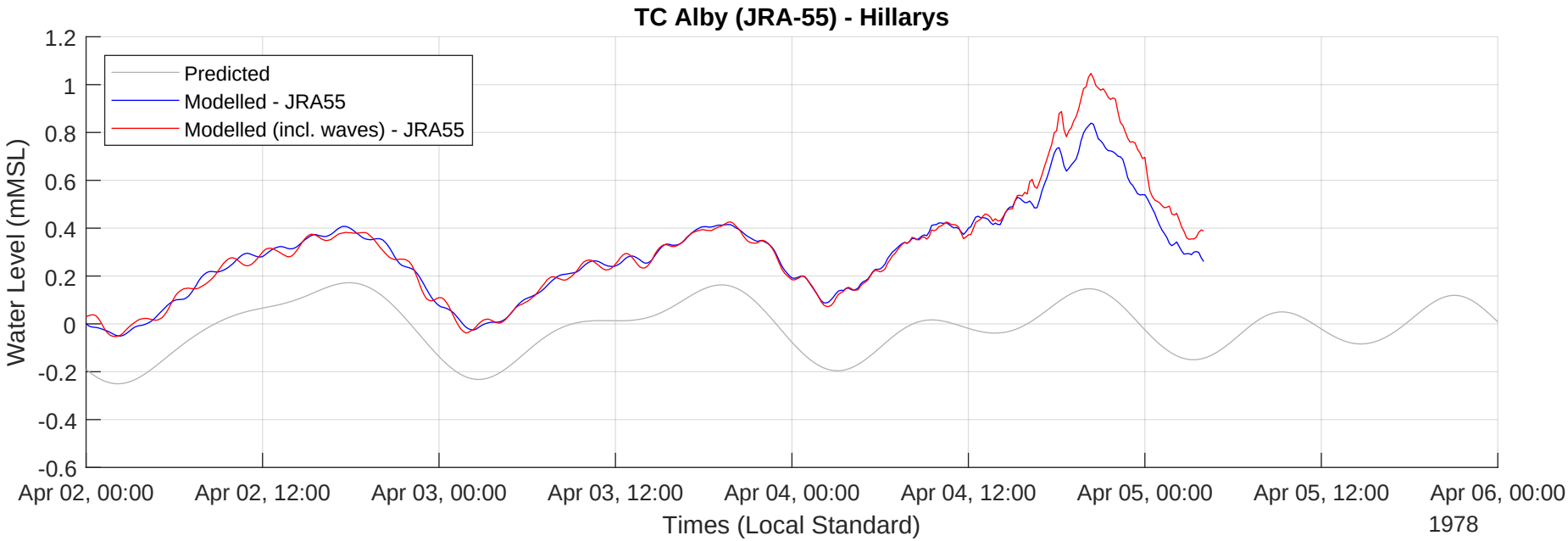
Appendix B

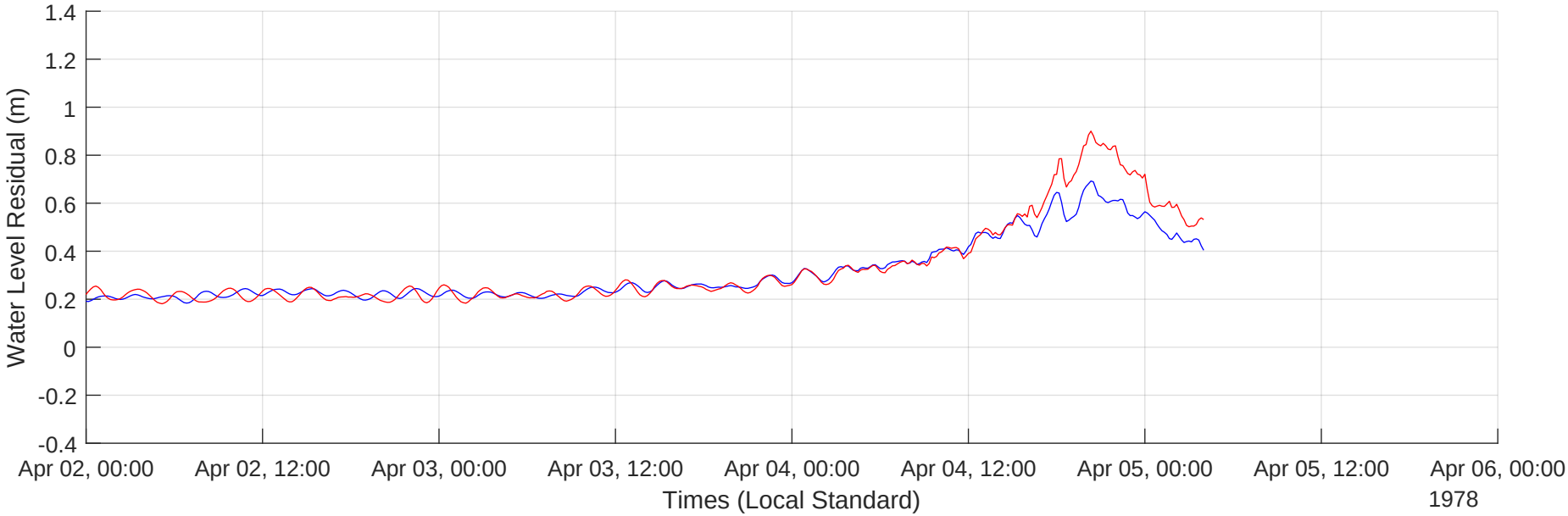
Hydrodynamic Model Storm Event Validation

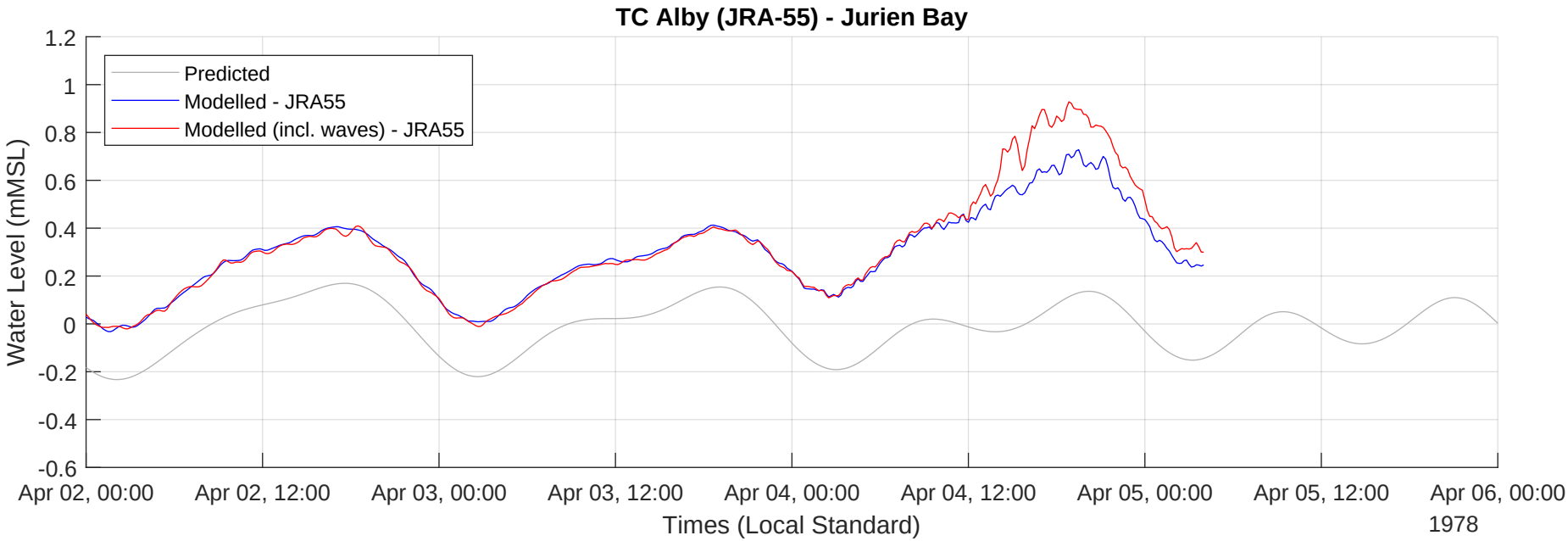
B.1 TC Alby (1978)

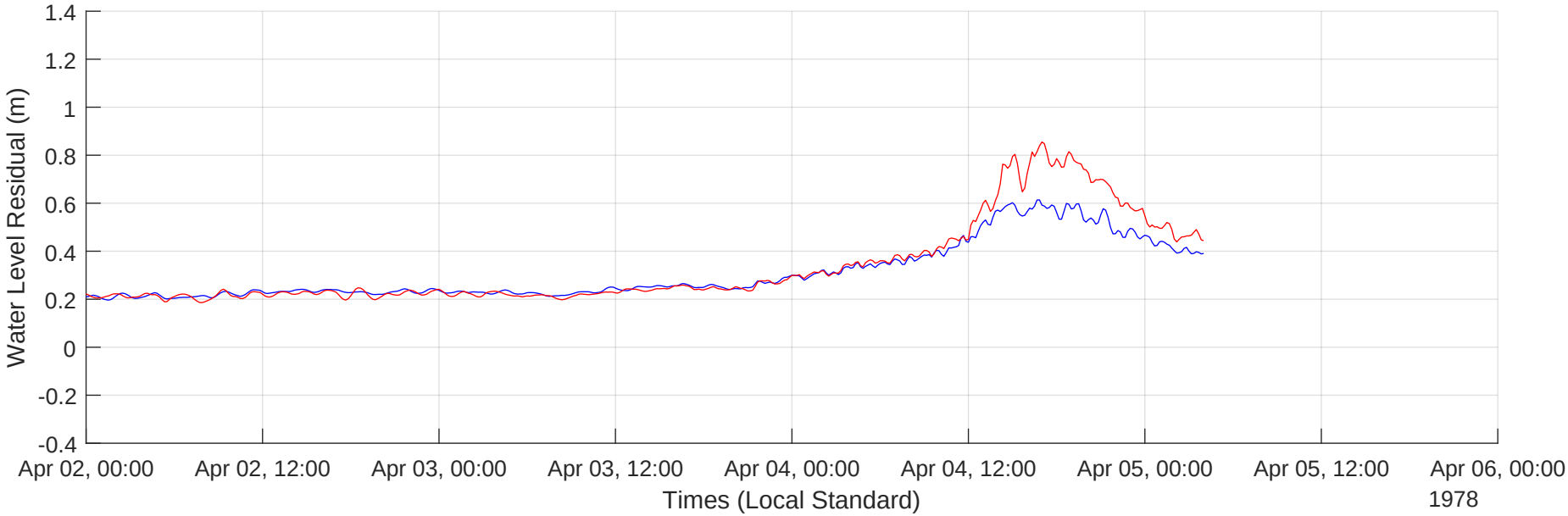

TC Alby (JRA-55) - Fremantle
Measured
Predicted
Modelled - JRA55
Modelled (incl. waves) - JRA55
Water Level (mMSL)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Apr 02, 00:00
Apr 02, 12:00
Apr 03, 00:00
Apr 03, 12:00
Apr 04, 00:00
Apr 04, 12:00
Apr 05, 00:00
Apr 05, 12:00
Apr 06, 00:00
1978
Times (Local Standard)

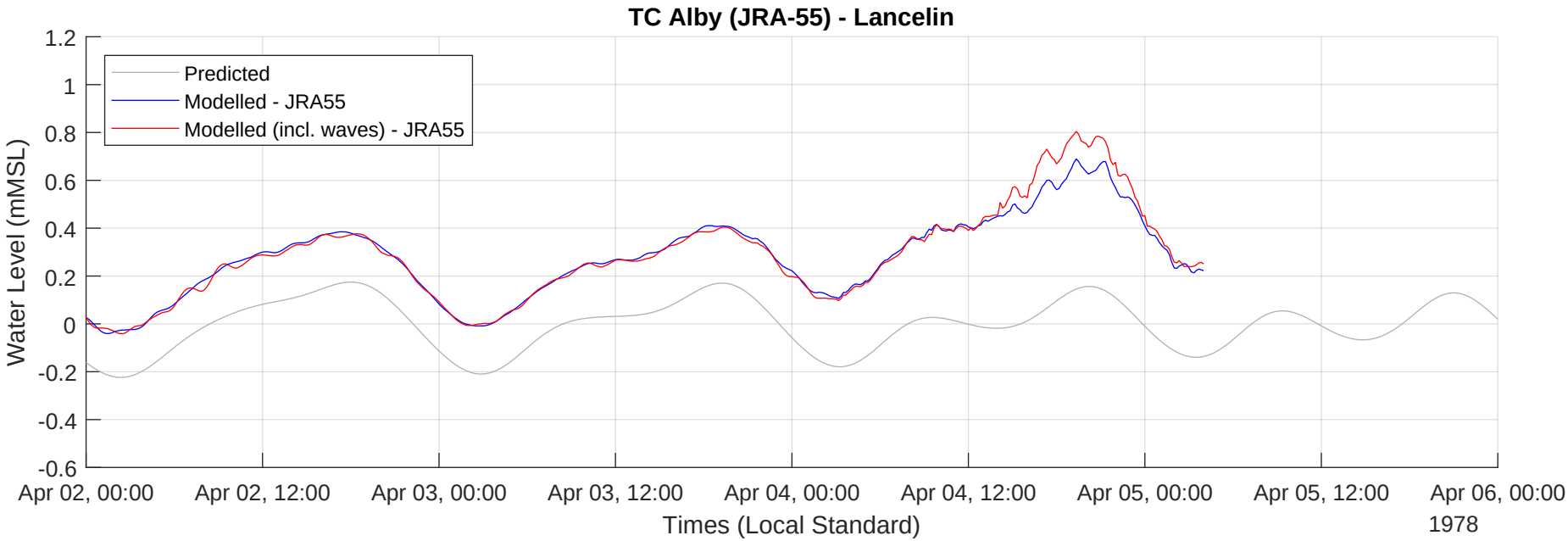

Water Level Residual (m)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Apr 02, 00:00
Apr 02, 12:00
Apr 03, 00:00
Apr 03, 12:00
Apr 04, 00:00
Apr 04, 12:00
Apr 05, 00:00
Apr 05, 12:00
Apr 06, 00:00
1978
Times (Local Standard)

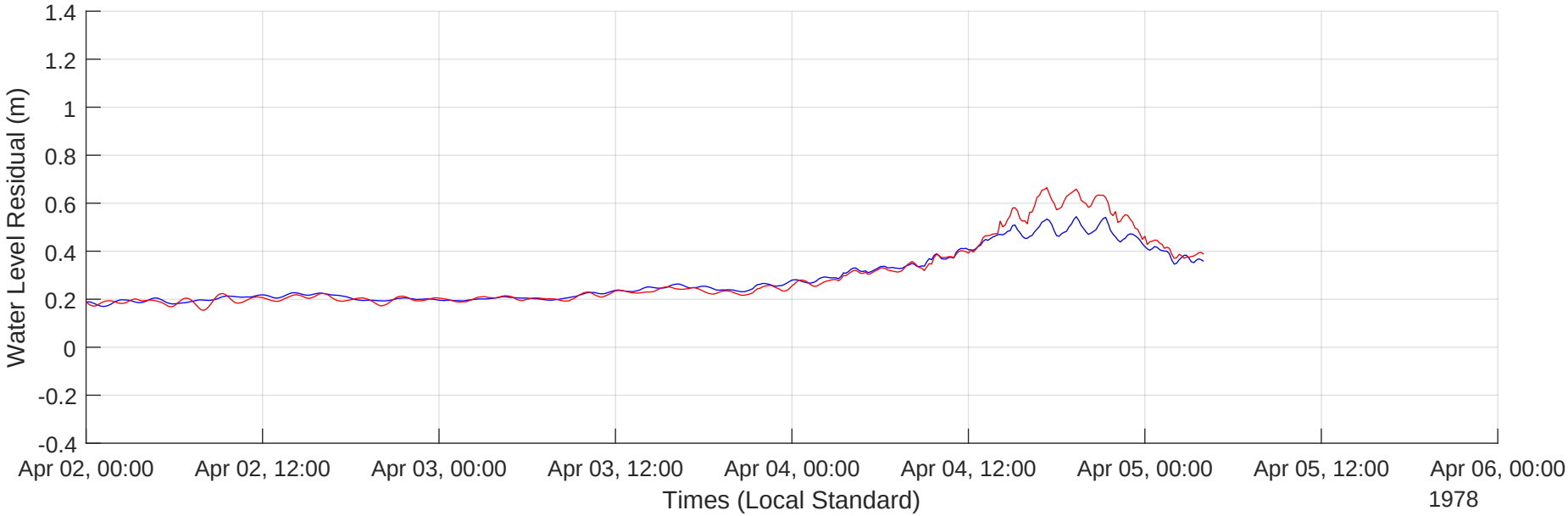

TC Alby (JRA-55) - Hillarys
Predicted
Modelled - JRA55
Modelled (incl. waves) - JRA55
Water Level (mMSL)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Apr 02, 00:00
Apr 02, 12:00
Apr 03, 00:00
Apr 03, 12:00
Apr 04, 00:00
Apr 04, 12:00
Apr 05, 00:00
Apr 05, 12:00
Apr 06, 00:00
1978
Times (Local Standard)

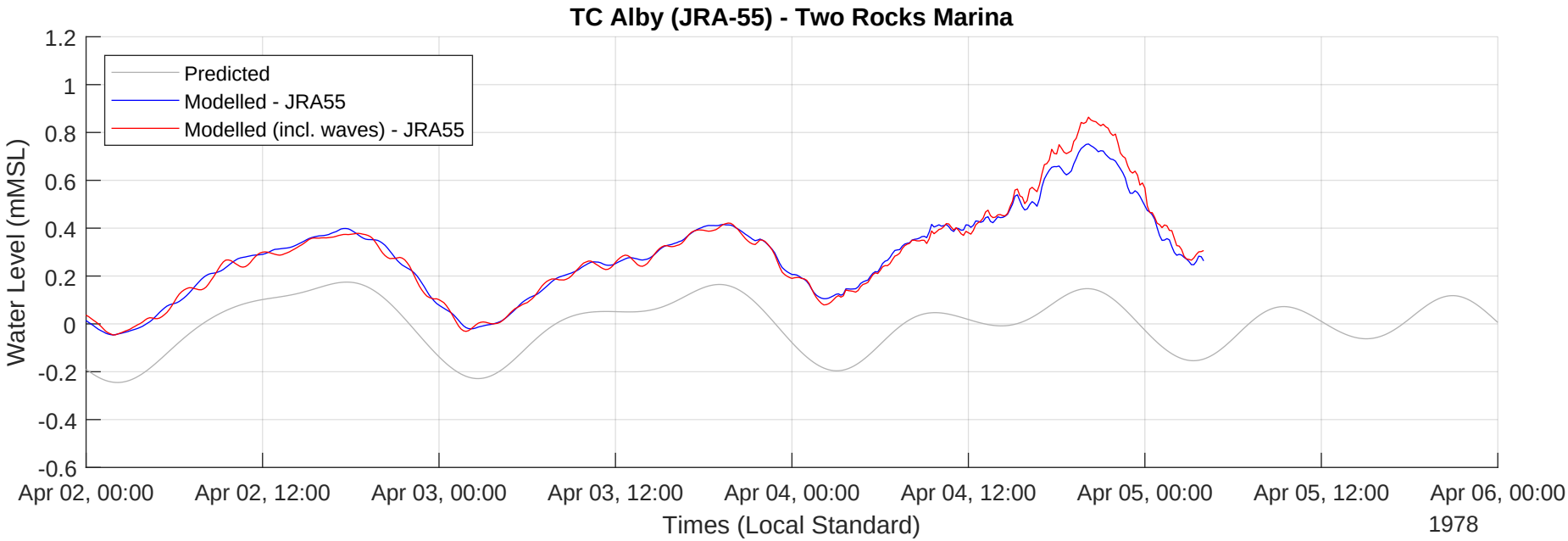

Water Level Residual (m)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Apr 02, 00:00
Apr 02, 12:00
Apr 03, 00:00
Apr 03, 12:00
Apr 04, 00:00
Apr 04, 12:00
Apr 05, 00:00
Apr 05, 12:00
Apr 06, 00:00
1978
Times (Local Standard)

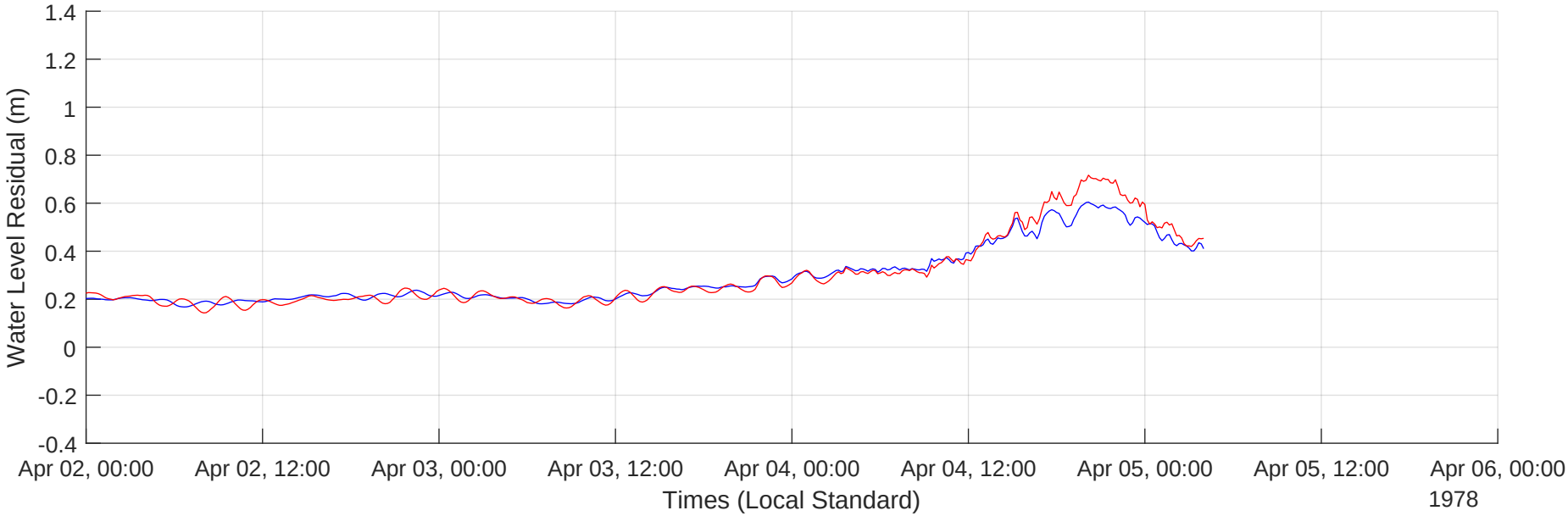

TC Alby (JRA-55) - Jurien Bay
Predicted
Modelled - JRA55
Modelled (incl. waves) - JRA55
Water Level (mMSL)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Apr 02, 00:00
Apr 02, 12:00
Apr 03, 00:00
Apr 03, 12:00
Apr 04, 00:00
Apr 04, 12:00
Apr 05, 00:00
Apr 05, 12:00
Apr 06, 00:00
1978
Times (Local Standard)

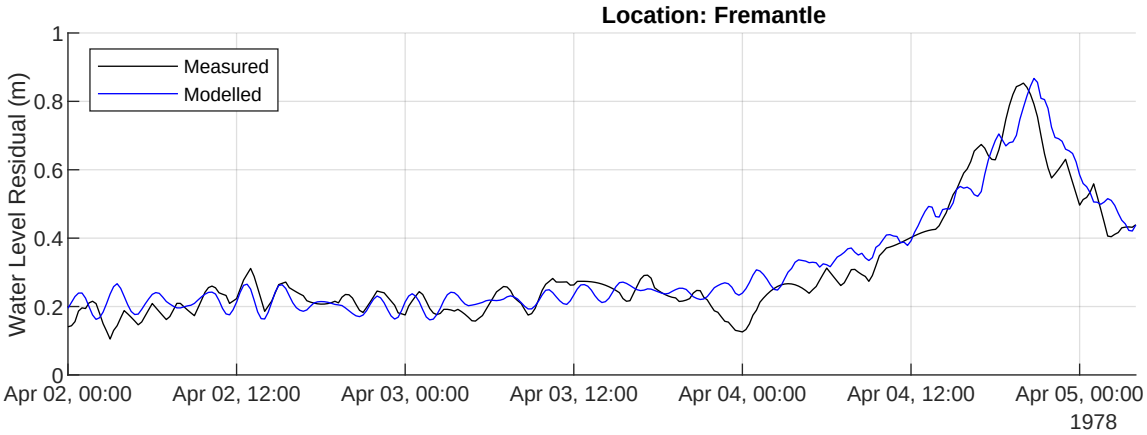

Water Level Residual (m)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Apr 02, 00:00
Apr 02, 12:00
Apr 03, 00:00
Apr 03, 12:00
Apr 04, 00:00
Apr 04, 12:00
Apr 05, 00:00
Apr 05, 12:00
Apr 06, 00:00
1978
Times (Local Standard)

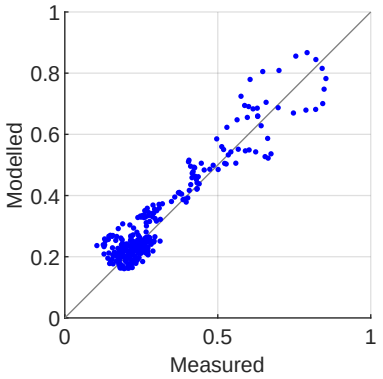

TC Alby (JRA-55) - Lancelin
Predicted
Modelled - JRA55
Modelled (incl. waves) - JRA55
Water Level (mMSL)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Apr 02, 00:00
Apr 02, 12:00
Apr 03, 00:00
Apr 03, 12:00
Apr 04, 00:00
Apr 04, 12:00
Apr 05, 00:00
Apr 05, 12:00
Apr 06, 00:00
1978
Times (Local Standard)


Water Level Residual (m)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Apr 02, 00:00
Apr 02, 12:00
Apr 03, 00:00
Apr 03, 12:00
Apr 04, 00:00
Apr 04, 12:00
Apr 05, 00:00
Apr 05, 12:00
Apr 06, 00:00
1978
Times (Local Standard)


TC Alby (JRA-55) - Two Rocks Marina
Predicted
Modelled - JRA55
Modelled (incl. waves) - JRA55
Water Level (mMSL)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Apr 02, 00:00
Apr 02, 12:00
Apr 03, 00:00
Apr 03, 12:00
Apr 04, 00:00
Apr 04, 12:00
Apr 05, 00:00
Apr 05, 12:00
Apr 06, 00:00
1978
Times (Local Standard)


Water Level Residual (m)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Apr 02, 00:00
Apr 02, 12:00
Apr 03, 00:00
Apr 03, 12:00
Apr 04, 00:00
Apr 04, 12:00
Apr 05, 00:00
Apr 05, 12:00
Apr 06, 00:00
1978
Times (Local Standard)





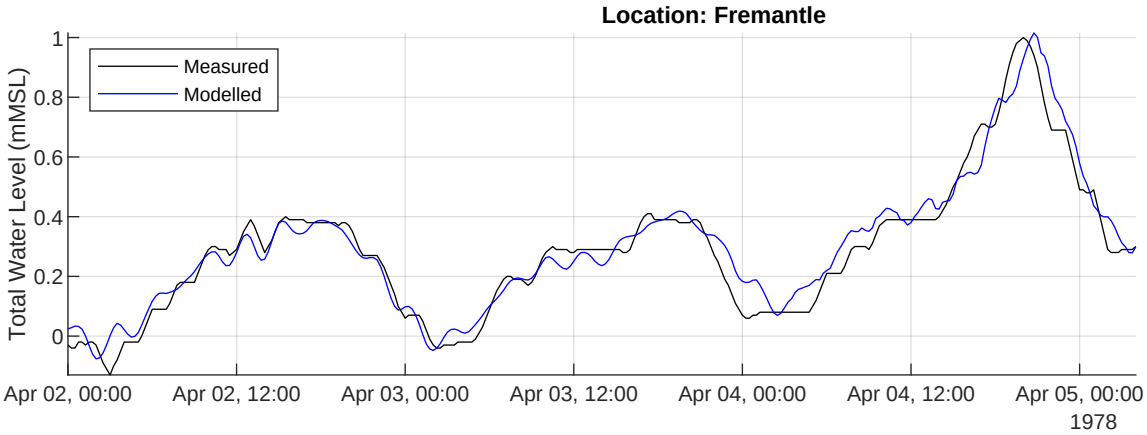
Water Level Residual (m)

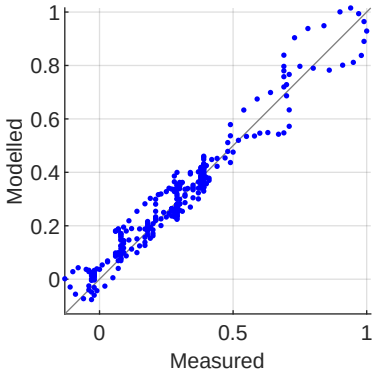
Scatter: 0.180

Bias: 0.014

Skill: 0.971

RMS error: 0.054





Total Water Level (mMSL)

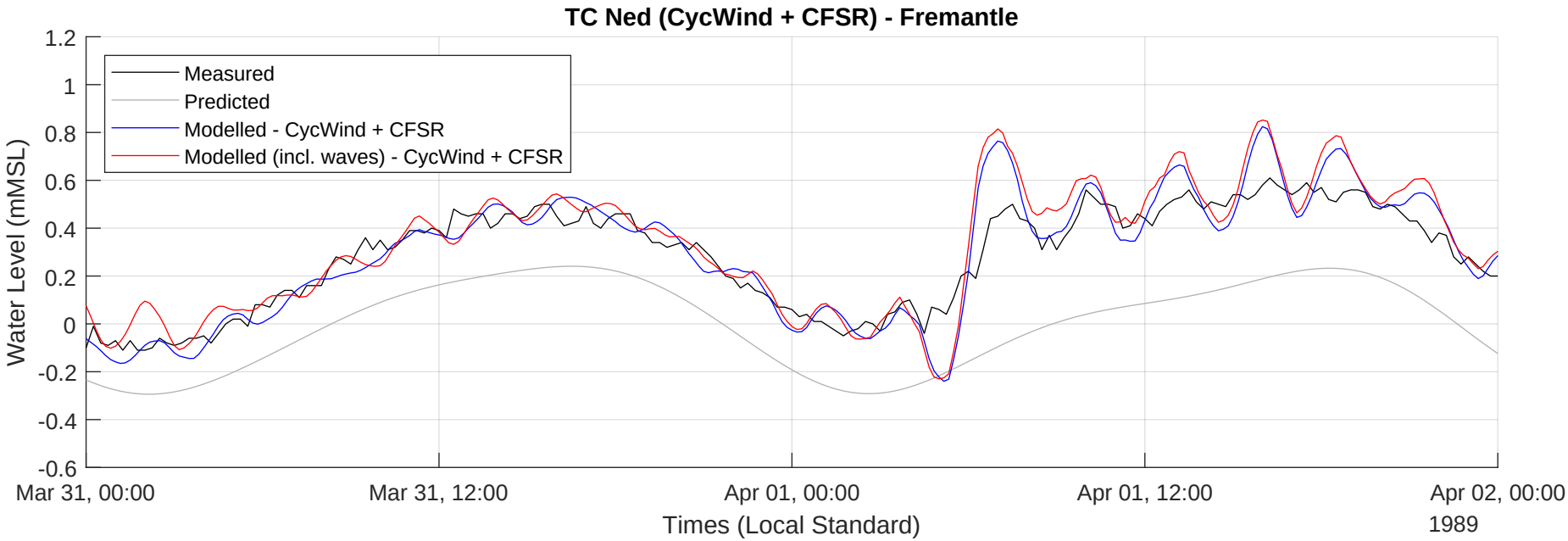
Scatter: 0.131

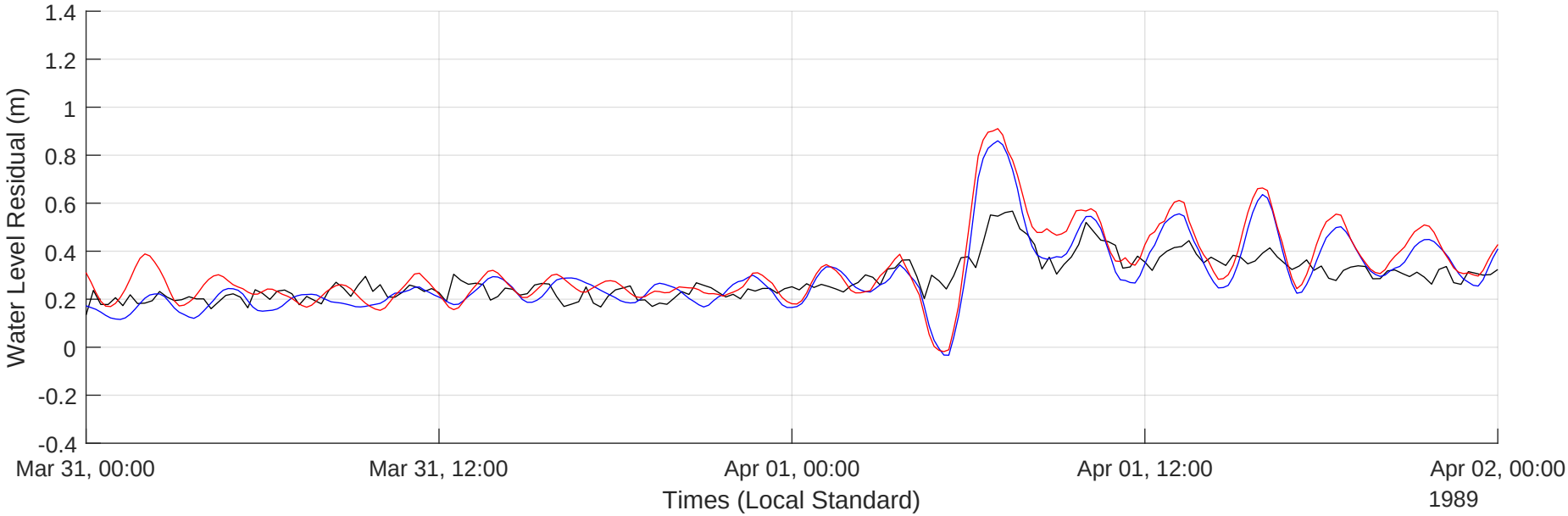
Bias: 0.014

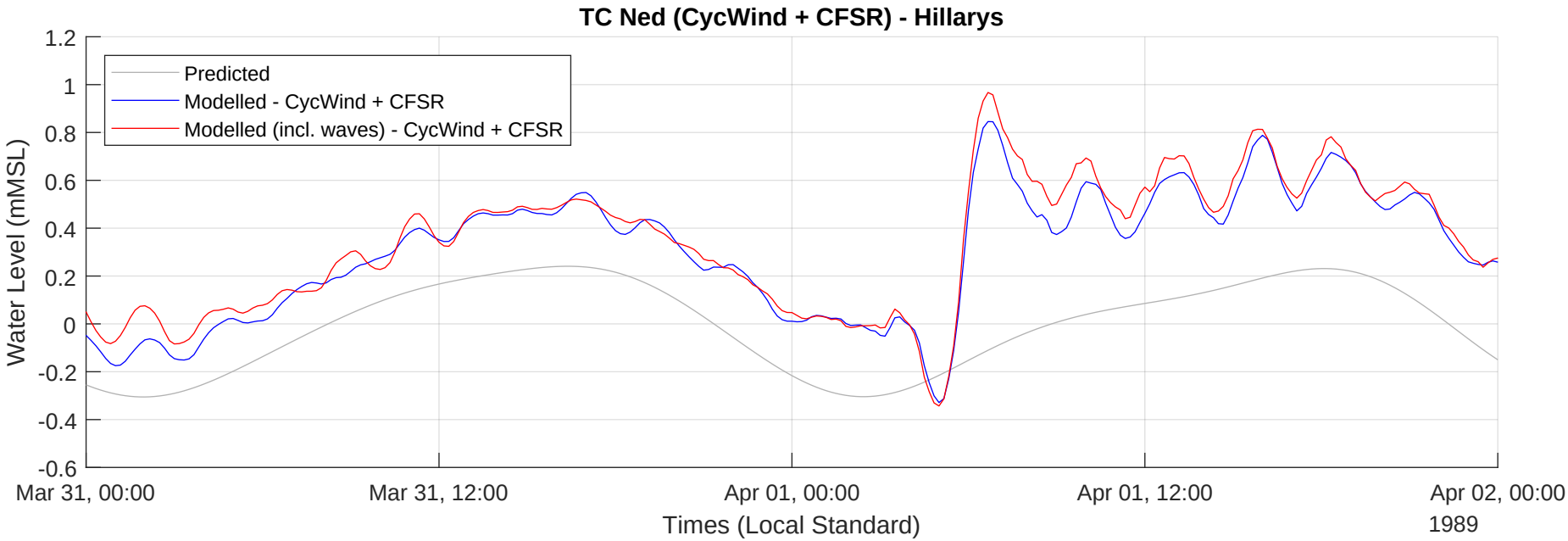
Skill: 0.985

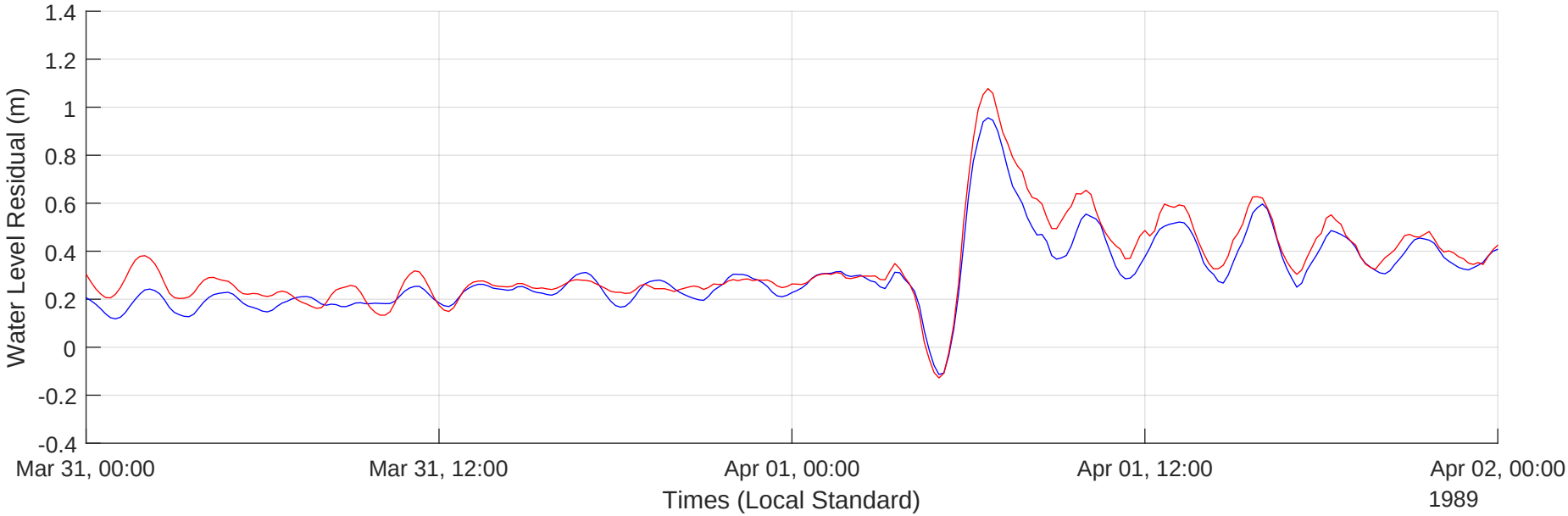
RMS error: 0.054

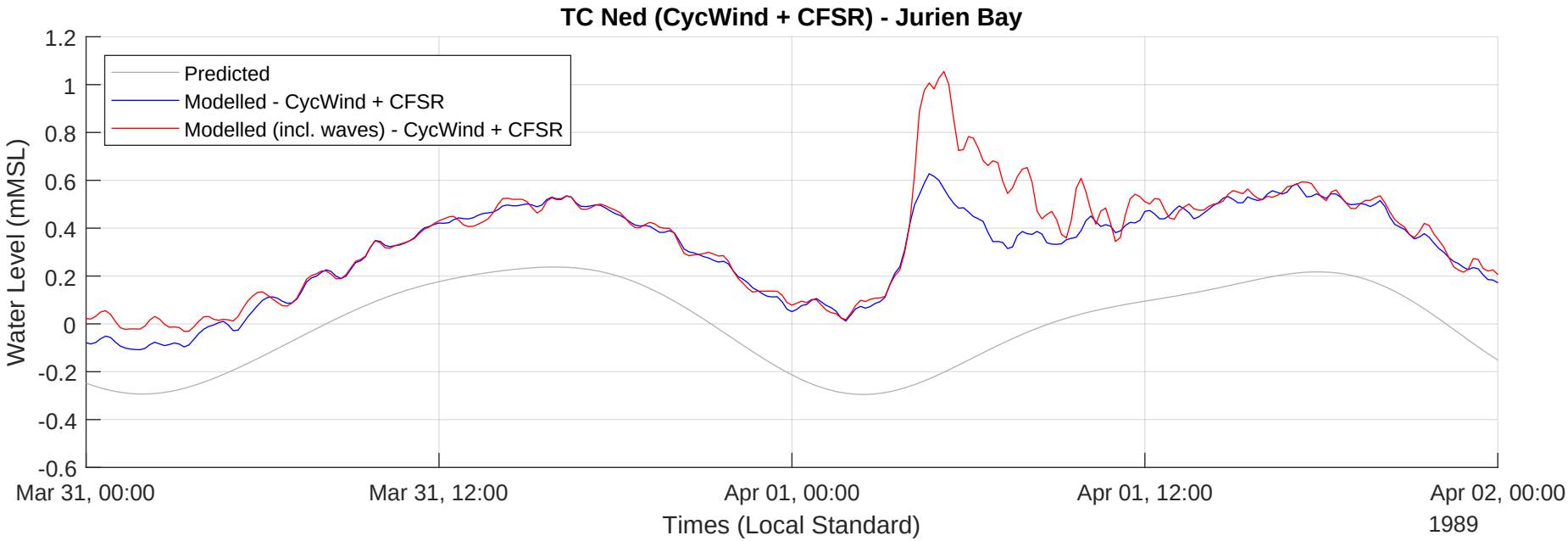
B.2 TC Ned (1989)

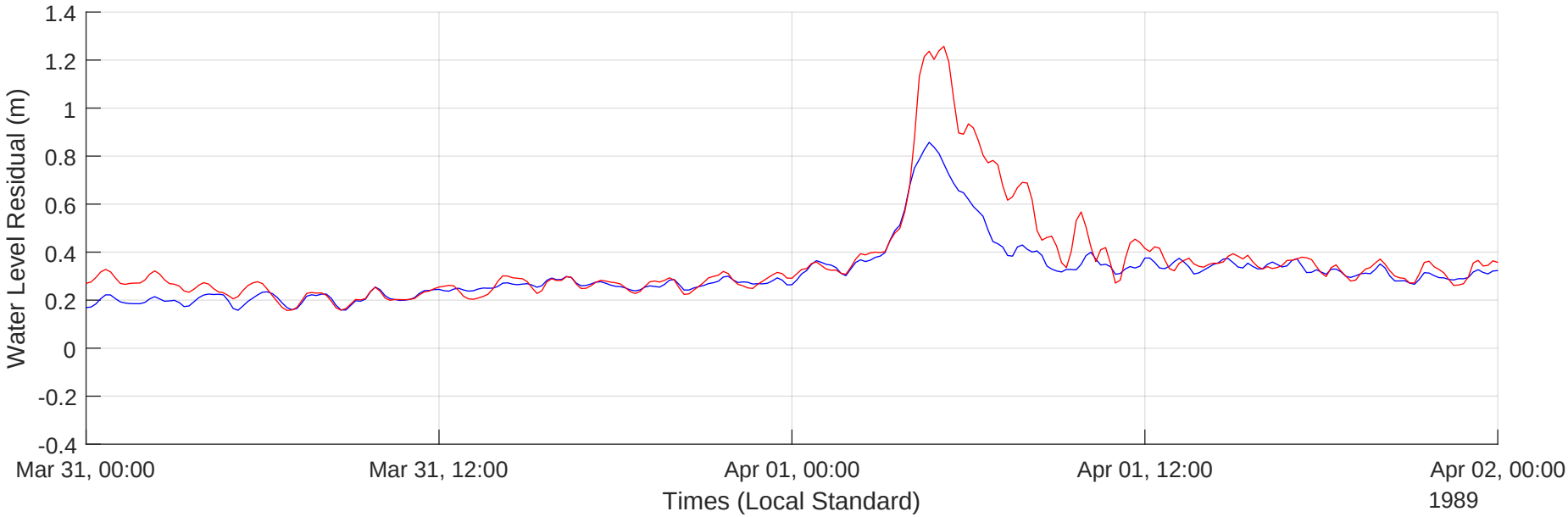

TC Ned (CycWind + CFSR) - Fremantle
Measured
Predicted
Modelled - CycWind + CFSR
Modelled (incl. waves) - CycWind + CFSR
Water Level (mMSL)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Mar 31, 00:00
Mar 31, 12:00
Apr 01, 00:00
Apr 01, 12:00
Apr 02, 00:00
1989
Times (Local Standard)

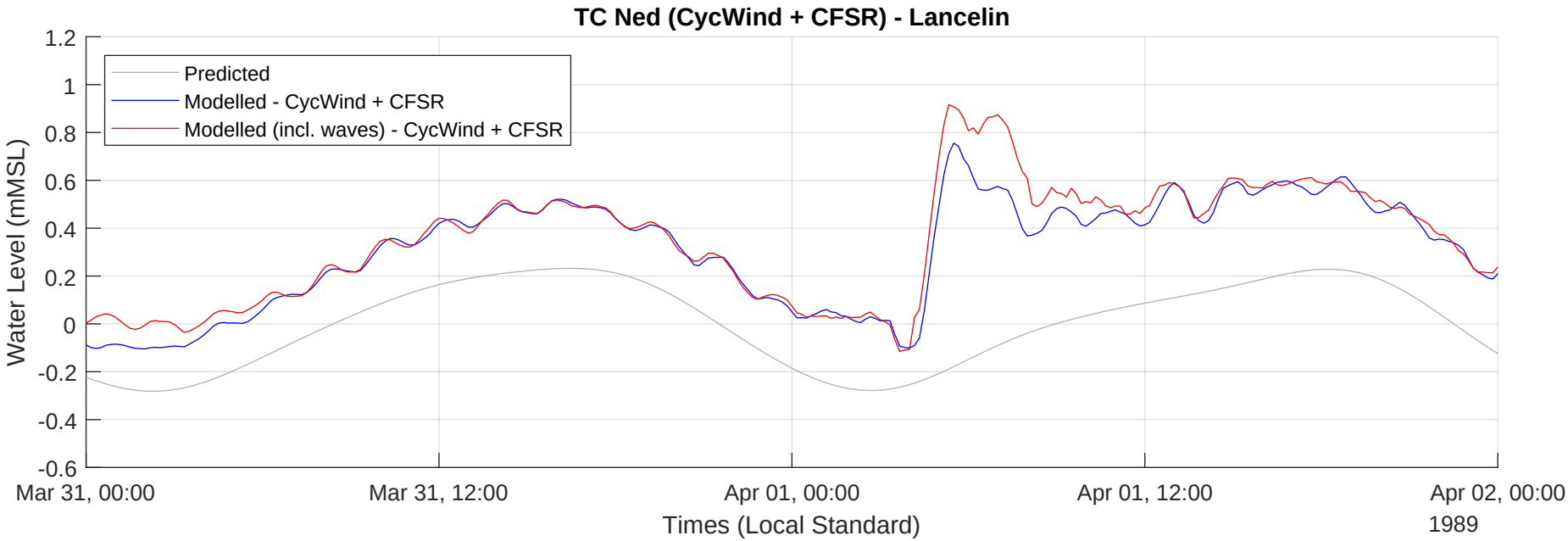

Water Level Residual (m)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Mar 31, 00:00
Mar 31, 12:00
Apr 01, 00:00
Apr 01, 12:00
Apr 02, 00:00
1989
Times (Local Standard)

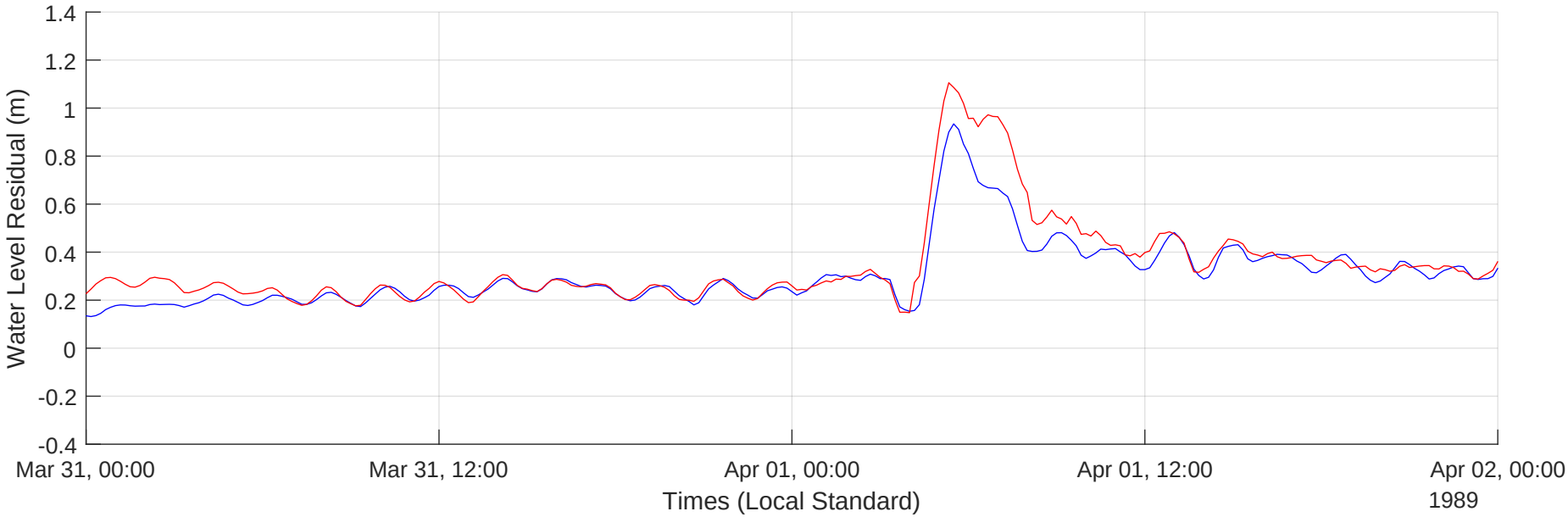

TC Ned (CycWind + CFSR) - Hillarys
Predicted
Modelled - CycWind + CFSR
Modelled (incl. waves) - CycWind + CFSR
Water Level (mMSL)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Mar 31, 00:00
Mar 31, 12:00
Apr 01, 00:00
Apr 01, 12:00
Apr 02, 00:00
1989
Times (Local Standard)

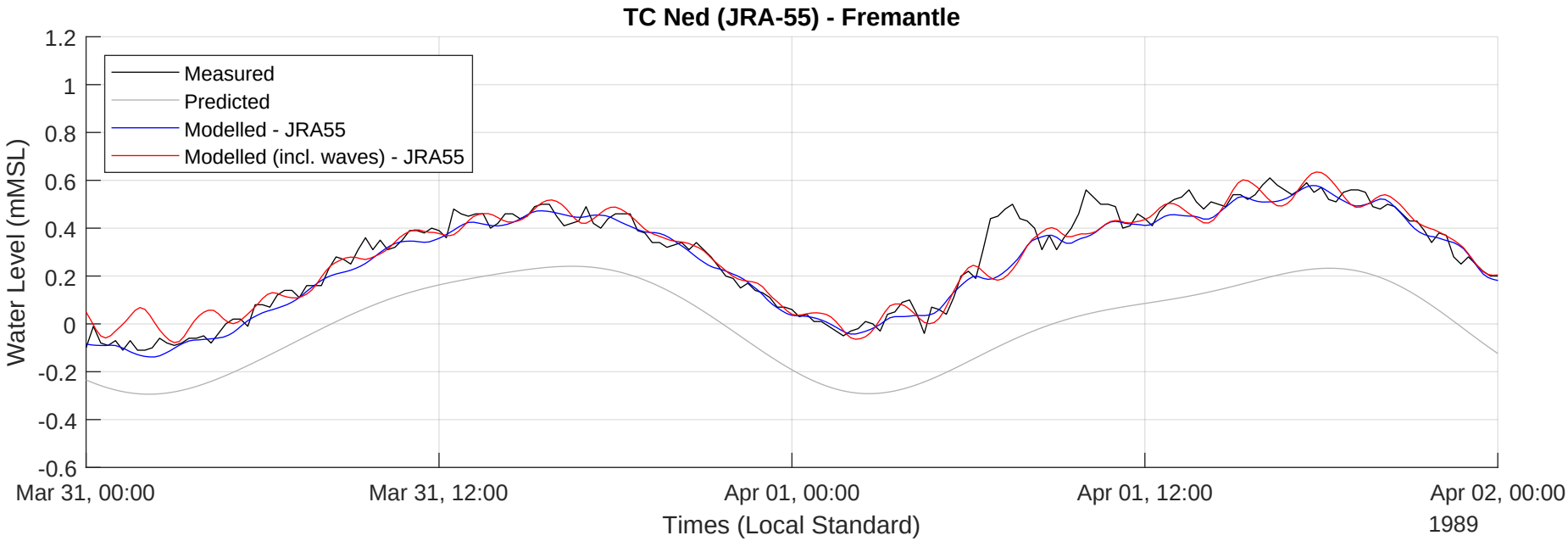

Water Level Residual (m)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Mar 31, 00:00
Mar 31, 12:00
Apr 01, 00:00
Apr 01, 12:00
Apr 02, 00:00
1989
Times (Local Standard)

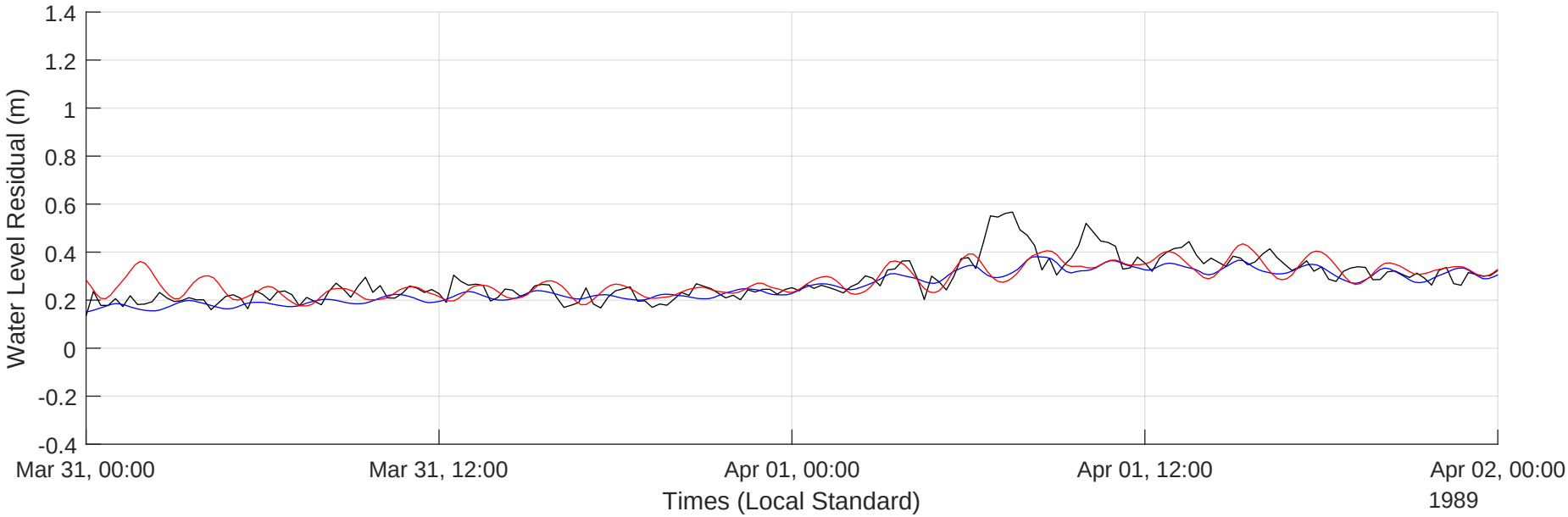

TC Ned (CycWind + CFSR) - Jurien Bay
Predicted
Modelled - CycWind + CFSR
Modelled (incl. waves) - CycWind + CFSR
Water Level (mMSL)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Mar 31, 00:00
Mar 31, 12:00
Apr 01, 00:00
Apr 01, 12:00
Apr 02, 00:00
1989
Times (Local Standard)

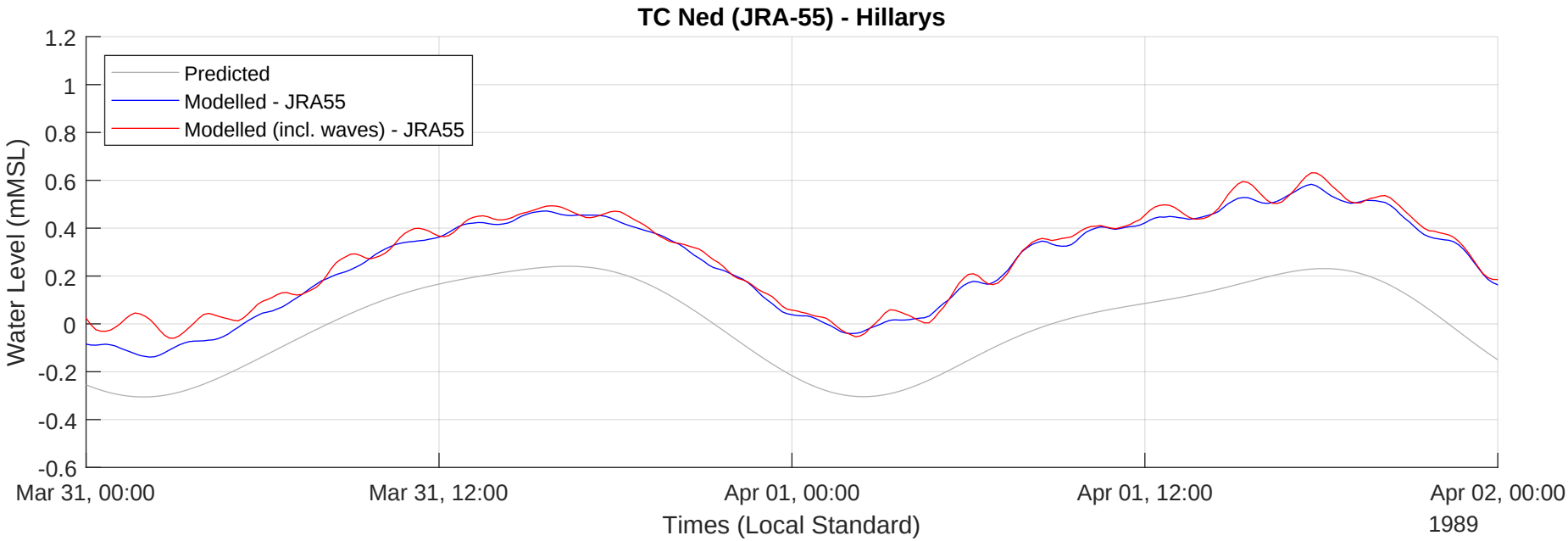

Water Level Residual (m)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Mar 31, 00:00
Mar 31, 12:00
Apr 01, 00:00
Apr 01, 12:00
Apr 02, 00:00
1989
Times (Local Standard)

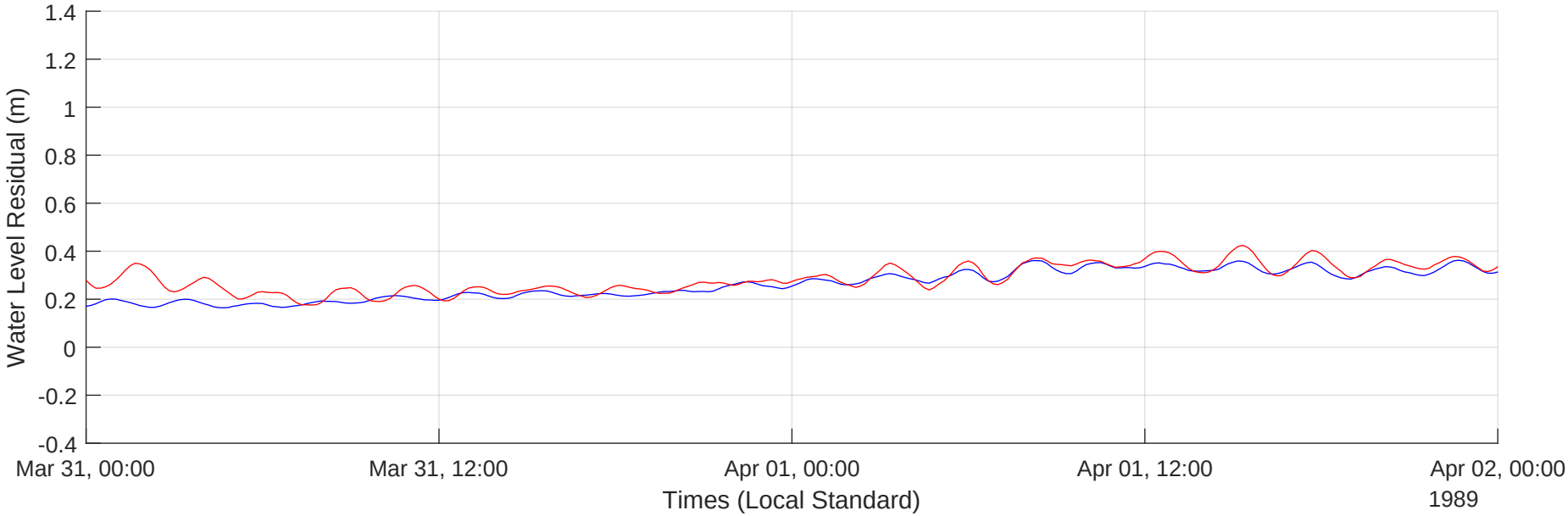

TC Ned (CycWind + CFSR) - Lancelin
Predicted
Modelled - CycWind + CFSR
Modelled (incl. waves) - CycWind + CFSR
Water Level (mMSL)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Mar 31, 00:00
Mar 31, 12:00
Apr 01, 00:00
Apr 01, 12:00
Apr 02, 00:00
1989
Times (Local Standard)

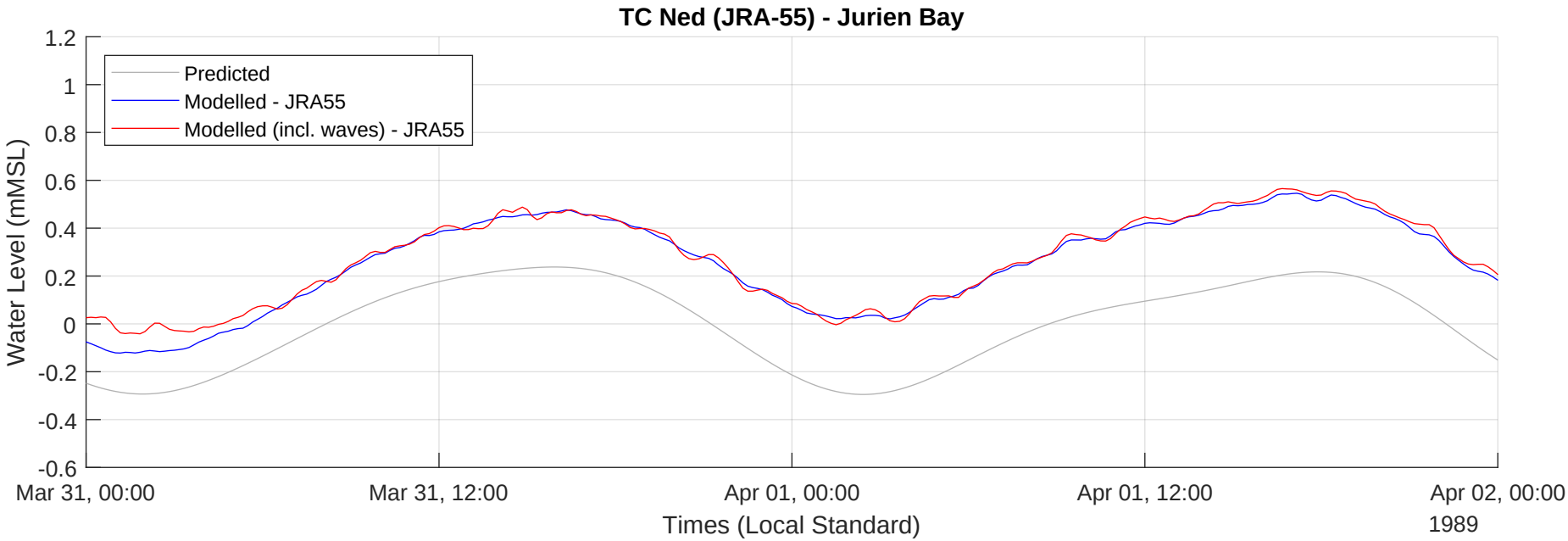

Water Level Residual (m)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Mar 31, 00:00
Mar 31, 12:00
Apr 01, 00:00
Apr 01, 12:00
Apr 02, 00:00
1989
Times (Local Standard)

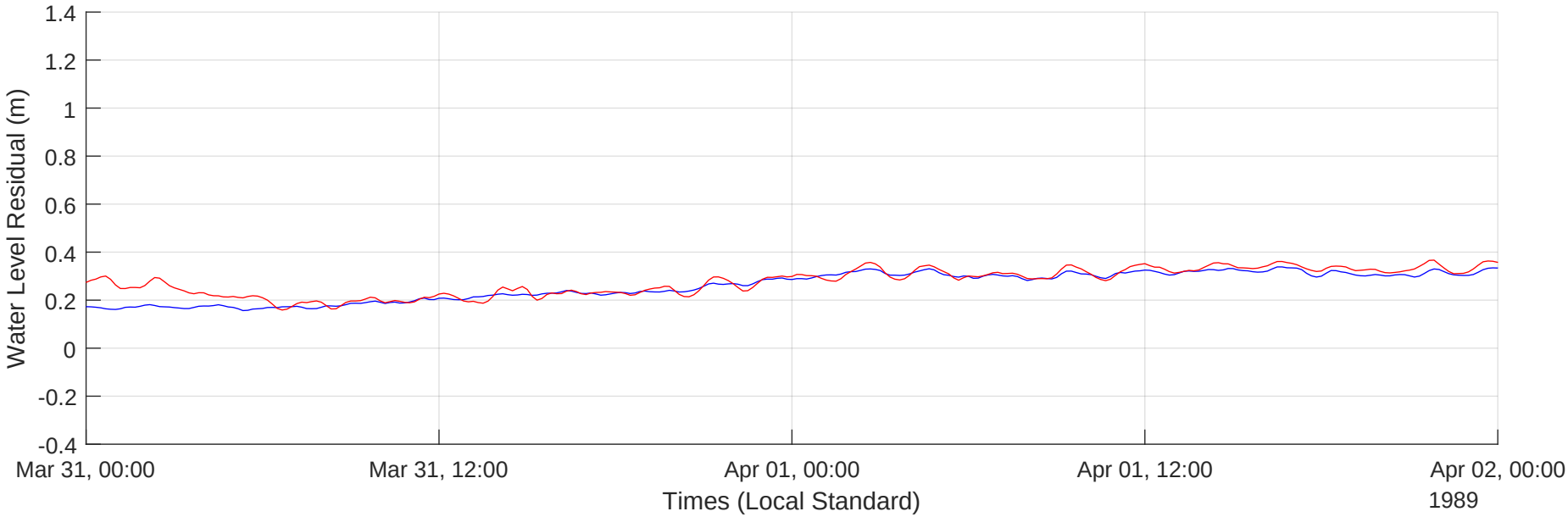

TC Ned (JRA-55) - Fremantle
Measured
Predicted
Modelled - JRA55
Modelled (incl. waves) - JRA55
Water Level (mMSL)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Mar 31, 00:00
Mar 31, 12:00
Apr 01, 00:00
Apr 01, 12:00
Apr 02, 00:00
1989
Times (Local Standard)

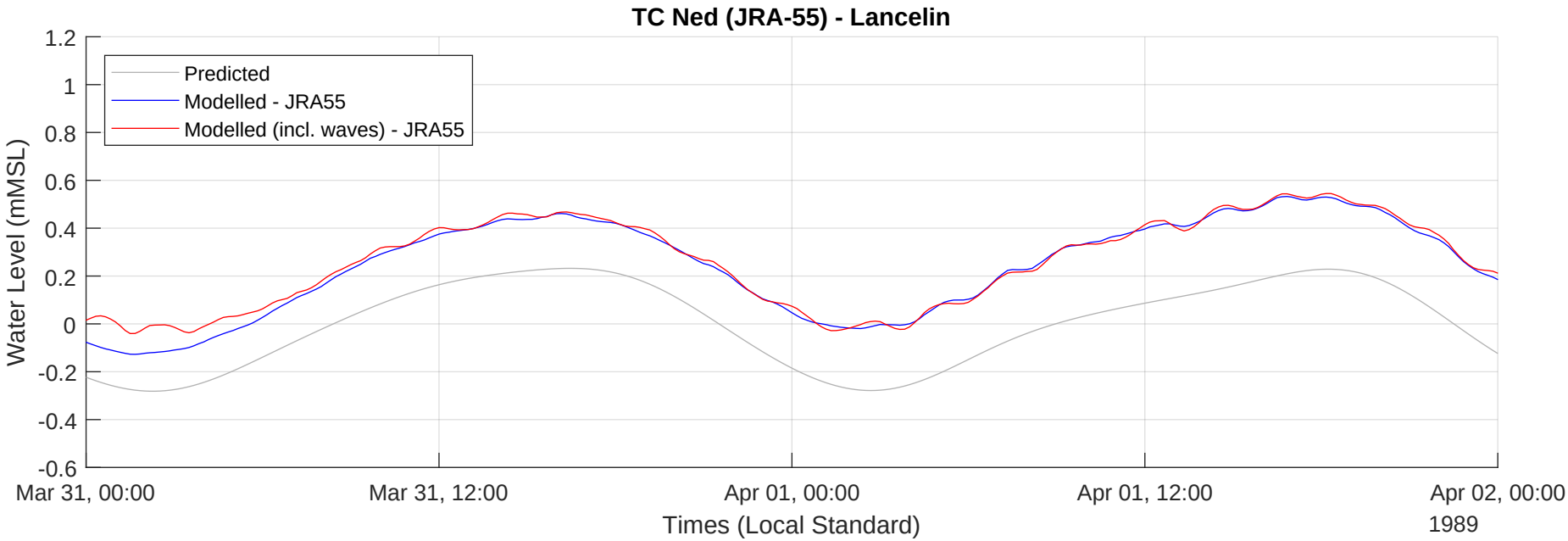

Water Level Residual (m)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Mar 31, 00:00
Mar 31, 12:00
Apr 01, 00:00
Apr 01, 12:00
Apr 02, 00:00
1989
Times (Local Standard)

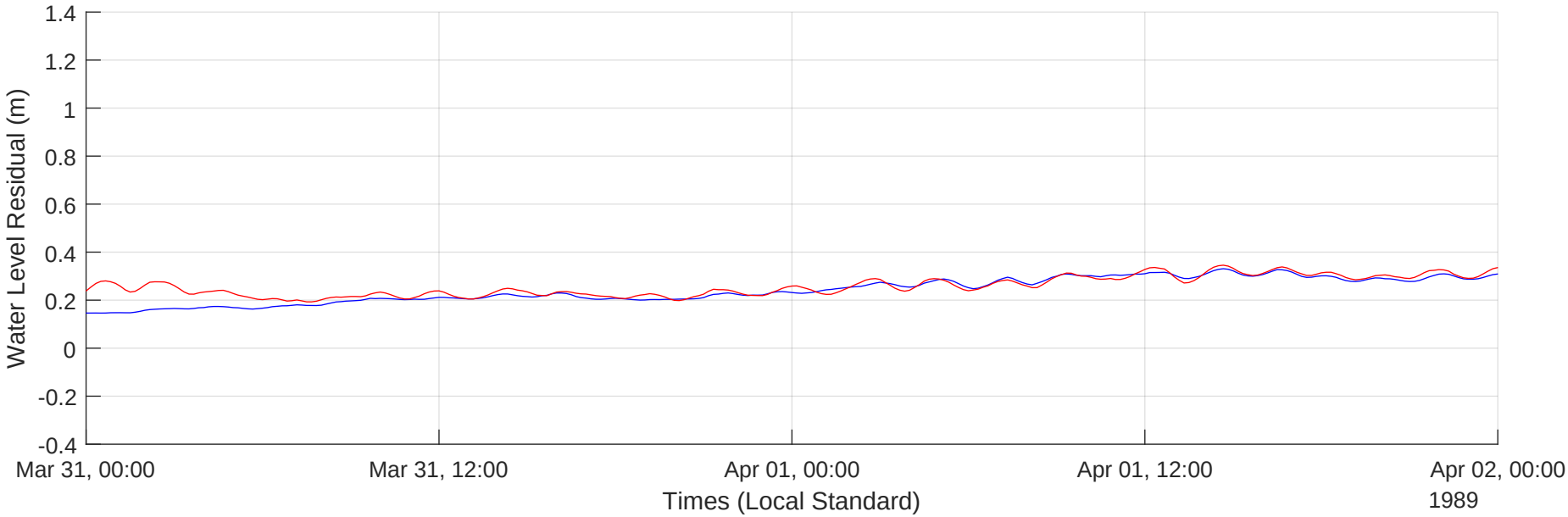

TC Ned (JRA-55) - Hillarys
Predicted
Modelled - JRA55
Modelled (incl. waves) - JRA55
Water Level (mMSL)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Mar 31, 00:00
Mar 31, 12:00
Apr 01, 00:00
Apr 01, 12:00
Apr 02, 00:00
1989
Times (Local Standard)

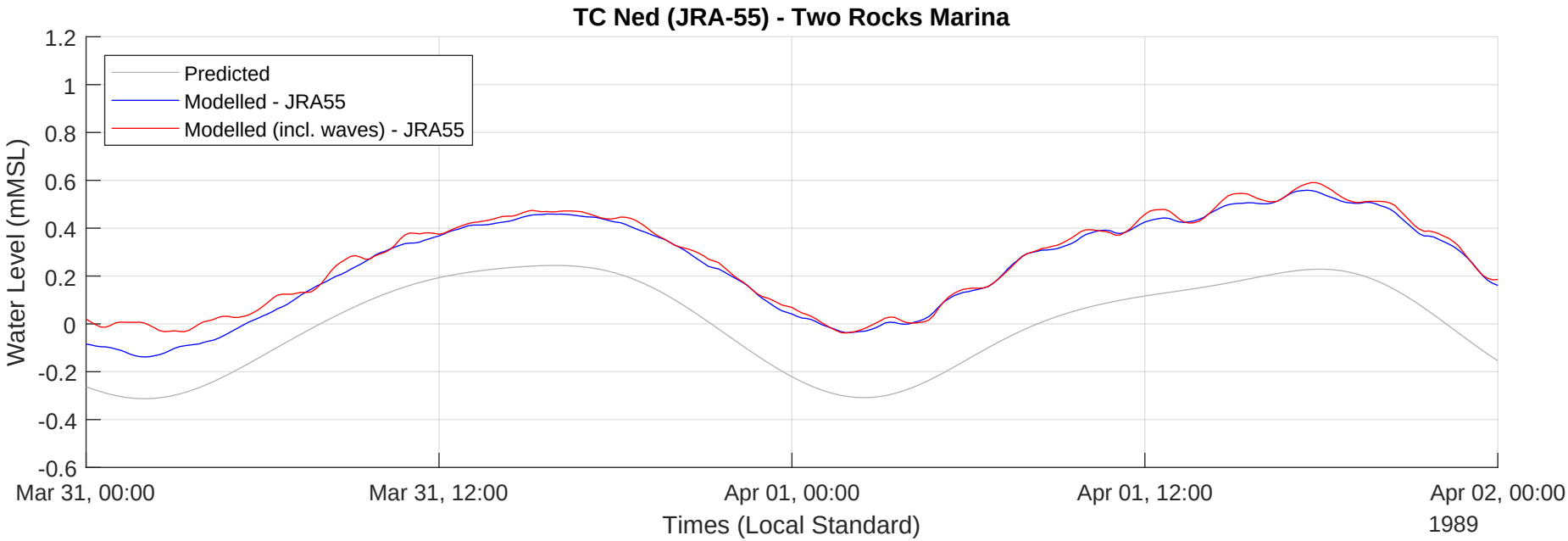

Water Level Residual (m)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Mar 31, 00:00
Mar 31, 12:00
Apr 01, 00:00
Apr 01, 12:00
Apr 02, 00:00
1989
Times (Local Standard)

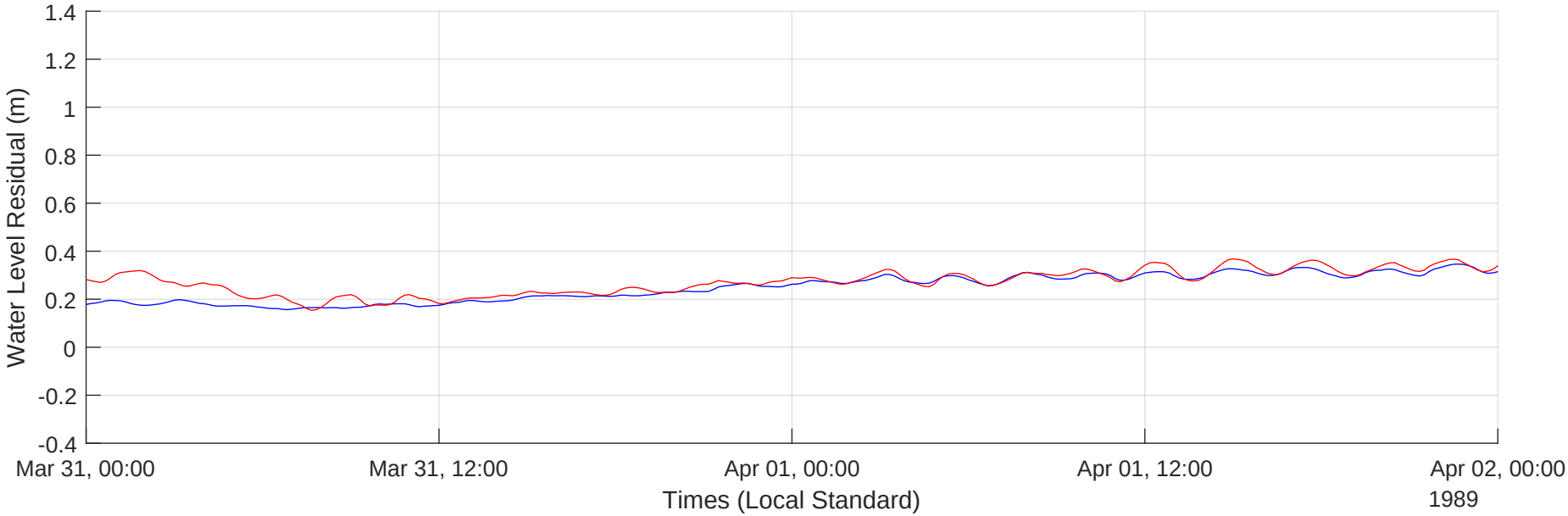

TC Ned (JRA-55) - Jurien Bay
Predicted
Modelled - JRA55
Modelled (incl. waves) - JRA55
Water Level (mMSL)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Mar 31, 00:00
Mar 31, 12:00
Apr 01, 00:00
Apr 01, 12:00
Apr 02, 00:00
1989
Times (Local Standard)

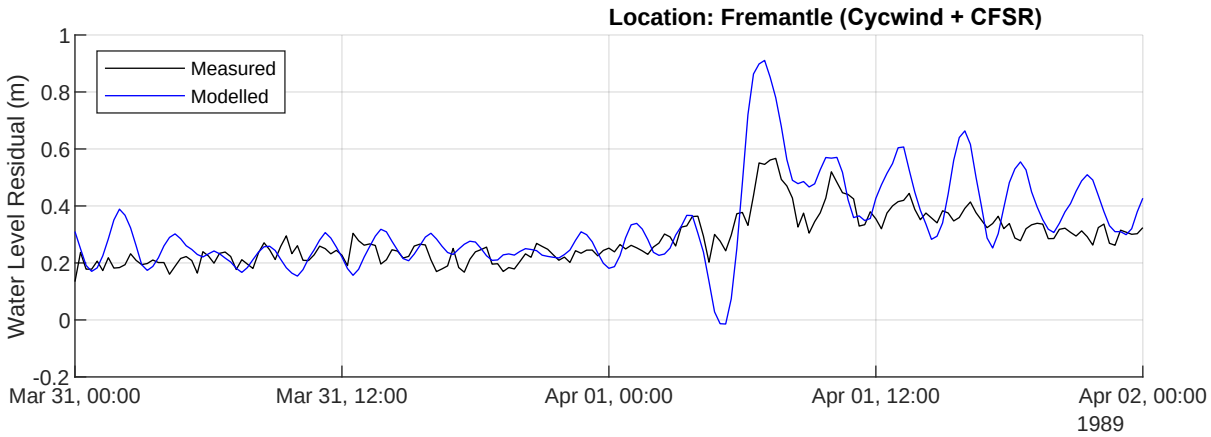

Water Level Residual (m)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Mar 31, 00:00
Mar 31, 12:00
Apr 01, 00:00
Apr 01, 12:00
Apr 02, 00:00
1989
Times (Local Standard)

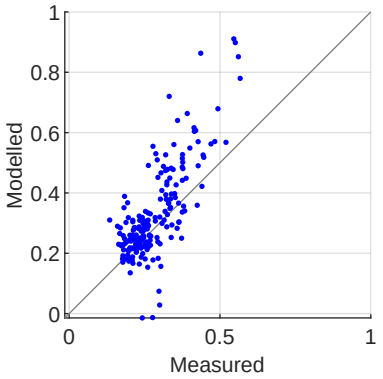

TC Ned (JRA-55) - Lancelin
Predicted
Modelled - JRA55
Modelled (incl. waves) - JRA55
Water Level (mMSL)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Mar 31, 00:00
Mar 31, 12:00
Apr 01, 00:00
Apr 01, 12:00
Apr 02, 00:00
1989
Times (Local Standard)


Water Level Residual (m)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Mar 31, 00:00
Mar 31, 12:00
Apr 01, 00:00
Apr 01, 12:00
Apr 02, 00:00
1989
Times (Local Standard)


TC Ned (JRA-55) - Two Rocks Marina
Predicted
Modelled - JRA55
Modelled (incl. waves) - JRA55
Water Level (mMSL)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Mar 31, 00:00
Mar 31, 12:00
Apr 01, 00:00
Apr 01, 12:00
Apr 02, 00:00
1989
Times (Local Standard)


Water Level Residual (m)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Mar 31, 00:00
Mar 31, 12:00
Apr 01, 00:00
Apr 01, 12:00
Apr 02, 00:00
1989
Times (Local Standard)





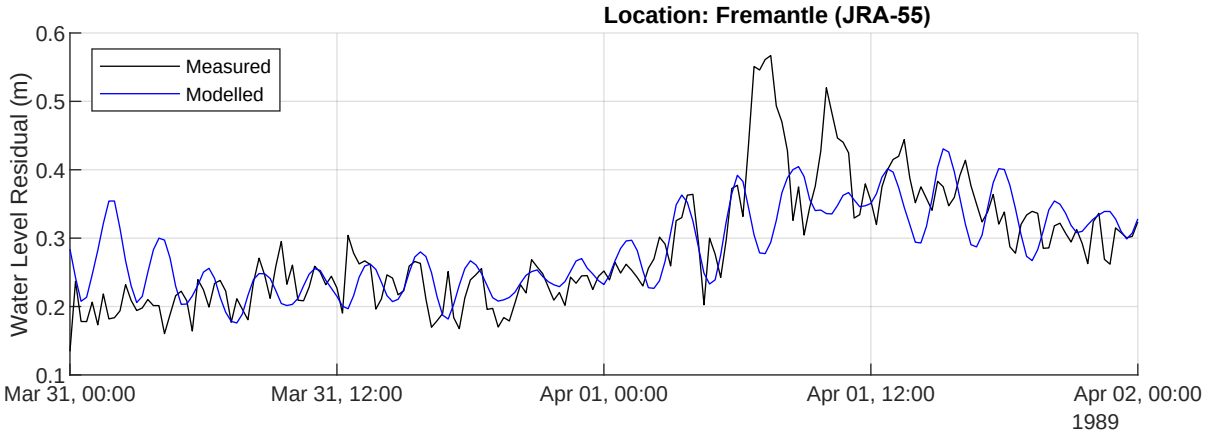
Water Level Residual (m)

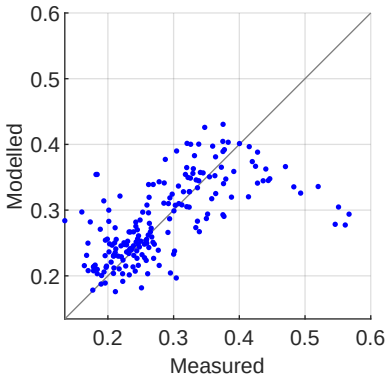
Scatter: 0.403

Bias: 0.046

Skill: 0.759

RMS error: 0.114





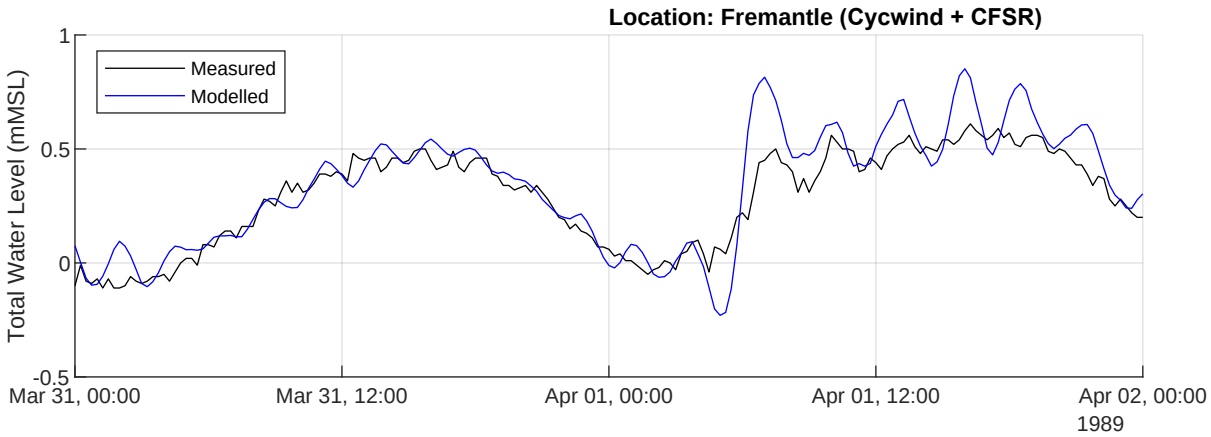
Water Level Residual (m)

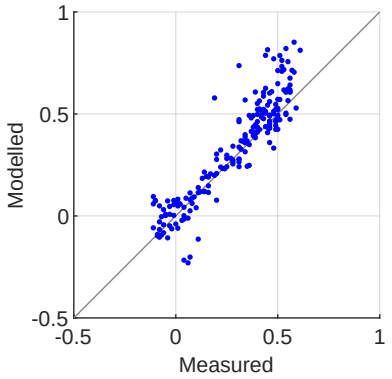
Scatter: 0.233

Bias: 0.000

Skill: 0.755

RMS error: 0.066





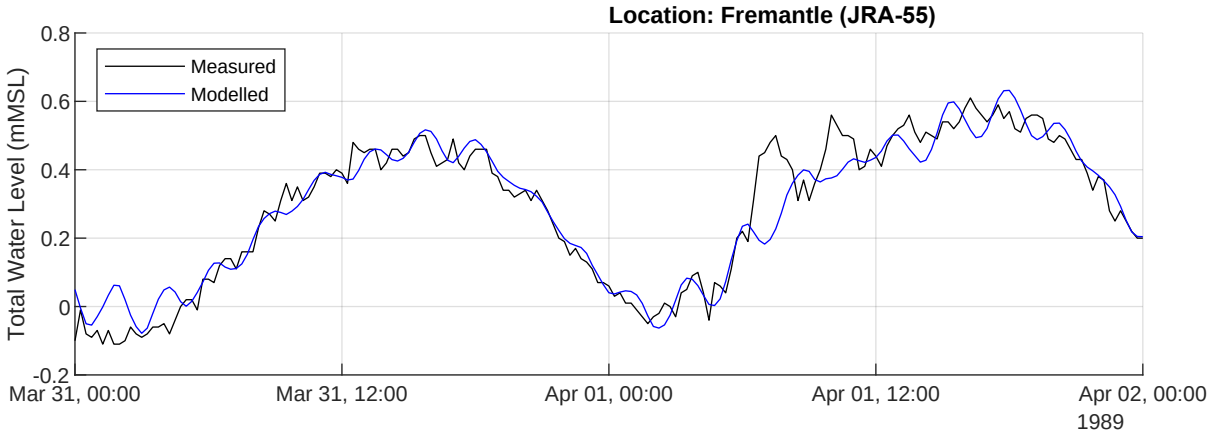
Total Water Level (mMSL)

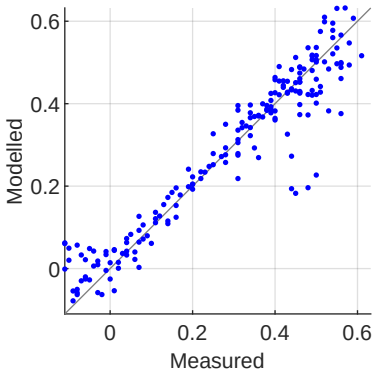
Scatter: 0.287

Bias: 0.046

Skill: 0.938

RMS error: 0.114





Total Water Level (mMSL)

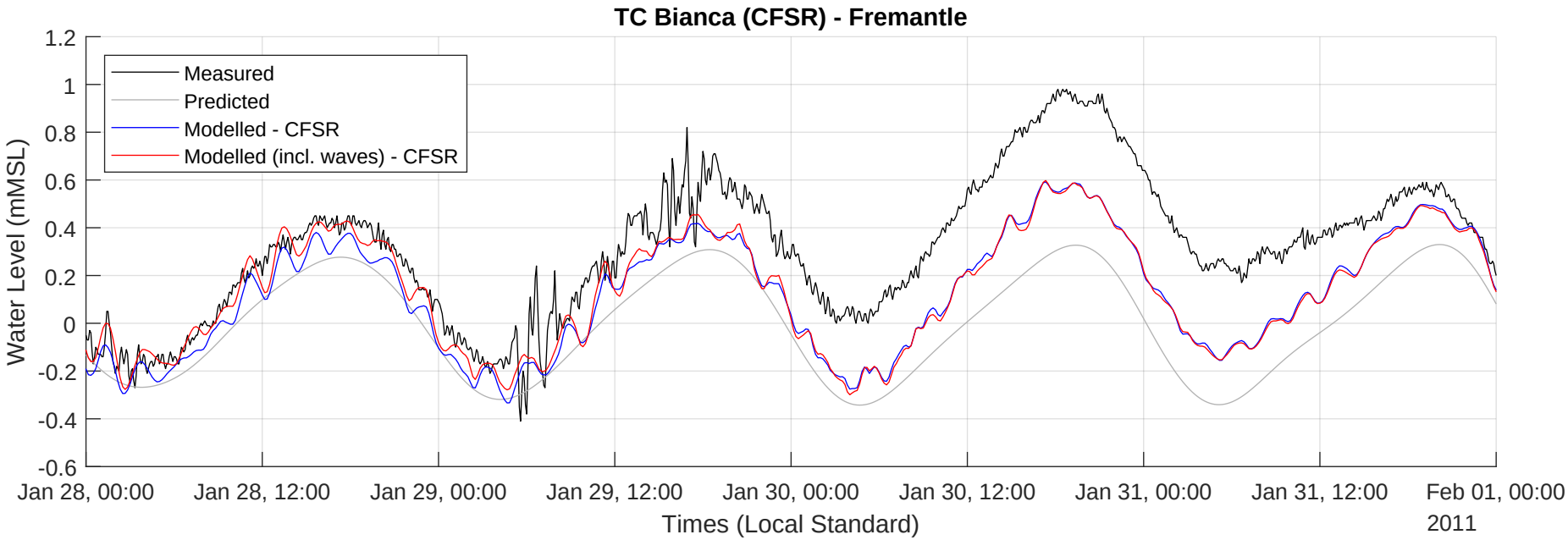
Scatter: 0.166

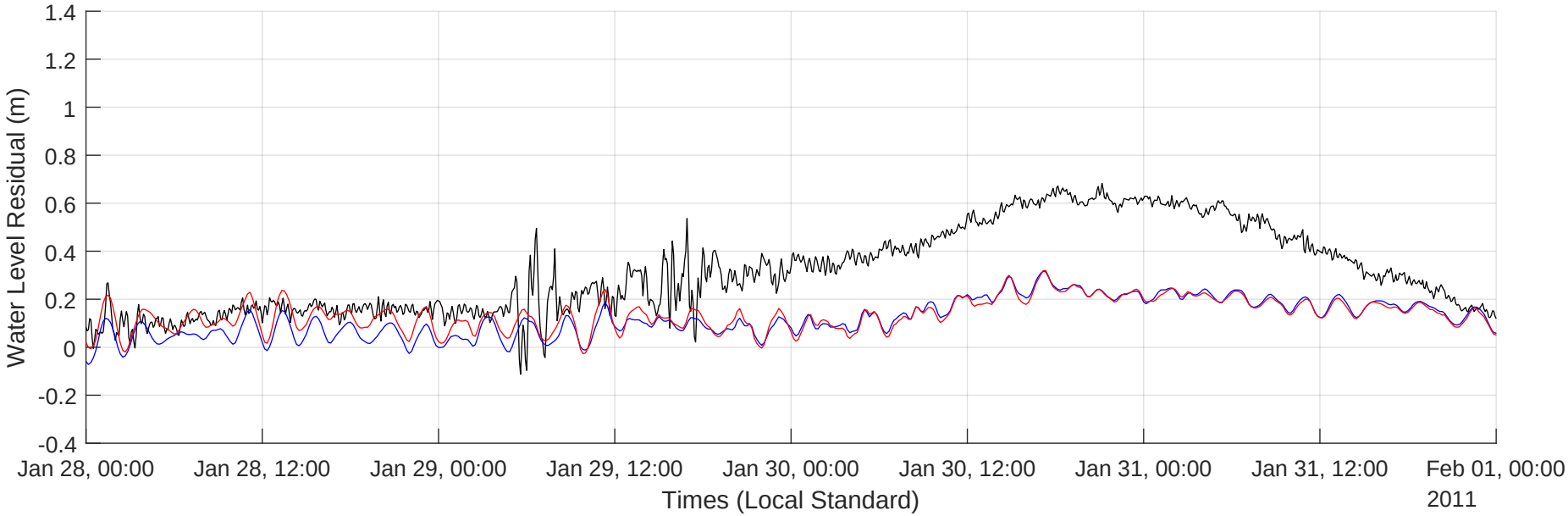
Bias: 0.000

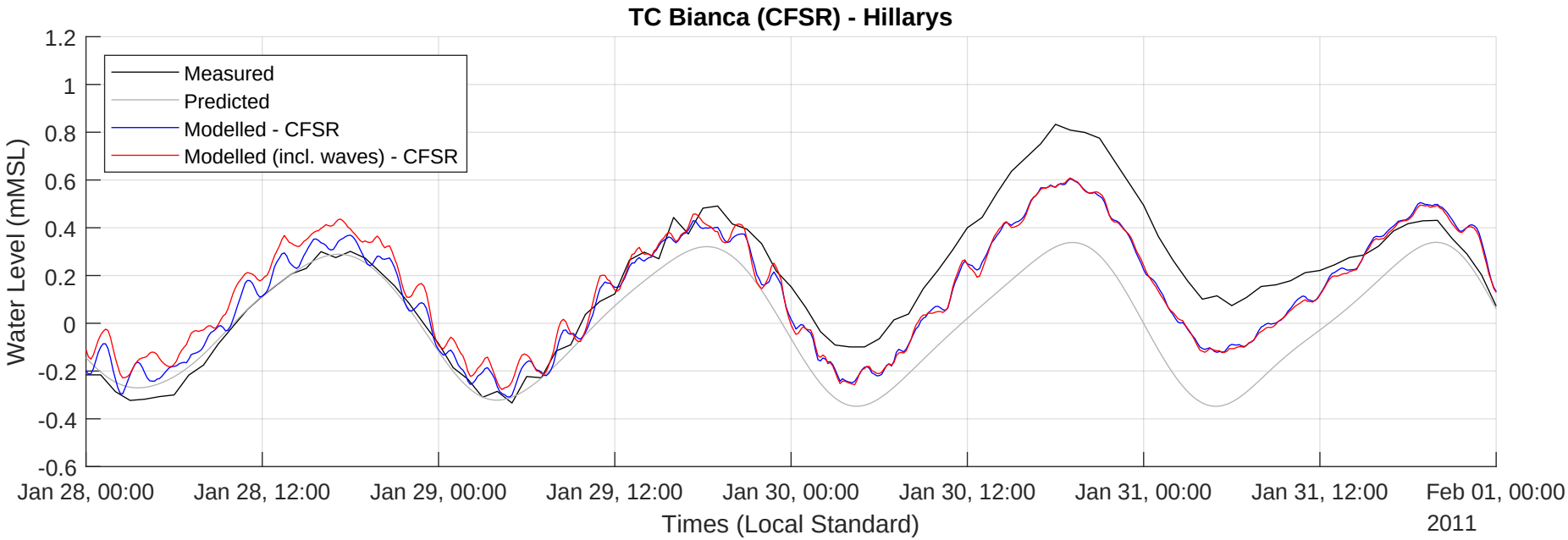
Skill: 0.973

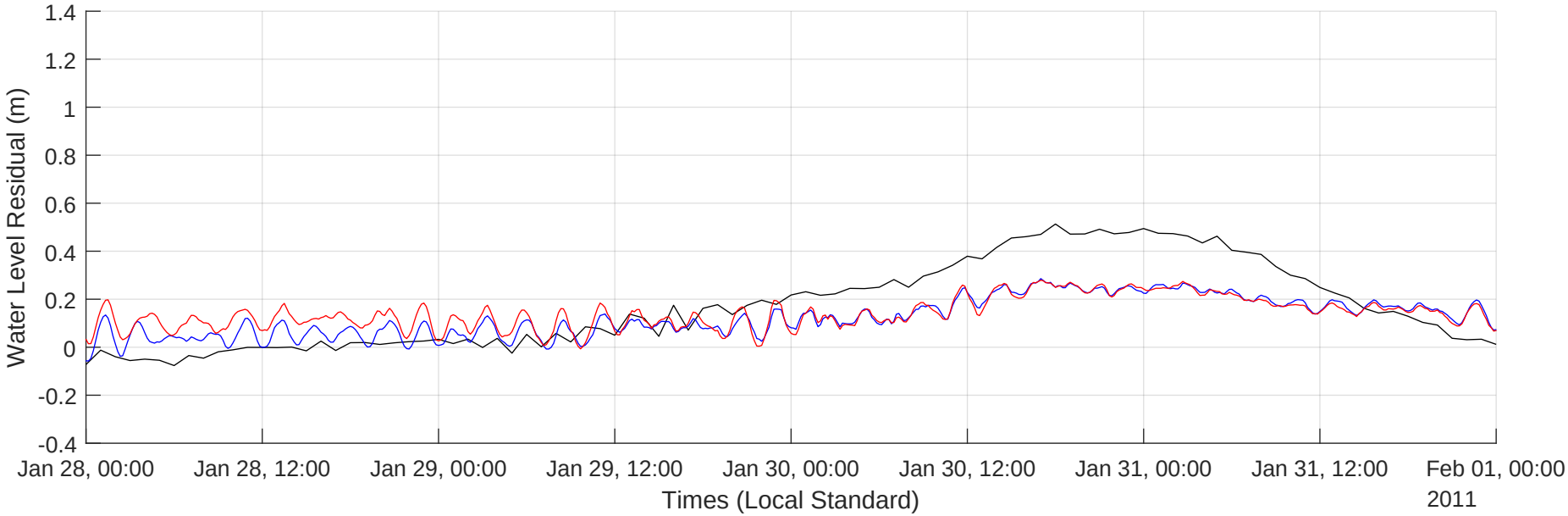
RMS error: 0.066

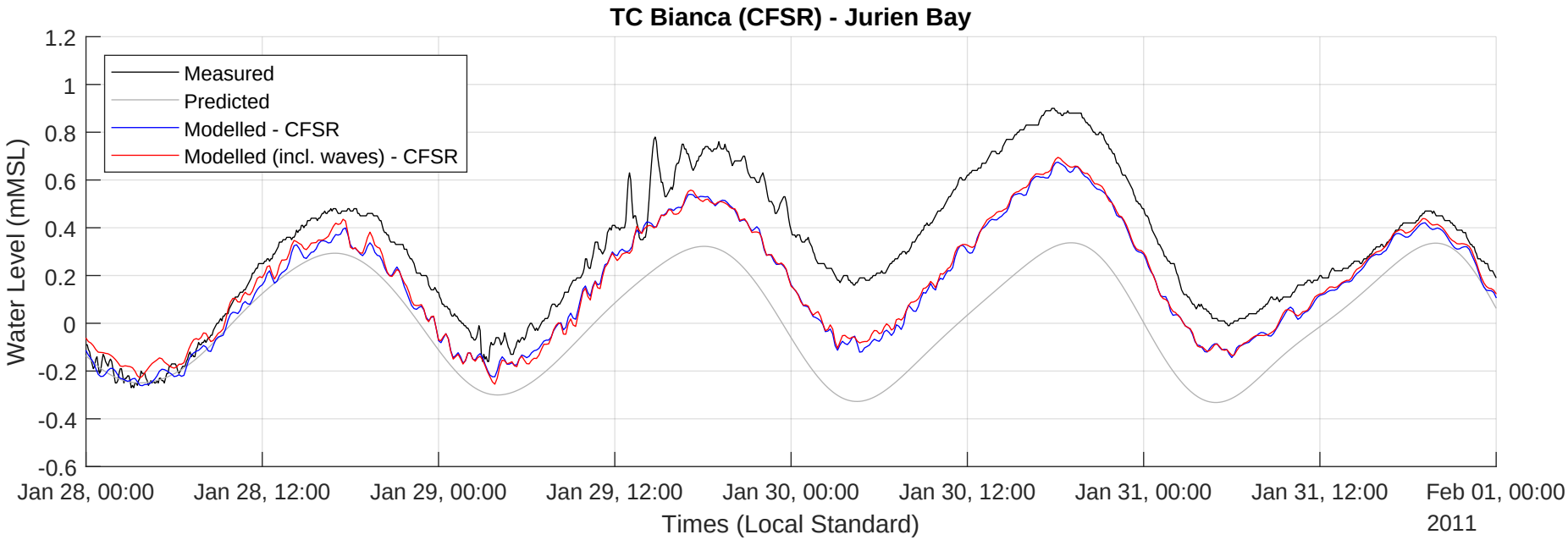
B.3 TC Bianca (2011)

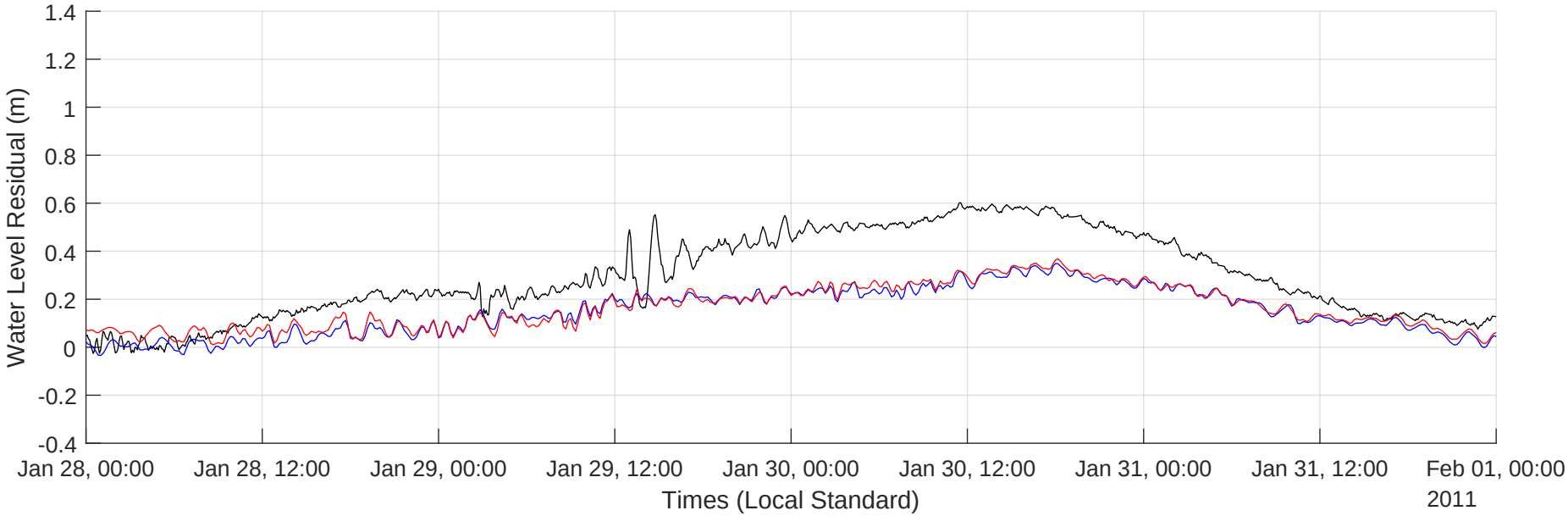

TC Bianca (CFSR) - Fremantle
Measured
Predicted
Modelled - CFSR
Modelled (incl. waves) - CFSR
Water Level (mMSL)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Jan 28, 00:00
Jan 28, 12:00
Jan 29, 00:00
Jan 29, 12:00
Jan 30, 00:00
Jan 30, 12:00
Jan 31, 00:00
Jan 31, 12:00
Feb 01, 00:00
2011
Times (Local Standard)

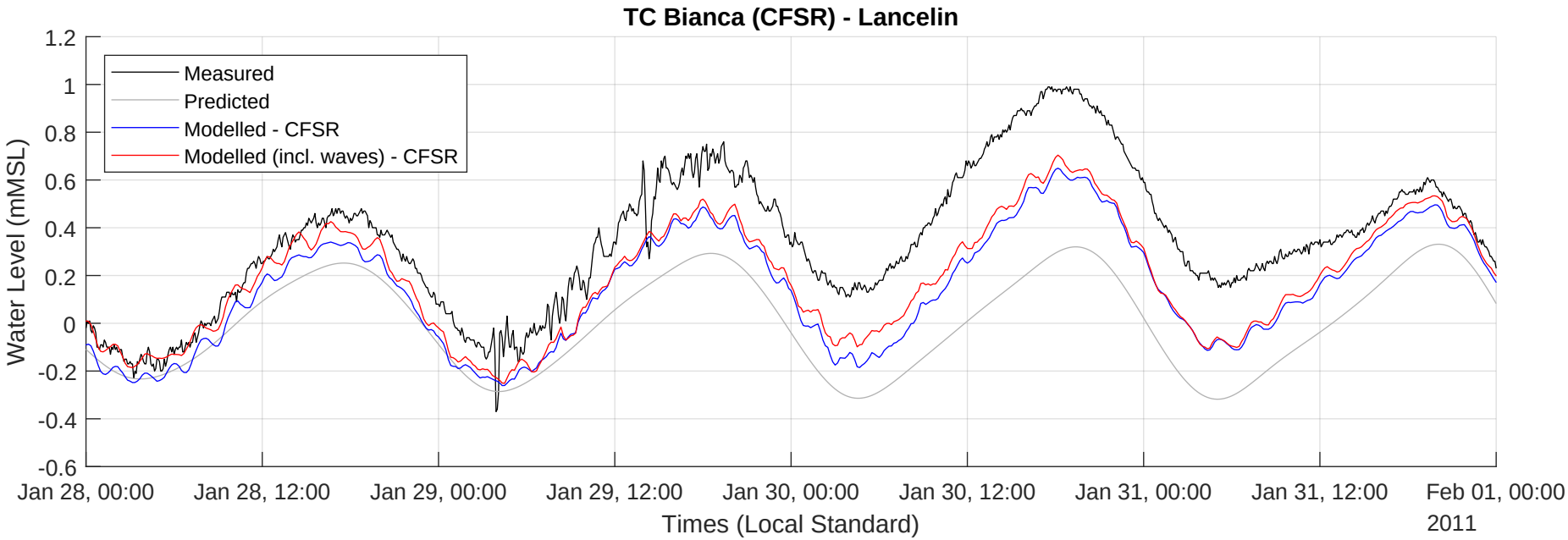

Water Level Residual (m)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Jan 28, 00:00
Jan 28, 12:00
Jan 29, 00:00
Jan 29, 12:00
Jan 30, 00:00
Jan 30, 12:00
Jan 31, 00:00
Jan 31, 12:00
Feb 01, 00:00
2011
Times (Local Standard)

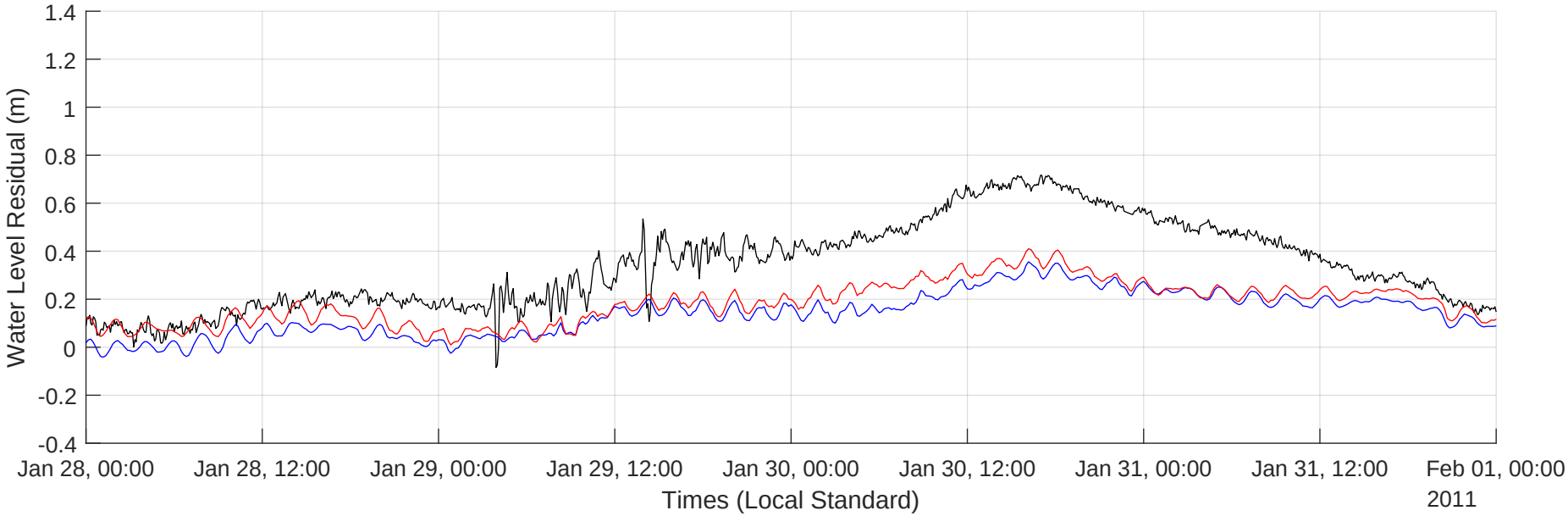

TC Bianca (CFSR) - Hillarys
Measured
Predicted
Modelled - CFSR
Modelled (incl. waves) - CFSR
Water Level (mMSL)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Jan 28, 00:00
Jan 28, 12:00
Jan 29, 00:00
Jan 29, 12:00
Jan 30, 00:00
Jan 30, 12:00
Jan 31, 00:00
Jan 31, 12:00
Feb 01, 00:00
2011
Times (Local Standard)

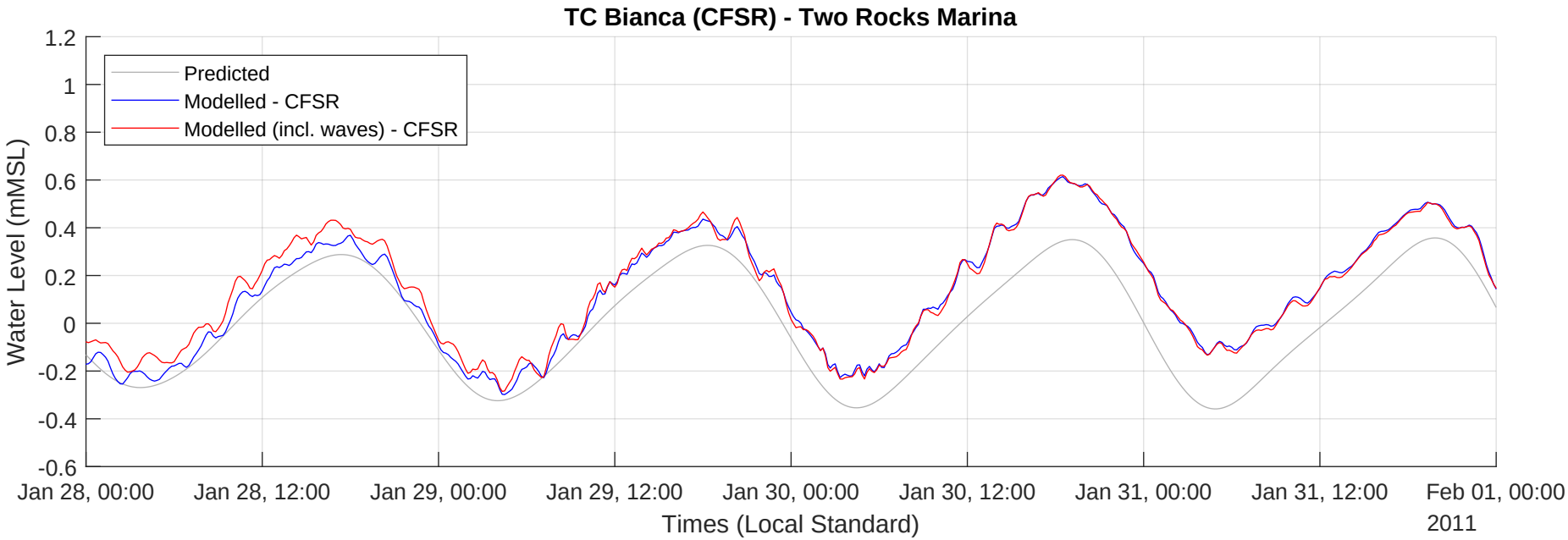

Water Level Residual (m)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Jan 28, 00:00
Jan 28, 12:00
Jan 29, 00:00
Jan 29, 12:00
Jan 30, 00:00
Jan 30, 12:00
Jan 31, 00:00
Jan 31, 12:00
Feb 01, 00:00
2011
Times (Local Standard)

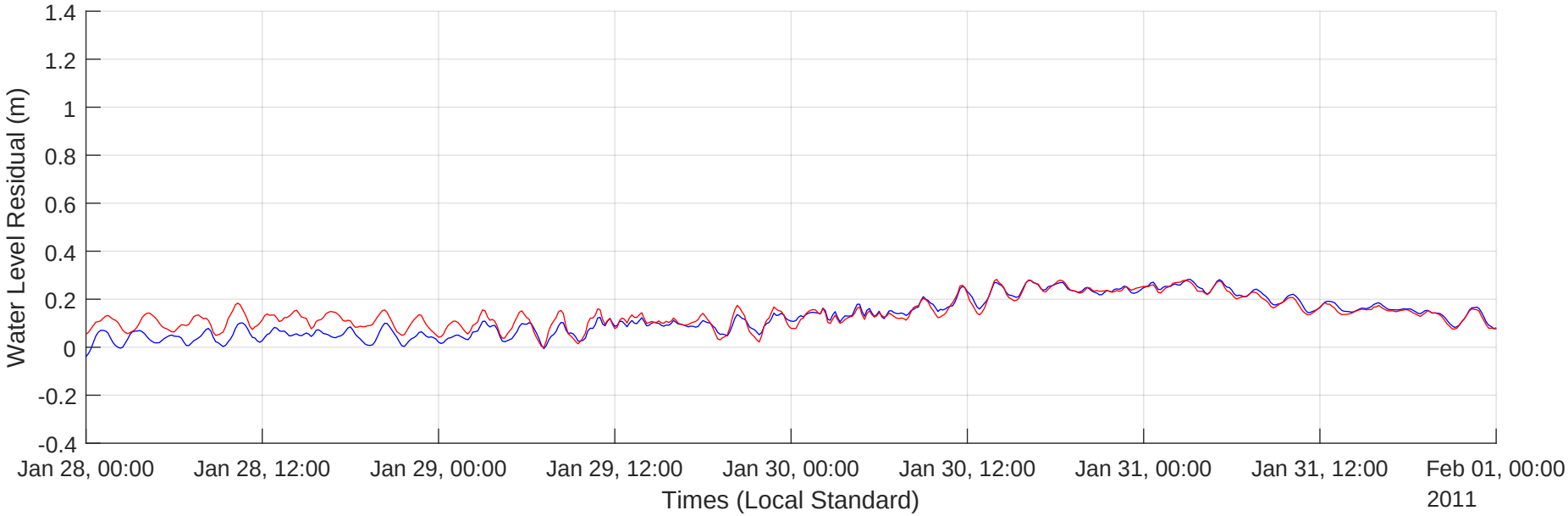

TC Bianca (CFSR) - Jurien Bay
Measured
Predicted
Modelled - CFSR
Modelled (incl. waves) - CFSR
Water Level (mMSL)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Jan 28, 00:00
Jan 28, 12:00
Jan 29, 00:00
Jan 29, 12:00
Jan 30, 00:00
Jan 30, 12:00
Jan 31, 00:00
Jan 31, 12:00
Feb 01, 00:00
2011
Times (Local Standard)

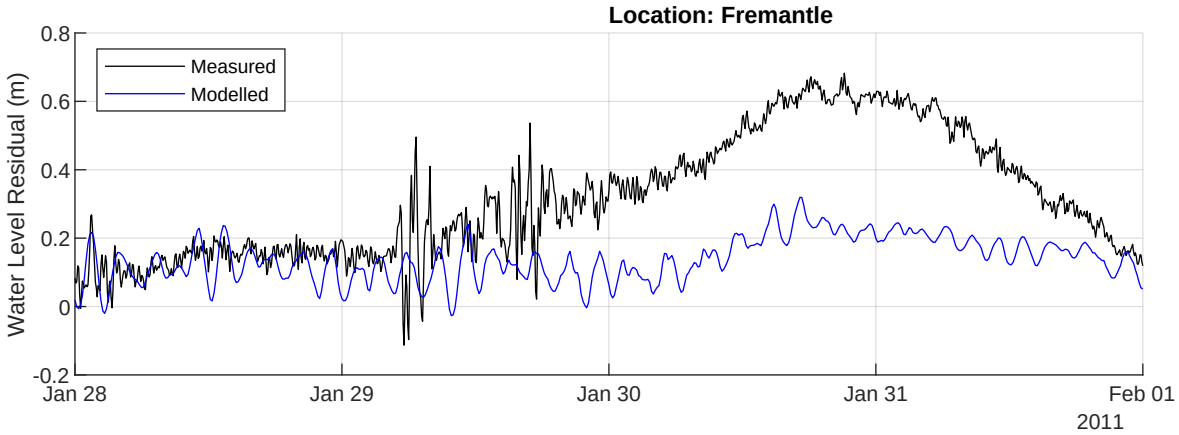

Water Level Residual (m)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Jan 28, 00:00
Jan 28, 12:00
Jan 29, 00:00
Jan 29, 12:00
Jan 30, 00:00
Jan 30, 12:00
Jan 31, 00:00
Jan 31, 12:00
Feb 01, 00:00
2011
Times (Local Standard)

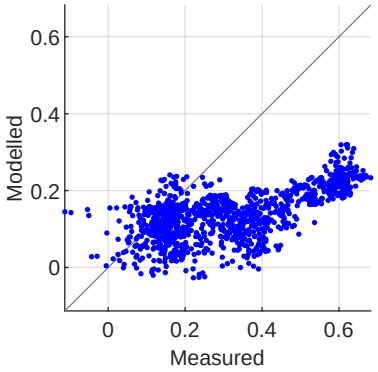

TC Bianca (CFSR) - Lancelin
Measured
Predicted
Modelled - CFSR
Modelled (incl. waves) - CFSR
Water Level (mMSL)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Jan 28, 00:00
Jan 28, 12:00
Jan 29, 00:00
Jan 29, 12:00
Jan 30, 00:00
Jan 30, 12:00
Jan 31, 00:00
Jan 31, 12:00
Feb 01, 00:00
2011
Times (Local Standard)


Water Level Residual (m)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Jan 28, 00:00
Jan 28, 12:00
Jan 29, 00:00
Jan 29, 12:00
Jan 30, 00:00
Jan 30, 12:00
Jan 31, 00:00
Jan 31, 12:00
Feb 01, 00:00
2011
Times (Local Standard)


TC Bianca (CFSR) - Two Rocks Marina
Predicted
Modelled - CFSR
Modelled (incl. waves) - CFSR
Water Level (mMSL)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Jan 28, 00:00
Jan 28, 12:00
Jan 29, 00:00
Jan 29, 12:00
Jan 30, 00:00
Jan 30, 12:00
Jan 31, 00:00
Jan 31, 12:00
Feb 01, 00:00
2011
Times (Local Standard)


Water Level Residual (m)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Jan 28, 00:00
Jan 28, 12:00
Jan 29, 00:00
Jan 29, 12:00
Jan 30, 00:00
Jan 30, 12:00
Jan 31, 00:00
Jan 31, 12:00
Feb 01, 00:00
2011
Times (Local Standard)





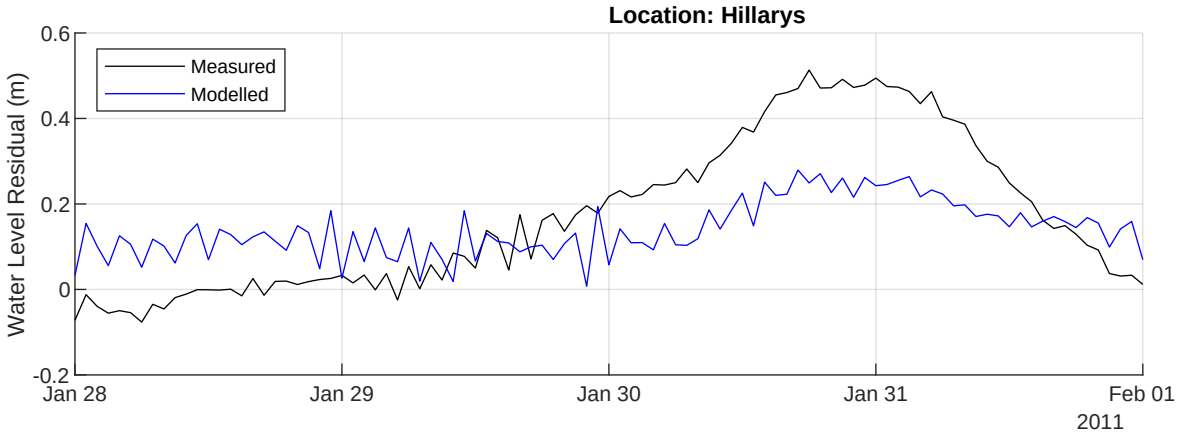
Water Level Residual (m)

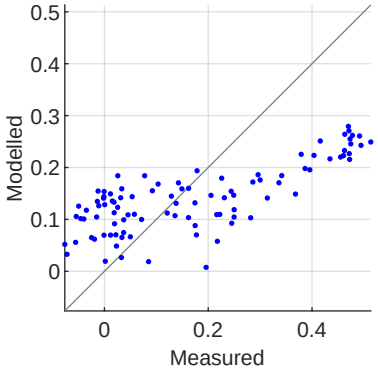
Scatter: 0.538

Bias: -0.178

Skill: 0.351

RMS error: 0.231





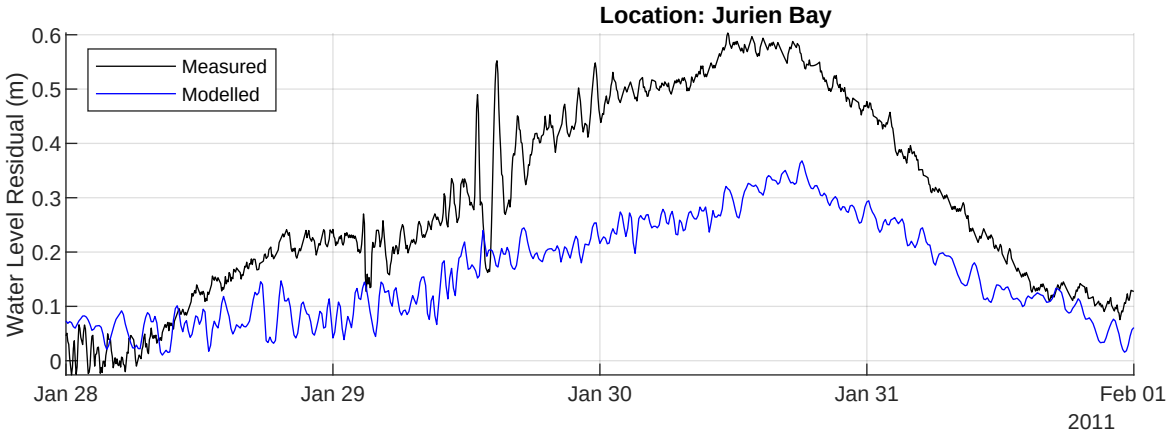
Water Level Residual (m)

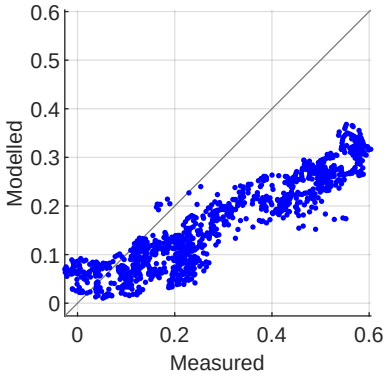
Scatter: 0.560

Bias: -0.031

Skill: 0.643

RMS error: 0.139





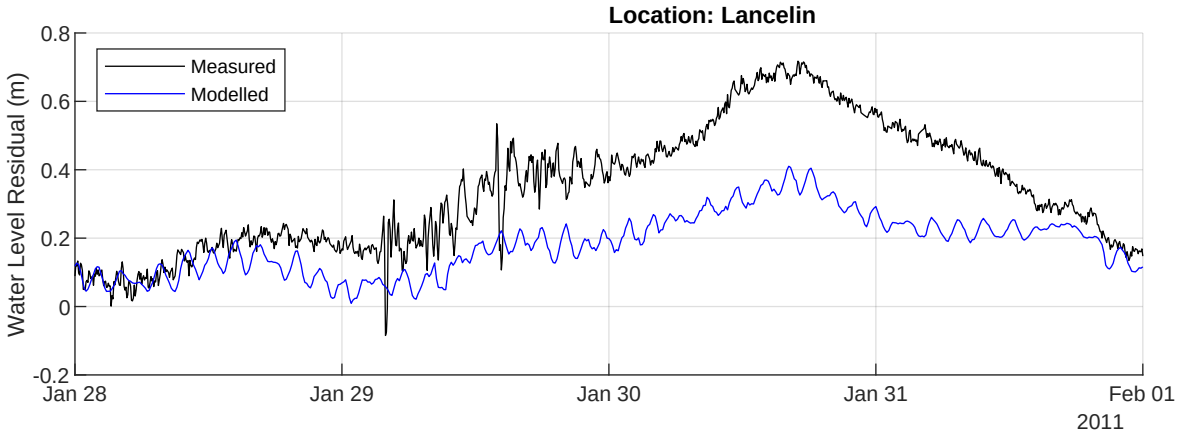
Water Level Residual (m)

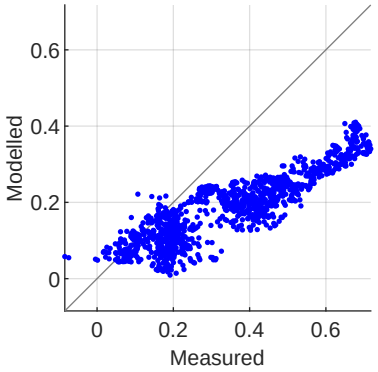
Scatter: 0.512

Bias: -0.132

Skill: 0.688

RMS error: 0.165





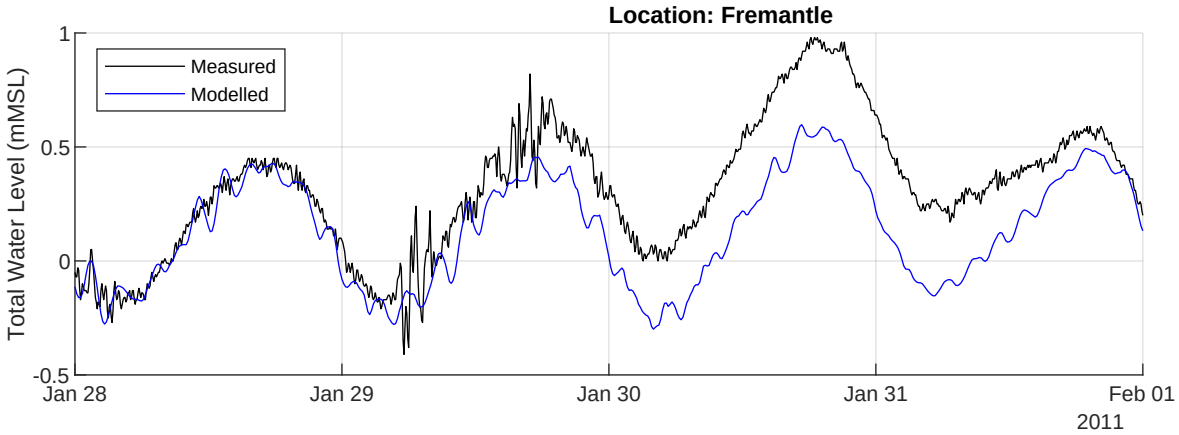
Water Level Residual (m)

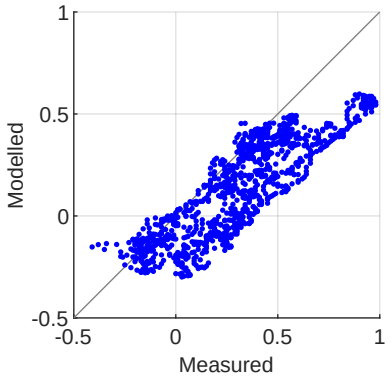
Scatter: 0.454

Bias: -0.159

Skill: 0.601

RMS error: 0.194





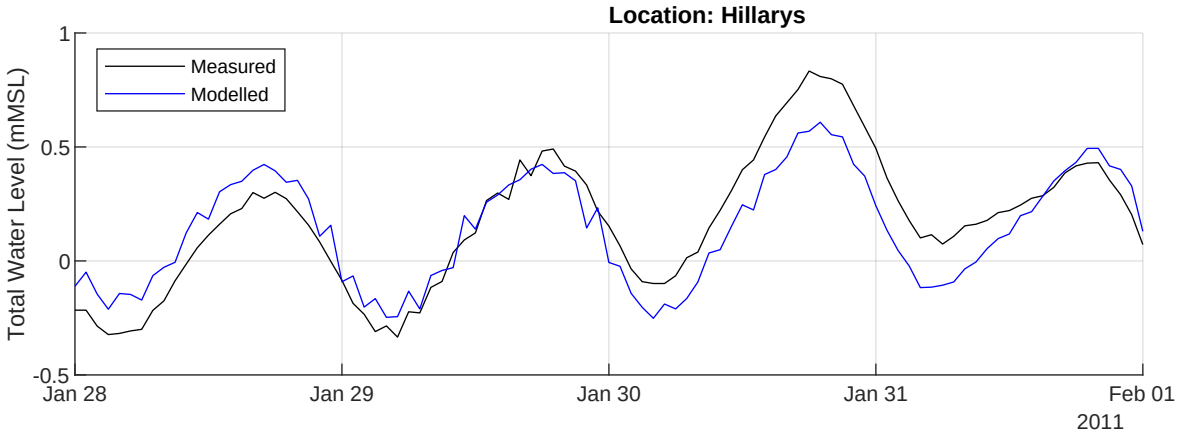
Total Water Level (mMSL)

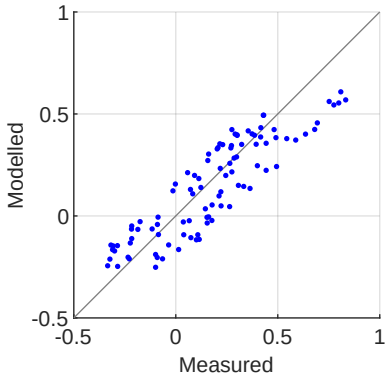
Scatter: 0.319

Bias: -0.178

Skill: 0.815

RMS error: 0.231





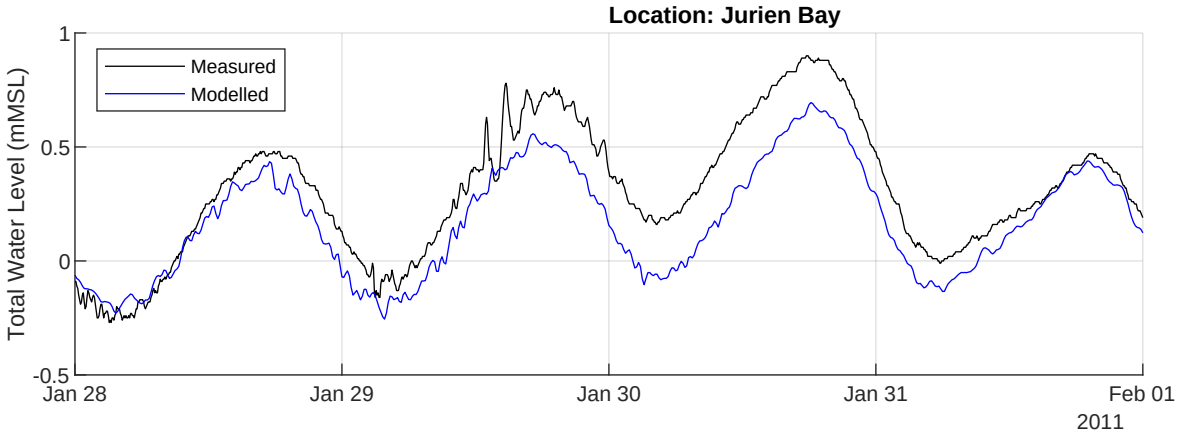
Total Water Level (mMSL)

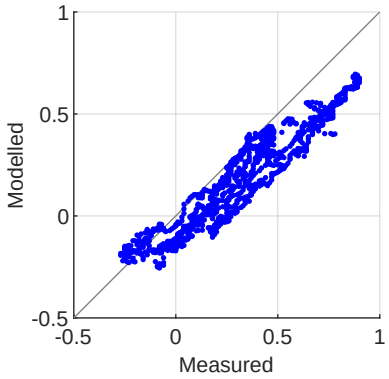
Scatter: 0.274

Bias: -0.031

Skill: 0.926

RMS error: 0.139





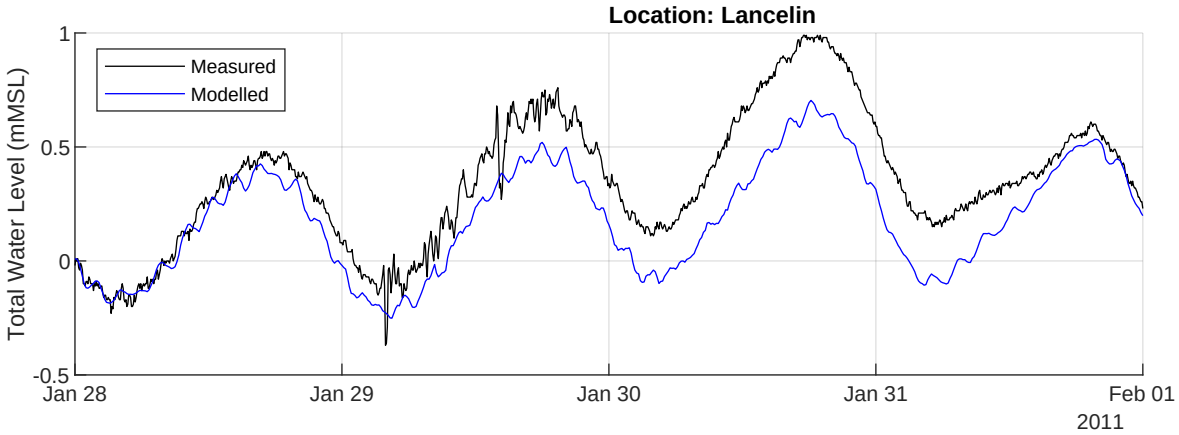
Total Water Level (mMSL)

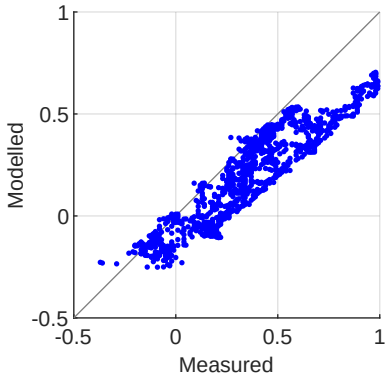
Scatter: 0.285

Bias: -0.132

Skill: 0.906

RMS error: 0.165





Total Water Level (mMSL)

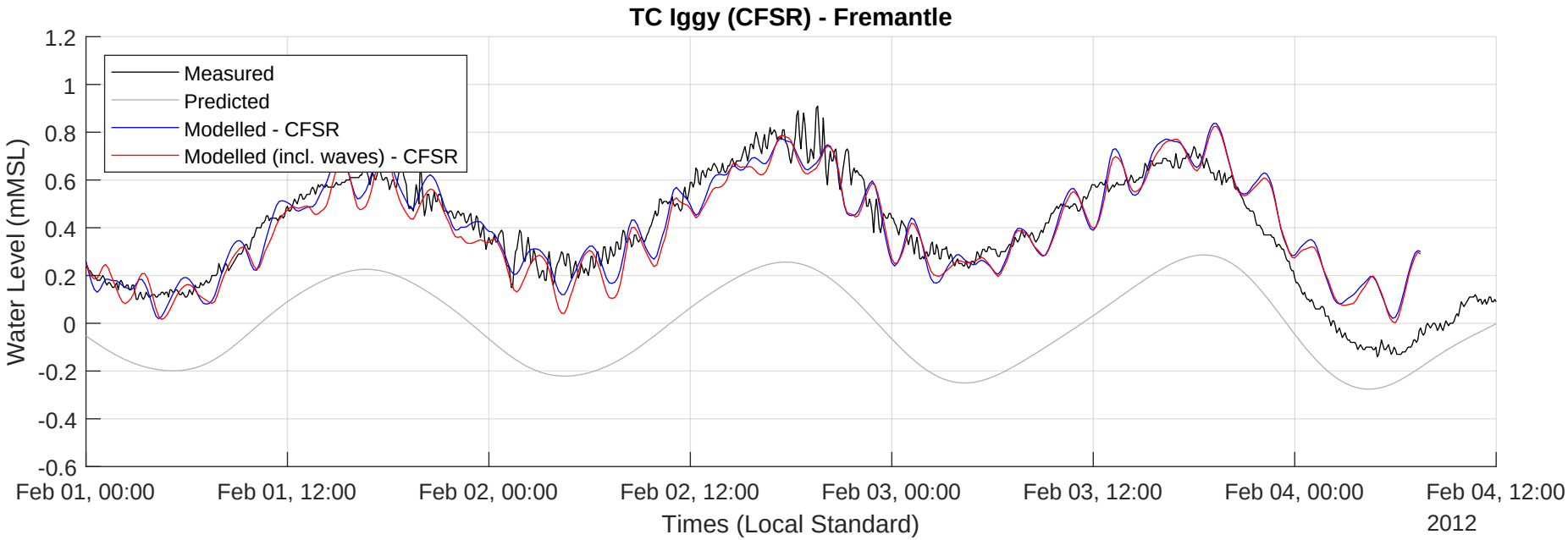
Scatter: 0.270

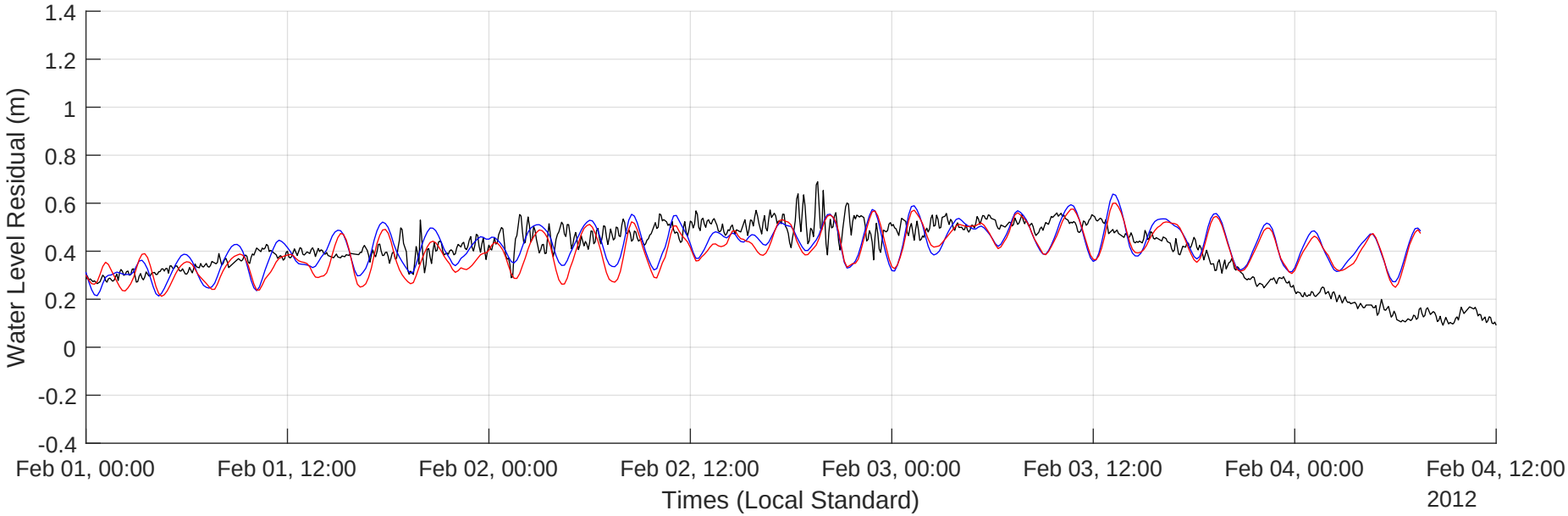
Bias: -0.159

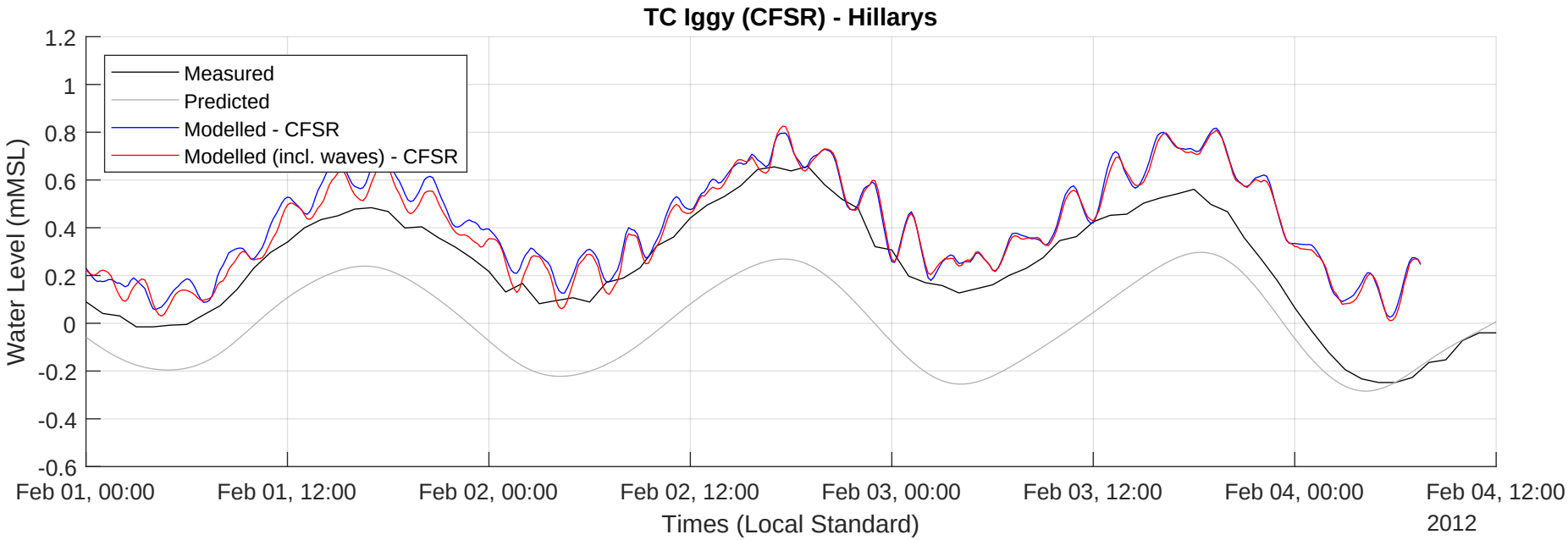
Skill: 0.872

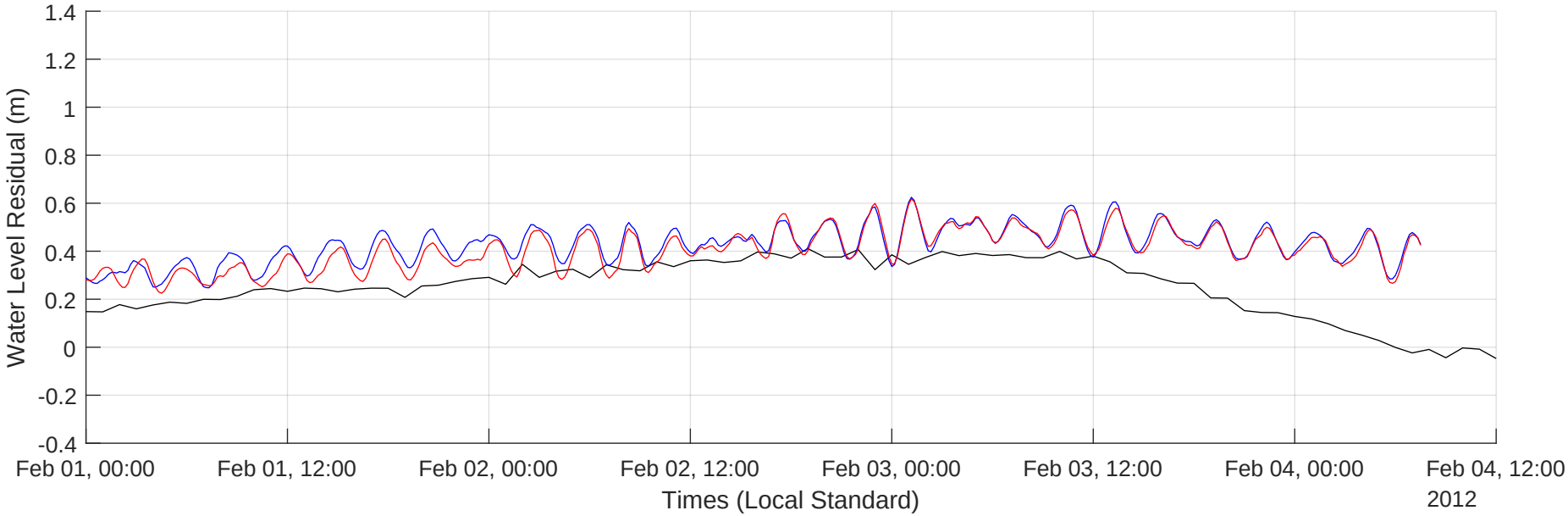
RMS error: 0.194

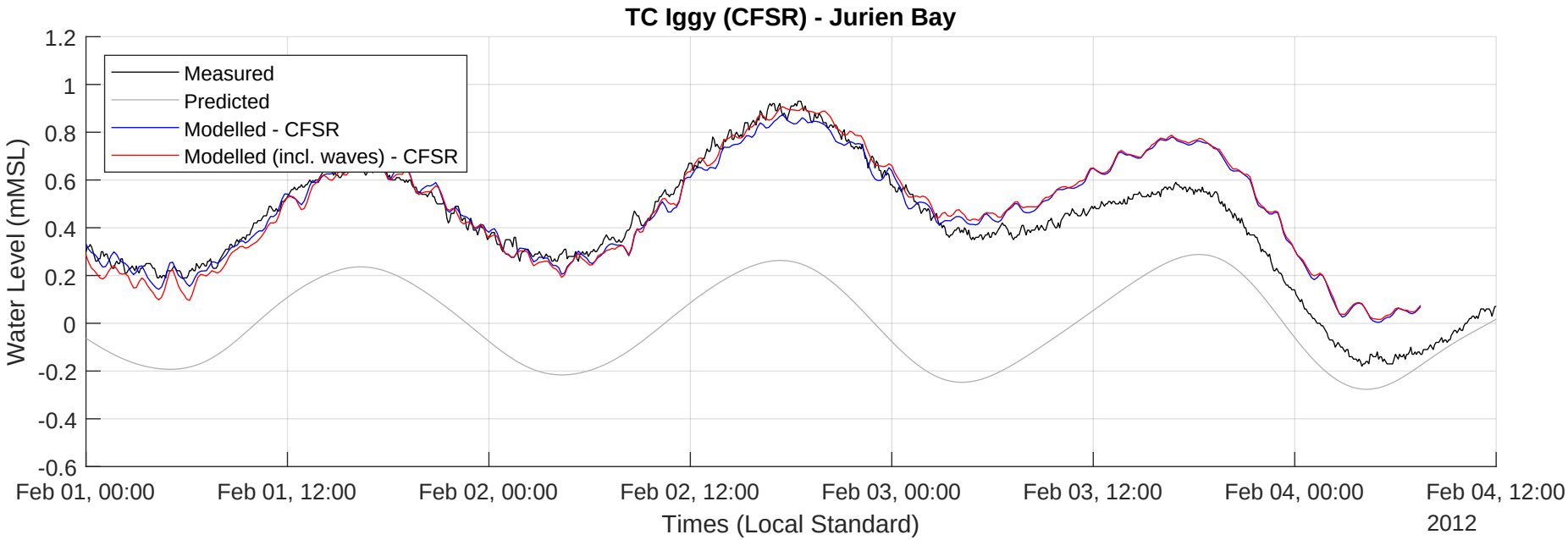
B.4 TC Iggy (2012)

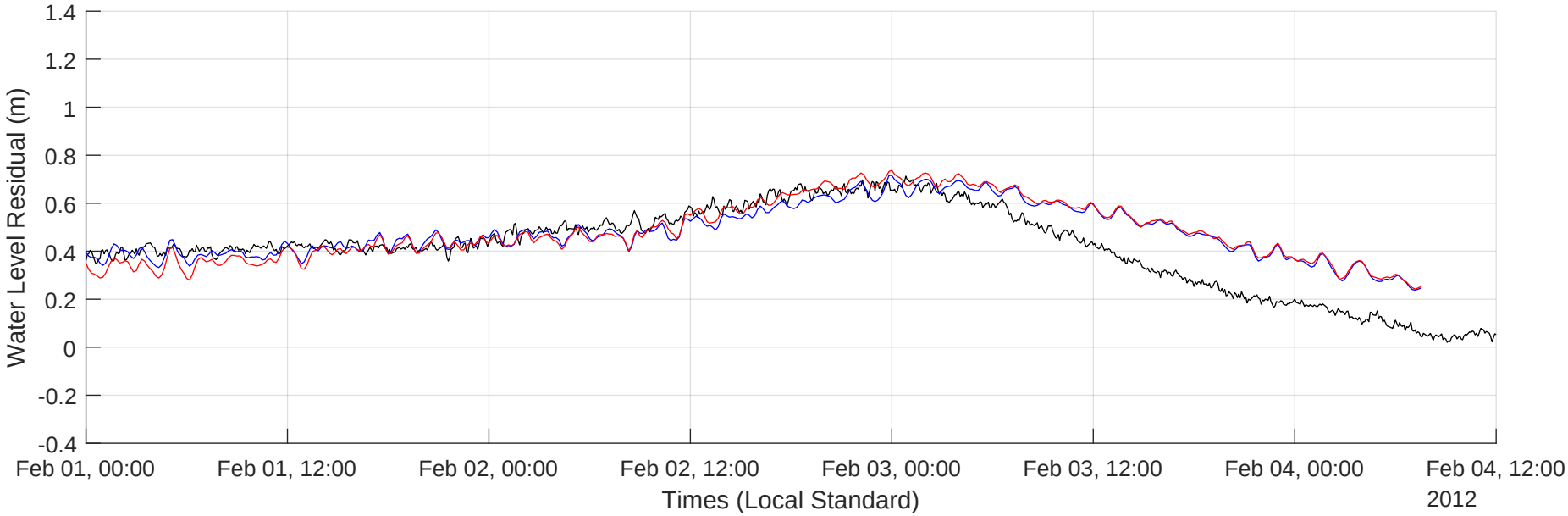

TC Iggy (CFSR) - Fremantle
Measured
Predicted
Modelled - CFSR
Modelled (incl. waves) - CFSR
Water Level (mMSL)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Feb 01, 00:00
Feb 01, 12:00
Feb 02, 00:00
Feb 02, 12:00
Feb 03, 00:00
Feb 03, 12:00
Feb 04, 00:00
Feb 04, 12:00
2012
Times (Local Standard)

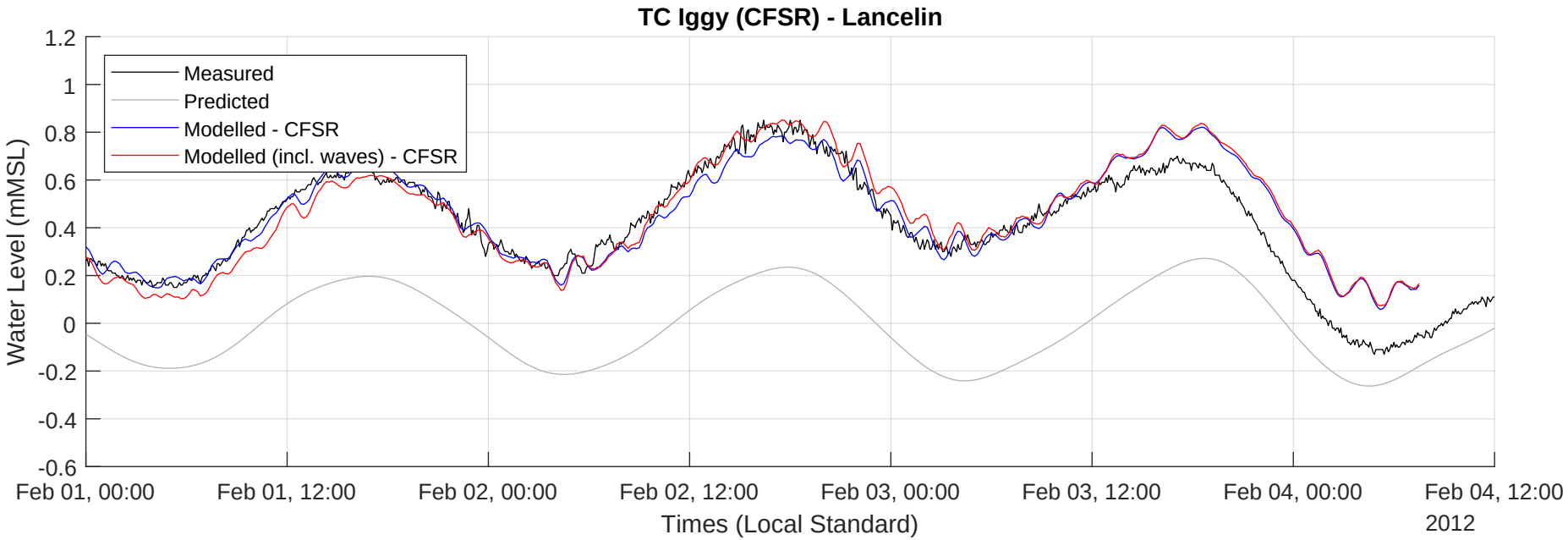

Water Level Residual (m)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Feb 01, 00:00
Feb 01, 12:00
Feb 02, 00:00
Feb 02, 12:00
Feb 03, 00:00
Feb 03, 12:00
Feb 04, 00:00
Feb 04, 12:00
2012
Times (Local Standard)

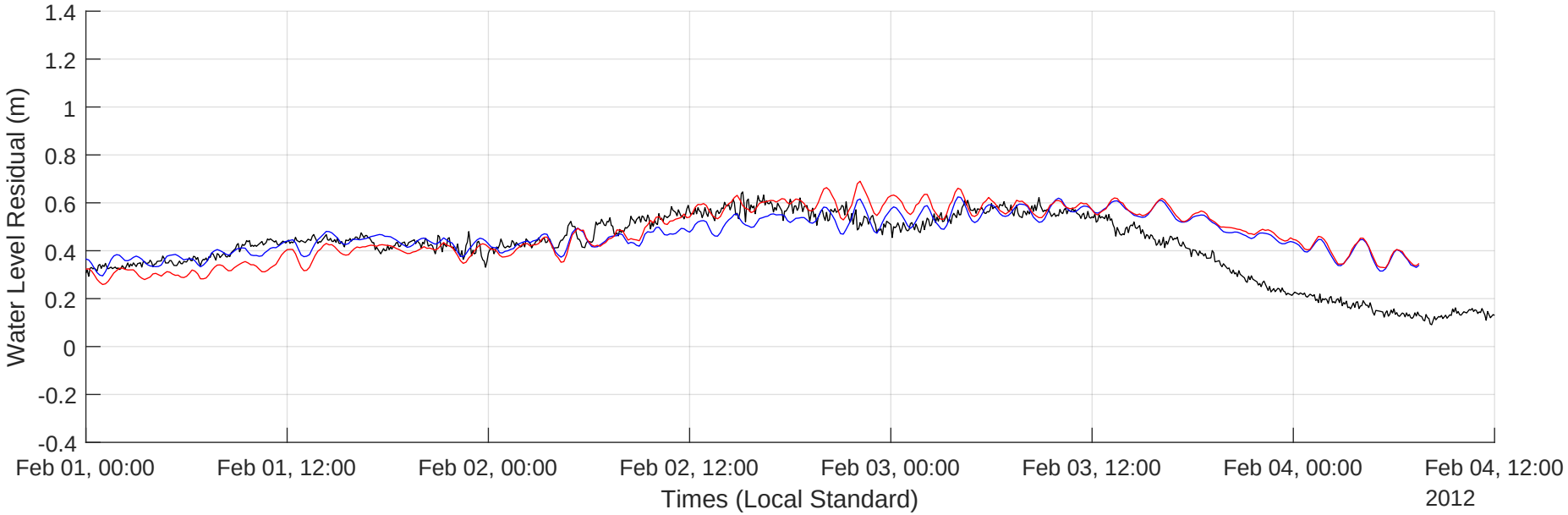

TC Iggy (CFSR) - Hillarys
Measured
Predicted
Modelled - CFSR
Modelled (incl. waves) - CFSR
Water Level (mMSL)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Feb 01, 00:00
Feb 01, 12:00
Feb 02, 00:00
Feb 02, 12:00
Feb 03, 00:00
Feb 03, 12:00
Feb 04, 00:00
Feb 04, 12:00
2012
Times (Local Standard)

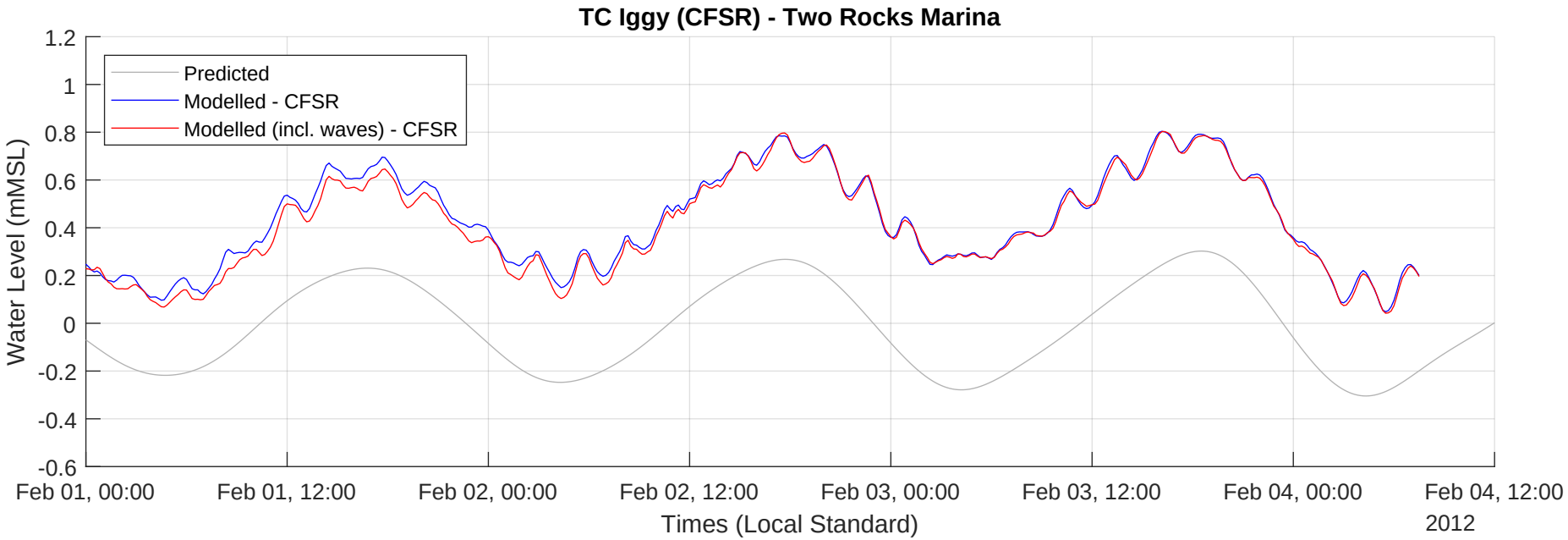

Water Level Residual (m)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Feb 01, 00:00
Feb 01, 12:00
Feb 02, 00:00
Feb 02, 12:00
Feb 03, 00:00
Feb 03, 12:00
Feb 04, 00:00
Feb 04, 12:00
2012
Times (Local Standard)

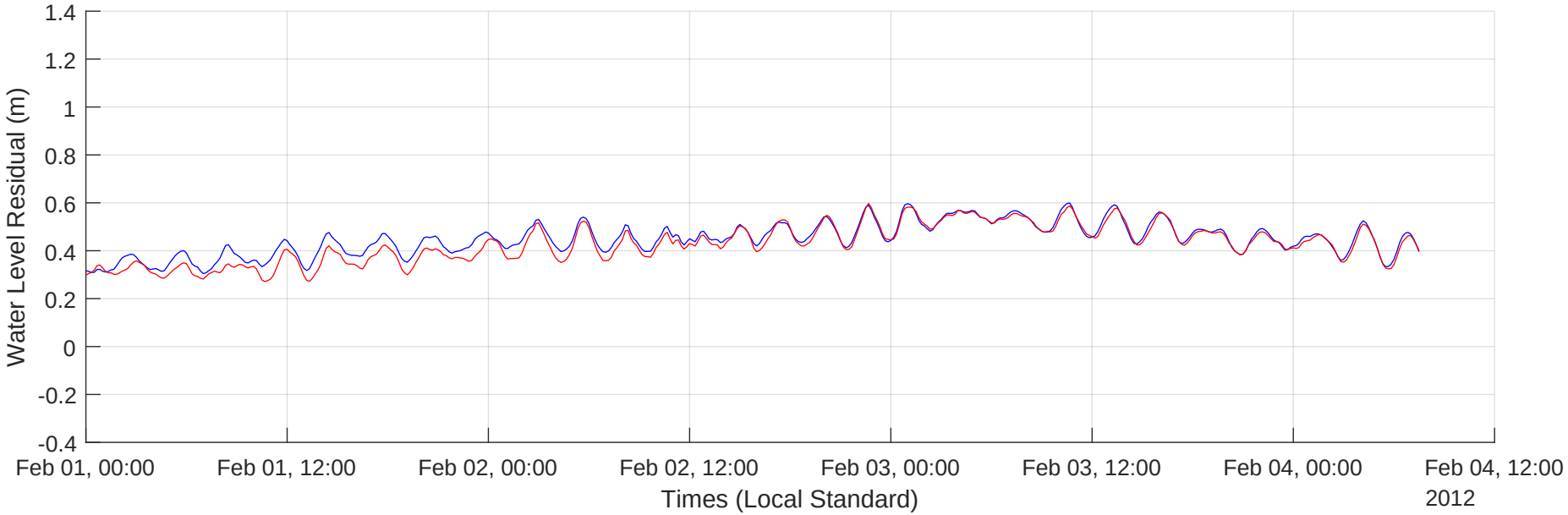

TC Iggy (CFSR) - Jurien Bay
Measured
Predicted
Modelled - CFSR
Modelled (incl. waves) - CFSR
Water Level (mMSL)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Feb 01, 00:00
Feb 01, 12:00
Feb 02, 00:00
Feb 02, 12:00
Feb 03, 00:00
Feb 03, 12:00
Feb 04, 00:00
Feb 04, 12:00
2012
Times (Local Standard)

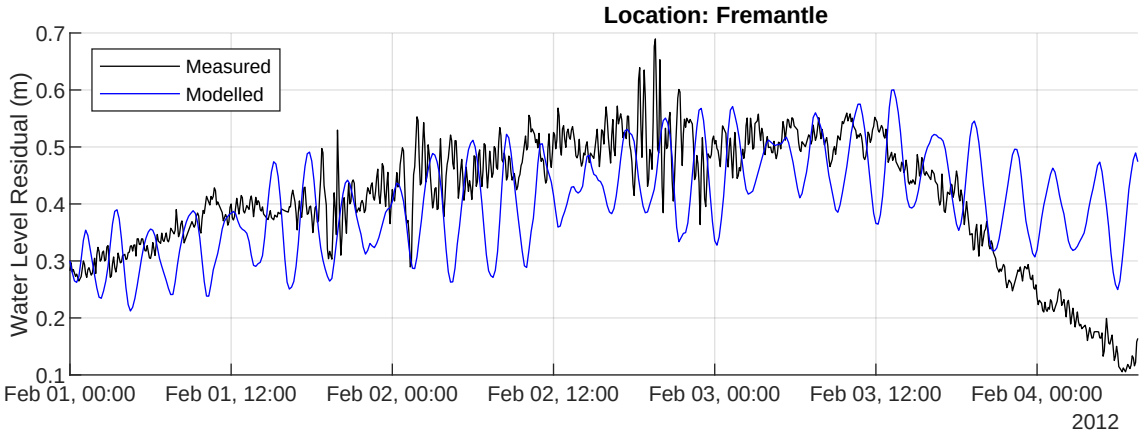

Water Level Residual (m)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Feb 01, 00:00
Feb 01, 12:00
Feb 02, 00:00
Feb 02, 12:00
Feb 03, 00:00
Feb 03, 12:00
Feb 04, 00:00
Feb 04, 12:00
2012
Times (Local Standard)

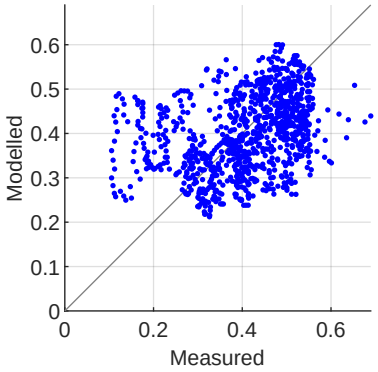

TC Iggy (CFSR) - Lancelin
Measured
Predicted
Modelled - CFSR
Modelled (incl. waves) - CFSR
Water Level (mMSL)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Feb 01, 00:00
Feb 01, 12:00
Feb 02, 00:00
Feb 02, 12:00
Feb 03, 00:00
Feb 03, 12:00
Feb 04, 00:00
Feb 04, 12:00
2012
Times (Local Standard)


Water Level Residual (m)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Feb 01, 00:00
Feb 01, 12:00
Feb 02, 00:00
Feb 02, 12:00
Feb 03, 00:00
Feb 03, 12:00
Feb 04, 00:00
Feb 04, 12:00
2012
Times (Local Standard)


TC Iggy (CFSR) - Two Rocks Marina
Predicted
Modelled - CFSR
Modelled (incl. waves) - CFSR
Water Level (mMSL)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Feb 01, 00:00
Feb 01, 12:00
Feb 02, 00:00
Feb 02, 12:00
Feb 03, 00:00
Feb 03, 12:00
Feb 04, 00:00
Feb 04, 12:00
2012
Times (Local Standard)


Water Level Residual (m)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Feb 01, 00:00
Feb 01, 12:00
Feb 02, 00:00
Feb 02, 12:00
Feb 03, 00:00
Feb 03, 12:00
Feb 04, 00:00
Feb 04, 12:00
2012
Times (Local Standard)





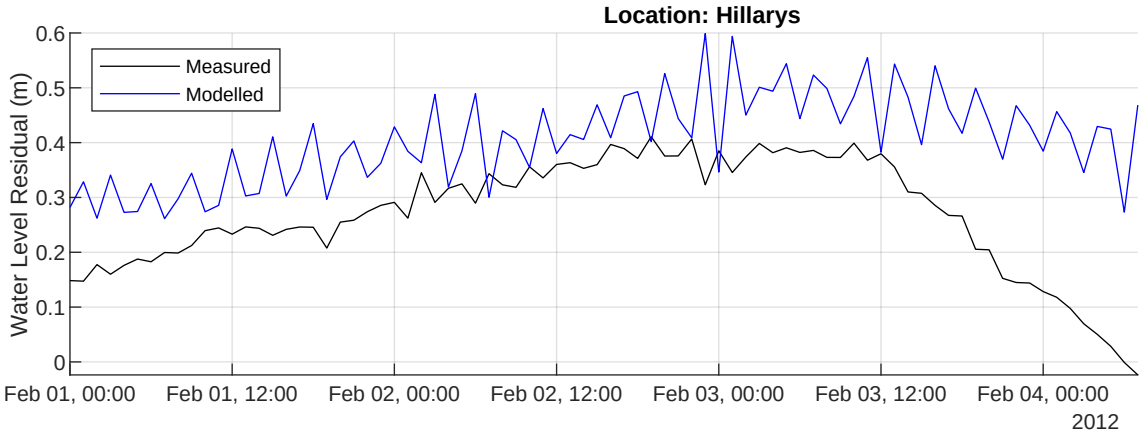
Water Level Residual (m)

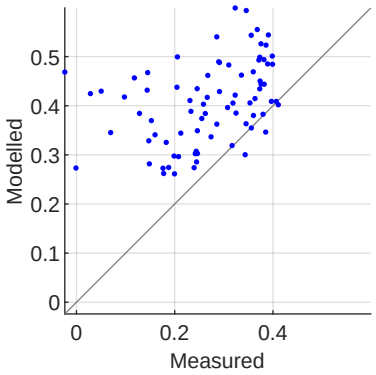
Scatter: 0.274

Bias: -0.008

Skill: 0.512

RMS error: 0.112





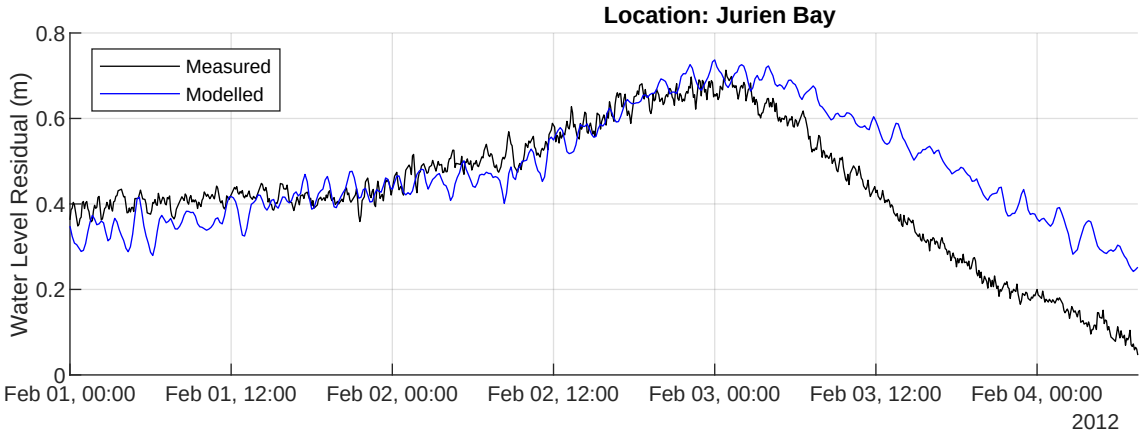
Water Level Residual (m)

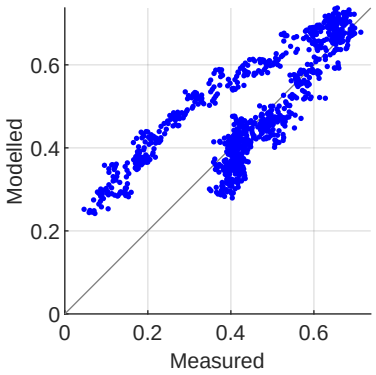
Scatter: 0.587

Bias: 0.137

Skill: 0.316

RMS error: 0.172





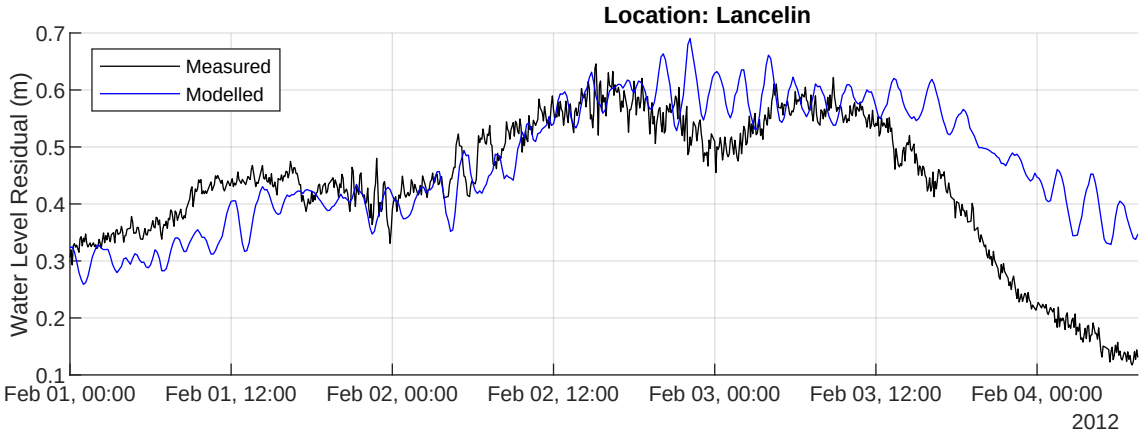
Water Level Residual (m)

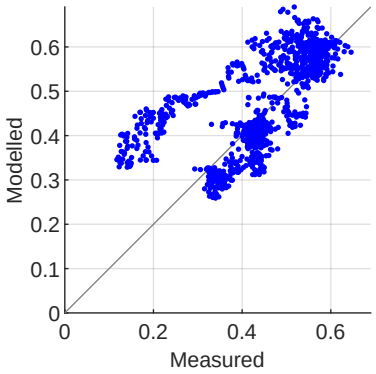
Scatter: 0.251

Bias: 0.047

Skill: 0.836

RMS error: 0.109





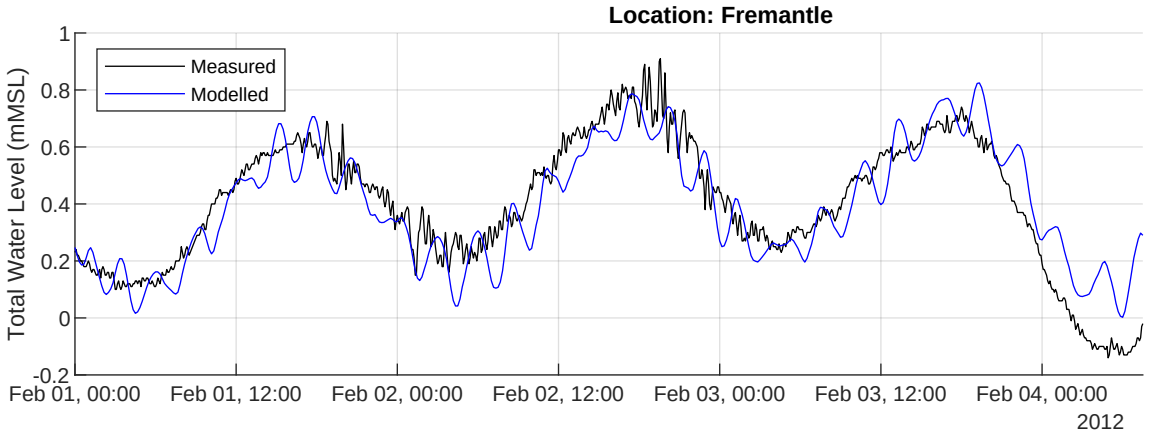
Water Level Residual (m)

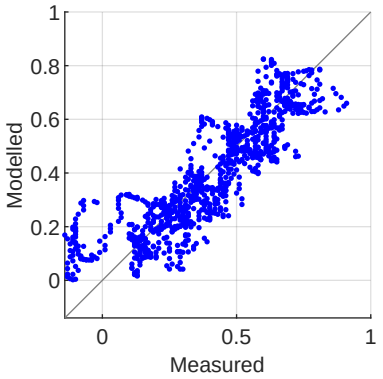
Scatter: 0.241

Bias: 0.037

Skill: 0.753

RMS error: 0.105





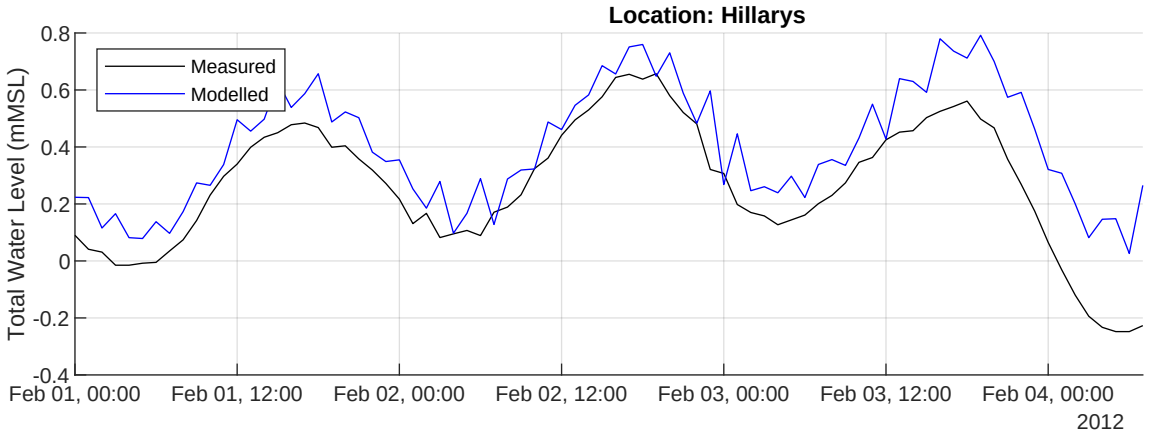
Total Water Level (mMSL)

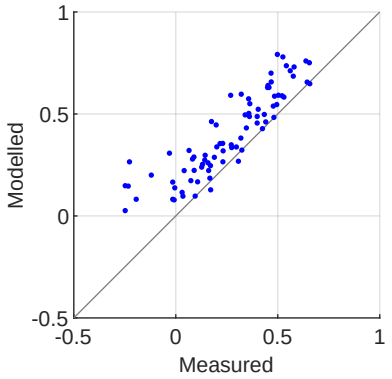
Scatter: 0.208

Bias: -0.008

Skill: 0.928

RMS error: 0.112





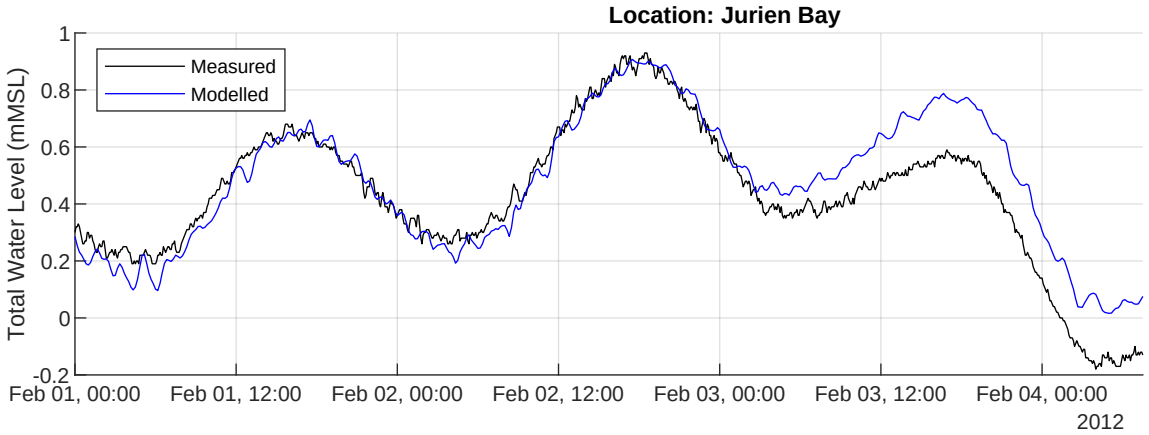
Total Water Level (mMSL)

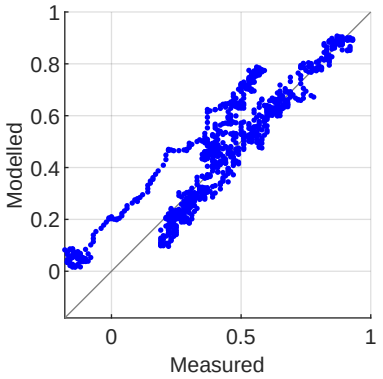
Scatter: 0.337

Bias: 0.137

Skill: 0.848

RMS error: 0.172





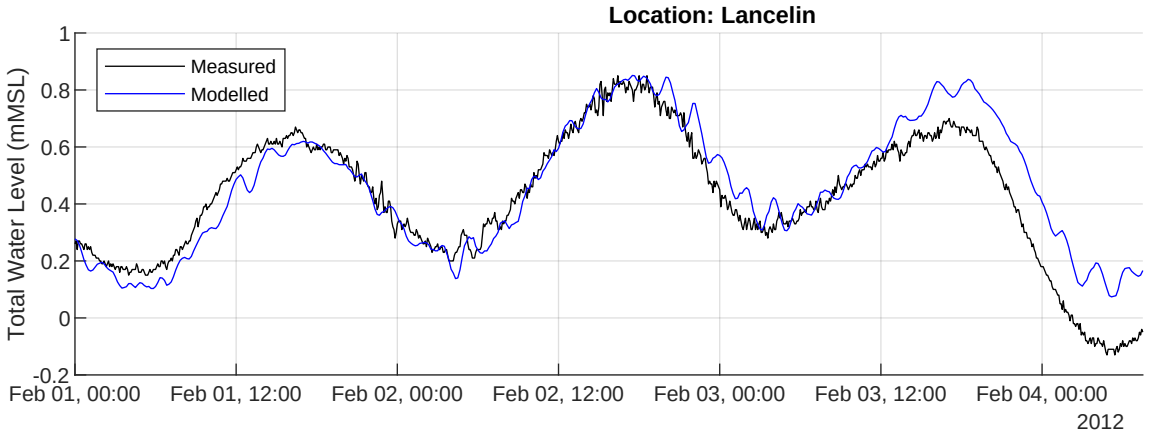
Total Water Level (mMSL)

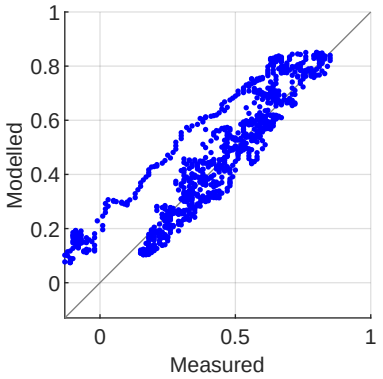
Scatter: 0.179

Bias: 0.047

Skill: 0.946

RMS error: 0.109





Total Water Level (mMSL)

Scatter: 0.190

Bias: 0.037

Skill: 0.943

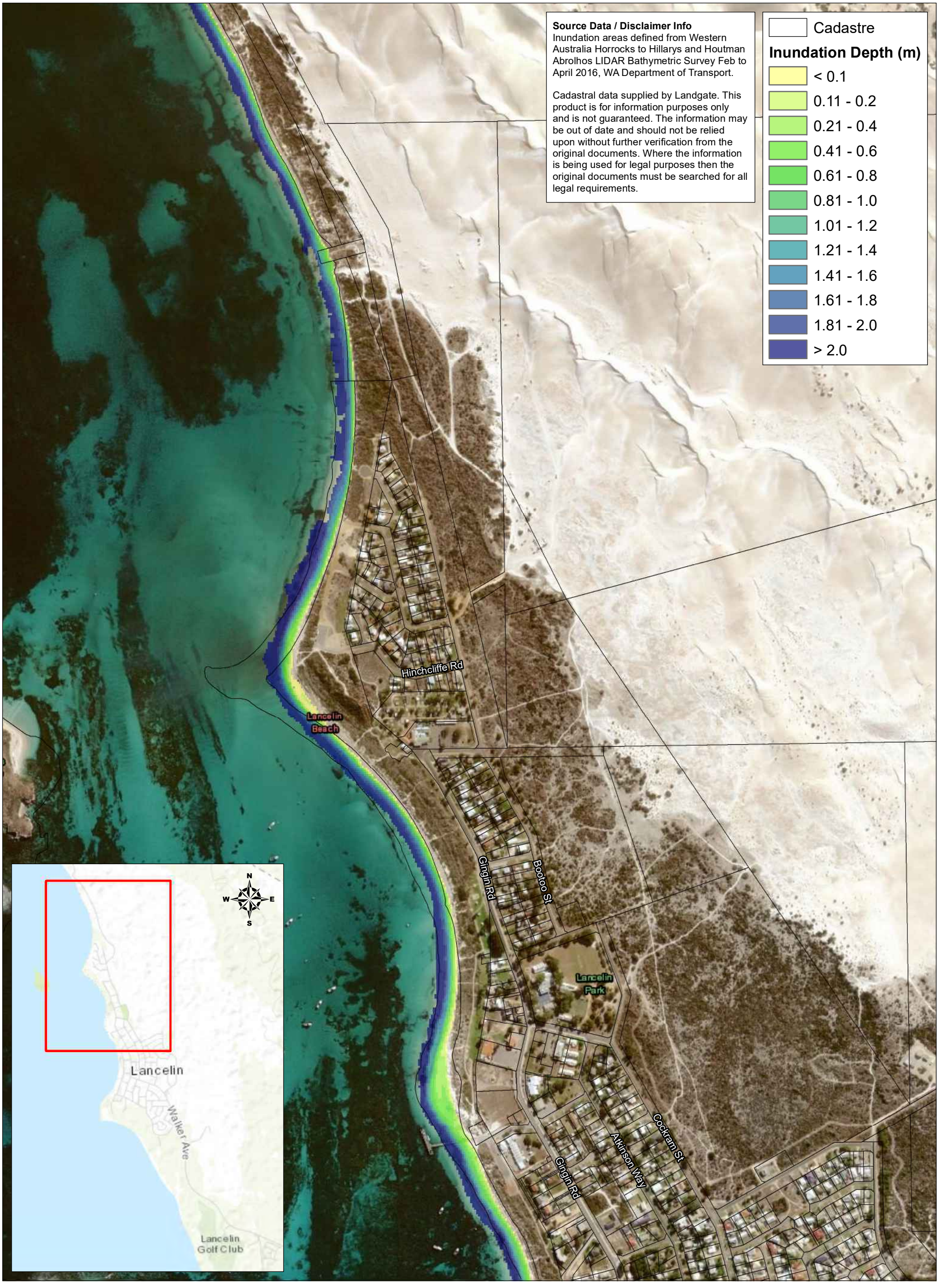
RMS error: 0.105

Appendix C

Inundation Mapping for Study Areas

C.1 Lancelin Inundation Mapping

Mapping Cases presented for the 20yrARI, 100yrARI and 500yr ARI events at planning years 2020, 2040, 2070 and 2120.



1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 20yr ARI design storm in planning year 2020 (includes 0m Sea Level Rise Allowance)

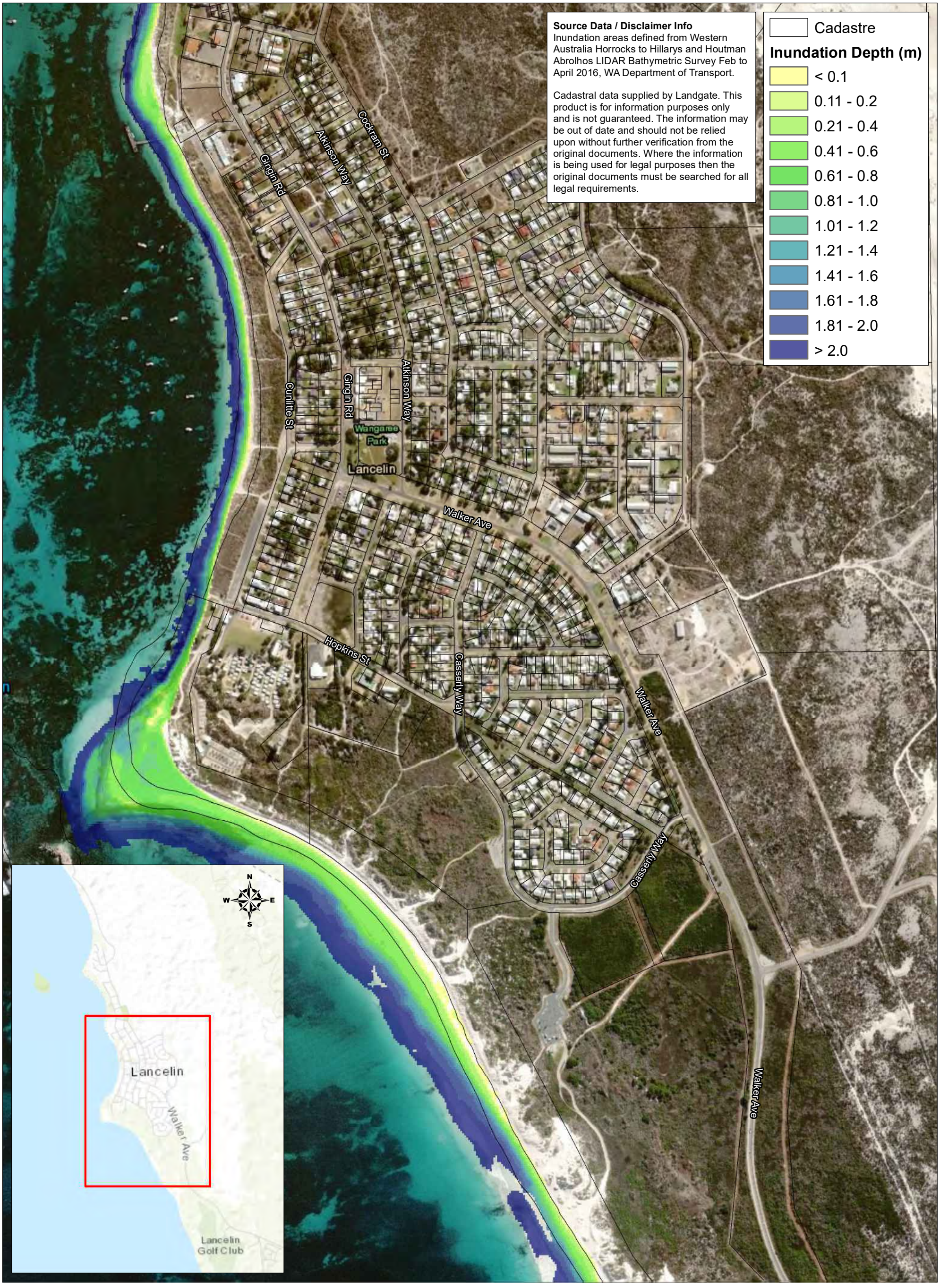
LANCELIN - AREA A

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 20yrARI Depth 2020_Rev02.mxd



1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 20yr ARI design storm in planning year 2020 (includes 0m Sea Level Rise Allowance)

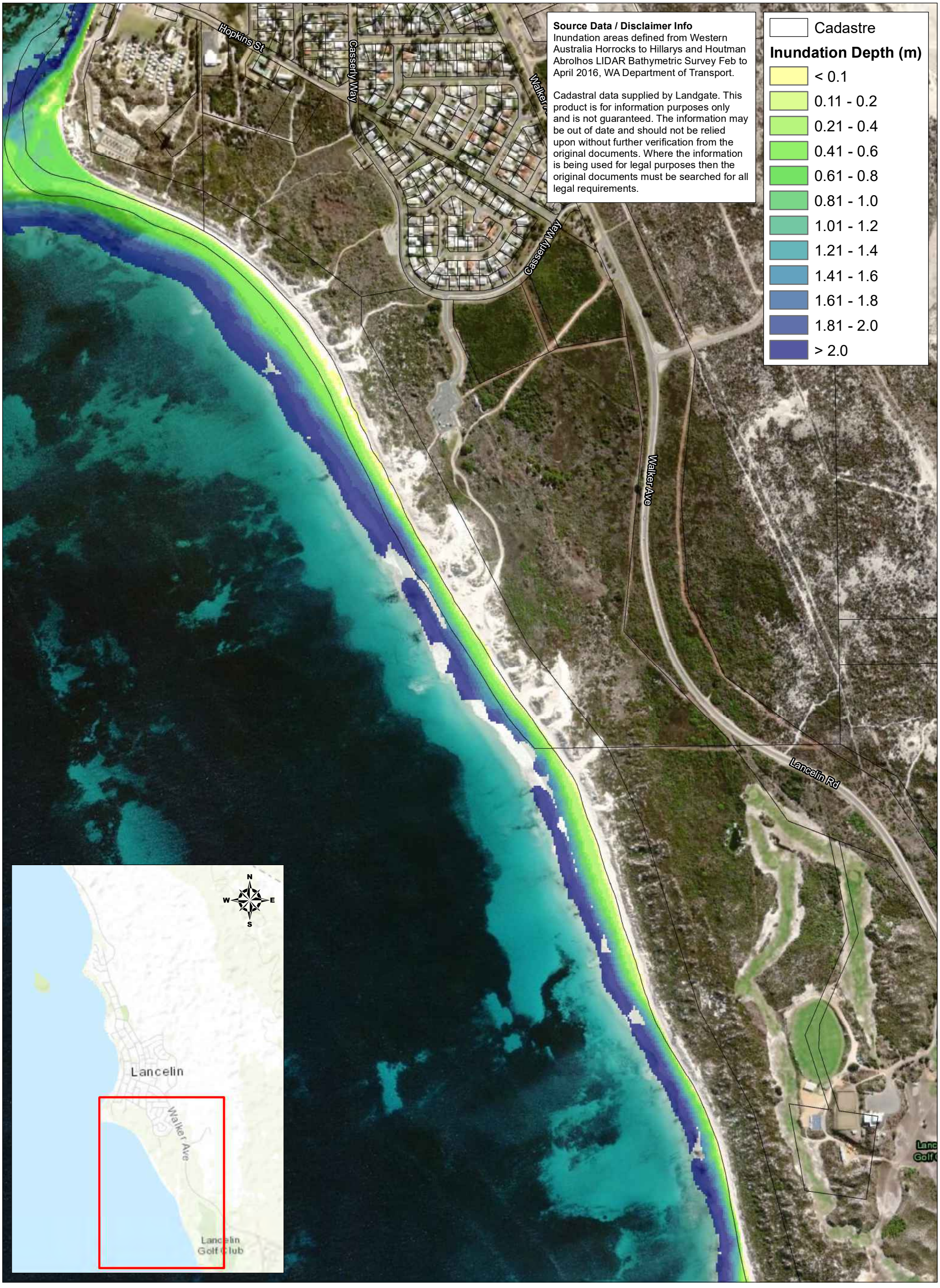
LANCELIN - AREA B

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 20yrARI Depth 2020_Rev02.mxd



1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 20yr ARI design storm in planning year 2020 (includes 0m Sea Level Rise Allowance)

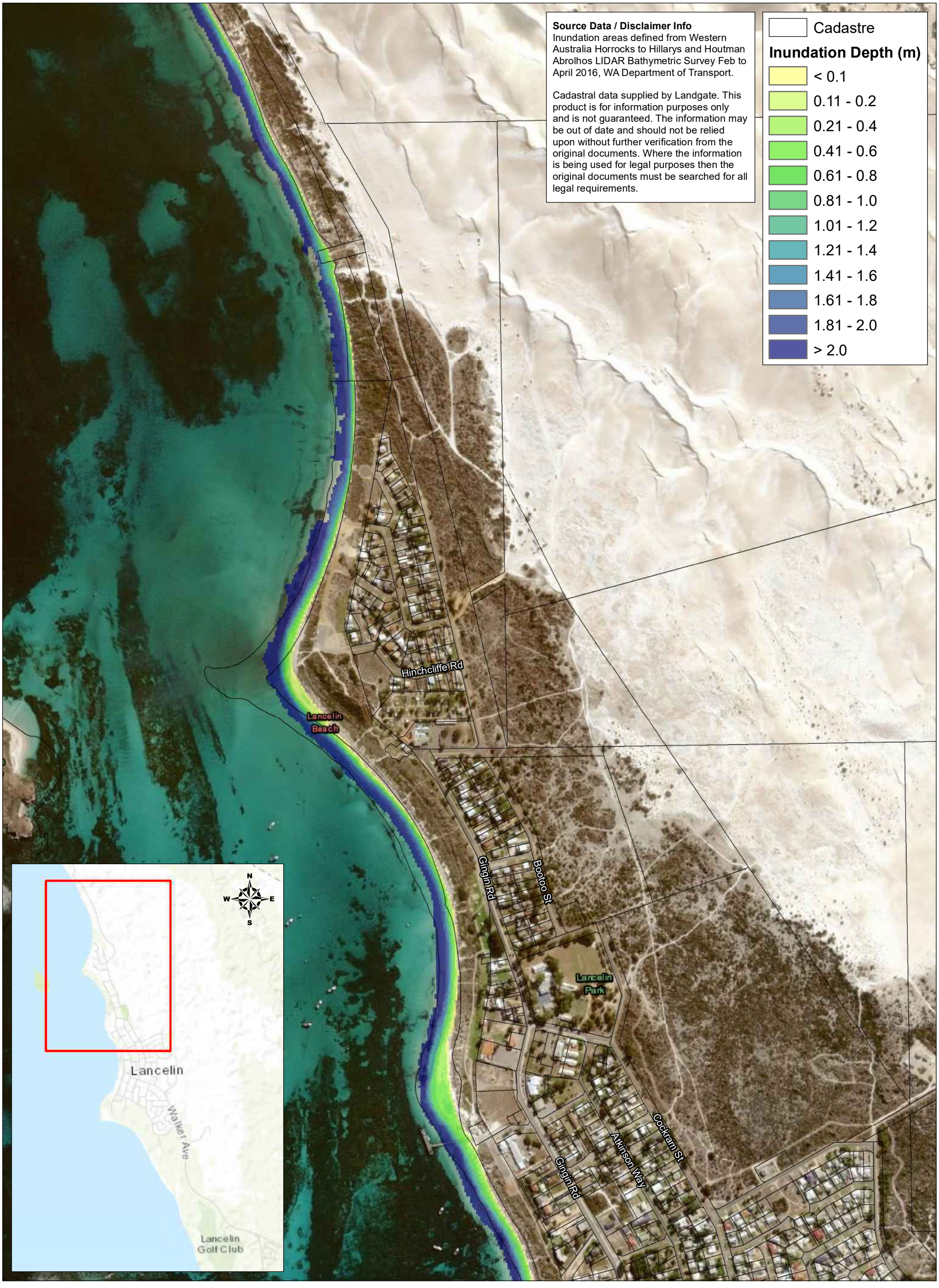
LANCELIN - AREA C

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 20yrARI Depth 2020_Rev02.mxd



1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 20yr ARI design storm in planning year 2040 (includes 0.1m Sea Level Rise Allowance)

LANCELIN - AREA A

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 20yrARI Depth 2040_Rev02.mxd

Source Data / Disclaimer Info
Inundation areas defined from Western Australia Horrocks to Hillarys and Houtman Abrolhos LIDAR Bathymetric Survey Feb to April 2016, WA Department of Transport.

Cadastral data supplied by Landgate. This product is for information purposes only and is not guaranteed. The information may be out of date and should not be relied upon without further verification from the original documents. Where the information is being used for legal purposes then the original documents must be searched for all legal requirements.

Cadastre

Inundation Depth (m)

- < 0.1
- 0.11 - 0.2
- 0.21 - 0.4
- 0.41 - 0.6
- 0.61 - 0.8
- 0.81 - 1.0
- 1.01 - 1.2
- 1.21 - 1.4
- 1.41 - 1.6
- 1.61 - 1.8
- 1.81 - 2.0
- > 2.0

Cockram St
Atkinson Way
Gingin Rd
Cunlite St
Wangaree Park
Lancelin
Walker Ave
Hopkins St
Casserly Way

N
W E
S

Lancelin
Walker Ave
Lancelin Golf Club

1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 20yr ARI design storm in planning year 2040 (includes 0.1m Sea Level Rise Allowance)

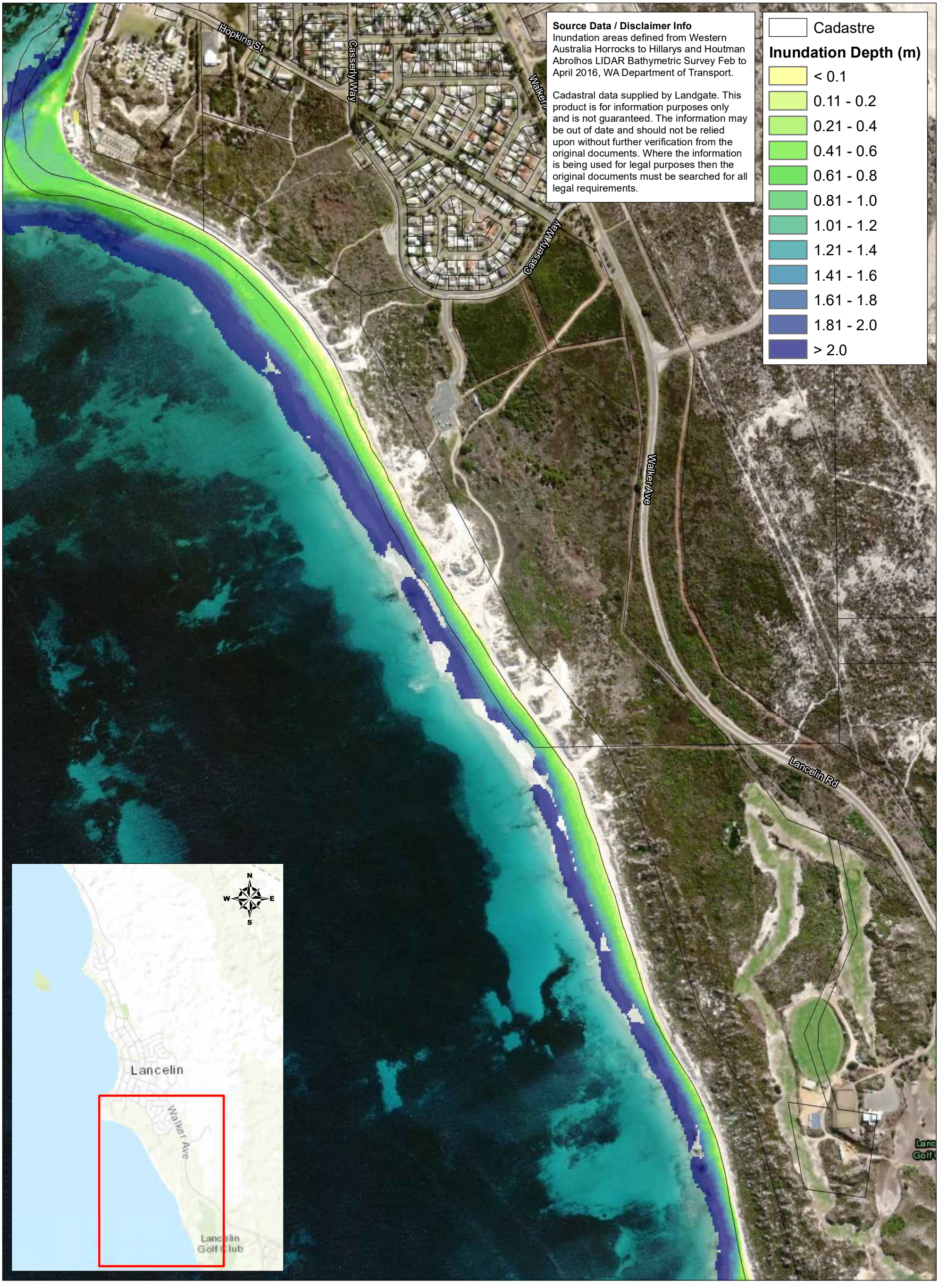
LANCELIN - AREA B

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 20yrARI Depth 2040_Rev02.mxd



1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 20yr ARI design storm in planning year 2040 (includes 0.1m Sea Level Rise Allowance)

LANCELIN - AREA C

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 20yrARI Depth 2040_Rev02.mxd

Source Data / Disclaimer Info
Inundation areas defined from Western Australia Horrocks to Hillarys and Houtman Abrolhos LIDAR Bathymetric Survey Feb to April 2016, WA Department of Transport.

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Potential for Dune Breach During Extreme Events

Cadastre

Inundation Depth (m)

- < 0.1
- 0.11 - 0.2
- 0.21 - 0.4
- 0.41 - 0.6
- 0.61 - 0.8
- 0.81 - 1.0
- 1.01 - 1.2
- 1.21 - 1.4
- 1.41 - 1.6
- 1.61 - 1.8
- 1.81 - 2.0
- > 2.0

Hinchcliffe Rd
Lancelin Beach
Gingin Rd
Bootoo St
Lancelin Park
Cockram St
Atkinson Way
Gingin Rd
Lancelin
Walker Ave
Lancelin Golf Club
N
W
E
S

1:8,000
0 100 200 300 m

Inundation Depth based on peak water level from 20yr ARI design storm in planning year 2070 (includes 0.35m Sea Level Rise Allowance)

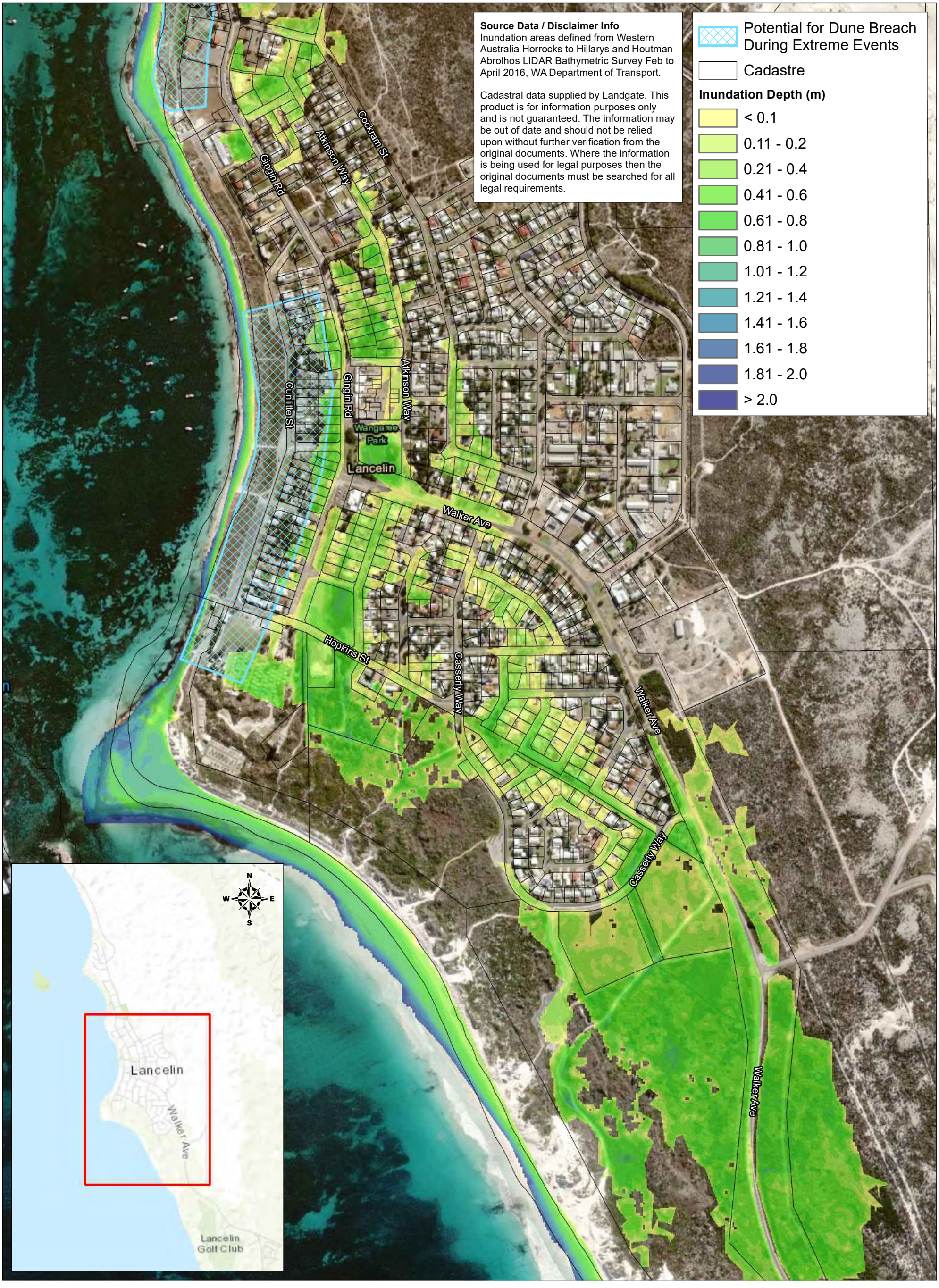
LANCELIN - AREA A

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 20yrARI Depth 2070_Rev02.mxd



1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 20yr ARI design storm in planning year 2070 (includes 0.35m Sea Level Rise Allowance)

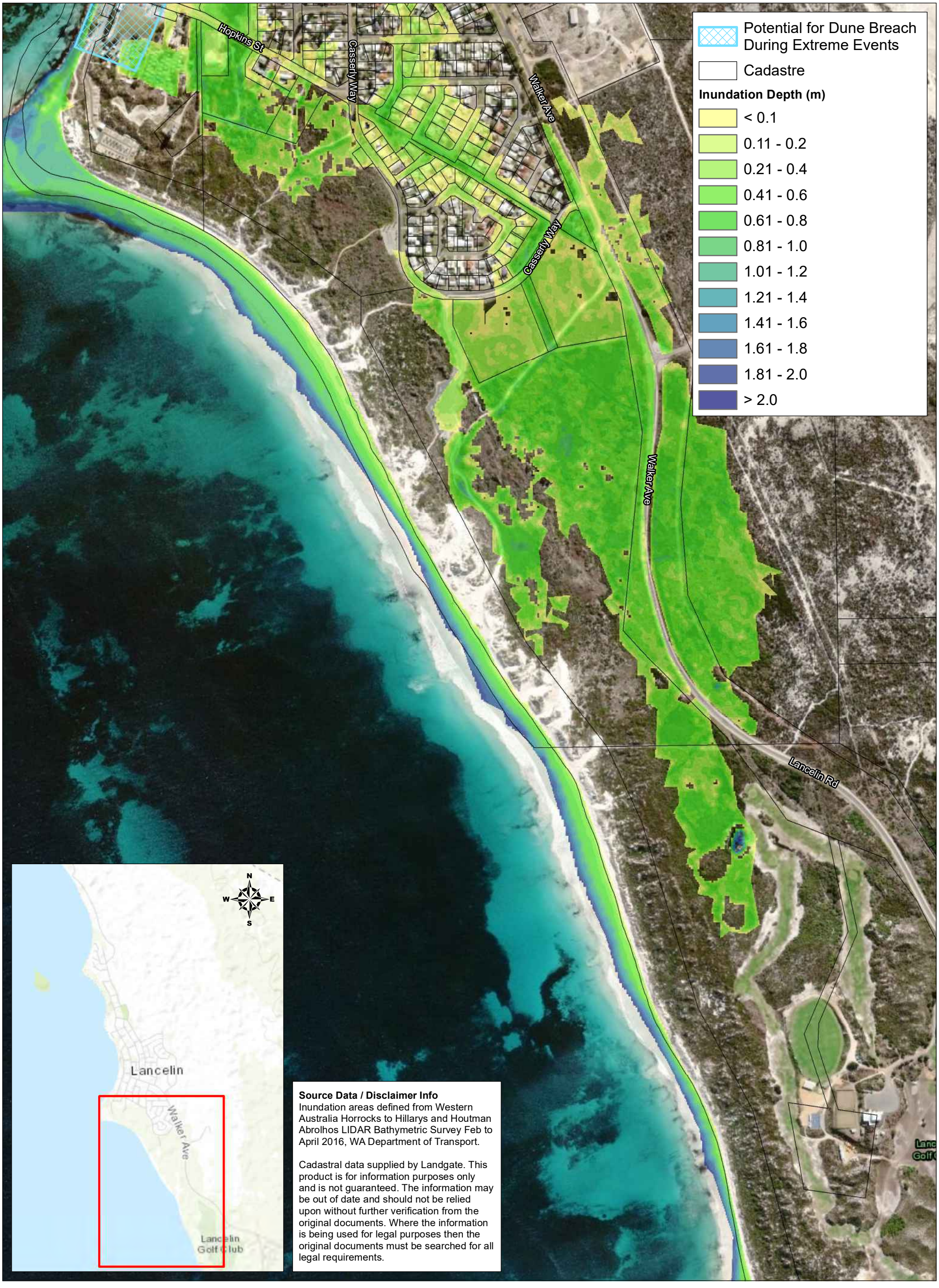
LANCELIN - AREA B

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 20yrARI Depth 2070_Rev02.mxd



Source Data / Disclaimer Info
Inundation areas defined from Western Australia Horrocks to Hillarys and Houtman Abrolhos LIDAR Bathymetric Survey Feb to April 2016, WA Department of Transport.

Cadastral data supplied by Landgate. This product is for information purposes only and is not guaranteed. The information may be out of date and should not be relied upon without further verification from the original documents. Where the information is being used for legal purposes then the original documents must be searched for all legal requirements.

1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 20yr ARI design storm in planning year 2070 (includes 0.35m Sea Level Rise Allowance)

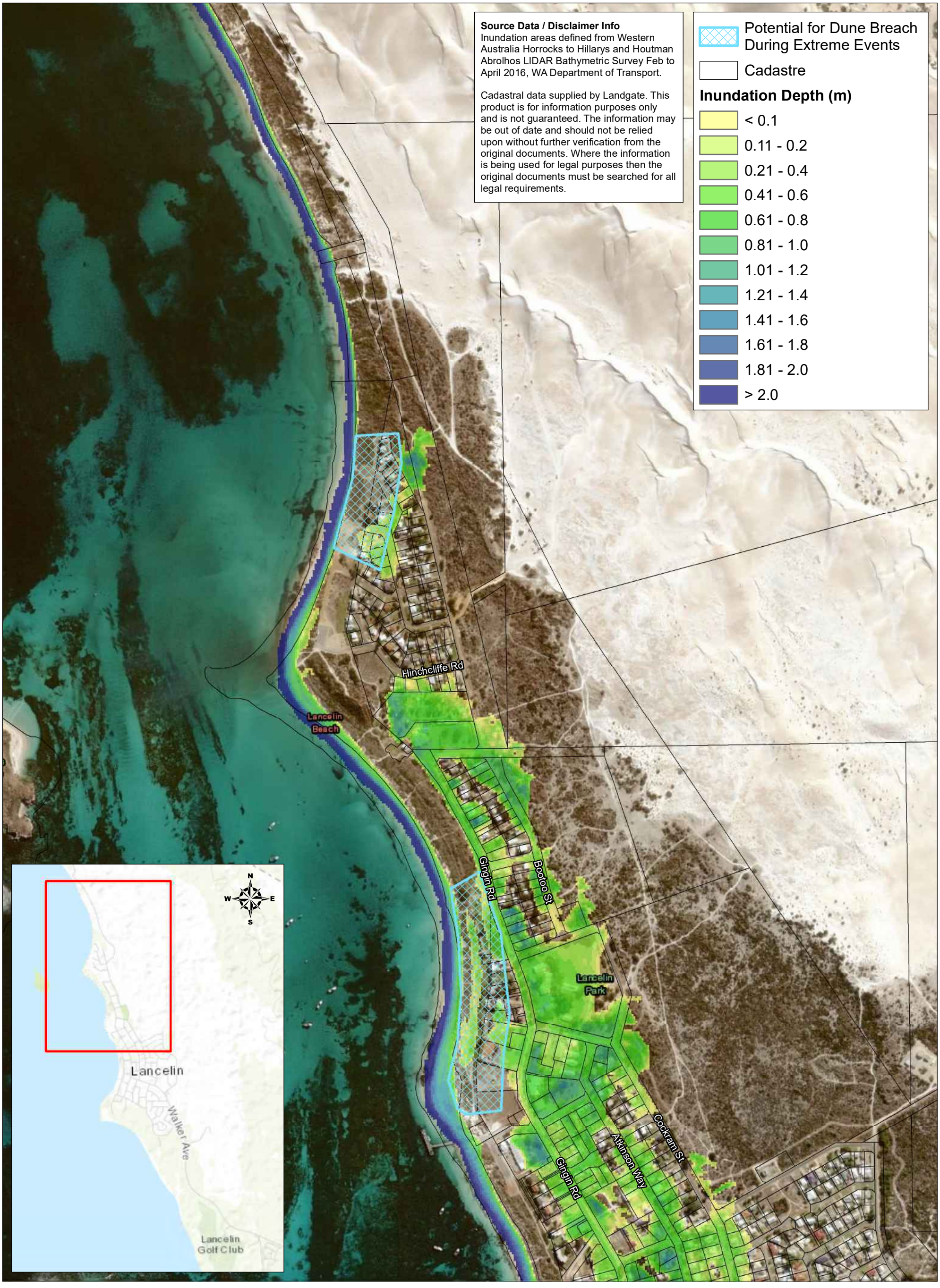
LANCELIN - AREA C

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 20yrARI Depth 2070_Rev02.mxd



1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 20yr ARI design storm in planning year 2120 (includes 0.9m Sea Level Rise Allowance)

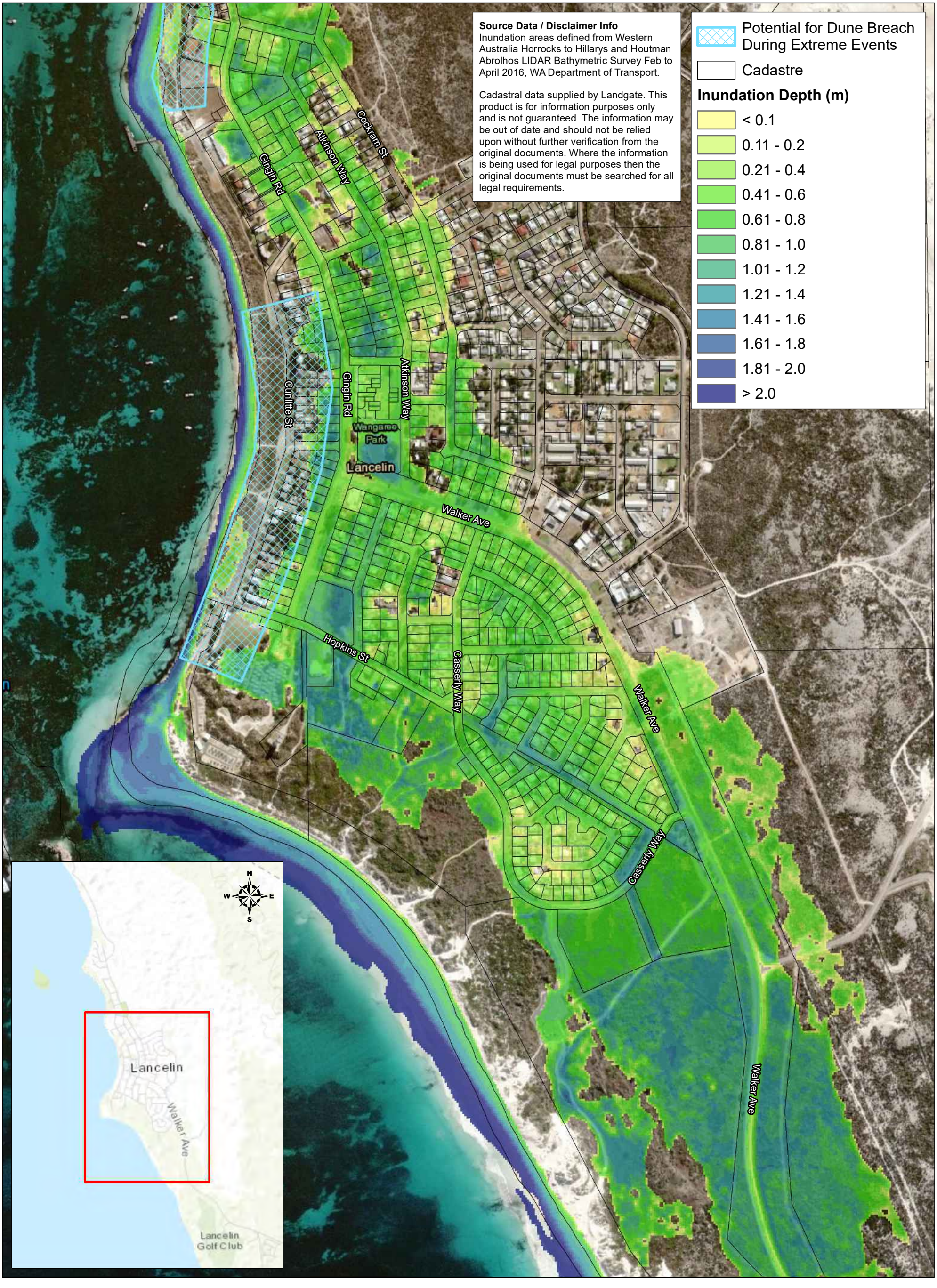
LANCELIN - AREA A

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 20yrARI Depth 2120_Rev02.mxd



1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 20yr ARI design storm in planning year 2120 (includes 0.9m Sea Level Rise Allowance)

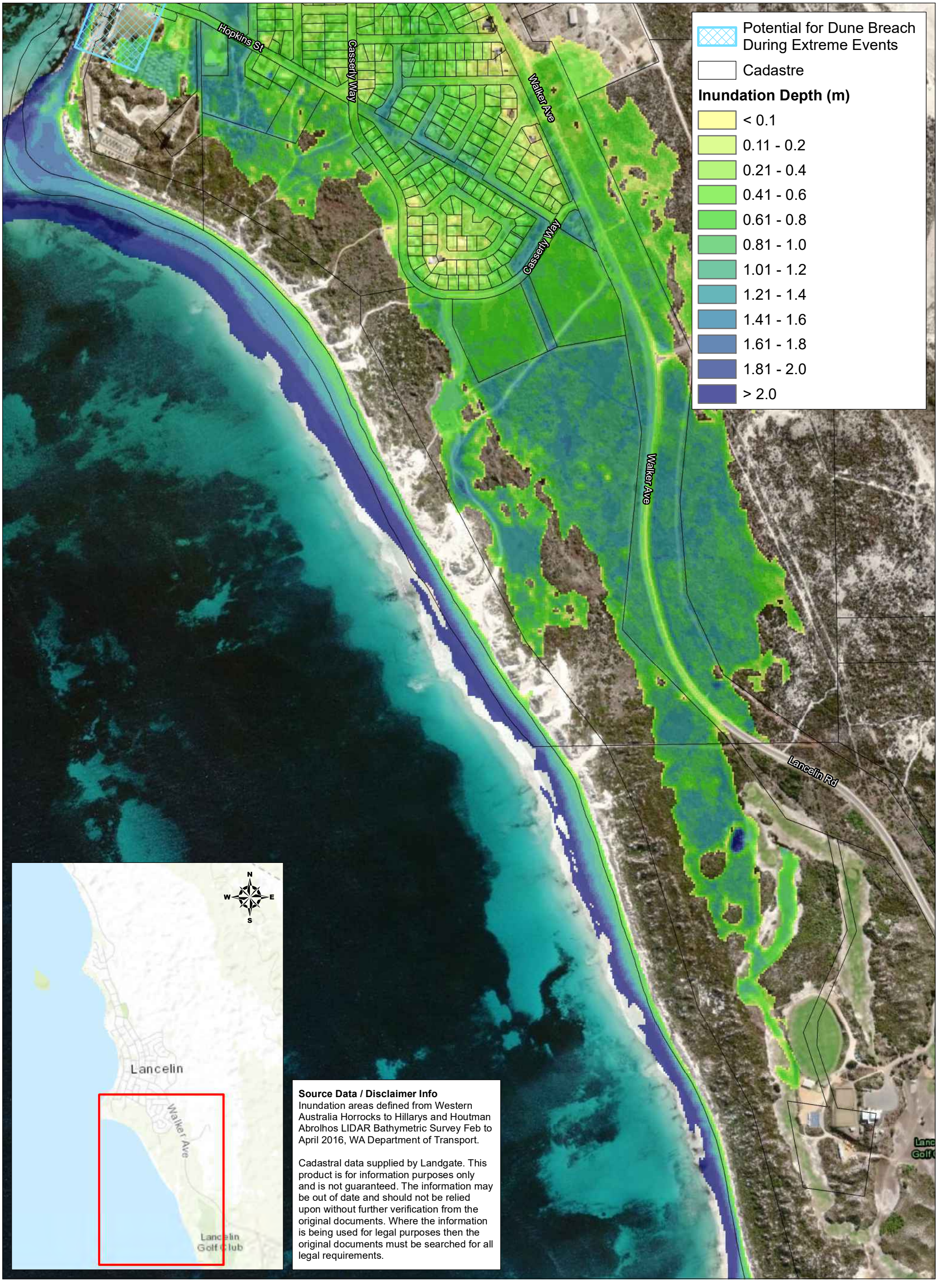
LANCELIN - AREA B

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 20yrARI Depth 2120_Rev02.mxd



Source Data / Disclaimer Info
Inundation areas defined from Western Australia Horrocks to Hillarys and Houtman Abrolhos LIDAR Bathymetric Survey Feb to April 2016, WA Department of Transport.

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1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 20yr ARI design storm in planning year 2120 (includes 0.9m Sea Level Rise Allowance)

LANCELIN - AREA C

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 20yrARI Depth 2120_Rev02.mxd

Source Data / Disclaimer Info
Inundation areas defined from Western Australia Horrocks to Hillarys and Houtman Abrolhos LIDAR Bathymetric Survey Feb to April 2016, WA Department of Transport.

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Cadastre

Inundation Depth (m)

- < 0.1
- 0.11 - 0.2
- 0.21 - 0.4
- 0.41 - 0.6
- 0.61 - 0.8
- 0.81 - 1.0
- 1.01 - 1.2
- 1.21 - 1.4
- 1.41 - 1.6
- 1.61 - 1.8
- 1.81 - 2.0
- > 2.0

Hinchcliffe Rd
Lancelin Beach
Gingin Rd
Bootoo St
Lancelin Park
Cockram St
Atkinson Way
Gingin Rd
Lancelin
Walker Ave
Lancelin Golf Club
N
W
E
S

1:8,000
0 100 200 300 m

Inundation Depth based on peak water level from 100yr ARI design storm in planning year 2020 (includes 0m Sea Level Rise Allowance)

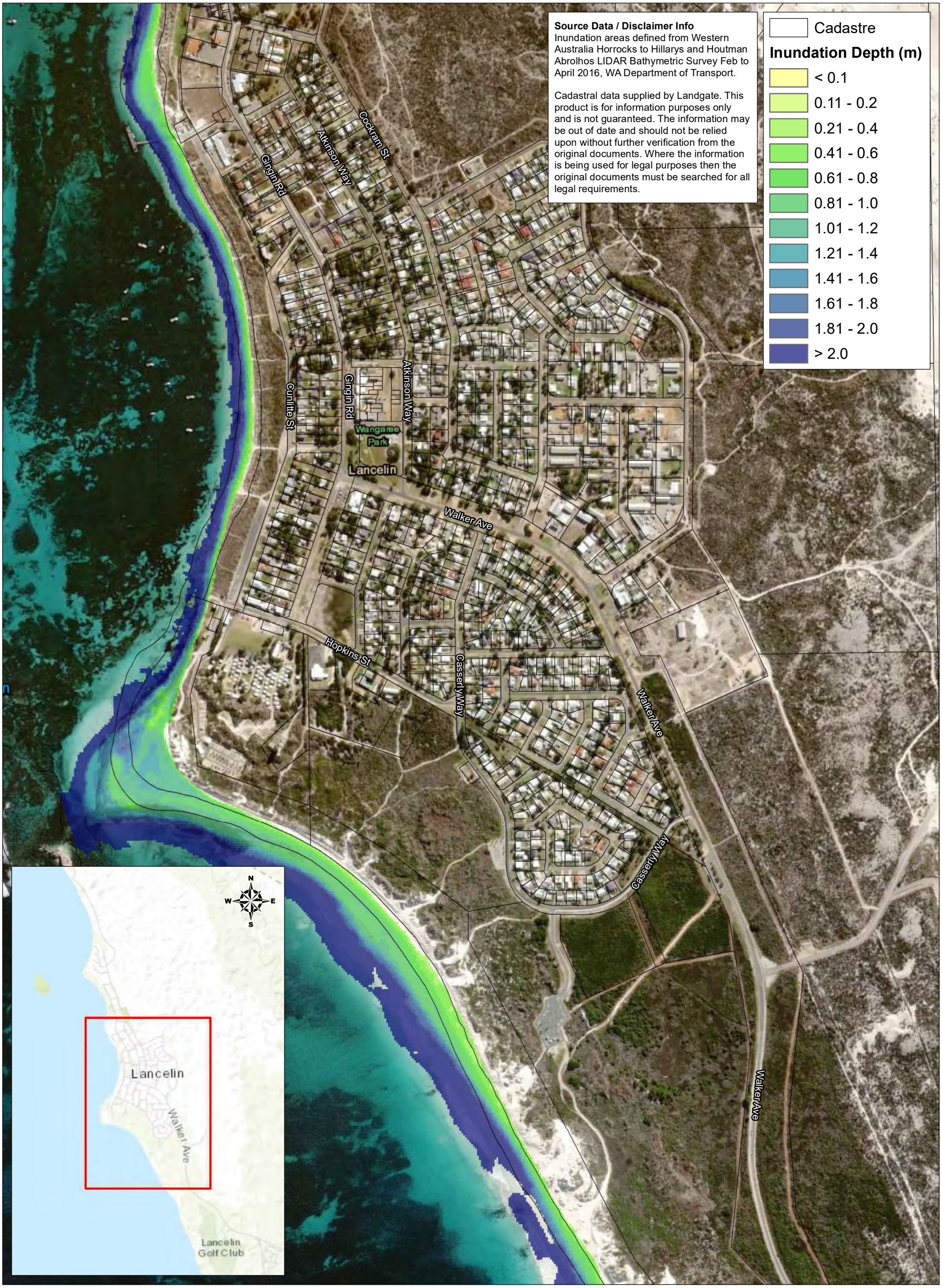
LANCELIN - AREA A

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 100yrARI Depth 2020_Rev02.mxd



1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 100yr ARI design storm in planning year 2020 (includes 0m Sea Level Rise Allowance)

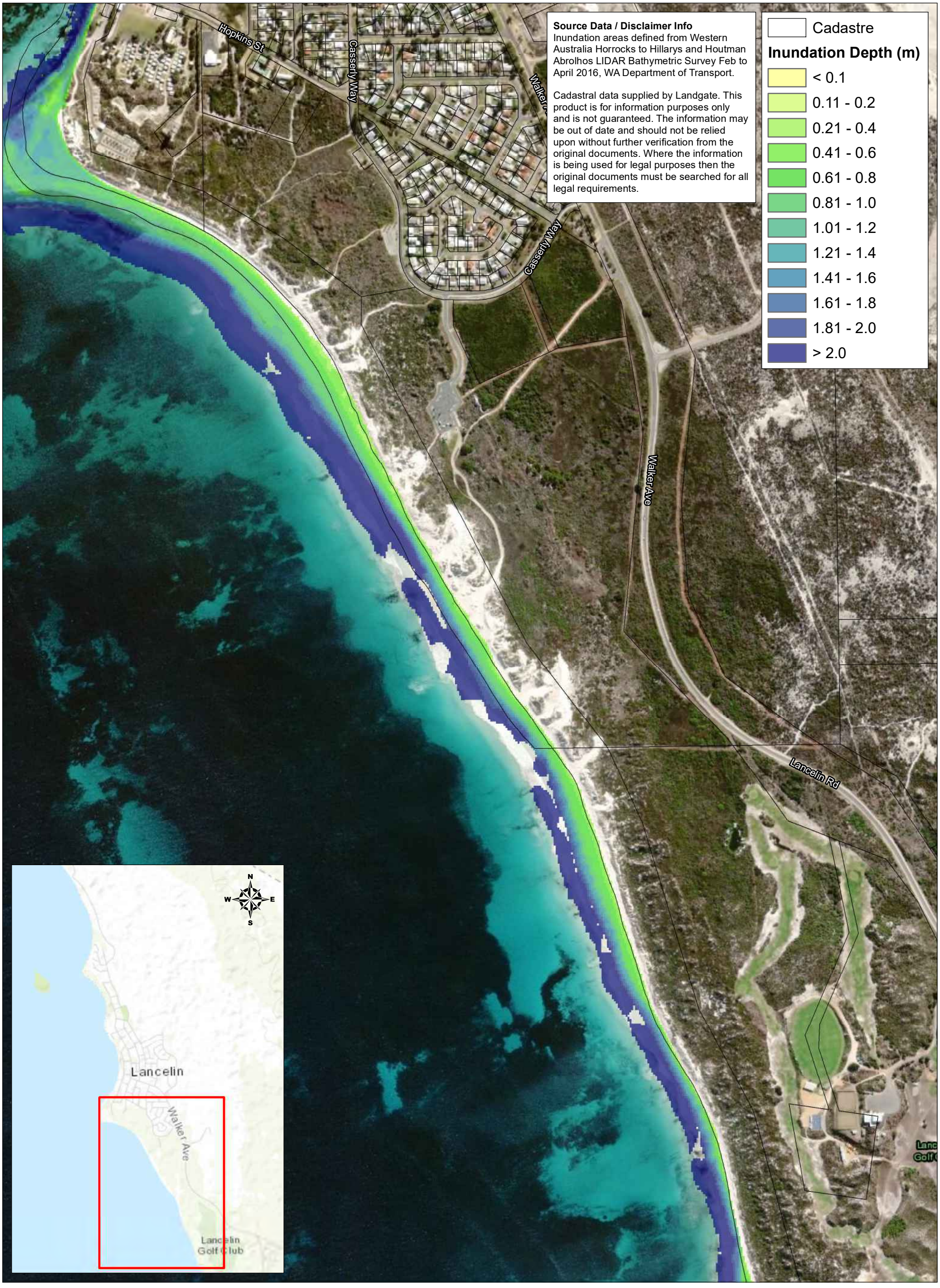
LANCELIN - AREA B

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 100yrARI Depth 2020_Rev02.mxd



1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 100yr ARI design storm in planning year 2020 (includes 0m Sea Level Rise Allowance)

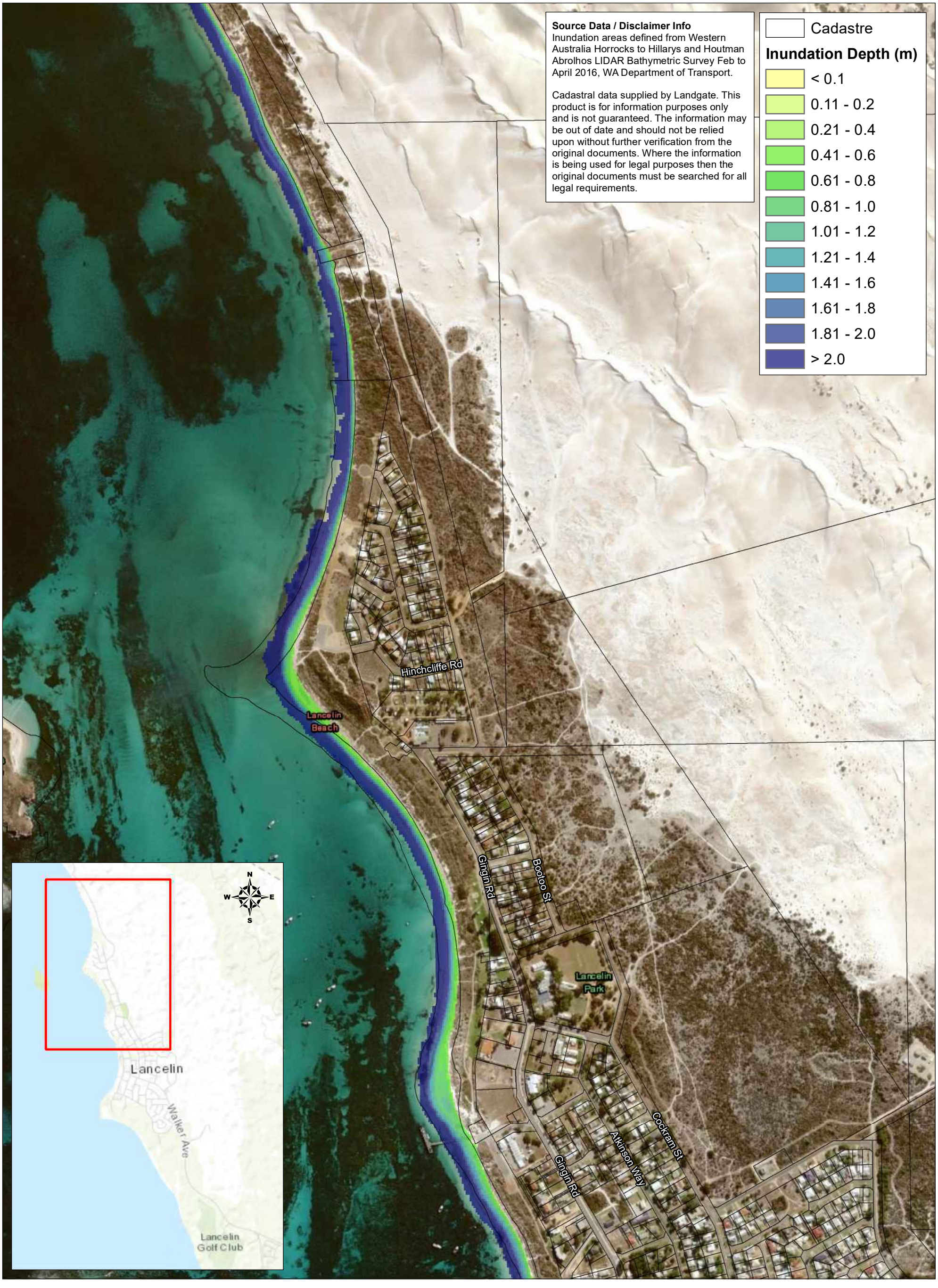
LANCELIN - AREA C

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 100yrARI Depth 2020_Rev02.mxd



1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 100yr ARI design storm in planning year 2040 (includes 0.1m Sea Level Rise Allowance)

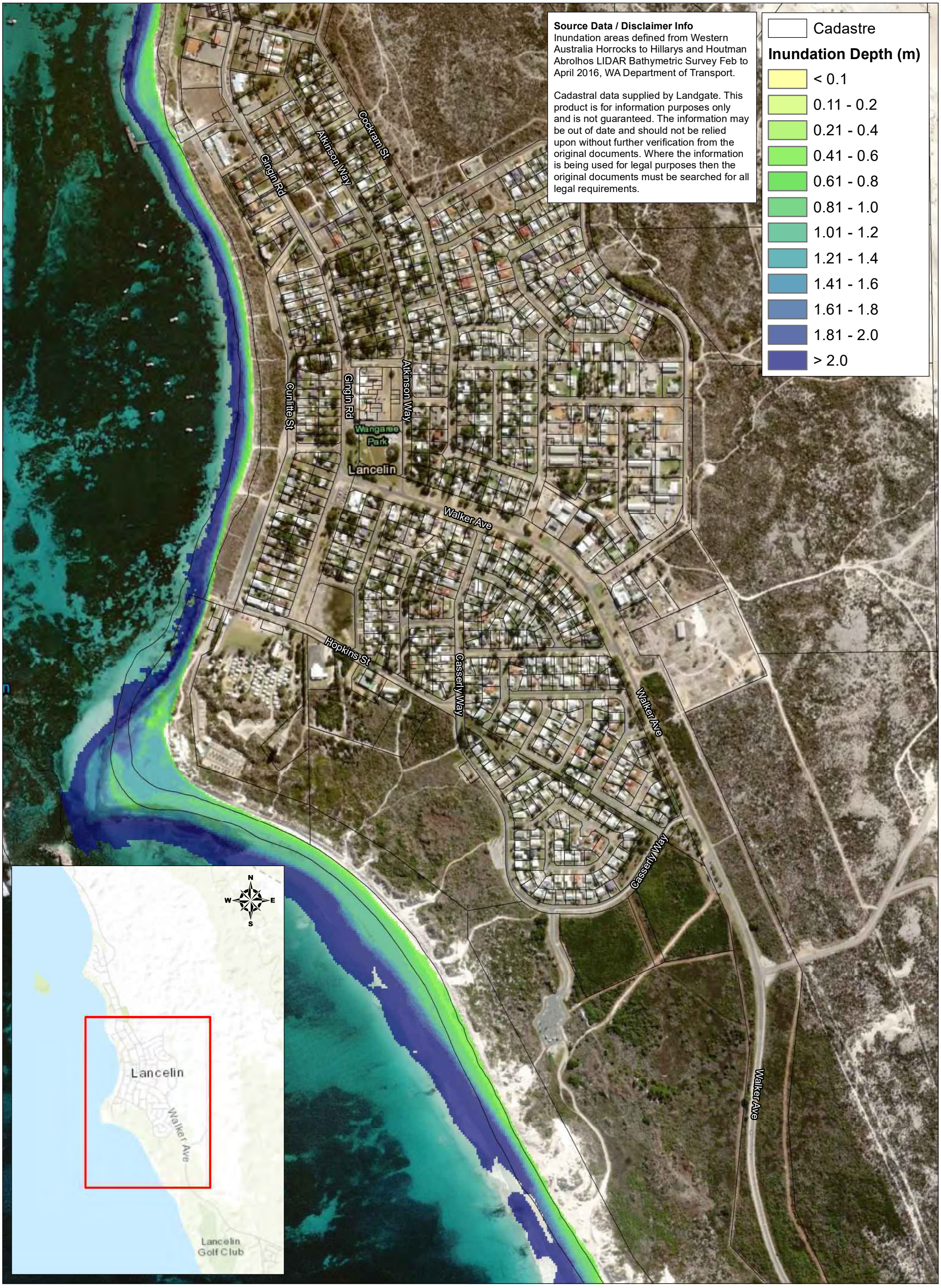
LANCELIN - AREA A

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 100yrARI Depth 2040_Rev02.mxd



1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 100yr ARI design storm in planning year 2040 (includes 0.1m Sea Level Rise Allowance)

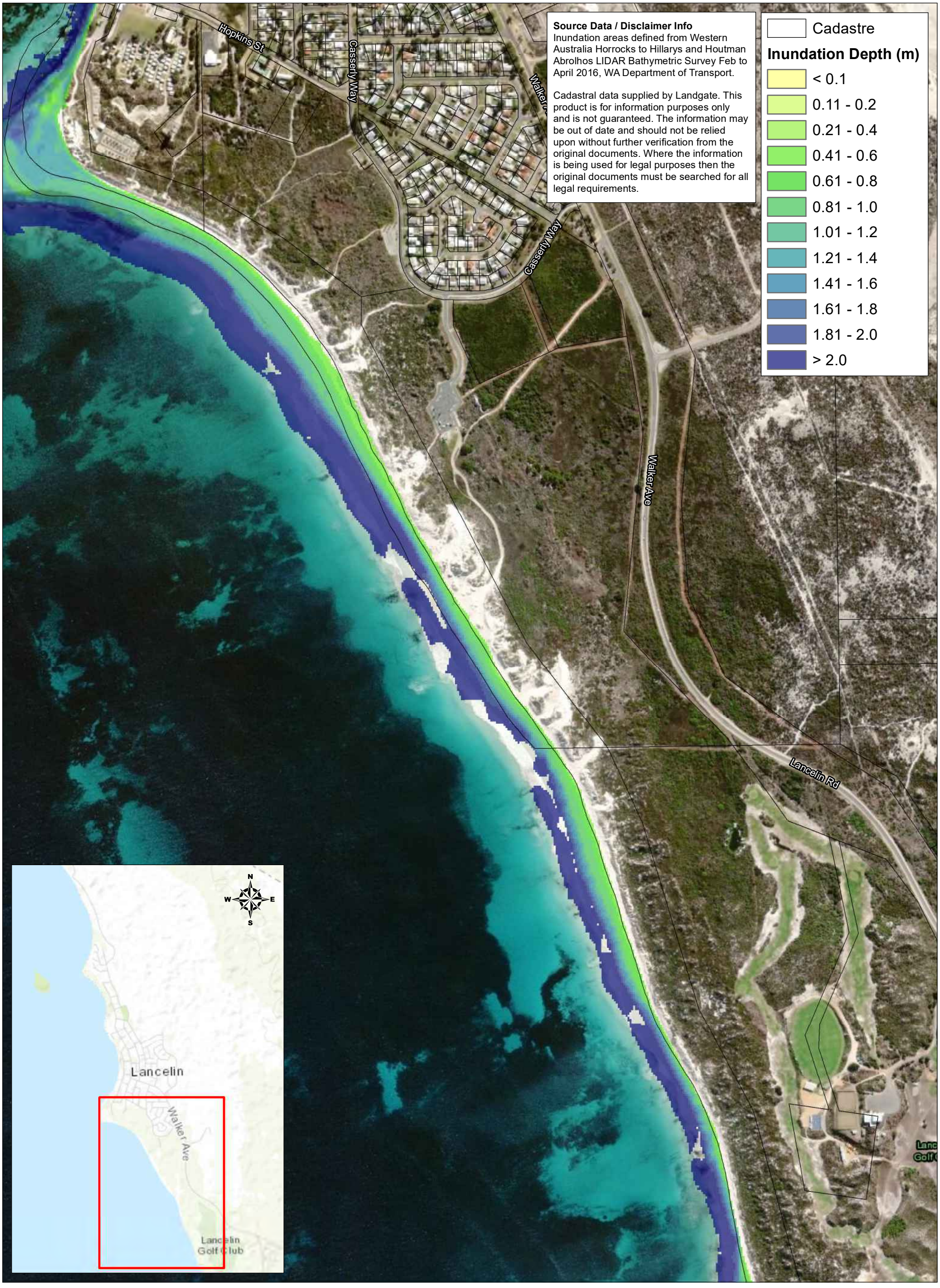
LANCELIN - AREA B

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 100yrARI Depth 2040_Rev02.mxd



1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 100yr ARI design storm in planning year 2040 (includes 0.1m Sea Level Rise Allowance)

LANCELIN - AREA C

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 100yrARI Depth 2040_Rev02.mxd

Source Data / Disclaimer Info
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Potential for Dune Breach During Extreme Events

Cadastre

Inundation Depth (m)

- < 0.1
- 0.11 - 0.2
- 0.21 - 0.4
- 0.41 - 0.6
- 0.61 - 0.8
- 0.81 - 1.0
- 1.01 - 1.2
- 1.21 - 1.4
- 1.41 - 1.6
- 1.61 - 1.8
- 1.81 - 2.0
- > 2.0

Hinchcliffe Rd
Lancelin Beach
Gingin Rd
Bootoo St
Lancelin Park
Cockram St
Atkinson Way
Gingin Rd
Lancelin
Walker Ave
Lancelin Golf Club
N
W
E
S

1:8,000
0 100 200 300 m

Inundation Depth based on peak water level from 100yr ARI design storm in planning year 2070 (includes 0.35m Sea Level Rise Allowance)

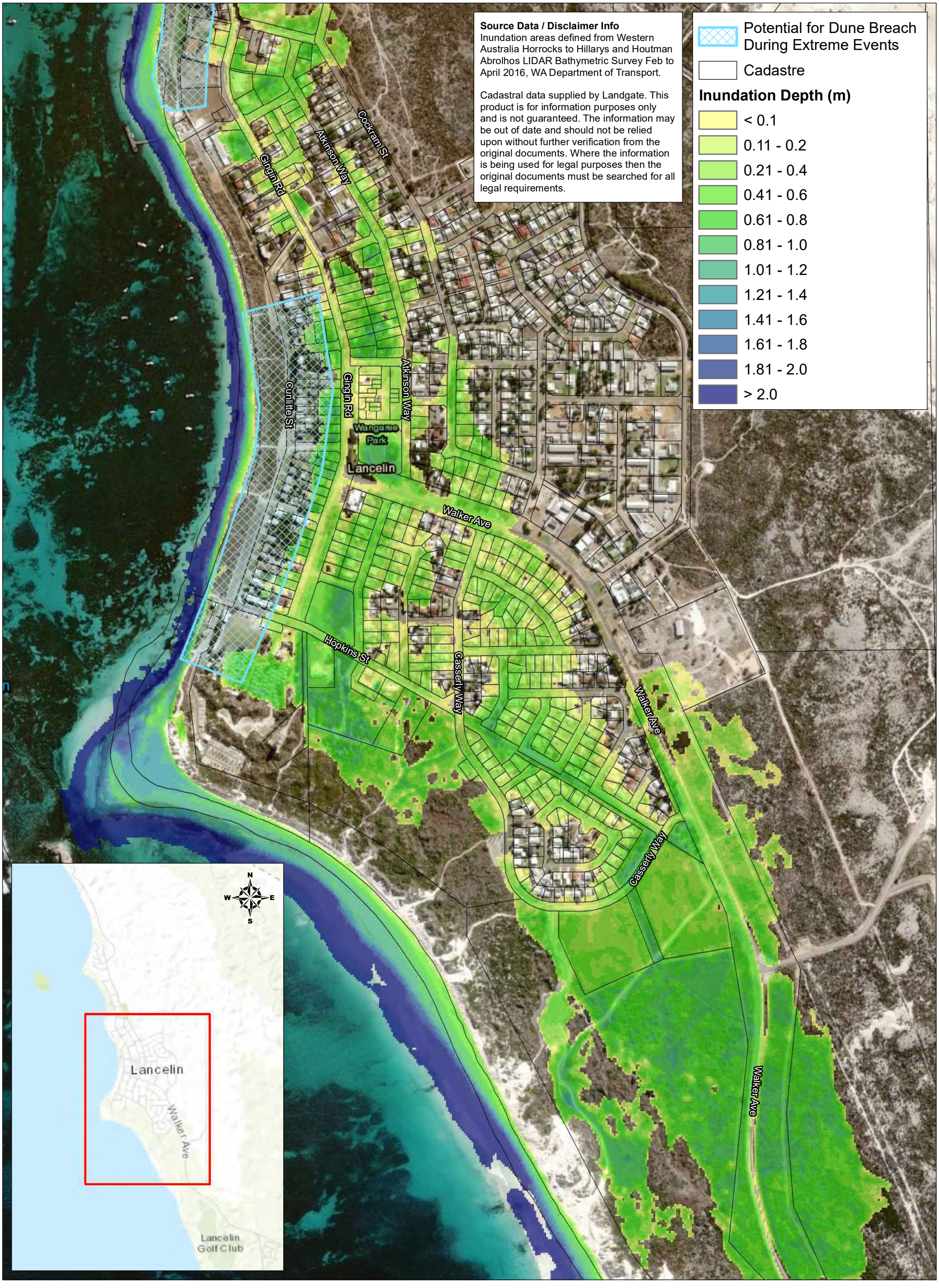
LANCELIN - AREA A

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 100yrARI Depth 2070_Rev02.mxd



1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 100yr ARI design storm in planning year 2070 (includes 0.35m Sea Level Rise Allowance)

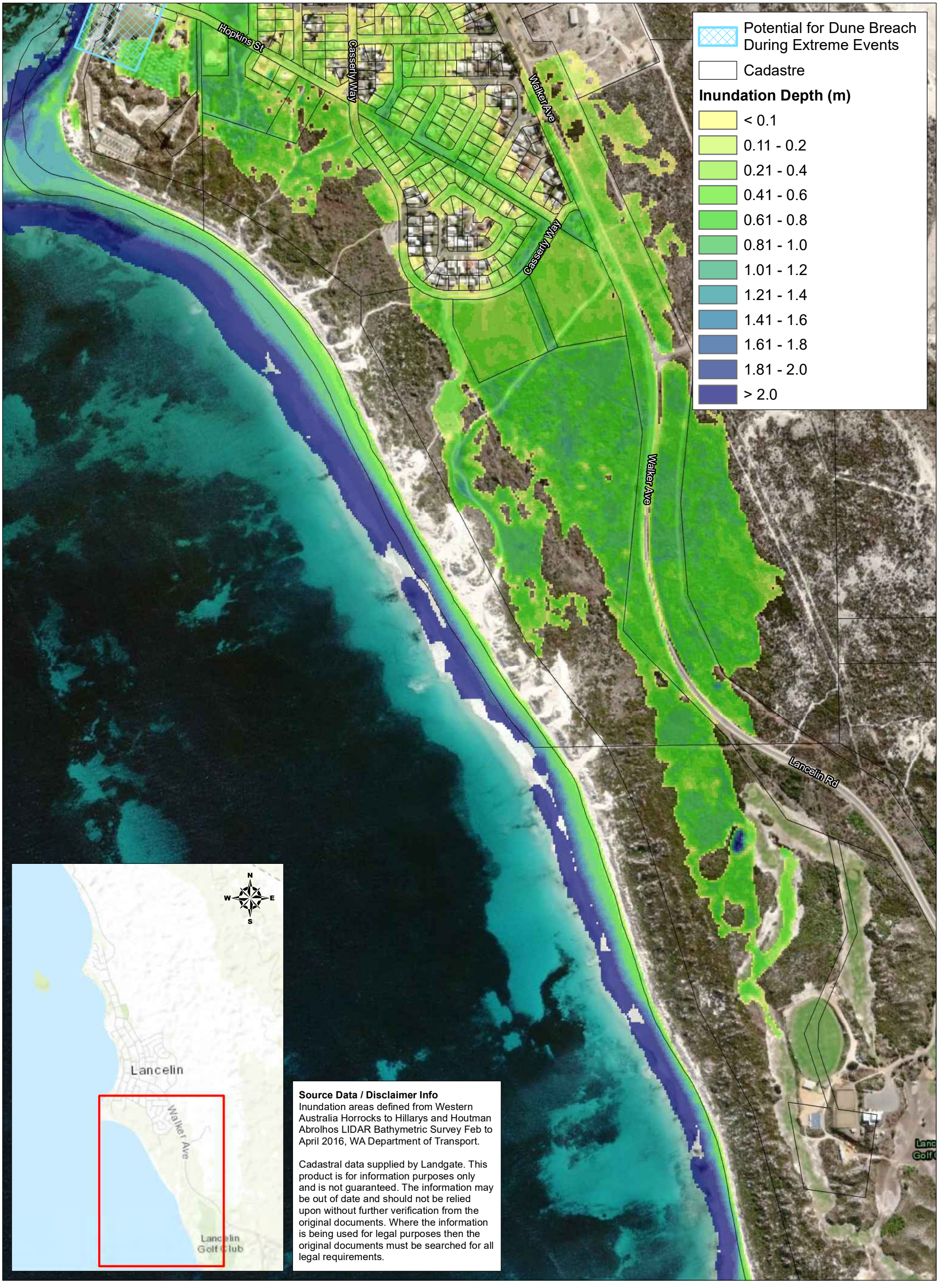
LANCELIN - AREA B

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 100yrARI Depth 2070_Rev02.mxd



1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 100yr ARI design storm in planning year 2070 (includes 0.35m Sea Level Rise Allowance)

LANCELIN - AREA C

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 100yrARI Depth 2070_Rev02.mxd

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Potential for Dune Breach During Extreme Events

Cadastre

Inundation Depth (m)

- < 0.1
- 0.11 - 0.2
- 0.21 - 0.4
- 0.41 - 0.6
- 0.61 - 0.8
- 0.81 - 1.0
- 1.01 - 1.2
- 1.21 - 1.4
- 1.41 - 1.6
- 1.61 - 1.8
- 1.81 - 2.0
- > 2.0

Hinchcliffe Rd
Lancelin Beach
Gingin Rd
Bootoo St
Lancelin Park
Cockram St
Atkinson Way
Gingin Rd

N
W
E
S

Lancelin
Walker Ave
Lancelin Golf Club

1:8,000
0 100 200 300 m

Inundation Depth based on peak water level from 100yr ARI design storm in planning year 2120 (includes 0.9m Sea Level Rise Allowance)

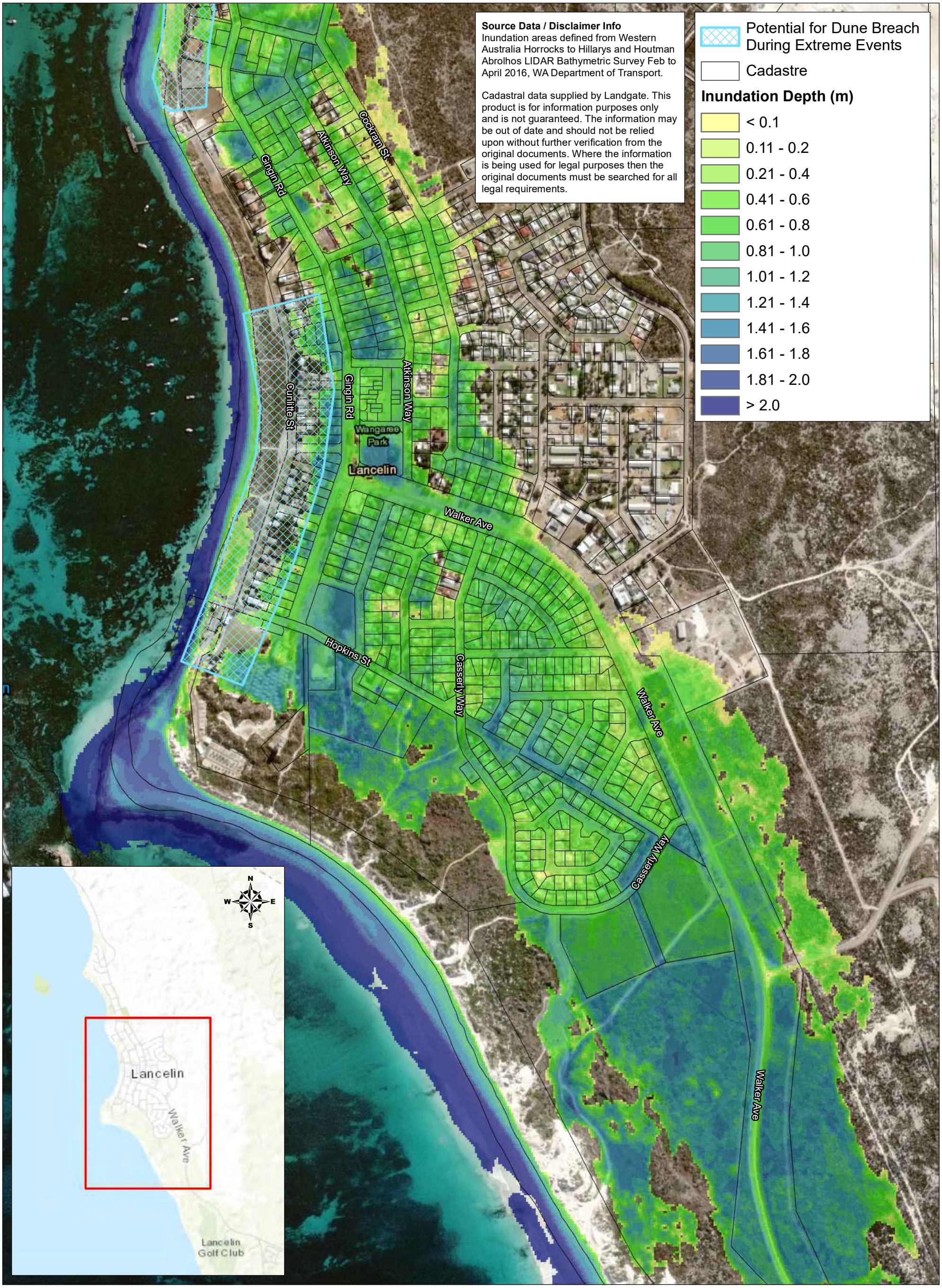
LANCELIN - AREA A

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 100yrARI Depth 2120_Rev02.mxd



1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 100yr ARI design storm in planning year 2120 (includes 0.9m Sea Level Rise Allowance)

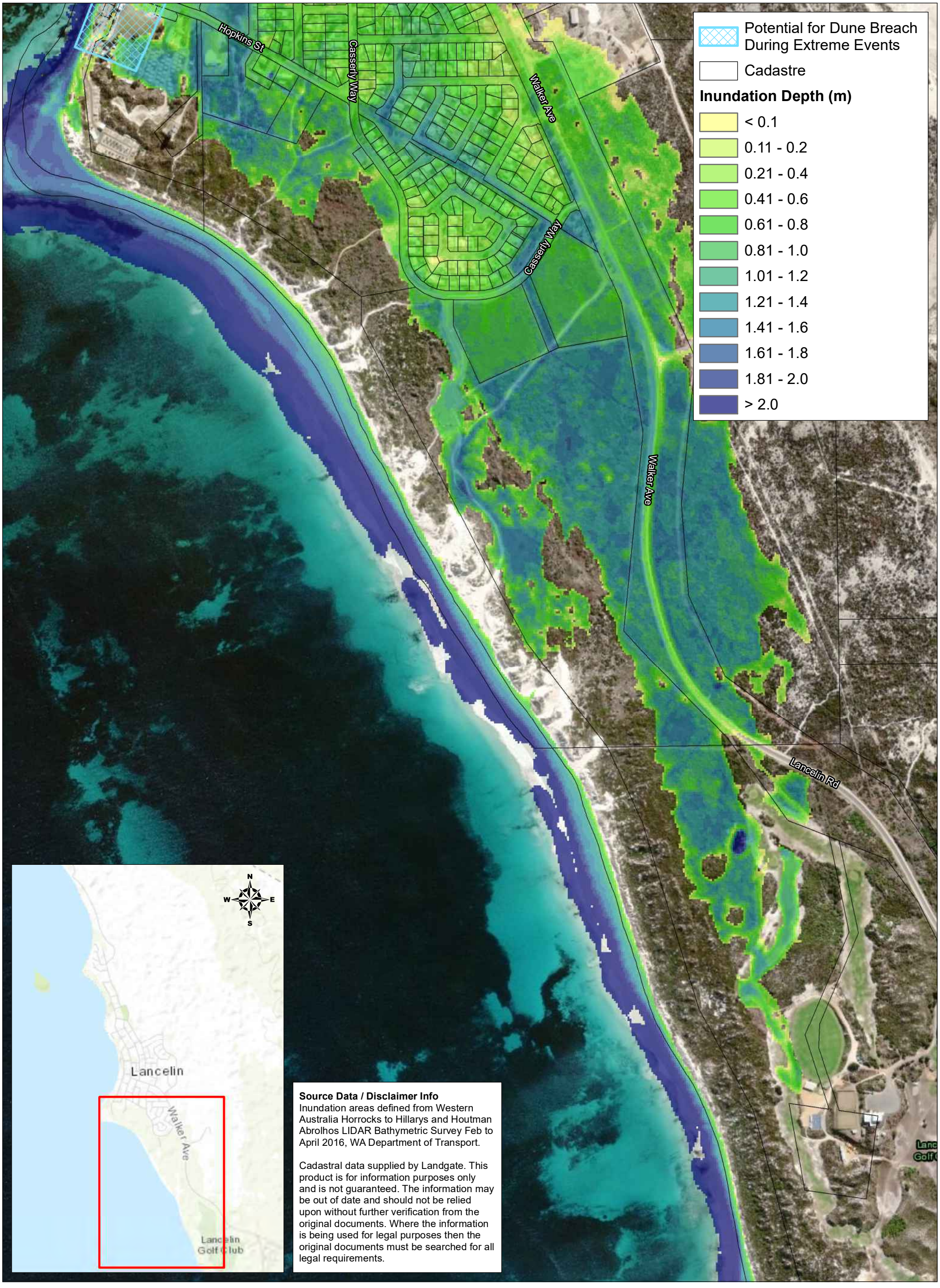
LANCELIN - AREA B

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 100yrARI Depth 2120_Rev02.mxd



Source Data / Disclaimer Info
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1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 100yr ARI design storm in planning year 2120 (includes 0.9m Sea Level Rise Allowance)

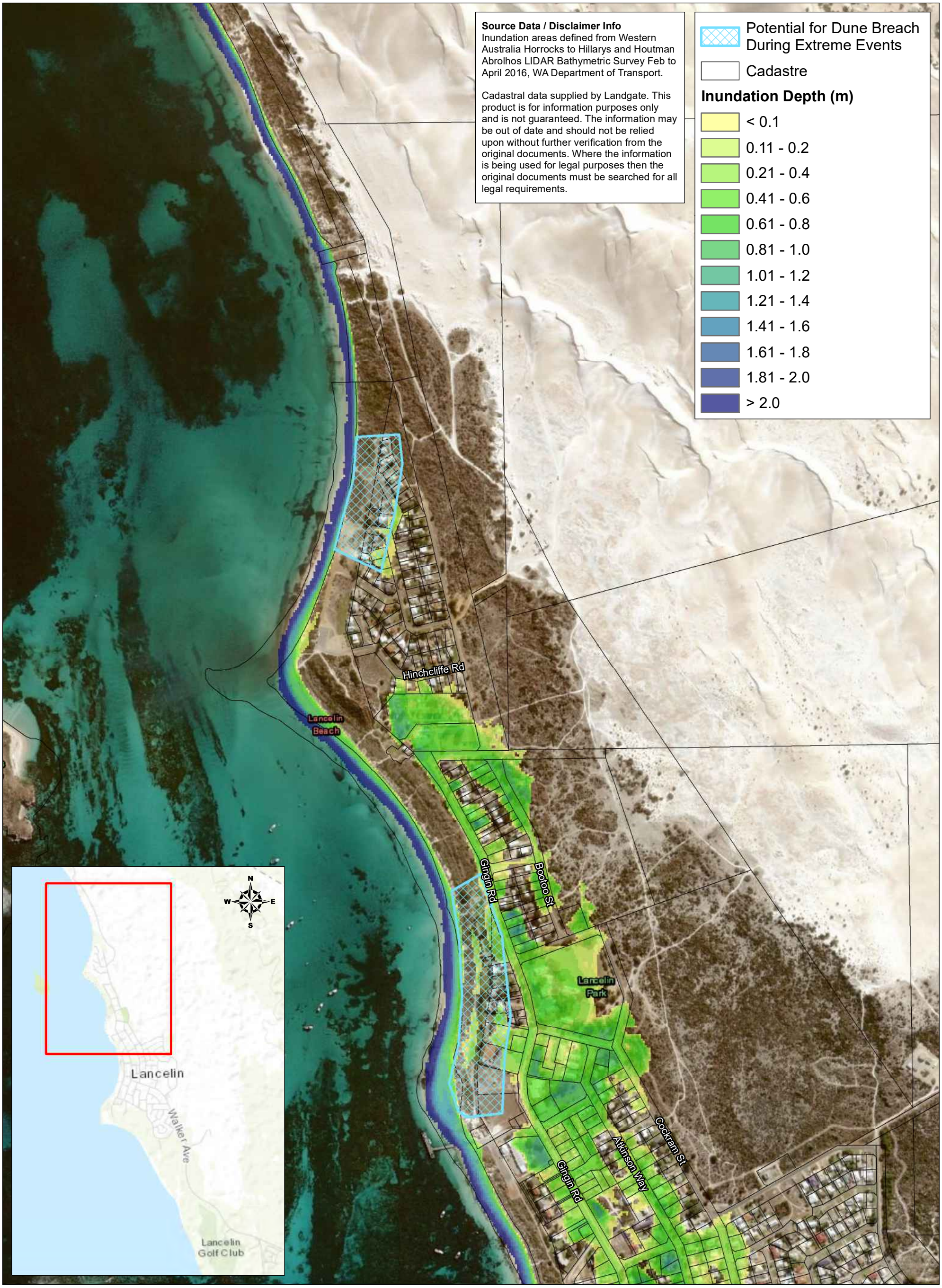
LANCELIN - AREA C

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 100yrARI Depth 2120_Rev02.mxd



1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 500yr ARI design storm in planning year 2020 (includes 0m Sea Level Rise Allowance)

LANCELIN - AREA A

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 500yrARI Depth 2020_Rev02.mxd

Source Data / Disclaimer Info
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Potential for Dune Breach During Extreme Events

Cadastre

Inundation Depth (m)

- < 0.1
- 0.11 - 0.2
- 0.21 - 0.4
- 0.41 - 0.6
- 0.61 - 0.8
- 0.81 - 1.0
- 1.01 - 1.2
- 1.21 - 1.4
- 1.41 - 1.6
- 1.61 - 1.8
- 1.81 - 2.0
- > 2.0

Cockram St
Atkinson Way
Gingin Rd
Cunlite St
Wangaree Park
Lancelin
Walker Ave
Hopkins St
Casserly Way

N
W
E
S

Lancelin
Walker Ave
Lancelin Golf Club

1:8,000
0 100 200 300 m

Inundation Depth based on peak water level from 500yr ARI design storm in planning year 2020 (includes 0m Sea Level Rise Allowance)

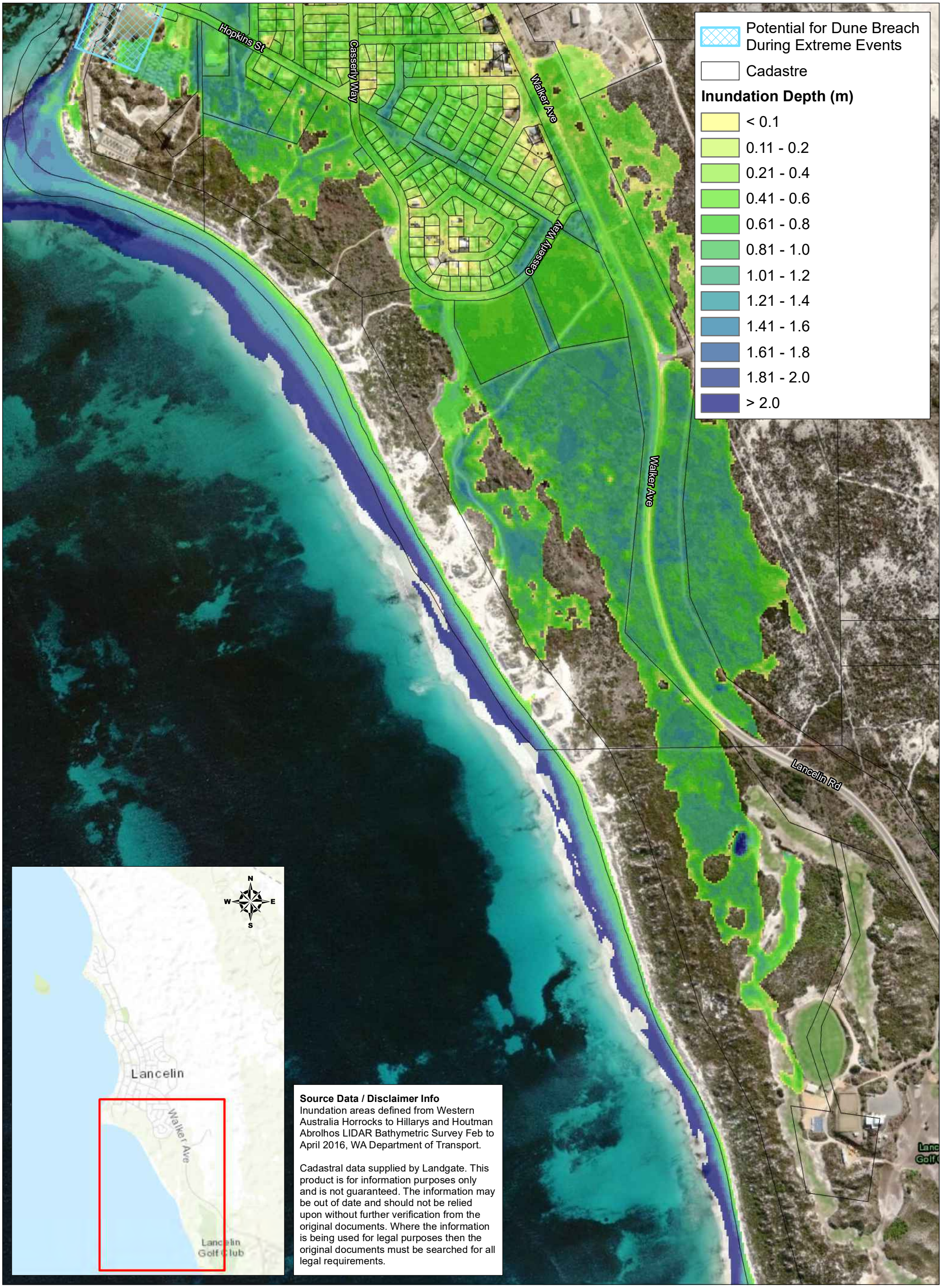
LANCELIN - AREA B

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 500yrARI Depth 2020_Rev02.mxd



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1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 500yr ARI design storm in planning year 2020 (includes 0m Sea Level Rise Allowance)

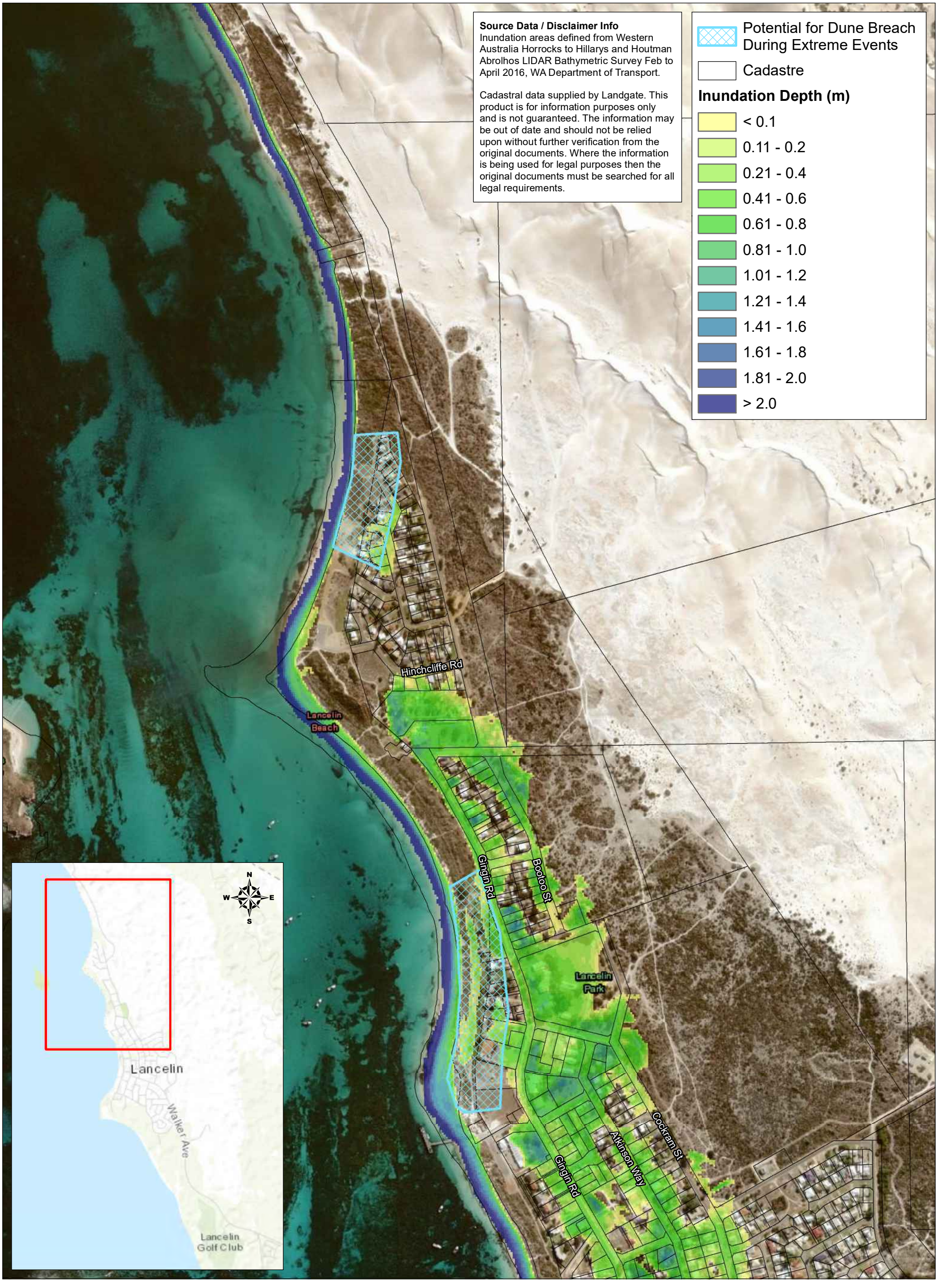
LANCELIN - AREA C

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 500yrARI Depth 2020_Rev02.mxd



1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 500yr ARI design storm in planning year 2040 (includes 0.1m Sea Level Rise Allowance)

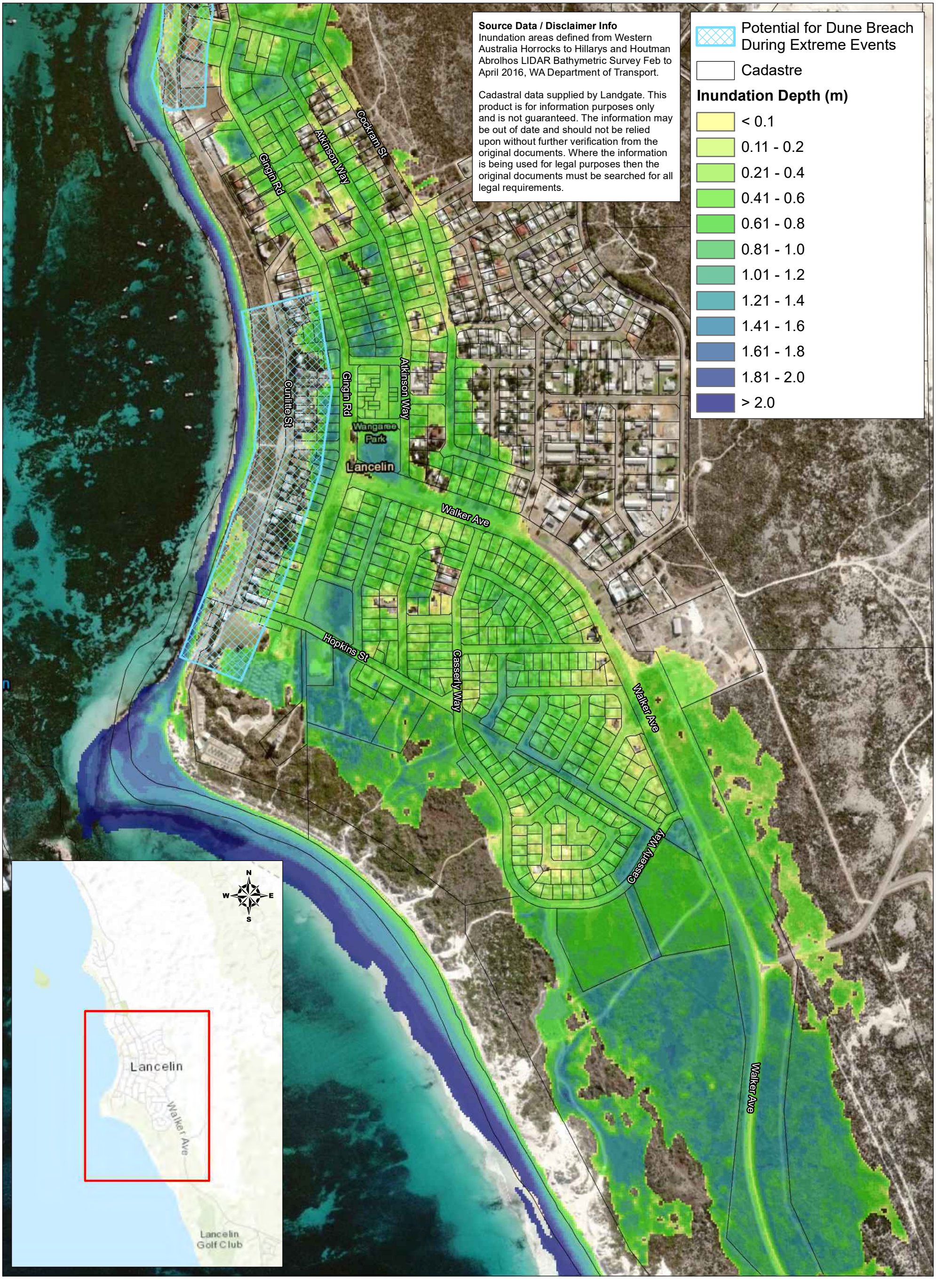
LANCELIN - AREA A

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 500yrARI Depth 2040_Rev02.mxd



1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 500yr ARI design storm in planning year 2040 (includes 0.1m Sea Level Rise Allowance)

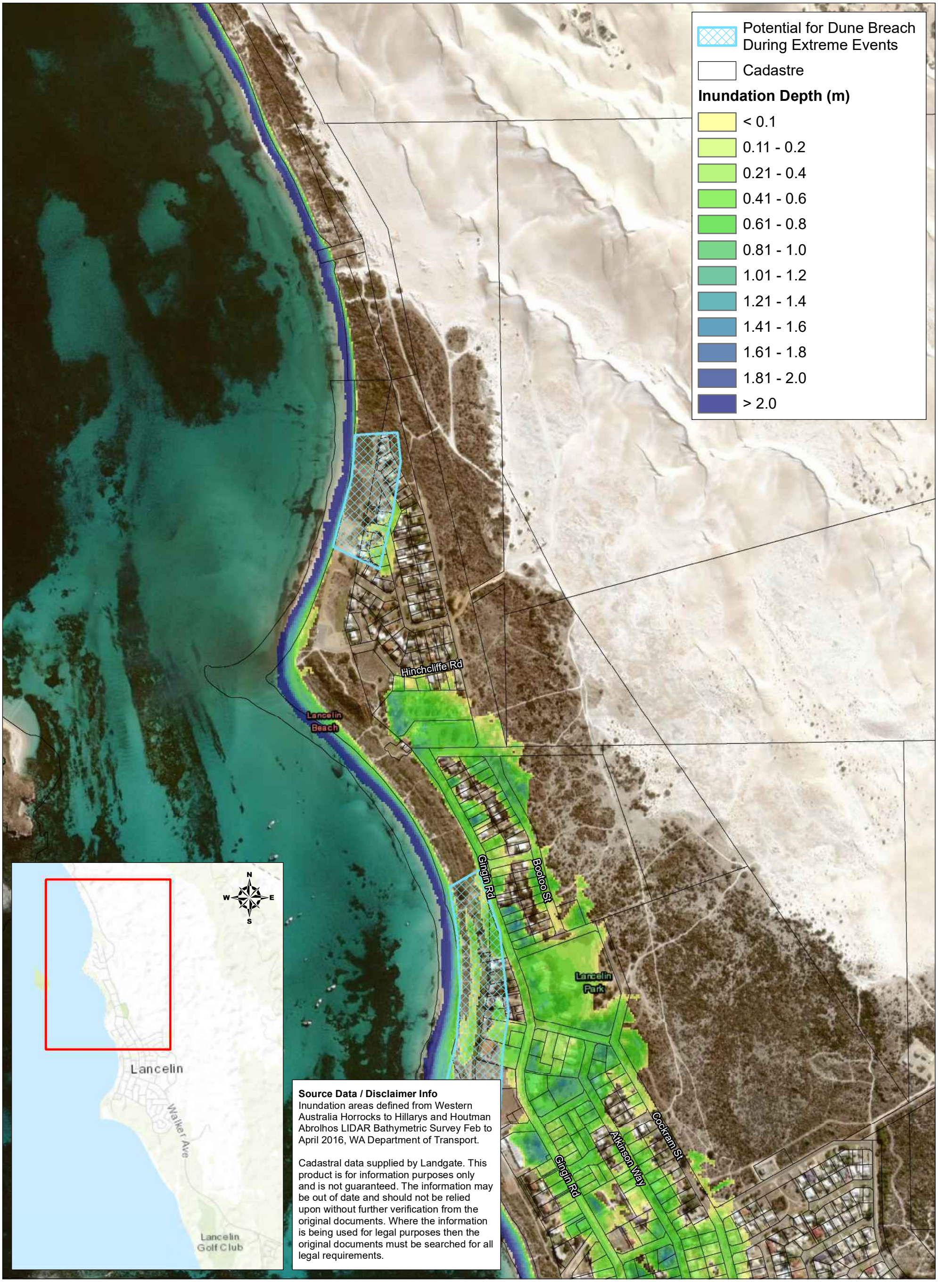
LANCELIN - AREA B

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 500yrARI Depth 2040_Rev02.mxd



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1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 500yr ARI design storm in planning year 2040 (includes 0.1m Sea Level Rise Allowance)

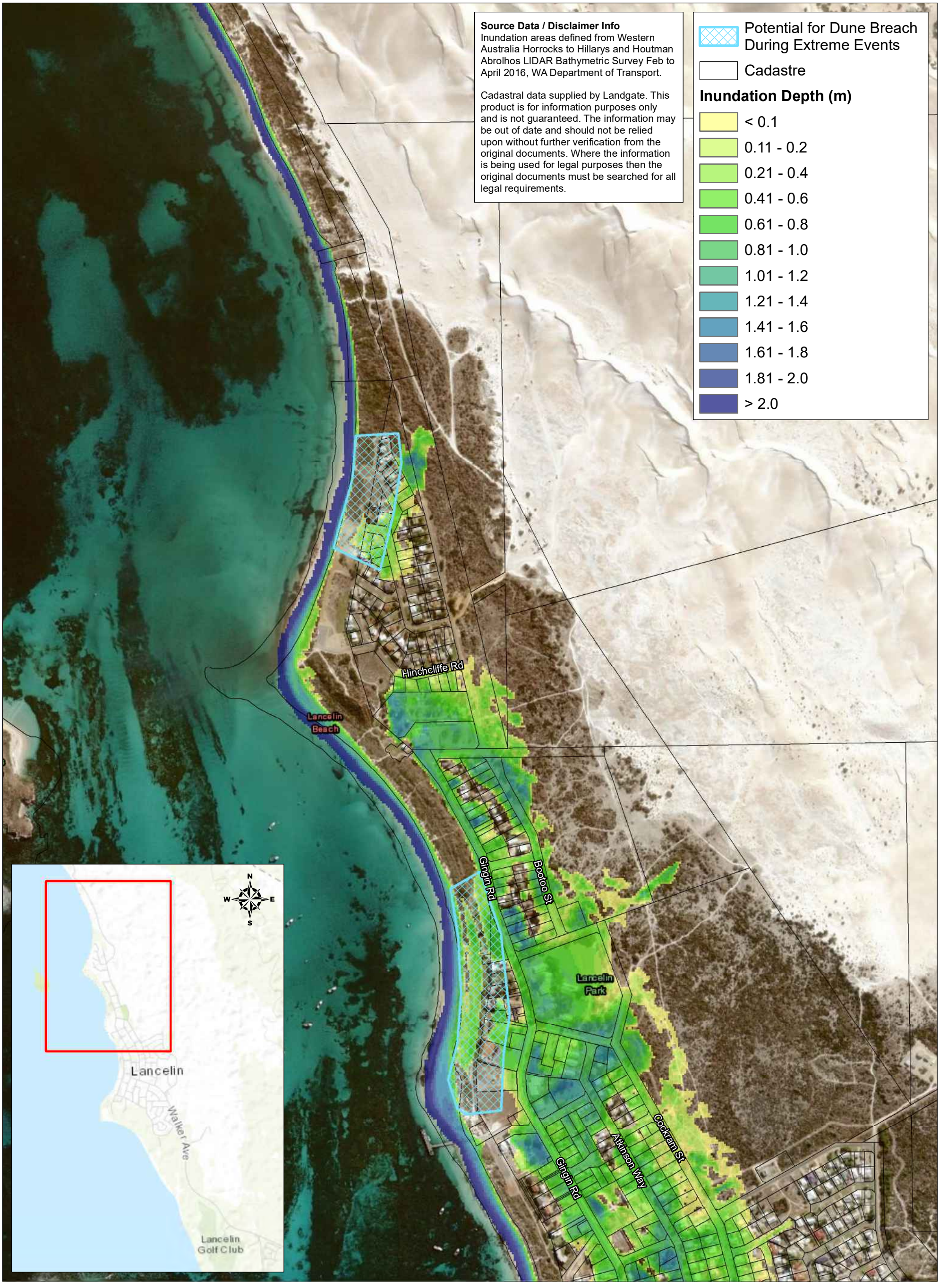
LANCELIN - AREA C

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 500yrARI Depth 2040_Rev02.mxd



1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 500yr ARI design storm in planning year 2070 (includes 0.35m Sea Level Rise Allowance)

LANCELIN - AREA A

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 500yrARI Depth 2070_Rev02.mxd

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Potential for Dune Breach During Extreme Events

Cadastre

Inundation Depth (m)

- < 0.1
- 0.11 - 0.2
- 0.21 - 0.4
- 0.41 - 0.6
- 0.61 - 0.8
- 0.81 - 1.0
- 1.01 - 1.2
- 1.21 - 1.4
- 1.41 - 1.6
- 1.61 - 1.8
- 1.81 - 2.0
- > 2.0

Cockram St
Atkinson Way
Gingin Rd
Cunlite St
Wangaree Park
Lancelin
Walker Ave
Hopkins St
Casserly Way

N
W
E
S

Lancelin
Walker Ave
Lancelin Golf Club

1:8,000
0 100 200 300 m

Inundation Depth based on peak water level from 500yr ARI design storm in planning year 2070 (includes 0.35m Sea Level Rise Allowance)

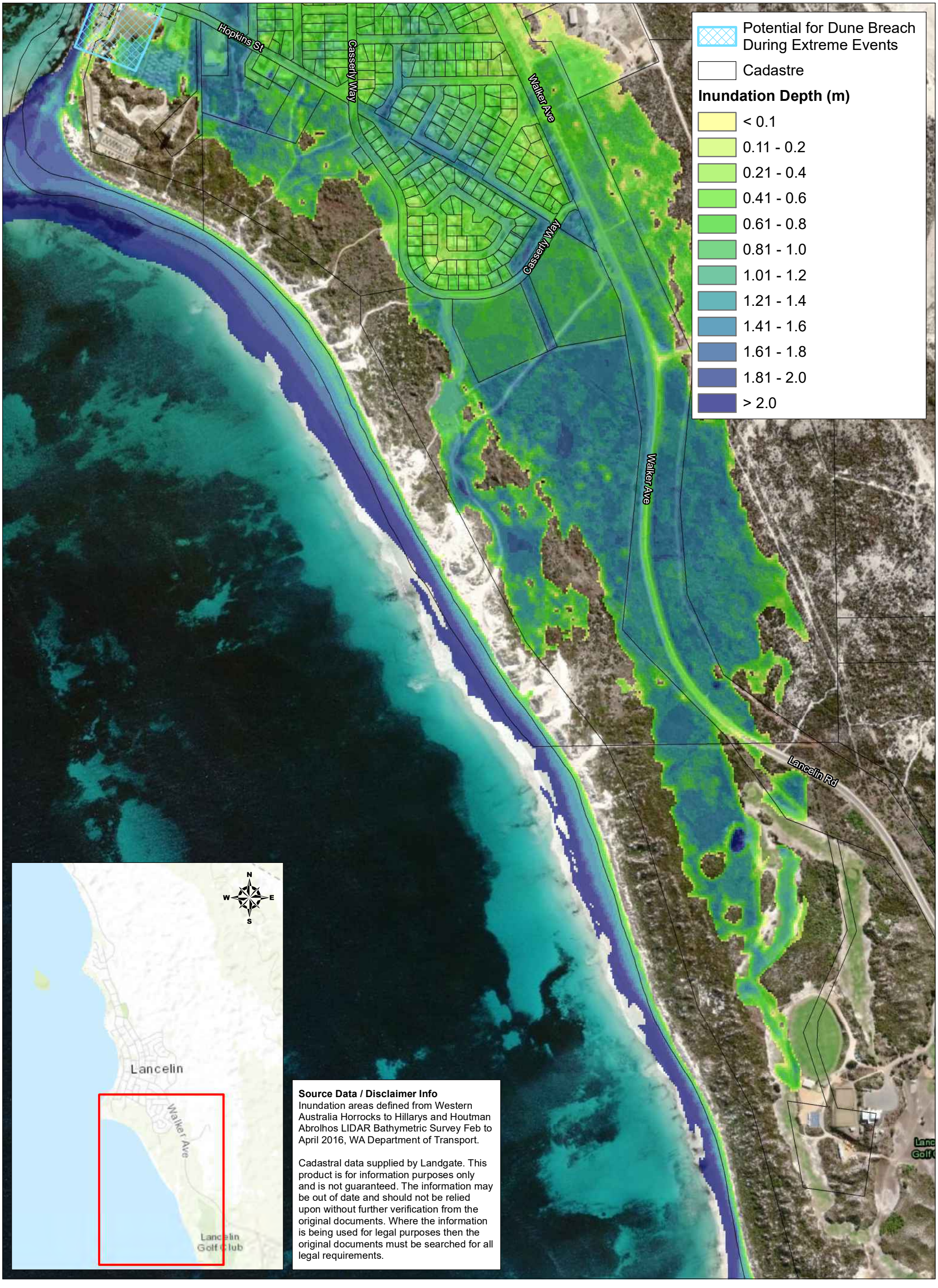
LANCELIN - AREA B

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 500yrARI Depth 2070_Rev02.mxd



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1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 500yr ARI design storm in planning year 2070 (includes 0.35m Sea Level Rise Allowance)

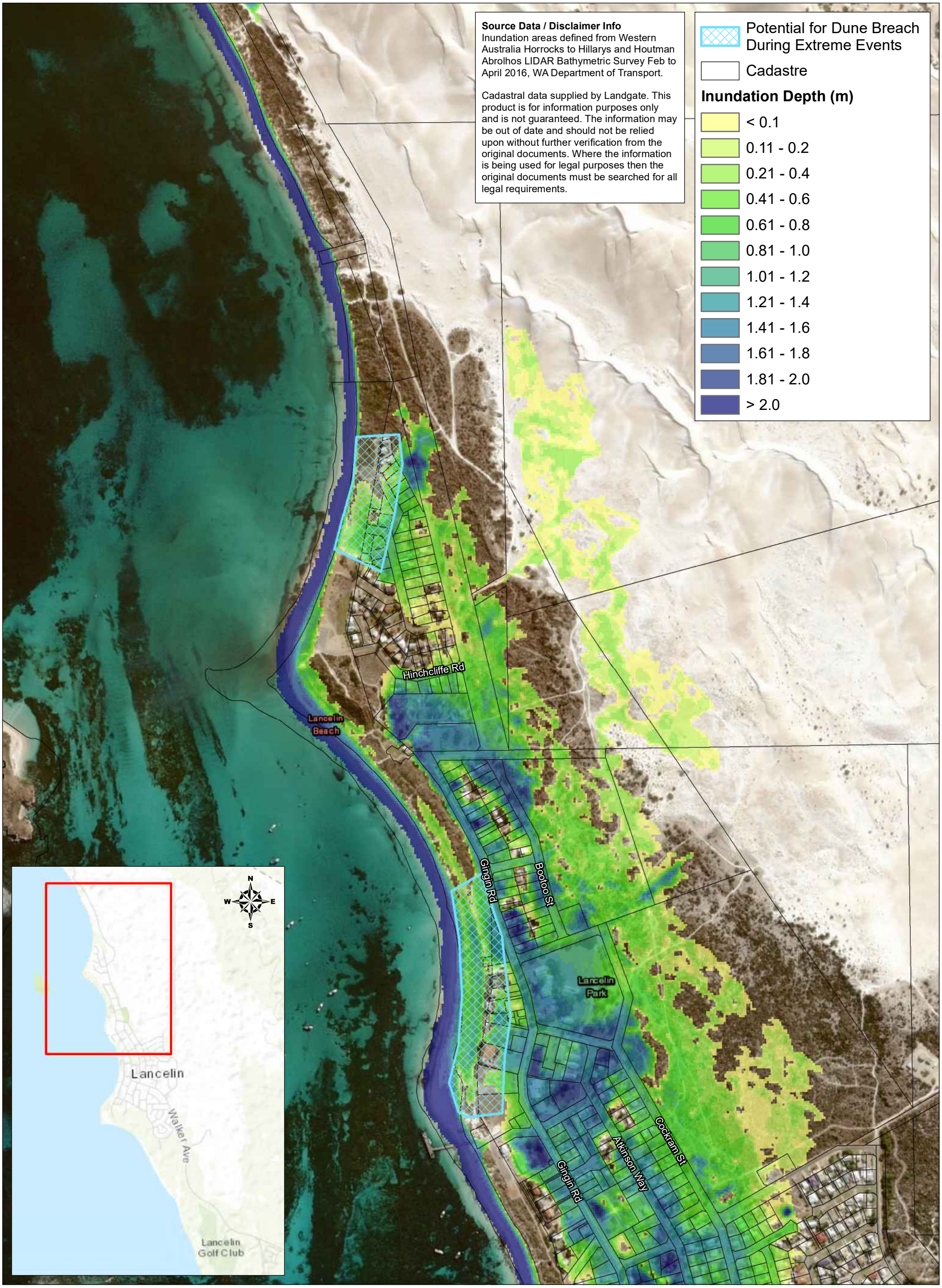
LANCELIN - AREA C

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 500yrARI Depth 2070_Rev02.mxd



1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 500yr ARI design storm in planning year 2120 (includes 0.9m Sea Level Rise Allowance)

LANCELIN - AREA A

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 500yrARI Depth 2120_Rev02.mxd

Source Data / Disclaimer Info
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Potential for Dune Breach During Extreme Events

Cadastre

Inundation Depth (m)

- < 0.1
- 0.11 - 0.2
- 0.21 - 0.4
- 0.41 - 0.6
- 0.61 - 0.8
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- 1.01 - 1.2
- 1.21 - 1.4
- 1.41 - 1.6
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- 1.81 - 2.0
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Cockram St
Atkinson Way
Gingin Rd
Cunlite St
Wangaree Park
Lancelin
Walker Ave
Hopkins St
Casserly Way

N
W E
S

Lancelin
Walker Ave
Lancelin Golf Club

1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 500yr ARI design storm in planning year 2120 (includes 0.9m Sea Level Rise Allowance)

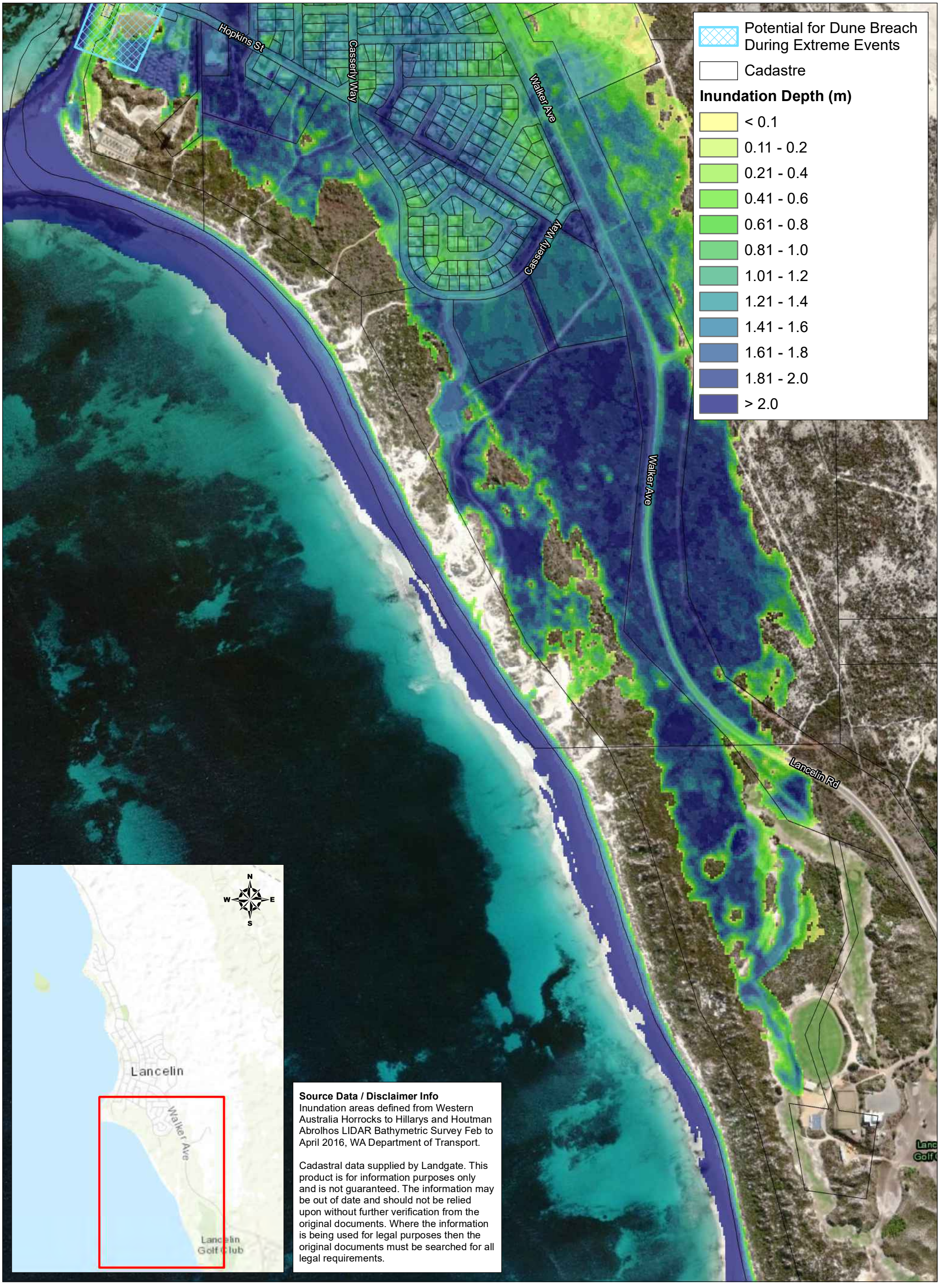
LANCELIN - AREA B

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 500yrARI Depth 2120_Rev02.mxd



Source Data / Disclaimer Info
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1:8,000

0 100 200 300 m

Inundation Depth based on peak water level from 500yr ARI design storm in planning year 2120 (includes 0.9m Sea Level Rise Allowance)

LANCELIN - AREA C

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-06-19

13288 Gingin - Lancelin - 500yrARI Depth 2120_Rev02.mxd

C.2 Ledge Point Inundation Mapping

Mapping Cases presented for the 500yr ARI events at planning year 2120.

Source Data / Disclaimer Info
Inundation areas defined from Western Australia Horrocks to Hillarys and Houtman Abrolhos LIDAR Bathymetric Survey Feb to April 2016, WA Department of Transport.

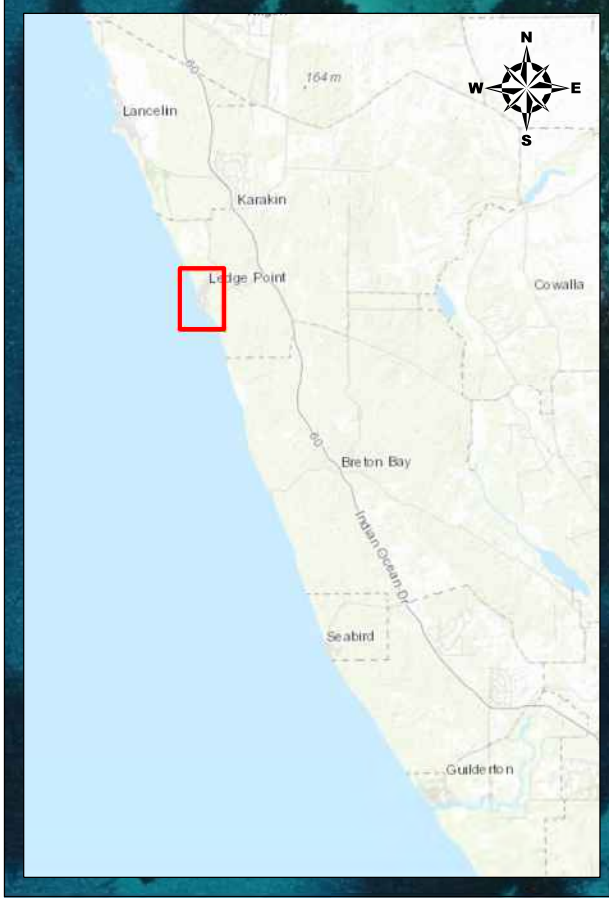
Cadastral data supplied by Landgate. This product is for information purposes only and is not guaranteed. The information may be out of date and should not be relied upon without further verification from the original documents. Where the information is being used for legal purposes then the original documents must be searched for all legal requirements.

Cadastre

Inundation Depth (m)

- < 0.1
- 0.11 - 0.2
- 0.21 - 0.4
- 0.41 - 0.6
- 0.61 - 0.8
- 0.81 - 1.0
- 1.01 - 1.2
- 1.21 - 1.4
- 1.41 - 1.6
- 1.61 - 1.8
- 1.81 - 2.0
- > 2.0

Ledge Point
Ledge Point Rd
Robertson Rd
Ledge Point Rd
Ledge Point Golf Club
Jones St
De Burgh St



1:9,000
0 100 200 300 m

Inundation Depth based on peak water level from 500yr ARI design storm in planning year 2120 (includes 0.9m Sea Level Rise Allowance)

LEDGE POINT

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

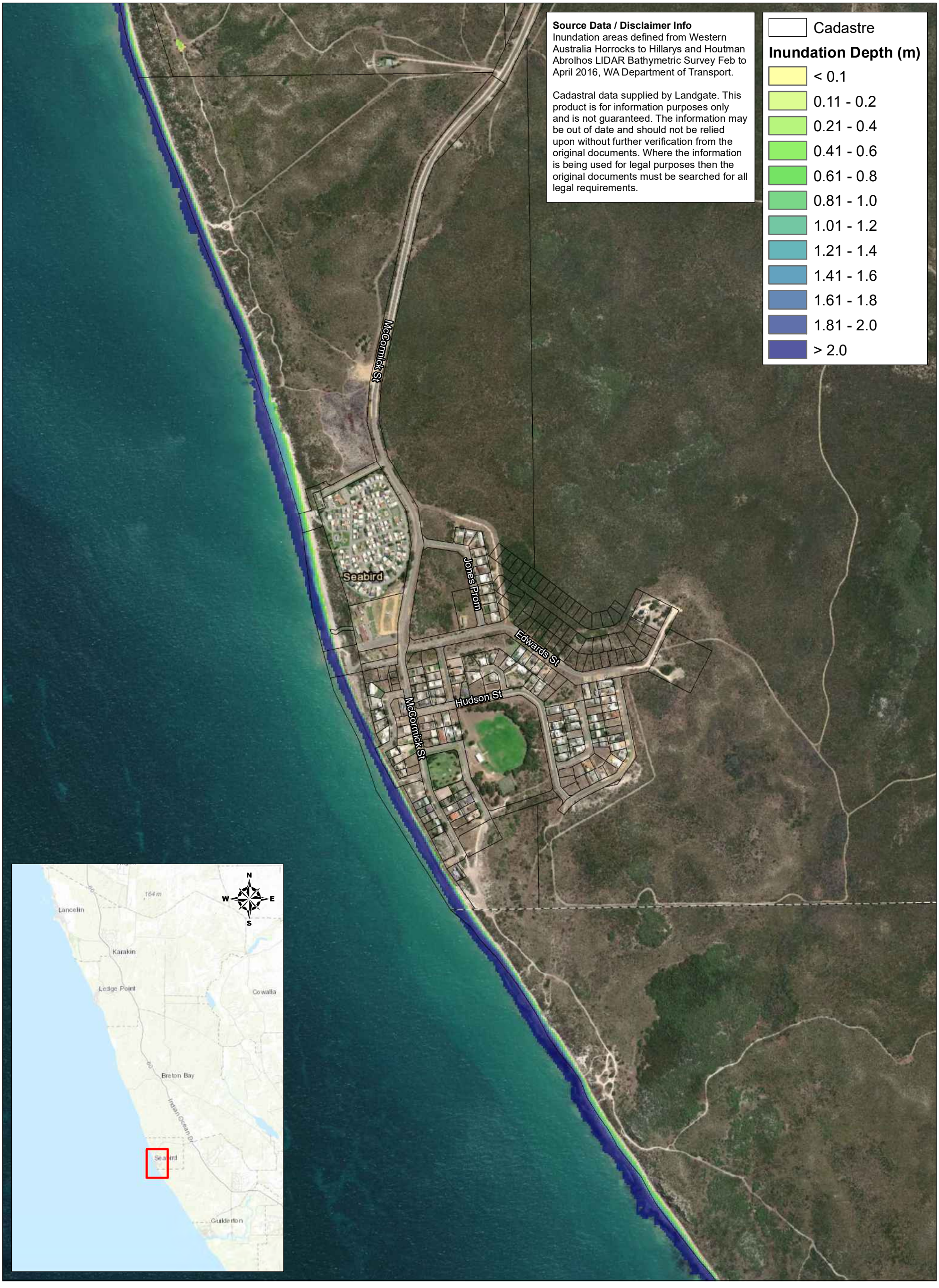
Baird. GINGIN

Map Published: 2020-04-30

13288 Gingin - Ledge Point - 500yrARI Depth 2120_Rev01.mxd

C.3 Seabird Inundation Mapping

Mapping Cases presented for the 500yr ARI events at planning year 2120.



1:9,000

0 100 200 300 m

Inundation Depth based on peak water level from 500yr ARI design storm in planning year 2120 (includes 0.9m Sea Level Rise Allowance)

SEABIRD

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-04-30

13288 Gingin - Seabird - 500yrARI Depth 2120_Rev01.mxd

C.4 Guilderton Inundation Mapping

Mapping Cases presented for the 500yr ARI events at planning year 2120.

Source Data / Disclaimer Info
Inundation areas defined from Western Australia Horrocks to Hillarys and Houtman Abrolhos LIDAR Bathymetric Survey Feb to April 2016, WA Department of Transport.

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Cadastre

Inundation Depth (m)

- < 0.1
- 0.11 - 0.2
- 0.21 - 0.4
- 0.41 - 0.6
- 0.61 - 0.8
- 0.81 - 1.0
- 1.01 - 1.2
- 1.21 - 1.4
- 1.41 - 1.6
- 1.61 - 1.8
- 1.81 - 2.0
- > 2.0

Guilderton
Forrester Rd
Guilderton
Mortimer Rd
Gordon St
Guilderton Golf Club
Guilderton Rd
Moore River Dr
Indian Ocean
Whitefield St
Moore River

Lancelin
Karakin
Ledge Point
Cowalla
Breton Bay
Indian Ocean Dr
Seabird
Guilderton
164 m

Gordon St
Whitfield St
Moore River
Caraban
0 50 100 m

1:14,000
0 150 300 450 m

Inundation Depth based on peak water level from 500yr ARI design storm in planning year 2120 (includes 0.9m Sea Level Rise Allowance)

GUILDERTON

Imagery: ESRI World Basemap
Spatial Reference: GDA 1994 MGA Zone 50

Baird. GINGIN

Map Published: 2020-04-30

13288 Gingin - Guilderton - 500yrARI Depth 2120_Rev01.mxd

APPENDIX C

Appendix C - Gingin Coastal Hazard Risk Management Adaptation Plan - Gap Analysis Technical Report (Shape Urban, 2022)

Shire or Gingin Coastal Hazard Risk Management Adaptation Plan

GAP ASSESSMENT (TECHNICAL REPORT)

May 2023

A report to address the gaps acknowledged
in coastal adaptation planning for
the Shire of Gingin's Coastal Settlements

SHAPE URBAN

ACKNOWLEDGEMENTS

Shape Urban acknowledge the Yued Nyoongar People as traditional custodians of the land on which we have worked for this project. We recognise their cultural heritage, beliefs and relationship to the land, which continue to be important to the Yued Nyoongar People today.

We pay our respects to Elders past and present, and to the land which they have cared for.

This document has been prepared with the support of many people from the Shire of Gingin community. We wish to acknowledge the community for your contributions.

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Shire of Gingin Coastal Hazard Risk Management Adaptation Plan - Technical Report - 2023

A report to address the gaps acknowledged in coastal adaptation planning for the Shire of Gingin's Coastal Settlements

NO	AUTHOR	REVIEWED BY	DATE	PURPOSE
1	A Chhabra	A Kelderman	Various	Stage 1-4 Draft Technical Report for Client
2	A Chhabra	A Kelderman	20/02/23	Draft Technical Report for Client
3	A Kelderman	A Kelderman	28/04/2023	Final for Client

This **CHRMAP GAP ASSESSMENT Technical Report** addresses the gaps in coastal planning for the four coastal townsites of Lancelin, Ledge Point, Seabird, Guilderton.

It:

- Complete a technical assessment of coastal erosion and combines this with the Baird 2020 inundation assessment to identify risks and challenges and develop responses for the **Guilderton** townsite.
- Recommends updates to previous coastal planning for the townsites from Cardno 2019 after combining this study with Baird 2020 to include inundation for the townsites of **Lancelin, Ledge Point** and **Seabird**.
- Is an appendix to a summary CHRMAP document which integrates the Cardno and Baird studies with this Shape Urban 2023 study into a single Shire of Gingin CHRMAP document.

It can be read in conjunction with the Shire of Gingin Coastal Management on the Gingin Coastline Summary 2023, which is an easy-to-read summary of the technical documents with clear implementation actions for the Shire, other decision makers and the local community.

ABBREVIATION LIST

AHD	Australian Height Datum
ARI	Annual Recurrence Interval
AS	Australian Standard
BDA	Benefit Distribution Analysis
CBA	Cost Benefit Analysis
CHRMAP	Coastal Hazard Risk Management Adaptation Plan
CMS	Coastal Management Strategy
CSEP	Community and Stakeholder Engagement Plan
DPLH	Department of Planning, Lands and Heritage
DoT	Department of Transport
FAQs	Frequently Asked Questions
GSC	Geotextile sand container
HSZ	Horizontal Shoreline Datum
IPCC	International Panel on Climate Change
LPS 9	Local Planning Scheme No. 9
MCA	Multi-criteria analysis
MSL	Mean Sea Level
MU	Management Unit
MWL	Mean Water Level
PSC	Project Steering Committee
SLR	Sea Level Rise
SPP 2.6	State Planning Policy 2.6 – State Coastal Planning Policy
TECs	Threatened Ecological Communities
The Shire	Shire of Gingin
WAPC	Western Australian Planning Commission

EXECUTIVE SUMMARY

The Shire of Gingin has approximately 70 kilometres of coastline and four coastal towns coastal towns; Lancelin, Ledge Point, Seabird and Guilderton. The adjacent land, the coastal zone, supports a variety of recreation, conservation, residential and commercial land uses. The coastal zone is a major asset for the Shire, is highly valued by the community and underpins the Shire's identity and lifestyle.

As the coastline changes, our planning system needs to respond to both visible and predicted changes. The Shire's coastal areas are subject to erosion and inundation risks, which already have and will continue to have a significant impact on its communities over time. In response, the Shire has been working to develop risk and impact specific planning to help it guide land use and development decision making for its coastal areas into the future.

A Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) needs to be prepared to guide land use and development decision making in coastal zones under the Western Australian Planning Commission's (WAPC's) State Planning Policy No. 2.6 - State Coastal Planning Policy (SPP 2.6; 2013a).

This **CHRMAP GAP ASSESSMENT Technical Repor**t addresses the gaps in coastal planning for the four coastal townsites.

It assesses coastal erosion and inundation risks and challenges and develops responses for the Guilderton townsite.

It also completes the inundation assessment for Lancelin, Ledge Point and Seabird by combining information from a previous CHRMAP completed by Cardno (2019) and a Coastal Inundation Study completed by Baird (2020), and advises on updates to previous coastal planning for the three townsites previously included in the Cardno study.

This technical report is an appendix to a new CHRMAP document which integrates the Cardno and Baird studies with this 2023 Shape Urban study into a single Shire of Gingin CHRMAP document. It can be read in conjunction with the Shire of Gingin Coastal Managemnt on the Gingin Coastline Summary 2023, which is an easy-to-read summary of the technical documents with clear implementation actions for the Shire, other decision makers and the local community.

Through both technical expert advice and community and stakeholder engagement, this technical report makes recommendations for coastal hazard adapatation options that can be implemented in the Shire for erosion and inundation (Guilderton) and for inundation (Lancelin, Ledge Point and Seabird).

Key observations of this gap analysis are:

Guilderton

Guilderton is likely to experience some impacts over the 100-year timeframe with some public assets at risk currently (in the foreshore park) and some private assets at risk beyond the middle of the century.

There is adequate time to plan for adaptation, whilst undertaking appropriate foreshore management in the short term.

Lancelin

The coastal hazard risk to Lancelin in both the short and long term is the most challenging output of this technical assessment. Large areas of this highly valued coastal community are subject to the effects of coastal inundation. Additionally, it is apparent that groundwater levels are also challenging for the coastal node, with existing evidence of drainage issues.

The two forces combined; coastal inundation and rising groundwater; make many options for coastal adapatation challenging, even if significant funding were available. Additional studies are required into groundwater matters.

The community of Lancelin is well informed and has begun to consider these challenges.

Ledge Point and Seabird

The assessment of inundation at Ledge Point and Seabird suggests that inundation is not a primary concern for these townsites. Notwithstanding, Cardno 2020 has indictaed decisions will need to be made with regard to erosion.

Next Steps

This document will be used to combine the previous studies into a single Shire of Gingin CHRMAP. The 2023 CHRMAP will include recommendation for all four townsites for both erosion and inundation, and provide recommendations for ongoing investigations and monitoring and review.

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SECTION 1. ESTABLISHING THE CONTEXT

1. ESTABLISHING THE CONTEXT

1.1 Introduction

The Shire of Gingin (the Shire) is located in the Wheatbelt central coast sub-region of Western Australia, 84 kilometres north of Perth. There are five townships within the Shire; the inland town of Gingin and the coastal towns of Guilderton, Lancelin, Ledge Point and Seabird. In 2021 there were 5,576 residents, 4,107 dwellings, 618 local businesses, 2,795 local jobs and 2,485 employed residents in the Shire. The largest industries (by employment) were agriculture, iron ore mining and local government administration. In addition to these industries, the Shire's economy is also based around tourism, with coastal areas in particular experiencing a large influx of people during the summer holiday season.

The Shire has approximately 70 kilometres (km) of coastline. The adjacent land, the coastal zone, supports a variety of recreation, conservation, residential and commercial land uses. The coastal zone is a major asset for the Shire, is highly valued by the community and underpins the Shire's identity and lifestyle.

The Intergovernmental Panel on Climate Change IPCC recognises that the mean sea level has been rising globally since the nineteenth century and is predicted to rise at an increasing rate in the future. Rising sea levels and intensifying storm activity will increase the risk of coastal inundation, storm erosion and long-term shoreline recession. As our coastline changes, our planning system needs to respond to both visible and predicted changes.

The Shire's coastal areas are subject to these erosion and inundation risks, which already have and will continue to have a significant impact on its communities over time. In response, the Shire has been working to develop risk and impact specific planning to help it guide land use and development decision making for its coastal areas into the future.

In Western Australia the governing policy for coastal management is the Western Australian Planning Commission's (WAPC's) State Planning Policy No. 2.6 - State Coastal Planning Policy (SPP 2.6; 2013a). SPP 2.6 recommends management authorities develop a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) to guide land use and development decision making in coastal zones. The WAPC has also developed specific CHRMAP guidelines to assist the preparation of CHRMAPs – the Coastal Hazard Risk Management and Adaptation Planning Guidelines (2019).

One of the key objectives of SPP 2.6 is to establish coastal foreshore reserves which include allowances for the protection, conservation and enhancement of coastal values across the state. A risk assessment framework is then applied to identify risks that are intolerable to the community, and other stakeholders such as local governments, indigenous and cultural interests, and private enterprise. Adaptation measures are then developed according to the preferential adaptation hierarchy outlined in SPP 2.6.

A CHRMAP was prepared by Cardno for the Shire in 2019 (the CHRMAP 2019). The CHRMAP 2019 identifies erosion risks and challenges, the vulnerability of assets, and identifies and prioritises risk management responses to those coastal hazards for the **Lancelin, Ledge Point** and **Seabird** townsites. It does not include the Guilderton townsite. The CHRMAP 2019 also does not include inundation risks for any of the studied townsites.

Baird (2020) produced a Coastal Inundation Study (CIS) for the **Lancelin, Ledge Point, Seabird** and **Guilderton** townsites. The CIS identifies potential areas subject to coastal inundation risk at Lancelin, Ledge Point, Seabird and Guilderton, however does not identify or prioritise risk management responses to the inundation hazards for the four townsites.

This **CHRMAP GAP ASSESSMENT Technical Repor**t addresses the gaps in coastal planning for the four coastal townsites.

It assesses coastal erosion and inundation risks and challenges and develops responses for the Guilderton townsite.

It also completes the inundation assessment for Lancelin, Ledge Point and Seabird by combining information from a previous CHRMAP completed by Cardno (2019) and a Coastal Inundation Study completed by Baird (2020), and advises on updates to previous coastal planning for the three townsites previously included in the Cardno study.

This technical report is an appendix to a new CHRMAP document which integrates the Cardno and Baird studies with this 2023 Shape Urban study into a single Shire of Gingin CHRMAP document. It can be read in conjunction with the Shire of Gingin CHRMAP Summary Report 2023, which is an easy-to-read summary of the technical documents with clear implementation actions for the Shire, other decision makers and the local community.

This report study area encompasses sediment sells that are classified into management units (MUs)/ coastal areas for the purpose of defining detail at an appropriate scale for assessment and management.

The MUs for Lancelin, Ledge Point and Seabird are taken from the CHRMAP 2019. These MUs are at Figure 1.

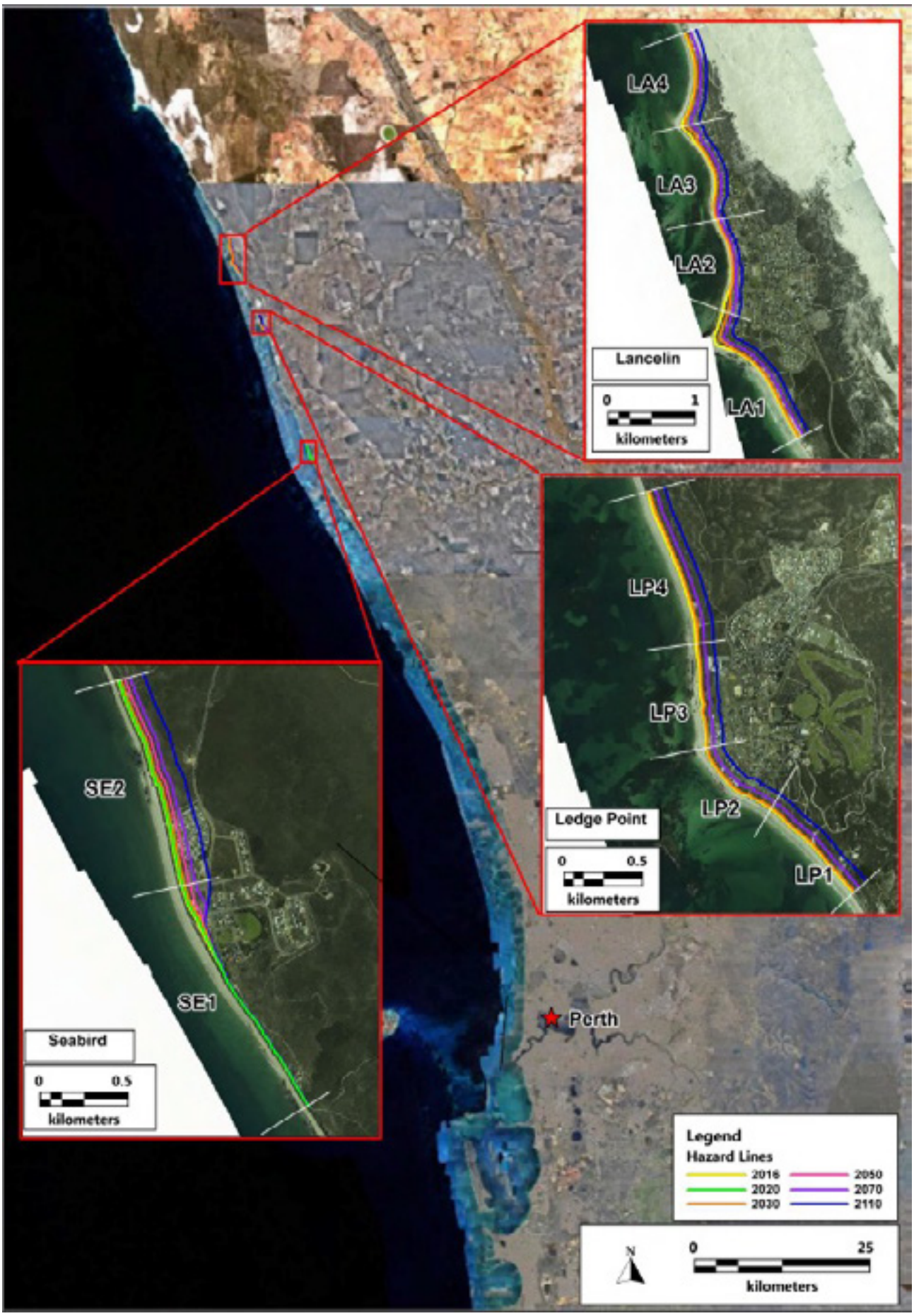


Figure 1: Managemente Units in the CHRMAP 2019 (Cardno, 2019)

The Guilderton study area is comprised of approximately two kilometres of coastline that has been divided into two management unit areas for the purposes of assessment:

- Guilderton Foreshore – the ocean coastline
- Moore River – the river foreshore, used to assess for oceanic hazards and corresponding risk and vulnerability of ocean forces impacting the assets in the area.

The Guilderton MUs are at Figure 2.



Figure 2: Guilderton Management Units

1.1.1 Guilderton Context

Guilderton is the least populous of the four coastal towns. Located at the mouth of the Moore River, it had a population of 172 people with a median age of 59 years in 2016. This made up 3.3% of the total population of 5,217 people in the Shire of Gingin in 2016 (ABS, 2016).

Guilderton functions as a tourist destination, with tourism becoming more prevalent and increasing numbers of metropolitan Perth-based residents becoming property owners of coastal holiday homes. The main economic activity for the town is tourism, with land use adjacent to the river mouth comprising a caravan park, kiosk, restaurant and associated car parking, recreational playground and boat launching facilities.

There are very few vacant lots available in the townsite for development, with potential urban expansion on the northern development front of the Moore River limited by a Crown reserve. On the south side of the Moore River, a large area of land has been zoned Future Development and is anticipated to provide for a significant resident population in the medium to long term. This land was zoned for urban development in the 1990s to provide an urban base for the proposed deep-water ports at Breton Bay or Wilbinga. Although it was eventually decided not to establish ports in those locations, the urban zoned land retained its status and in 2012, the Moore River South Outline Development Plan was finalised. The plan provides for approximately 2,000 dwellings, and a population of approximately 5,000 people.

The Moore River begins beyond the north-eastern boundary of the Shire and flows in a westerly direction across the Dandaragan Plateau towards the Swan Coastal Plain. Approximately 17km from the coast, the river meanders south for 25km and joins Gingin Brook where it turns westwards to enter the ocean at Guilderton. The Moore River gradually widens downstream from Indian Ocean Drive (at the bridge crossing), showing some estuarine characteristics near the Guilderton townsite (anecdotal tidal impact, presence of shallow bed and mobile sand bar etc.). As the mouth is only intermittently open to the coast, the estuarine effects are not felt much upstream.

The Guilderton coast is characterised by a low lying and predominantly sandy foreshore, sensitive coastal dunes, and variable mixed sandy and rocky offshore bathymetry featuring nearshore reefs and islands, seagrass meadows, fishing stocks and rare vegetation communities. The complex offshore bathymetry is a feature of the region that creates a dynamic coastal zone and is often associated with mobile cusps on the shoreline (Searle and Semenuik, 1985).

Dunes typically rise 10 to 20 metres (m) above sea level and can be naturally unvegetated, allowing them to migrate landwards under wind-driven processes. The regional area has previously been identified as sensitive to coastal processes meaning that coastal development in the area is vulnerable to changes in these processes (Eliot et al., 2012). The regional and local coastal processes relevant to Guilderton are described in greater detail in Section 1.5.2.

This document acknowledges the challenges associated with managing risks in a dynamic coastal environment, together with the need to balance environmental, social and economic values to ensure the long-term sustainable use and management of the Shire's unique coastline. The CHRMAP process is designed to be ongoing, with regular updates associated with the emergence and collection of new information. The Shire should continue to engage with the local community and stakeholders to undertake all updates to the final CHRMAP.

1.1.2 Coastal Planning Framework

SPP 2.6 recommends management authorities develop a CHRMAP for land use or development that is potentially vulnerable to coastal hazards. Specific guidelines have been developed to assist in this process (WAPC, 2019).

The objectives of SPP 2.6 are to:

- Ensure that 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.

One of the key objectives of SPP 2.6 is to establish coastal foreshore reserves which include allowances for the protection, conservation and enhancement of coastal values across the state. A risk assessment framework is then applied to identify risks that are intolerable to the community, and other stakeholders such as local governments, indigenous and cultural interests, and private enterprise. Adaptation measures are then developed according to the preferential adaptation hierarchy outlined in SPP 2.6.

1.2 Purpose

The purpose of this CHRMAP technical report is to fill in the gaps between the existing studies and what would constitute a full and complete CHRMAP under the SPP 2.6 guiding documents. This report will:

1. Establish the coastal context via erosion mmodelling and risk assessment and identification of assets in Guilderton;
2. Combine the inputs from Baird 2020 for Guilderton to complete all technical elements of a typical CHRMAP assessment for Guilderton;
3. Combine the inputs from Baird 2020 with the erosion assessment of Cardno 2019 and review the CHRMAP 2019 recommendations to complete a combined risk assessment;
4. Identify / confirm trigger points and timeframes for management units to establish when adaptation is required;
5. Reconfirm level of risk on assets (in the context of their service, function and assigned values by the community and stakeholders); and
6. Identify / confirm management and adaptation actions.

It involved stakeholders and the community in the planning and decision-making process and ensured an understanding of the implications of possible treatment options including trade-offs, costs and possible negative aspects of management actions.

This will address the gaps in coastal planning for the Shire's coastal communities and provide a framework of options (management actions) so the Shire can make strategic, well-informed and proactive decisions along it's entire coastline.

Relevant data from the previous assessments has been included in this report.

This technical report informs the **Shire of Gingin CHRMAP 2023 (CHRMAP 2023)**, which is a comprehensive coastal hazard risk management adaptation plan for Lancelin, Ledge Point and Seabird and Guilderton.

CHRMAP 2023 will be supported by a Coastal Management Strategy (CMS). The CMS will build on the outcomes and recommendations of the CHRMAP and previous coastal studies. It will detail baseline information about the coastal zone, including flora and fauna and the Shire's owned or managed assets, relevant to planning and management of the coastline.

The management responses and implementation pathways to adapt to the changing future oceanic and coastal conditions outlined in these documents aim to ensure the Shire, community and stakeholders are well placed to deal with impacts to the coastal zone at established and defined triggers. The CHRMAP and the CMS will form the blueprint for the future use of the Shire's coastal areas.

1.3 Objectives

SPP 2.6 informs and guides decision making by the WAPC, and guides local governments, state government agencies and other decision makers on those aspects of state planning policy concerning the coastal zone that should be taken into account in planning decision-making.

SPP 2.6 recommends coastal hazard risk management and adaptation planning be undertaken by responsible management authorities or proponents in an area of risk of being affected by coastal hazards over the planning timeframe. It provides for implementation through state planning policy, regional strategies, local planning strategies and regional and local planning schemes. Implementation will also occur through the day-to-day decision-making on zoning, structure plans, subdivision, strata subdivision and development applications, and actions of decision-makers in carrying out their responsibilities.

The aim of CHRMAP 2023 is to provide a decision-making framework to allow the Shire and other key stakeholders to:

1. Ensure land in the coastal area is continuously provided for coastal foreshore management, public access, recreation and conservation;
2. Ensure public safety and reduce risks associated with coastal erosion and inundation;
3. Avoid inappropriate land use and development of land at risk from coastal erosion and inundation; and
4. Ensure land use and development does not accelerate coastal erosion or inundation risks or have a detrimental impact on the functions of public reserves.

The specific objectives of the CHRMAP are to:

- Improve the understanding of coastal features, processes and hazards in the study area;
- Gain an understanding of the vulnerability of the coastal zone;
- Identify significant vulnerability trigger points and respective timeframes for the study area management units (MUs) to establish when short and long-term risk management and adaptation action is required;
- Identify assets (natural and man-made) and the services and functions they provide in the coastal zone;
- Identify the value of the assets that are vulnerable to adverse impacts from coastal hazards;
- Determine the likelihood and consequence of the adverse impacts of coastal hazards on the assets and assign a level of risk, identify possible management and adaptation measures (‘actions’) and how these can be incorporated into decision making;
- Engage stakeholders and the community in the planning and decision-making process; and
- Ensure that stakeholders understand the implications of possible treatment options including trade-offs, costs and possible negative aspects.

These objectives align with the Shire's Local Planning Strategy, which places importance on both planning for long-term predicted shoreline movement and other impacts of climate variability, such as storm surge. The CHRMAP objectives address the Shire's identification of coastal erosion and management of coastal dunes as key issues.

CHRMAP 2023 for the Shire of Gingin will also address the LPS objective for a strategic approach to manage coastal land use, future development and the impacts of coastal processes, including dune movement, blow outs and erosion. It does this by addressing the following LPS objective for the Shire of Gingin:

"Recognise and protect the attractive and fragile coastal environment along the Gingin coast and promote a comprehensive and strategic approach to coastal land use and future development."

A critical part of this project has been more in-depth engagement with the local community and stakeholders to inform them about the extent of potential coastal hazards and the adaptation strategies available to respond to those hazards. That process has confirmed community values along the coastline, allowed better communication of state and local government responsibilities and capacity to respond to potential coastal hazards, and enabled the community to bring their local knowledge, expertise and lived experience to the process. These local community and stakeholder participants have provided key input to selection of appropriate adaptation strategies to respond to the risks.

1.4 Scope

The Guilderton CHRMAP assessment is built around the following steps, as shown in the risk management process flow chart adapted from the CHRMAP Guidelines (WAPC, 2019) at Figure 3.

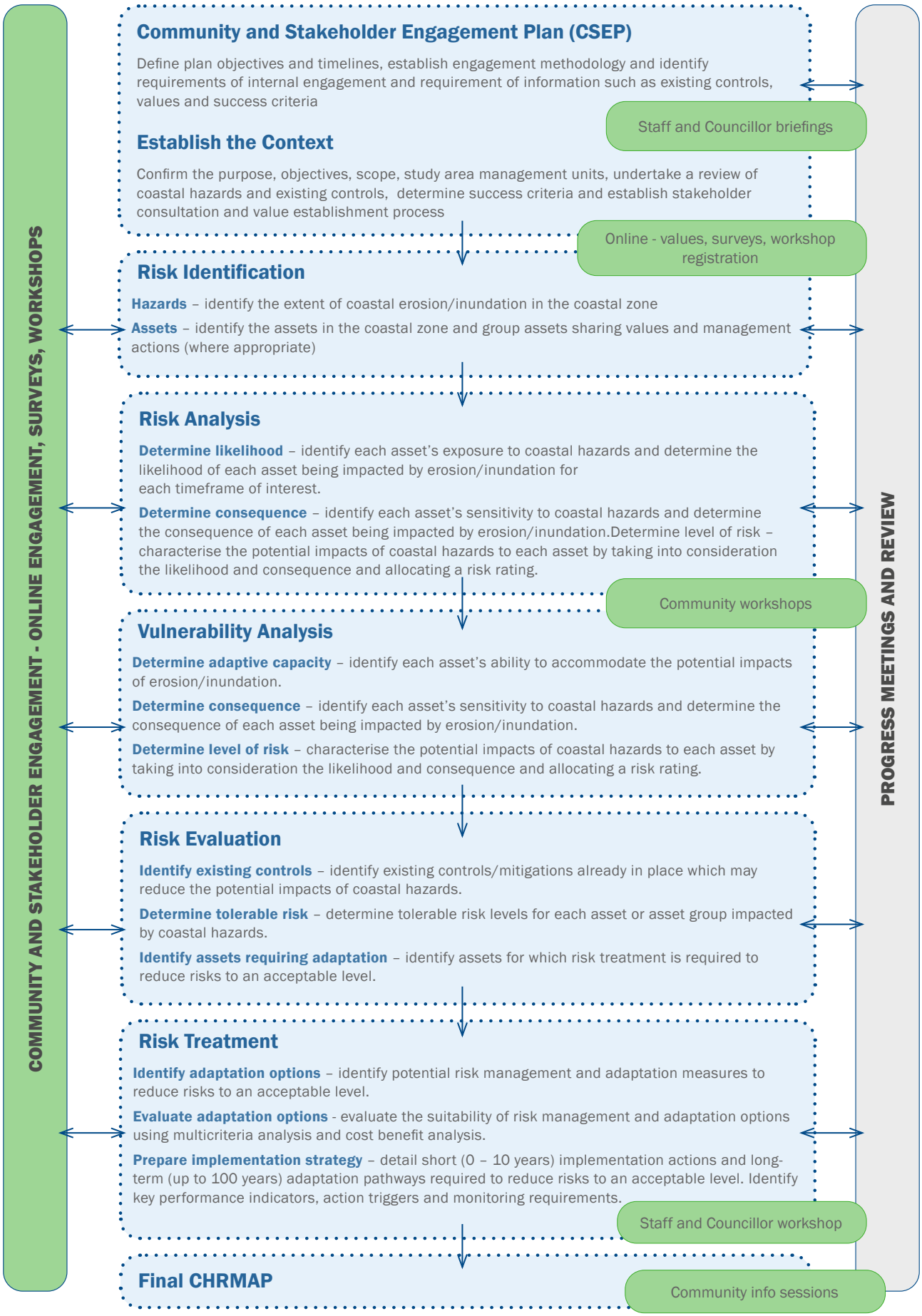


Figure 3: Shire of Gingin CHRMAP process flow chart, adapted from the CHRMAP Guidelines

1.5 Study Area

This report focuses on the Guilderton coastline and active coastal zone, following an erosion risk assessment and identification of assets in Guilderton, and combining inputs from Baird, 2020.

At Guilderton, a sandbar closes off the river mouth, although it is open intermittently (see Figure 2). The sandy beach is backed by a vegetated coastal reserve, a bitumen coastal access road and then residential development.

Information from the Shire indicated that two significant flood events had occurred within the estuary within the last 40 years and could last two to three weeks. During a riverine flood, outflows break through the sandbar. Anecdotal evidence suggests that the river outlet has moved both north and south of the estuary periodically, resulting in erosion of the foreshore dunes adjacent to the river mouth and an increase in beach vulnerability. It has also been indicated that since the construction of the groyne in North Guilderton in 1967 (Picture 1), the river outlet has not moved north, only flowing out south of the estuary. Significant accretion of the beach has been observed north of the river, while erosion has been observed to the south in conjunction with strong river outflows.

On 25th February 2021, a site visit was undertaken to inspect the condition of the beach and river foreshore at Guilderton. The beach was in a stable condition with a wide dry sandy beach and healthy foreshore vegetation. There were some indications of minor erosion at the toe of the primary dune in the past year - a small scarp was present in places (see Picture 2). Some outcrops of limestone were present on the beach and in the foreshore reserve, but they did not look consistent in size, height and occurrence along the study area (see Picture 3). The river foreshore was also in a stable condition with some limestone rock outcropping and protection by a limestone revetment wall and boat launching infrastructure (see Picture 6 and Picture 7). Key observations and images are presented in the Table 1.

TABLE 1: GUILDERTON STUDY AREA CONDITIONS, SITE VISIT 25 FEBRUARY 2021

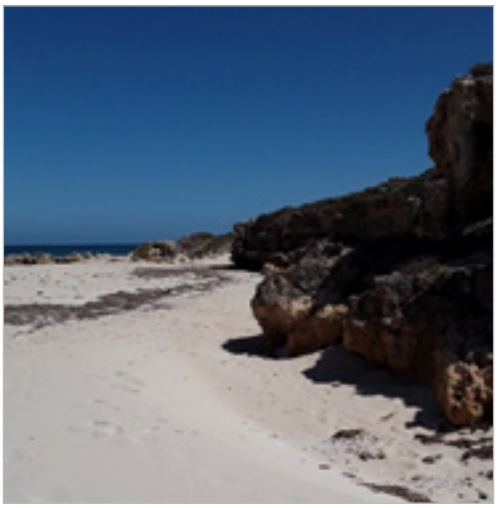
LOCATION	PICTURE	COMMENTS
Guilderton Northern Groyne	 Picture 1: Low crest groyne with sand and seagrass accumulation	Low crest groyne with random positioning of rocks. Poor condition, lack of maintenance.
Ocean beach seaward of town	 Picture 2: Ocean beach seaward of townsite	The beach was in a stable condition with a wide dry sandy beach and healthy foreshore vegetation. There were some indications of minor erosion at the toe of the primary dune within the past year - small scarp present in places
Limestone rock outcrop on beach between town and Guilderton beach groyne	 Picture 3: Limestone rock outcrops	Some outcrops of limestone were present on beach and in foreshore reserve, but they did not look consistent in size, height and occurrence along the study area.

Table 1: Guilderton study area conditions, site visit 25 February 2021 (Cont'd)

LOCATION	PICTURE	COMMENTS
Moore River shoreline along the walkway connecting to the car park	 Picture 4: Sandy riverbank with foreshore vegetation	Sandy riverbank covered by foreshore vegetation. Shallow foreshore with no sign of erosion scrap.
Limestone revetment along Moore River shoreline adjacent to car park	 Picture 5: River foreshore with limestone rock outcrop, limestone block wall and rubble limestone revetment	The river foreshore is in a stable condition with some limestone rock outcropping and protection by a limestone revetment wall and boat launching infrastructure. Combination of vertical limestone block wall and rubble limestone revetment.

Table 1: Guilderton study area conditions, site visit 25 February 2021 (Cont'd)

LOCATION	PICTURE	COMMENTS
Moore River floating finger jetty and universal access ramp	 Picture 6: Moore River coastal infrastructure and limestone seawall	Coastal infrastructures and limestone seawall
Moore River boat launching ramps and floating finger jetty.	 Picture 7: Boat launching ramps and finger jetty	
Sandbar	 Picture 8: Sandbar between Moore River and ocean	A narrow sandbar separating the Moore River from the ocean Loose sand which can be breached during severe river flood/storm events.

Table 1: Guilderton study area conditions, site visit 25 February 2021 (Cont'd)

LOCATION	PICTURE	COMMENTS
Moore Riverbank	 Picture 9: Riverbank slope with vegetation	Steady riverbank with heathy coverage of vegetation. Steep slope indicating presence of rock outcrops/ stiff soil. No sign of erosion scrap.
Overview of Holiday Park Foreshore	 Picture 10: Holiday Park foreshore	Foreshore of Holiday Park are protected by rock seawall. Area close to the lookout has a shallow foreshore which is not protected. The southern bank consists of naturally formed hills with presence of rock outcrops (not accessible during the site visit).

1.5.1 Previous Assessments

A literature review was undertaken to compile relevant information on coastal processes and hazards and past and present management activities for the Shire coast. Additional data sets, and information that was utilised in compiling the document has been referenced throughout. The following documents were reviewed in preparation of this CHRMAP:

1.5.1.1 Coastal Hazard Risk Management and Adaptation Plan – Shire of Gingin (Cardno, 2019)

The Shire of Gingin engaged Cardno to consider the threats of climate change and sea level rise to the coastal settlements of Seabird, Ledge Point and Lancelin through the preparation of a CHRMAP. The CHRMAP provides a long-term view of the potential future coastal erosion impacts to the townships of Seabird, Ledge Point and Lancelin and highlights possible strategies to adapt to the changing future oceanic and coastal conditions.

Development of the Gingin CHRMAP followed the requirements of SPP 2.6 and supporting guideline documents. The coastal zones of each township were divided into management units (two at Seabird, four at Ledge Point and four at Lancelin) with similar asset types and exposure to coastal hazards. The erosion hazard assessment utilised previous work undertaken by MP Rogers (MRA, 2016a and 2016b) for the three townships which determined erosion allowances for the different management units for the then present day (2016) and several future timeframes - 2030, 2070 and 2110.

The erosion hazard assessment was combined with a values and assets assessment to determine the risk to various assets and parcels of land through the 100-year planning horizon. This information was then considered along with the adaptive capacity of the assets/land to complete a vulnerability assessment for the eight management units. The risk and vulnerability assessments were applied to each management unit and results highlighted the most vulnerable management unit within each township, for which more detailed assessment of adaptation options were investigated. A range of options for addressing coastal erosion over the next century have been outlined.

The CHRMAP did not include consideration of inundation hazards and did not include investigation for the township of Guilderton.

1.5.1.2 Gingin Coastal Inundation Study – Lancelin, Ledge Point, Seabird and Guilderton (Baird, 2020)

The Shire engaged Baird Australia (Baird) to undertake the CIS which examines extreme water levels in coastal areas during severe storms and tsunami events. The study has determined design water levels that will be used to inform coastal planning in the Shire at the key coastal townsites of Lancelin, Ledge Point, Seabird and Guilderton, consistent with the guidelines of SPP 2.6. Present day design water levels across the four townships were found to range between:

- 1.1 - 1.3m AHD for the 20-year Average Recurrence Interval (ARI) event
- 1.2 - 1.5m AHD for the 100-year ARI event
- 1.7 - 2.0m AHD for the 500-year ARI event

These values were combined with sea level rise (SLR) projections to present water levels and associated spatial inundation mapping for a range of future timeframes – 2020, 2040, 2070 and 2120.

An assessment of the hazard associated with tsunami within the study area was also completed by Baird using Geoscience Australia's 2018 Australian Probabilistic Tsunami Hazard Assessment. A 500year ARI tsunami event was modelled for each township to produce peak water level determinations for a range of future timeframes:

- 2020 (1.9 - 2.2m AHD)
- 2040 (2.0 - 2.3m AHD)
- 2070 (2.3 - 2.6m AHD)
- 2120 (2.8 - 3.1m AHD)

1.5.2 Coastal Processes and Hazards – Guilderton focus

The Shire's coast is characterised by variable mixed sandy and rocky offshore bathymetry and sand dunes approximately parallel to the coast. Offshore reefs rise to between 10-5m depth several kilometres offshore with intervening sandy depressions. Dunes reach heights of ~40m but are more commonly 10-20m high and are often present as naturally unvegetated dune "blowouts" migrating landwards, which demonstrates the importance of wind-driven processes in the area. A feature of the region is the interruption of sandy beaches by occasional rock outcrops and fringing reef platforms, and the presence of several nearshore islands, often associated with accretionary cusps onshore (Searle_and_Semenuik, 1985).

The Shire coast experiences a Mediterranean climate with mild wet winters and hot, dry summers. The region is dominated in summer by eastward travelling high pressure systems which cross the coast every three (3) to 10 days. During winter, the impact of mid-latitude low-pressure systems increases, through fronts or more direct synoptic winds systems. The influence of tropical systems is rare, although it may be significant, as amply illustrated by the impact of TC Alby in April 1978 (Eliot_et_al., 2012)

1.5.2.1 Water Levels

Astronomical Tides

Water levels along the Shire coast are dominated by the astronomical tide and are diurnal – meaning that the region experiences one high tide and one low tide per day. The region is characterised by a micro-tidal climate, with a maximal range of ~1m. The tidal planes from Two Rocks (to the south) and Jurien Bay (to the north) are presented in Table 2.

Table 2: Tidal Planes at Two Rocks and Jurien Bay

TIDAL PLANE	TWO ROCKS (M AHD)	JURIEN BAY (M AHD)
Highest Astronomical Tide (HAT)	0.52	0.53
Mean Higher High Water (MHHW)	0.27	0.26
Mean Lower Low Water (MLHW)	0.17	0.16
Mean Sea Level (MSL)	-0.07	-0.08
Mean Higher Low Water (MHLW)	-0.31	-0.29
Mean Lower Low Water (MLLW)	-0.41	-0.42
Lowest Astronomical Tide (LAT)	-0.63	-0.56

Storm Surge

Variations in water level are caused not only by the astronomical tides, but also by phenomena such as wind setup, wave setup, atmospheric pressure, and oceanographic variations. Wind blowing over the surface of the water causes water to “pile up” against the coast towards which the wind is blowing (wind setup). Wave dissipation and breaking also causes water to “pile up” against the coast (wave setup). Atmospheric pressure leads to local changes in sea level, with high pressure lowering the sea level and low pressure increasing the sea level, a process referred to as the inverse barometric effect.

Along the Western Australian coastline, it has long been recognised that ocean climate variability can have a substantial influence on seasonal and interannual variability in coastal sea levels which shows some correlations with the El Nino Southern Oscillation (ENSO) cycle (Pearce & Feng, 2013). Since the 1990s, the Pacific Decadal Oscillation (PDO), with its multidecadal time scale of 20–30 years, has also swung to a negative phase sustaining positive heat content and more frequent cyclonic winds off the WA coast. These large-scale ocean climate drivers are thought to have led to stronger La Nina over the past two decades. These oceanographic processes led to approximately 0.3m water level increase during the 2011 La Nina event which is not related to either tide or local winds. Impacts from these oceanographic processes may be enhanced in the future due to the increased risk of extreme La Nina events under a warmer climate.

There are numerous other oceanic processes that can cause local variations in sea level at the coast. All these mechanisms combine, resulting in observed water level deviations from astronomical tides. They are often grouped under the term “storm surge” since their combined effects are greatest during a storm event. The study area’s small tidal range means that non-tidal drivers of sea level change (storm surge) are much more important drivers of coastal processes than at locations with larger tidal ranges.

In the Midwest WA region, storm surges arise in relation to strong winter storms moving out of the Southern Ocean or tropical cyclones travelling south into the area. The higher water levels associated with these events are significant because they allow high-energy waves from the same storms to propagate into the foredunes and erode them away.

Extreme Water Levels

Extreme water levels are reviewed and presented in Table 3. This includes peak steady water level reported by BMT Oceanica (BMT, September 2015) at Wedge & Grey (north of Lancelin), extreme water levels reported by MPRA (MPRA, 2018) at Jurien Bay and by Baird (BAIRD, July 2020) at Gingin. During extratropical cyclone Mangga in May 2020, Jurien Bay recorded a water level of 1.18m above Australian Height Datum (AHD).

DoE (DoE, 2002) has suggested the water level at lower Moore River will reach approximately 2.0m AHD before the sandbar breaks.

Table 3: Extreme water levels in the vicinity of Guilderton

ARI (YEAR)	PEAK STEADY WATER LEVEL (M AHD) AT WEDGE & GREY	EXTREME WATER LEVEL (M AHD) AT JURIEN BAY	LANCELIN (M AHD)	LEDGE POINT (M AHD)	SEABIRD (M AHD)	GUILDERTON (M AHD)	JURIEN BAY WATER LEVEL RECORD (M AHD, DOT TIDAL GAUGE)
HAT		0.53					
1		0.72					
10		0.88					
20			1.3	1.2	1.3	1.3	
100	+1.2	0.92	1.5	1.3	1.4	1.4	
500	+1.4	0.95	2.0	1.9	1.7	1.8	
May 2020							1.18 (TC Mangga)

1.5.2.2 Wind Climate

The Shire coast experiences a synoptic climate mainly influenced by typical summer anticyclonic high-pressure systems which are associated with daily seabreezes – easterly winds in the morning and westerly winds in the afternoon. Winter storms bring wind regimes variable in direction and intensity. The wind climate in the study area is characterised as follows (see Figure 4 for wind roses at Guilderton):

- Summer is usually very calm while occasionally interrupted by periodic low-pressure ex-tropical cyclones from the north. Typical summer wind comprises of a moderate to afternoon sea breeze with wind blowing from the south-south-west. Wind generated by dissipating tropical cyclones in summer can have extremely dramatic but noticeably short term affects.
- Winter climate is characterised by mild weather and winds interspersed by winter storms. Winter wind is variable due to the presence of winter storms from various directions. Strong winds are predominantly from the west/north.

- Diurnal sea breeze is one of the typical meteorological features. It is generated by thermal gradients between land and sea as land absorbs and releases heat a lot quicker than the ocean. In Western Australia, the sea breeze is among the strongest worldwide. Eliot et al. (2012) analysed wind data from the four long-term wind observation stations near to Guilderton - Rottnest Island, Lancelin, Jurien Bay and Geraldton. Across all stations the dominant wind directions are NE in the morning and S to SSW in the afternoon, the latter indicating the significance of sea breezes in the region.
- Although uncommon, the Shire coast may occasionally experience tropical cyclones (e.g., Mangga, Alby) from the Indian Ocean. These strong storm events are typically stronger than winter storms and bring strong wind gusts and heavy rainfalls along the track of the cyclone and often result in flooding from rainfall, coastal inundation, and major erosion hazards.

1.5.2.3 Wave Climate

The wave climate along the Shire coast is dominated by deep-water waves generated by large-scale weather systems over the Indian Ocean. Seasonal variability in the wave climate is driven by the following mechanisms:

- Continuous west to southwest offshore swells from the southern Indian Ocean.
- Seas generated by the local sea breeze pattern with short periods (e.g., <8 seconds (s)) from the west to southwest predominantly from October to April.
- Seas generated by winter storms from various directions.
- Infrequent tropical/extratropical cyclones (e.g., Alby in 1978 and Bianca in 2011)

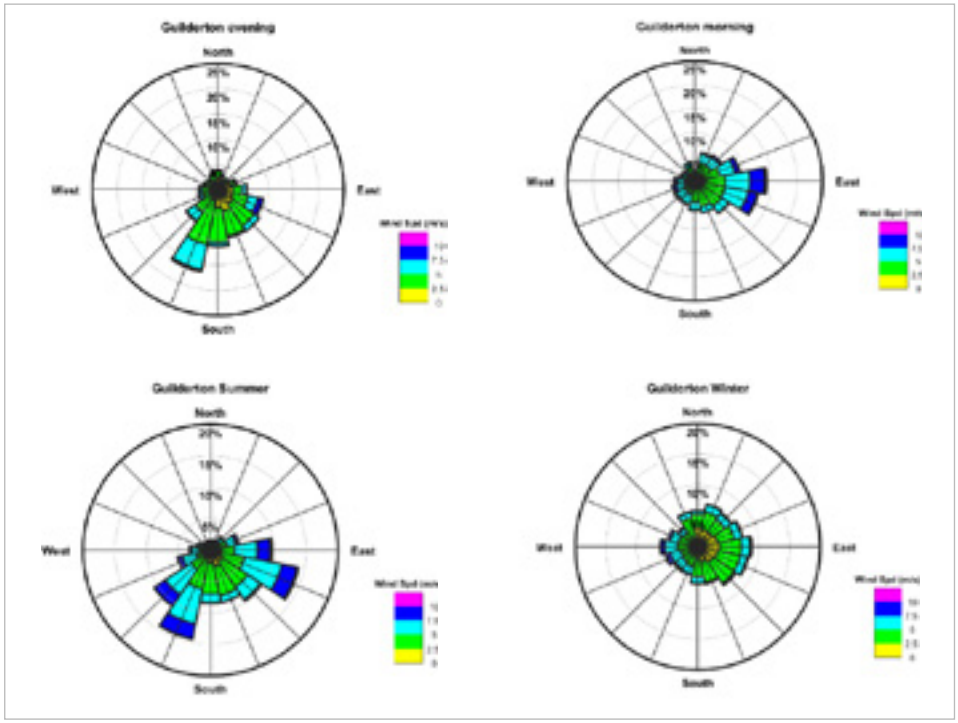


Figure 4: Wind Rose at Gingin BoM Station (station num: 009178)

Reef ridges play a key role to diffuse the wave energy approaching the shoreline. This has some notable effects on the nearshore wave climate, alongshore variation of waves and coastal processes. Attenuation of wave heights has been observed at all sites of Gingin coast as shown in Figure 5. As per the measurement record, the nearshore wave at Guilderton (at ~10m depth) has a typical height of one to two metres and a typical wave period ranging from 12s to 16s for swell waves, and 2s-8s for wind seas. Wave height reduces further once waves enter the surf zone.



Figure 5: Wave Data Recorded by Wave Buoy at Rottnest Island and AWACs at Ledge Point, Seabird and Guilderton

1.5.2.4 Coastal Landforms and Geomorphology

The coast at Guilderton alternates between sections of intertidal rocky reef and sandy beaches free of rock. Waves break across the rocks or surge up the beach face. Vegetated dunes from 10 to 40m high back the beach, with active dune blowouts also present. The most significant coastal feature is the Moore River mouth and the intermittent sandbar that crosses it. A rubble-mound rock groyne is present approximately 1.3km north of the river mouth. Two lines of offshore reefs shelter the local beach to incoming waves. The low waves produce a steep beach, with a narrow continuous bar, which is cut by rips during periods of larger waves (Beachsafe, 2020).

1.5.2.5 Sediment Cells and Beach Formation

A hierarchy of sediment cells is used to assist coastal planning, management, engineering, science, and governance along the coast. Sediment cells are spatially discrete areas of the coast within which marine and terrestrial landforms are likely to be connected through processes of sediment exchange, often described using sediment budgets. They include areas of sediment supply (sources), sediment loss (sinks), and the sediment transport processes linking them (pathways).

Sediment transport pathways include both alongshore and cross-shore processes, and therefore cells are best represented in two-dimensions. They are natural management units with a physical basis and commonly cross jurisdictional boundaries (Stul et al., 2014). Figure 6 depicts the relevant sediment cells for Guilderton. Guilderton is located at the boundary of primary cell R06I and R07A. Moore River separates the two cells, and there is a broad area of sediment transport convergence likely influenced by the (submerged) Moore River paleochannel (Stul et al. 2014).

Presence of submerged rock outcrops and discontinuities is also observable at the foreshore.

Sediment transport along the Shire coast is summarised by:

- Prevailing southerly/south-westerly sea breezes and waves driving sediment northwards in the wave-breaking zone and nearshore areas.
- Long-term patterns are interrupted by storm events from the northwest which can temporarily reverse sediment transport – moving sand from north to south.
- Seasonal changes in beach width due to changes in seasonal wave climate – more large energetic waves in winter causing erosion and narrowing of beaches.
- Intensive erosion from very severe storms such as Cyclone Alby in 1978. These exceptionally large events may cause stepwise changes as opposed to seasonal changes generated by typical winter storms.
- A lack of detailed datasets and quantitative analysis – the information above is largely based on metocean weather information and shoreline movement analysis as opposed to local beach 2D or 3D beach profile changes in formation.

1.5.2.6 Coastal Classification

Following the site visit in February 2021, review of available aerial photos and historical reports, the Guilderton coast can be classified as a Sandy Coast in accordance with SPP 2.6 (WAPC, 2013a). Although some limestone rock is present in the area it is not dominant. Prevalent rocky outcrops were observed near the groyne structure, but their continuity could not readily be determined from a site visit alone. It is possible that these structures are not continuous and will be outflanked erosion as sea levels rise.

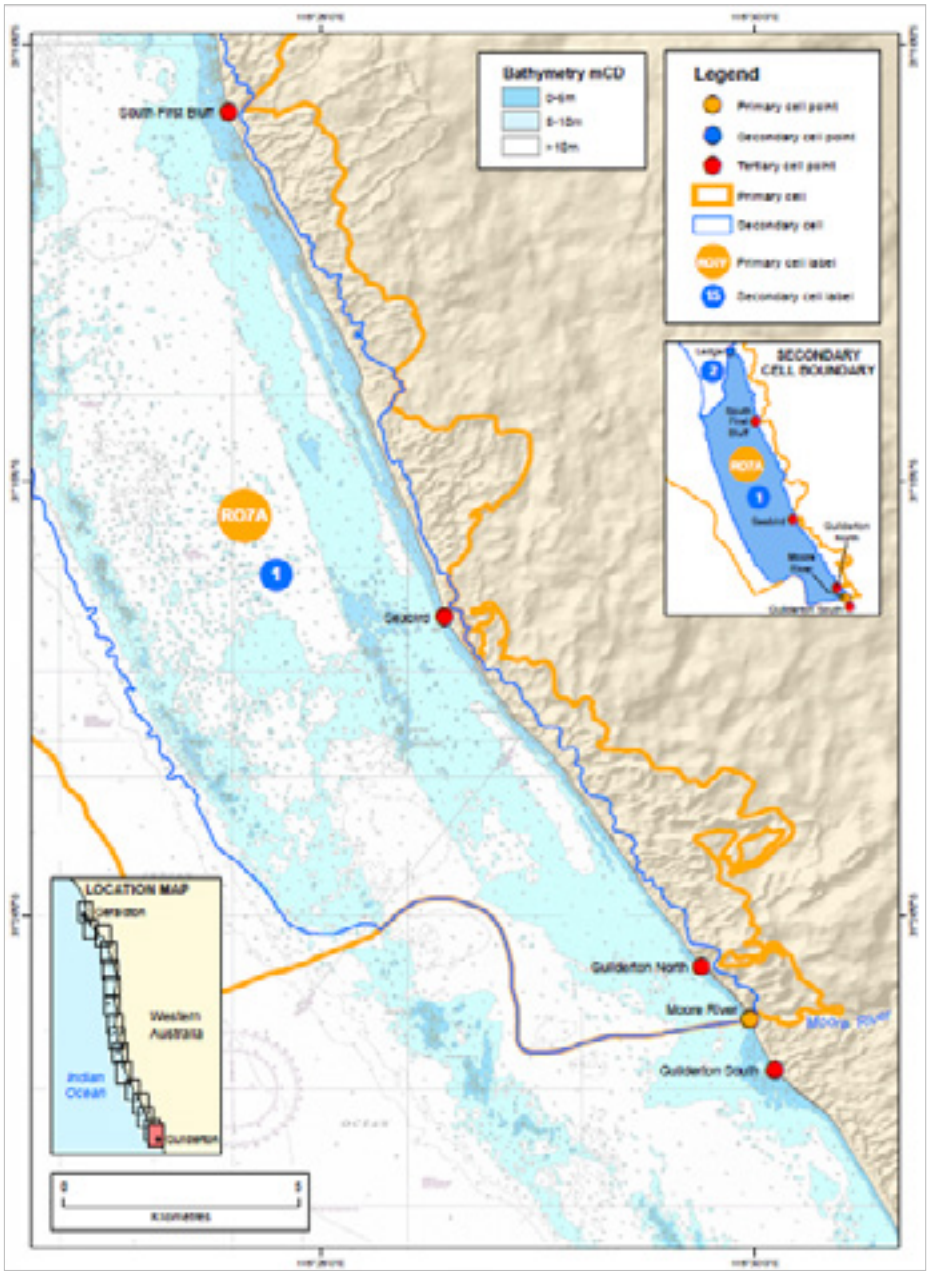


Figure 6: Sediment cells of the Shire coast (Stul et al 2014)

1.6 Community and Stakeholder Engagement

It is imperative to complete coastal hazard planning alongside the community affected by the decision-making process. The engagement process for this CHRMAP provides multiple opportunities for the community to be involved.

The overall objective of the CHRMAP engagement process is to facilitate an understanding of coastal challenges, hazards and risks, what the appropriate adaptation pathways to respond to the risks are, and what the implications and trade-offs of these adaptation pathways look like and mean for the community.

The engagement undertaken for the CHRMAP 2019 (Cardno, 2019) focused on capturing the coastal values of the community, informing the public about coastal hazards and the CHRMAP process, and gauging attitudes towards various adaptation options.

A comprehensive engagement strategy was established for this project to re-engage the community on coastal challenges, hazards and risks, establish community values for Guilderton and confirm or update values for the other three coastal towns, present the updated adaptation pathways to respond to risks and what the implications and trade-offs of these pathways look like and mean for the community, and get community feedback on the pathways.

Specific engagement objectives were to:

- Inform the community about the extent of potential coastal hazards and the adaptation strategies available to respond to those hazards.
- Understand community values along the coastline.
- Explain State and local governments' responsibilities and capacity to respond to potential coastal hazards.
- Invite the community to bring their local knowledge, expertise and lived experience to the process and give them adequate opportunity to contribute in a way that suited their needs and circumstances.
- Ensure that stakeholder advice and recommendations were incorporated into the decisions to the maximum extent possible.
- Undertake fair, equitable, transparent and honest engagement.
- Develop positive relationships between the Shire and the community.
- Gain an understanding of the community's preferred methods of continued engagement with the Shire.

In accordance with the CHRMAP Guidelines, a community and stakeholder engagement plan was prepared to set out engagement objectives, key stakeholders and the program of engagement activities.

The engagement methods were designed to provide the community and stakeholders with opportunities to 'ground truth' and confirm values provided in previous stages of CHRMAP development, investigate qualitative criteria used in the multi-criteria analysis process, and to examine trade-offs of management options. In addition to these principles, the approach to stakeholder engagement for the project includes principles based on the recognised benefits of community engagement.

These additional principles are:

- Public participation promotes local agents for implementation, bestowing decision-making power to communities and enabling local support for delivery.
- Public participation develops a shared agenda and alignment to shared tasks and activities.

Shire staff and Councillors and the project steering committee (PSC) were also identified as important stakeholders. Workshops and meetings were held through the project with this stakeholder group.

1.6.1 Engagement Phases

Information about the process was made available throughout the process, with specific community and stakeholder activities undertaken in three CHRMAP project phases as outlined below.

1. **CHRMAP Stage 2** – Risk Identification: launch of project, community values re-establishment, introduction of adaptation strategies and CHRMAP methodology to assess adaptation options

   Information posters and postcards, a Shire website article and social media (Facebook) were used to launch the project, Social Pinpoint project website and advertise the first set of workshops. Workshops were held in Guilderton on 31 July 2021 and in Lancelin on 1 August 2022. On the project website at https://getinvolved.mysocialpinpoint.com.au/shire-of-gingin-coastal-planning, community members could read about the project, review erosion and inundation hazard mapping, read the Frequently Asked Questions (FAQs), undertake an interactive mapping exercise, answer a community values survey and register to attend the workshops and to be kept informed.

   This engagement period was run between June and September 2021. The key purpose of this phase of engagement was to understand how the community use and value the coast, and to initiate conversation about proposed management options for the coast and gain initial feedback on these options from the community.

2. **CHRMAP Stage 5** – Risk Treatment: discuss re-established coastal values and technical findings, review criteria used to assess management options, and test findings

   After technical work by the project team involving the assessment of erosion and inundation risks for Guilderton, a review of the impact of inundation assessments in the CIS on the erosion pathways developed in the CHRMAP 2019, and the confirmation or update of adaptation strategies for the four towns, the second round of stakeholder engagement was commenced. This involved targeted and deliberate engagement with affected landowners and the community about management options that will affect them. Engagement comprised an updated interactive Social Pinpoint project page, direct meetings with affected landowners in the four towns, and a Community Panel process, and was completed in October 2022.

3. **Draft CHRMAP**: obtain feedback from the community and stakeholders on the draft CHRMAP

   Once the Project Steering Committee (PSC) and the Shire Council have endorsed the draft CHRMAP for advertising, the CHRMAP advertising will commence. The project website will be updated, communications will be developed including updated FAQs, and two information sessions will be held in Lancelin and Guilderton.

1.6.2 Values

Stakeholders had an opportunity to share their coastal values for Guilderton in Stage 2 and Stage 5 of the project via an online platform project page mapping exercise, values survey and through exercises / activities at workshops. Stakeholders could also contact the Shire project manager and the consultant project team directly.

The surveys for community members and local businesses and online map where people could pin values to specific locations along the Guilderton coastline on the Social Pinpoint project page helped guide the Stage 2 community values workshops. The Social Pinpoint project page map is at Figure 7.

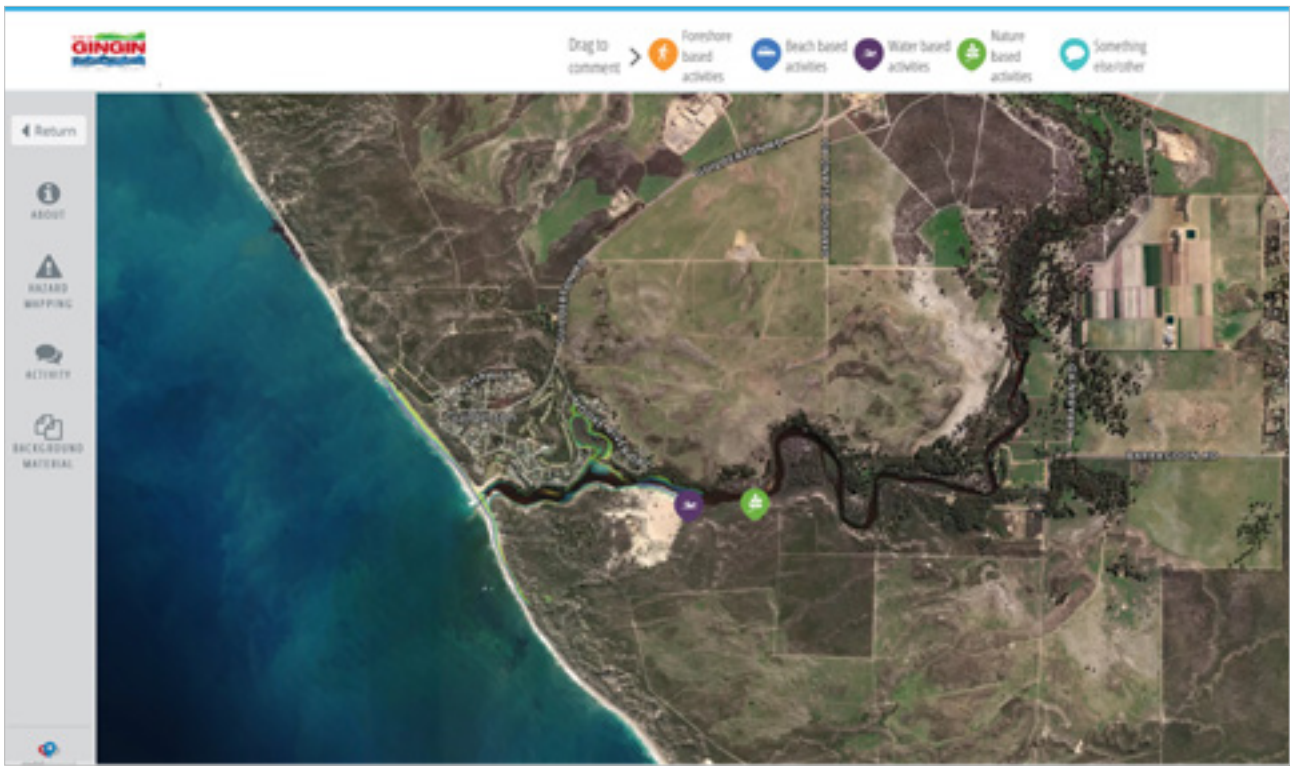


Figure 7: Social Pinpoint Interactive Mapping Engagement Tool – Guilderton location

The survey questions and mapping tool exercise were aligned with the CHRMAP Guidelines (WAPC, 2019) and the values it articulates for consideration through the stage of the CHRMAP and specifically to be incorporated into the MCA.

These values are:

- **Social** – those that support quality of life, health and wellbeing of a community, providing social benefits and services. It includes things like beaches and foreshore reserves, car parking and formal access paths.
- **Environmental** – those that support coastal habitats for their geological, biodiversity and ecosystem integrity. Examples include ecosystem services provided by dune habitats for local flora and fauna, trapping of and storing sand, and providing a source of sand to replenish beaches following erosion events.

- **Infrastructure** – values of the assets that support economic, social and environmental values including physical assets for transport, services and the community. Examples include buildings, road and rail, water and sewer and electricity services, and Surf Life Saving Clubs and foreshore infrastructure including footpaths, dune fencing and ablution facilities.
- **Economic** – those that support industry, tourism, employment or relate to matters that have an economic implication.
- On the Social Pinpoint interactive map, the community identified that Moore River is the perfect place for children and older adults to swim in safety, but that over the years more and more power boats have been ignoring the yellow marker buoys and cutting through children playing to pull up on the limited shoreline.

Stakeholders also identified that it was a beautiful area especially for younger children to enjoy the easy walks. They also noted that it was well used, with car parking at a premium after mid-morning. There was a desire to see paths be regularly maintained and more rubbish bins.

The CHRMAP survey related to all four townsites along the Shire coastline (Lancelin, Ledge Point, Seabird and Guilderton). Survey respondents were asked which beach or foreshore area they visited the most (with 63% of respondents selecting Guilderton). Respondents tended to visit the beach daily (44%), weekly (19%) or monthly (31%).

Respondents use the beach and foreshore area for a variety of activities including walking, swimming, watching the sunset, wildlife watching, fishing, boat launching, four-wheel driving, exercise, picnics, cycling, using facilities and for events such as picnics and weddings.

At the community values workshops held in Lancelin and Guilderton on 31 July and 1 August 2021, workshop participants identified the following values:

- Fishing and swimming at Silver Creek
- That parking is an issue at the parking overlooking the Moore rivermouth beach
- Sandboarding in the dunes south-east of Silver Creek
- Boat launching at the Guilderton North Groyne.

They also noted that the area is under pressure from tourism growth and further residential subdivision – both these may have an impact on the coast and coastal values and will need to be investigated further in the development of the CHRMAP.

These values helped inform the development of management actions for the Guilderton coastline.

In accordance with the CHRMAP Guidelines (WAPC, 2019), private assets and associated values at risk from coastal hazards were considered but the community and stakeholders were made aware that public resources available for risk management should primarily be allocated to preserving assets and values which provide public benefit.

The management unit values for Guilderton can be summarised as:

- Guilderton Foreshore – beach, coastal/dune vegetation, beach access, foreshore reserve and amenity, carpark, lookout, residential land on Gordon Street between Mortimer Street and Anderson Street and unsealed road to the Guilderton North Groyne.
- Moore River – beach, riverbank, beach access, the holiday park, toilet block and other foreshore facilities, and roads (Whitfield Street, Silver Creek Road, Guilderton Road, Mill Road, Moore River Drive).

Values for the CHRMAP 2019 (Cardno) are at Appendix B.

1.7 Existing Controls

1.7.1 Physical Controls

The existing physical controls at Guilderton from a coastal management perspective are the Guilderton North groyne, Guilderton Holiday Park seawall, boat ramps/landing facilities and current management activities.

The Guilderton beach groyne is a rubble mound rock structure constructed in 1967 to provide sheltered water for boat launching and swimming on adjacent beach to the north (DPI, 1995). It is understood to have been constructed using undersized armour due to a lack of availability of sufficient size. The reduced size armour resulted in increased damage and subsequent maintenance requirements. DPI (1995) considered various upgrade and refurbishment options for the structure, but it is understood that these were never undertaken. Ad-hoc maintenance was carried out on occasion, but the structure remains in poor condition (as per photograph Picture 3 in Section 1.4).

Review of aerial photographs shows that the Guilderton groyne has had some influence on local longshore sediment transport. Most available photographs are in summer months and suggest the groyne has helped contain sand to its south side as summer conditions have driven sediment transport towards the north. Aerial photographs also suggest that as the groyne condition has deteriorated, sand has been able to pass through the trunk of the groyne, limiting its influence on sediment transport. The most likely impact of the groyne is an historical influence on vegetation lines in the 1970s and 1980s while the structure was intact, and this will be considered further in the erosion hazard assessment.

The site visit on the 25th of February, 2021 identified a minor seawall running approximately 200m along the northern side of the river estuary. Newer parts of the structure tie into the boat launching facilities and ramp. Older parts of the structure are comprised of rock armour units designed to protect the foreshore from erosion. The rock armour component appeared to be designed to accommodate low energy processes within the estuary and not for potential wave energy from the ocean in the event that the beach berm (river entrance) is eroded.

The older rock armour component of the seawall appeared to be in moderate condition with potential stability issues and was fenced off from public access. The newer vertical limestone wall and armour associated with the boat ramp and dock were in good condition.

The Shire also undertake various monitoring and management practices along the Guilderton coast including:

- Visual monitoring after storm events and the collection of field photographs as required.
- Collaboration with DoT for collection of bathymetric and beach survey data for specific projects. DoT also collects aerial photographs to monitor changes to vegetation line position.
- Beach access way maintenance including removing sand and rubbish, pruning vegetation, weed control, and reporting any damage to paths and fencing.
- Inspection of beach foreshores to monitor vegetation, general beach condition (erosion etc.), sandbar and river mouth
- Grant funding applications.
- Beach signage inspections and maintenance (SLSWA signs and BEN signs)

1.7.2 Planning Controls

The CHRMAP has regard for/ is aligned with the following statutory and strategic planning frameworks including:

Statutory Plans

- Shire of Gingin Local Planning Scheme No. 9
- Local Planning Policy 1.2 Foreshore Protection Areas

Strategic Plans

- State Planning Strategy 2050
- Planning and Development Act 2005
- Planning and Development (Local Planning Schemes) Regulations 2015
- WA Coastal Zone Strategy
- State Planning Policy 2.6 – Coastal Planning
- Coastal Hazard Risk Management and Adaptation Planning Guidelines 2019
- Wheatbelt Regional Planning and Infrastructure Framework 2015
- Shire of Gingin Local Planning Strategy

1.7.2.1 Statutory Plans

State Planning Policies (SPPs) provide the highest level of planning policy control and guidance in Western Australia and are prepared under Part 3 of the Planning and Development Act 2005 (the P&D Act). SPP 2.6 is state coastal policy, consistent with the higher order SPP 2 Environmental and Natural Resources Policy.

The key statutory planning document for the Shire of Gingin is Local Planning Scheme No. 9 (LPS 9), gazetted on 27 September 2012 and amended several times since. LPS 9 applies zones and reserves to land within the Shire and outlines permissibility of land uses, requirements for development and processes for seeking proposed development approval.

Relevant amendments to LPS 9, regarding coastal development, planning and hazards, require compliance with the provisions of SPP 2.6, in accordance with the P&D Act. This amendment thereby gives statutory effect to the SPP 2.6 under LPS 9.

Local Structure Plans and Outline Development Plans (SPs and ODPs) can be made under LPS 9 via the mechanisms provided in Part 4 of the Deemed Provisions set out in the Planning and Development (Local Planning Scheme) Regulations 2015. SPs and ODPs provides guidance for the future subdivision and development of land. The Shire has one ODP relating to coastal land, the ODP for Moore River South which was adopted in August 2014. This ODP considers the same coastal hazard mapping used for the CHRMAP 2019 and the CHRMAP 2023, and provides for coastal foreshore reserves and public open space.

Shire of Gingin Local Planning Strategy

The Shire's Local Planning Strategy (LPS) was endorsed in 2012 and provides a vision for planning and development in the Shire to inform the local planning scheme. The LPS aligns with the Wheatbelt PIF strategic direction, placing importance on both planning for long-term predicted shoreline movement and other impacts of climate variability, such as storm surge.

It identifies coastal erosion and management of coastal dunes as key issues for the Shire, acknowledging that vulnerability is predicted to worsen as sea level rises in response to climate change. The LPS recognises that a strategic approach is needed in managing coastal land use, future development and the impacts of coastal processes, including dune movement, blow outs and erosion.

The LPS provides the following objective for the entirety of the Shire:

"Recognise and protect the attractive and fragile coastal environment along the Gingin coast and promote a comprehensive and strategic approach to coastal land use and future development."

Specific LPS policy positions and actions for the Shire are:

"Require the preparation of a comprehensive coastal strategy (or similar strategic plan) for all or part of the Gingin coast, prior to supporting intensified non rural development (eg. Urban, Tourist, etc) in any location beyond the identified town site nodes. Such a Coastal Strategy is to be prepared with due regard to the existing regional and local planning framework."

"Promote, facilitate or undertake the preparation and implementation of localised coastal foreshore management plans which recognise the importance and attraction of the coast for urban townsite and nodal development whilst simultaneously ensuring the reinstatement and ongoing protection of coastal systems."

"Promote, facilitate or undertake the preparation and implementation of localised coastal management plans which recognise the importance and attraction of the coast for urban and nodal development, while simultaneously ensuring the re-instatement and ongoing protection of coastal systems in the context of townsite growth and activities. Consider the Potential Tourist Activity Node shown on the Lancelin Townsite Strategy map, subject to further investigation of the coastal setback."

There are no specific coastal management objectives for the Guilderton townsite, but the LPS does map the area north of the Moore River with a note stating that 'Coastal setbacks required in accordance with State Planning Policy'.

The Shire is currently in the process of reviewing its Local Planning Strategy.

Shire of Gingin Local Planning Scheme No. 9

The Shire's LPS 9 sets out the Shire's planning aims and intentions for the scheme area, sets out land as reserves for public purposes and zones land for various land uses, and sets out processes to guide land use and development within the Shire.

Relevant aims include to:

- Improve and expand infrastructure in all towns to lessen environmental degradation.
- Recognise the importance of the existing fishing industries within the coastal townsites, particularly in the context of potentially competing pressures of urban growth and tourism.
- Enhance and protect Gingin's unique physical environment as an asset for sustainable and dynamic tourism opportunities.

Part 4.74 of LPS 9 requires all coastal development to comply with the provisions of SPP 2.6 and that SPP 2.6 applies as if it were part of the scheme (in accordance with section 77(1)(b) of the Act.

The land adjacent to the coast is reserved Parks and Recreation, with the exception of the Moore River which is reserved Drainage and Waterways. The majority of the built up townsite areas are zoned for residential purposes, however the caravan park, holiday park and general store are zoned Tourism (Figure 8 refers).

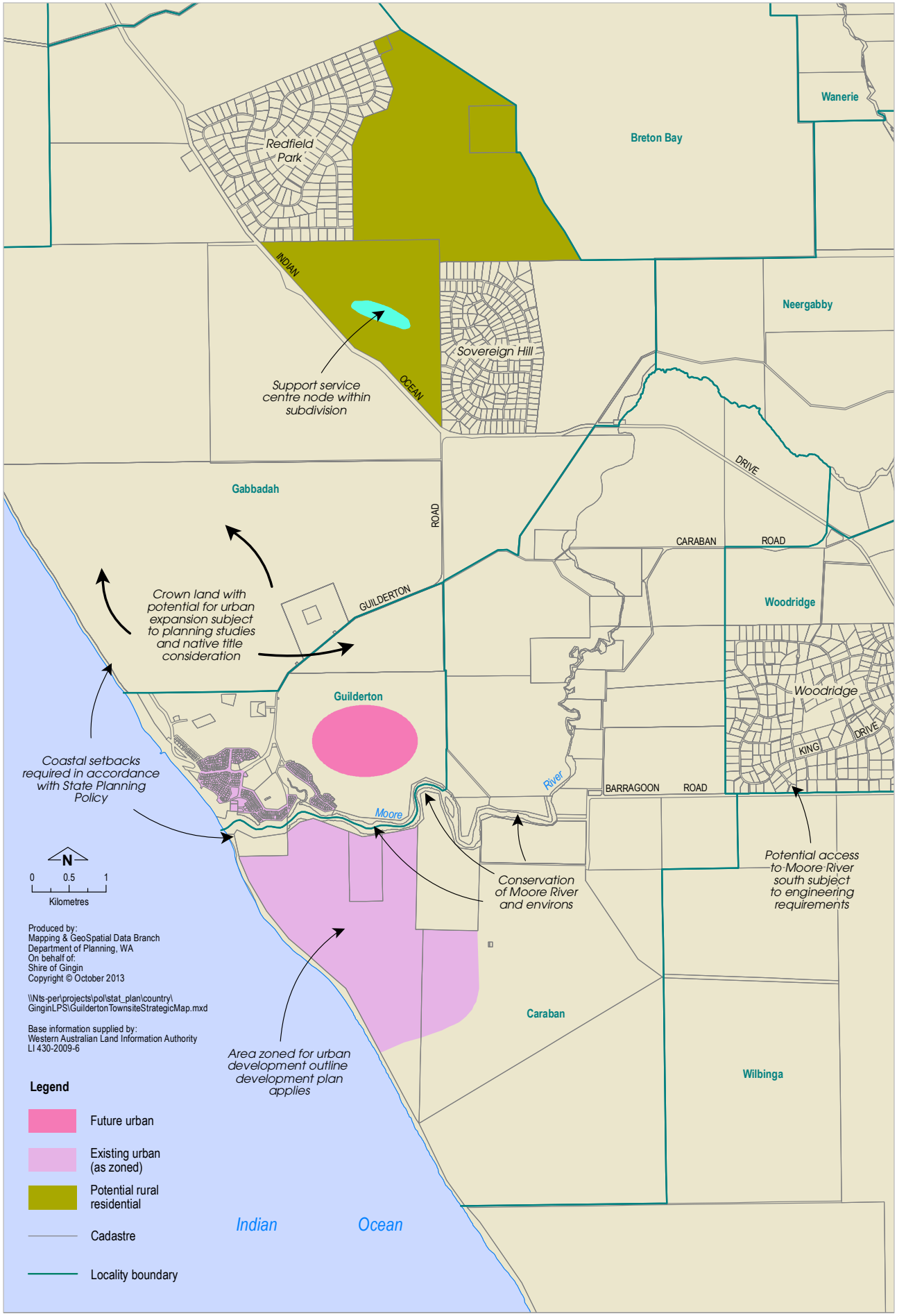


Figure 8: Guilderton Townsite Strategic Map (LPS, 2012)



Figure 9: Shire of Gingin LPS 9 – Guilderton Townsite

SCA No. 1 – River Environs Management Area applies to the Moore River and parts of the land adjacent to the river (see Figure 9). The SCA has been designated to retain the physical and biological features of the waterway and to provide recreational activities and facilities where appropriate. Planning approval is required for all development in the SCA. Local Planning Policy 1.2 Foreshore Protection Areas

This policy applies to areas labelled as Foreshore Protection Areas on the LPS maps. It provides general development guidelines including setbacks, building height, pedestrian access and parking in areas where development in permitted in the Foreshore Area.

The policy requirements are:

- All structures should be constructed behind the primary dune.
- The Council will use a combination of Reservations, zonings and discretion with regard to applications for development.
- The design and siting of all new structures in the policy area will be assessed with regard for their effect on views of significance.
- Unless Council approves otherwise in a particular case a two-storey height limit will apply to all building within this area.

1.7.2.2 Strategic Plans

State Planning Strategy 2050

The CHRMAP 2019 describes the State Planning Strategy 2050 as providing a strategic framework, principles, strategic goals and strategic directions for planning and development in Western Australia. In relation to climate change, this strategy identifies the Shire of Gingin coast as being at risk of coastal landform change. It makes the following key statements that are fundamental to the approach taken to coastal hazard risk assessment and adaptation planning, including:

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

Planning and Development Act, 2005

The Planning and Development Act 2005 (P&D Act) provides the overarching state planning framework for guiding planning and development within Western Australia. The P&D Act provides the power for creating subsidiary state and local planning frameworks including state planning policies, regional and local planning schemes.

Planning and Development (Local Planning Schemes) Regulations, 2015

The Planning and Development (Local Planning Schemes) Regulations 2015 (the P&D Regulations) provides the framework and standard provisions for all local planning schemes in Western Australia.

WA Coastal Zone Strategy

The WA Coastal Zone Strategy provides a whole-of-government integrated framework for collective action to manage and adapt to threats and pressures along the coast, complimenting existing State legislation, strategies and policies, including SPP 2.6. The document identifies all relevant legislation and policies related to coastal management and defines stakeholder roles and responsibilities for coastal stewardship. It provides that all levels of government, as well as individuals, businesses, and the community, each have important and complementary roles in adapting to coastal hazards.

In particular, it outlines the following principles which have relevance to this CHRMAP:

- Private parties are responsible for managing risks to their private assets; and
- Governments (i.e.: the Shire), on behalf of the community, are primarily responsible for managing risks and impacts to public goods and public assets which they own and manage; they should also seek to:
- Develop local policies and regulations consistent with state adaptation approaches.

- Facilitate building resilience and adaptive capacity within the local community.
- Work in partnership with community to identify and manage risks/ impacts.

State Planning Policy 2.6 – Coastal Planning, 2013a

SPP 2.6 provides detailed information to evaluate the risk of coastal inundation and erosion and specifies the storm events to be considered for these analyses. SPP 2.6 is supported by the CHRMAP Guidelines.

The SPP aims to avoid future development within areas identified to be at risk within the planning timeframe, generally 100-years. For areas at risk, all potential adaptation options need to be identified under the risk management categories. The State's coastal planning policy adaptation preferences in order of priority, as outlined in SPP 2.6, are:

Avoid > Planned or Managed Retreat > Accommodate > Protect

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

Coastal Hazard Risk Management and Adaptation Planning Guidelines 2019

The CHRMAP guidelines provide a comprehensive CHRMAP process be undertaken to inform and enable the adoption of a planned or managed retreat policy to guide implementation.

The coastal suite of documents (WA Coastal Strategy, SPP 2.6, CHRMAP Guidelines and associated appendices) outline the following planning mechanisms relevant to this CHRMAP to enact planned or managed retreat:

- Local structure planning (SP) – where comprehensive redevelopment of land remains an option
- Local planning scheme (LPS) amendment – to inform the classification of vulnerable areas as Special Control Areas (SCAs) as applicable.
- SCA – establishing an SCA enables land use and development at risk to be identified in the SPP 2.6 100-year planning timeframe, establish intention to retreat from the area and provide the special planning instrument required to implement the approach. Part 5, Schedule 1 of the P&D Regulations provides the template for local governments to follow when amending their LPSs to include an SCA.

- Taking of land – triggers for initiating a taking of land process should be included in any policy arising from the CHRMAP process to support implementation of the planned or managed retreat. The taking of land needs to be in agreement with the requirements under section 168 of the Land Administration Act 1997.
- Special circumstances for state government control – this would be enacted through mechanisms set out in the P&D Act and the relevant Region Scheme and would include a Planning Control Area (PCA) declaration and/or an Improvement Plan and Scheme over/for the relevant area.
- PCA – the Western Australian Planning Commission (WAPC) can declare the requirement for a PCA under Section 112 of the P&D Act to ensure that no development occurs on this land which might prejudice its purpose. The WAPC would take over control of applications within PCA land.
- Improvement plans are strategic instruments used to facilitate the development of land in areas identified by the WAPC as requiring special planning. The WAPC can recommend to the Minister for Planning that an improvement plan is made "for the purpose of advancing the planning, development and use" of land. An improvement plan can authorise the making of an improvement scheme.

Wheatbelt Planning and Infrastructure Framework 2015

The Wheatbelt Planning and Infrastructure Framework 2015 (Wheatbelt PIF) identifies the following key regional strategic planning initiatives:

- Identification required planning responses following completion of the Coastal Hazard Risk Management and Adaptation Planning Study being carried out by the shires of Dandaragan and Gingin, and
- Facilitation of long-term strategic planning for the lower Gingin – Indian Ocean Drive corridor, focussing on possible economic and employment opportunities, service provision and the preservation of environmental assets (the latter including coastal assets).

Shire of Gingin Local Planning Strategy 2012

The CHRMAP 2019 summarises the Shire's Local Planning Strategy as generally aligning with the Wheatbelt PIF strategy direction, placing importance on both planning for long-term predicted shoreline movement and other impacts of climate variability, such as storm surge.

The Local Planning Strategy identifies coastal erosion and management of coastal dunes as key issues for the Shire, acknowledging that the vulnerability is predicted to worsen as sea level rises in response to climate change. It recognises that a strategic approach is needed in managing coastal land use, future development and the impacts of coastal processes, including dune movement, blow outs and erosion.

1.8 Success Criteria

The desired outcome of the CHRMAP process is for the Shire's Council to support and adopt the recommended specific planning controls and actions for short term risk (0- 10 years) and for specific planning and implementation pathways for longer-term risks.

These recommendations will be based on community and stakeholder consultation and engagement, plus economic, environmental and cultural considerations.

The key success criteria are:

- The outcomes of the integrated CHRMAP are understood and supported by key stakeholders and decision makers
- The local community is involved in the development of these adaptation measures and outcomes, and understands their selection
- Protection of the environmental assets of the study area / planning to retain environmental integrity
- Protection of the recreational value of the coastline
- Protection of the cultural values of the coastline & town centre
- Maintenance of a level of public recreational assets
- Development controls not to inhibit the landscape

SECTION 2: RISK IDENTIFICATION

2. RISK IDENTIFICATION

The coastline at Guilderton is exposed to open ocean swell energy, somewhat mitigated by offshore reef. The coastal lifestyle and environment are strongly valued by the Guilderton resident community, as well as those who visit the area. Therefore, as well as the legislative requirements, the increasing pressures on the coastline due to climate change have precipitated the need for a CHRMAP for the town.

The CHRMAP identifies the strategic direction for coastal adaptation scenarios from the present-day to 2120 (100-year management time frame). This technical report will inform the CHRMAP 2023 which will develop a flexible adaptation pathway for the region and serve as a key reference for management, planning and policy making for the short-term (0-10 years), medium-term (10-50 years), and long-term (50-100 years).

This chapter presents the results of the coastal hazard assessment for the Guilderton study area. Hazard maps have been produced that define the erosion and inundation extents of varying magnitude (severity) for present day (2020), 2030, 2050, 2070, 2090 and 2110, in accordance with the CHRMAP Guidelines (WAPC, 2019).

For the purposes of planning, the present-day differences between the CHRMAP 2019 and this report (2016 and 2020) and future timeframe differences (2090, 2110 and 2120) should be considered negligible and planning should be attributed to the 2090 timeframes.

2.1 Planning Timeframe and Sea Level Rise

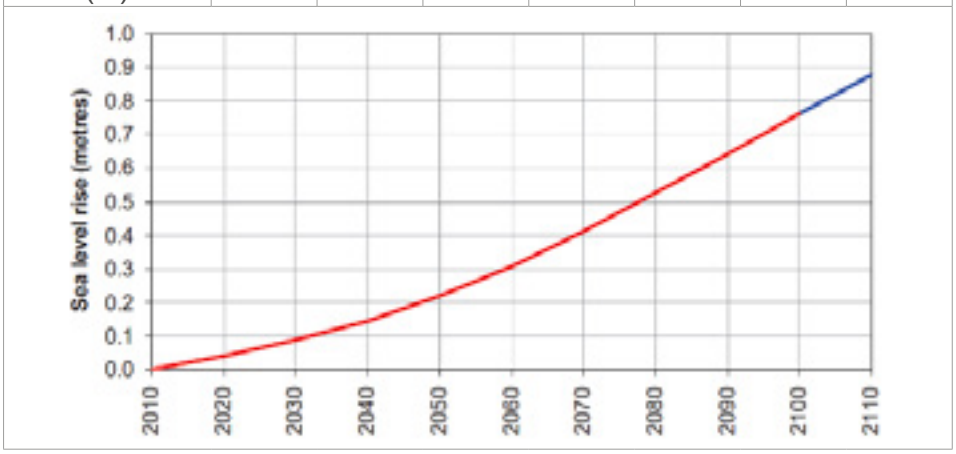
The coastline is constantly changing from storm events, sea level rise and human modifications. As it changes it can impact the infrastructure (e.g. footpaths, roads, houses, beach access, services) in the coastal zone and how the coast can be used. So that the coast can continue to be used and enjoyed, it is important to understand coastal hazards and the risks.

It is internationally recognised that increasing sea levels and storm intensities due to climate change will intensify coastal hazards such as coastal inundation (temporary coastal flooding), storm erosion, and long-term shoreline recession (IPCC, 2014). The combined impact of climate change will vary around the Western Australian coast and require consideration on a local scale. Consequently, state governments across Australia have introduced obligations that require local governments to consider and plan for the effects of these hazards over various planning timeframes.

Sea level rise (SLR) is the climate change impact considered in SPP 2.6. The Department of Transport (DoT, 2010) has recommended that a vertical SLR of 0.9m be adopted when considering the impact of coastal processes over a 100-year planning timeframe (2010 to 2110). It is recommended for planning timeframes beyond 100 years that a vertical SLR of 0.01m per year be added for every year beyond 2110. Given the slower rate of change between 2010 and 2020, a reasonable adjustment to the total SLR between 2020 and 2120 is 0.98m. For this CHRMAP, the 0.9m value is extrapolated to a value of 0.98m in 2120. Sea Level Rise from DoT 2010 is presented in Table 4.

Table 4: Sea level rise

PLANNING TIME FRAME (YRS.)	2010	2020	2030	2050	2070	2070	2120
Sea Level Rise (m)	0	0.04	0.08	0.22	0.42	0.64	0.98



This CHRMAP uses these values to determine the relative hazards from erosion and inundation due to climate change over the next century.

The primary projected impacts of SLR are its contribution to increased shoreline erosion and inundation. Natural coastlines composed primarily of loose sediment respond to changes in the long-term mean sea level (MSL) by receding (eroding) inland until a new equilibrium shoreline is found.

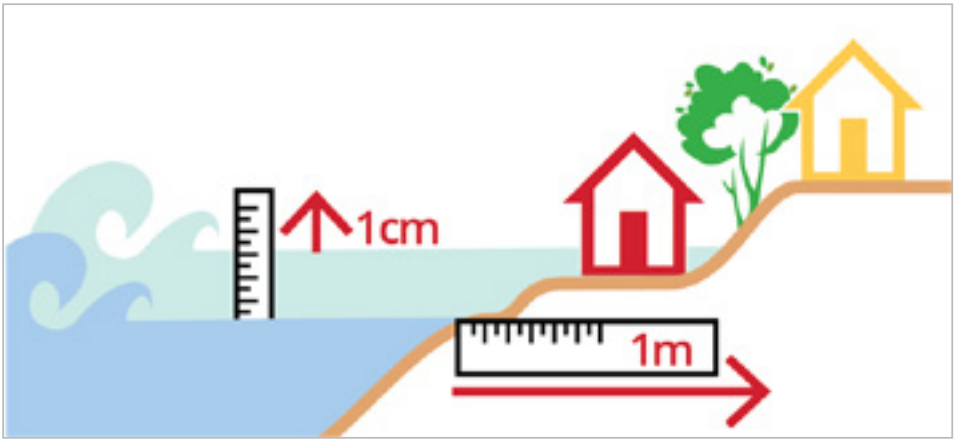


Figure 10: Representation of horizontal erosion allowance from projected vertical sea level rise – a factor of 100 (CoastAdapt, 2017)

SPP 2.6 recommends that a risk zone due to SLR be defined as 1.0 m landward (of the existing shoreline location) for every 0.01 m increase in MSL (i.e., 100 times the SLR, Figure 10 refers).

In addition, as the MSL rises, coastal inundation will become more frequent and reach further inland. This may be exacerbated by greater storm surge and wave run-up as coastal waters deepen. For inundation, SPP 2.6 requires consideration of the 500-year average return interval (ARI) storm combined with 100-years of SLR to identify areas of risk over the planning horizon. By considering both erosion and inundation, this CHRMAP ensures that the Guilderton community has identified potential risks and has begun to efficiently plan and implement adaptive strategies to address potential changes.

The recommended management actions are based on the coastal risk adaptation planning hierarchy outlined in SPP 2.6 (Figure 11 refers);

1. **Avoid** the presence of new development within an area identified to be affected by coastal hazards.
2. **Planned or Managed Retreat**: the relocation or removal of assets identified as likely to be subject to intolerable risk of damage from coastal hazards over the planning time frame.
3. If sufficient justification can be provided for not avoiding development of land that is at risk from coastal hazards then **Accommodation** adaptation measures should be provided that suitably address the identified risks. Such measures would involve design and/or management strategies that render the risks from the identified coastal hazards acceptable.
4. 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.

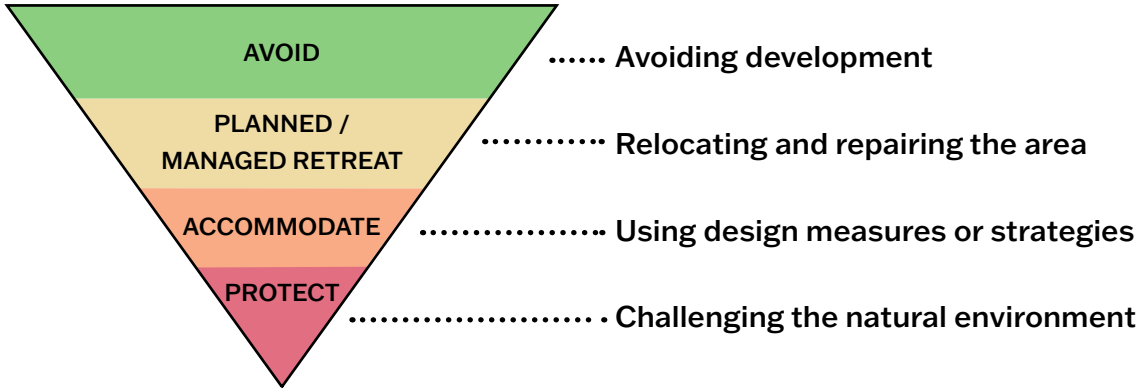


Figure 11: Coastal risk adaptation planning hierarchy adapted from SPP 2.6 (WAPC, 2013a)

2.2 Coastal Geomorphology

The evolution of the coast, including the location of beach waterlines and vegetation lines occurs over a range of time scales including:

- At the geological scale (10-100,000+years), coastal change is dominated by sea level movements and large-scale geological processes primarily dealing with the location and movement of rock.
- At geomorphic scales (100-10,000years), coastal evolution is determined by the sediment transport driven by regional and local metocean climate and sediment provenance and availability.
- Over planning scales (10-100years), sediment sources and sinks and pathways due to local landform changes and metocean climate and weather events.
- Over coastal management scales (days to 10years), significant changes occur due to storms – generally cross-shore erosion.

At a geological scale, sand dune evolution is continuing at present as sediment is moved along and across the shore which contributes to development of the sand dunes and blowouts. The formation of dunes and their migration currently utilises sediment supply from offshore and alongshore from the south. Alongshore variations in beach erosion, foredune formation and dune development occur because of the complex processes resulting from modern metocean process reworking the geological scale landforms (reefs, islands, rock outcrops).

The Shire coast is dominated by Quindalup Dunes, comprised of Safety Bay Sands, which have been reworked over the Holocene period, approximately the last 6,000 years (Searle and Semenuik, 1985). Beach sands are made up of a majority of calcareous sand from adjacent seagrass beds and also quartz from re-working of Holocene deposits. Particle grain size analysis at Lancelin indicates medium sands are prevalent with median grain size of 0.25-0.50mm (Nicholson, 2009).

Coastal landform development on the Shire coast is controlled by limited sediment supply and is substantially controlled by the local geology. Typical landforms include sediment lobes, sand banks and shoals between reef gaps; subtidal terraces and sand banks spilling into nearshore basins; and tombolos, spits, cuspate forelands and coastal dune barriers along the coast. These landforms provide an indication of the source areas, transport pathways and sinks. Longshore sediment supply is controlled by the degree of bypassing at rocky coastal features. Offshore, discontinuous reef ridges and inshore reef chains provide a limited constraint to onshore and offshore sediment movement, which can occur as “pulses” of sand (Stul et al 2014 & 2015).

The coast alternates between sections of intertidal rocky reef and sandy beaches free of rock. Waves break across the rocks or surge up the beach face. Vegetated dunes from 10 to 40m high back the beach, with active dune blowouts also present. The most significant coastal feature is the Moore River mouth and the intermittent sandbar that crosses it. A rubble-mound rock groyne is present approximately 1.3km north of the river mouth. The groyne was built to assist boat launching across the soft beach. Two lines of offshore reefs shelter the local beach to incoming waves. The low waves produce a steep beach, with a narrow continuous bar, which is cut by rips during periods of larger waves (Surf Life Saving Australia, 2020).

Review of satellite images (Table 5) suggests the overall landform of the region is reasonably stable, except the river outlet which changes whenever a breach of the sand bar occurs (e.g., 2010-2011). Since 2017, the overall shape of Moore River outlet has not changed.

Table 5: Historic Satellite Images

	
2010	2011
	
2017	2020

2.3 Coastal Erosion Hazard Assessment

2.3.1 Assessment Approach

Shoreline Segmentation

To determine allowances for coastal processes, the following shoreline segmentation/ classifications have been considered (Figure 12):

- Sandy Coast for exposed shoreline (GT1, GT2 and GT3) – as specified by SPP 2.6
- Sandy Coast along the walkway connecting the Holiday Park to the beach (GT4) – as specified by SPP 2.6
- Seawall revetment at the foreshore of Holiday Park (GT5) – as specified by SPP 2.6
- Vegetated riverbank where SPP 2.6 is not directly applicable (GT6). – as specified by WAPC SPP 2.9: Water Resources (SPP 2.9; WAPC, 2006).

SPP 2.6 Erosion Allowances

SPP 2.6 (WAPC, 2013a) provides guidance for decision-making within the coastal zone including managing development and land use change; establishment of foreshore reserves; and to protect, conserve and enhance coastal values. The natural coastline is subject to erosion through both short-term processes such as storm surge, and long-term processes such as rising sea levels and changes to alongshore sediment transport. The various forms of erosion allowances are defined in SPP 2.6:

- S1 Erosion - Allowance for the current risk of erosion (requires modelling of the 1 in 100-year ARI storm event).
- S2 Erosion - Allowance for historic shoreline movement trends; and
- S3 Erosion - Allowance for erosion caused by future sea level rise.

The overall hazard extent associated with these processes is calculated by the summation of the above allowances, plus an additional allowance for uncertainty. The values are measured from the Horizontal Shoreline Datum (HSD) which is the active limit of present storm activity.

SPP 2.9 Erosion Allowances

SPP 2.9 (WAPC, 2006) has been used to assess the erosion allowance along the riverbank of Moore River. SPP 2.9 has suggested a ‘foreshore reserve width’ of 30m for waterways and a ‘development setback’ of 50m for estuaries. In this project, the 30m allowance has been considered for the riverbank along Moore River for the 100-year planning period as the river mouth is mostly closed (not an estuary).

2.3.2 Numerical Modelling

Model simulations are required to evaluate the storm erosion allowance (S1) under different storm likelihoods:

- DHI's MIKE21 Spectral Wave (SW) model is evaluated to transfer the offshore wave condition to nearshore area as inputs for beach erosion modelling. The model is based on an unstructured flexible mesh comprising of triangular elements. It is a fully spectral wave model that simulates the growth, propagation, refraction and diffusion of wind waves.
- The potential for storm-induced acute erosion (S1) is simulated using the SBEACH numerical model.



Figure 12: Shoreline Segments, Classification, SBEACH profile

2.3.2.1 Model Grid

The coverage of the model mesh and bathymetry are shown in Figure 13. The model boundary extends for about 120 km in the long shore direction and about 50km in the cross-shore direction. This is to allocate the offshore boundary at sufficient depth to reduce any boundary impacts.

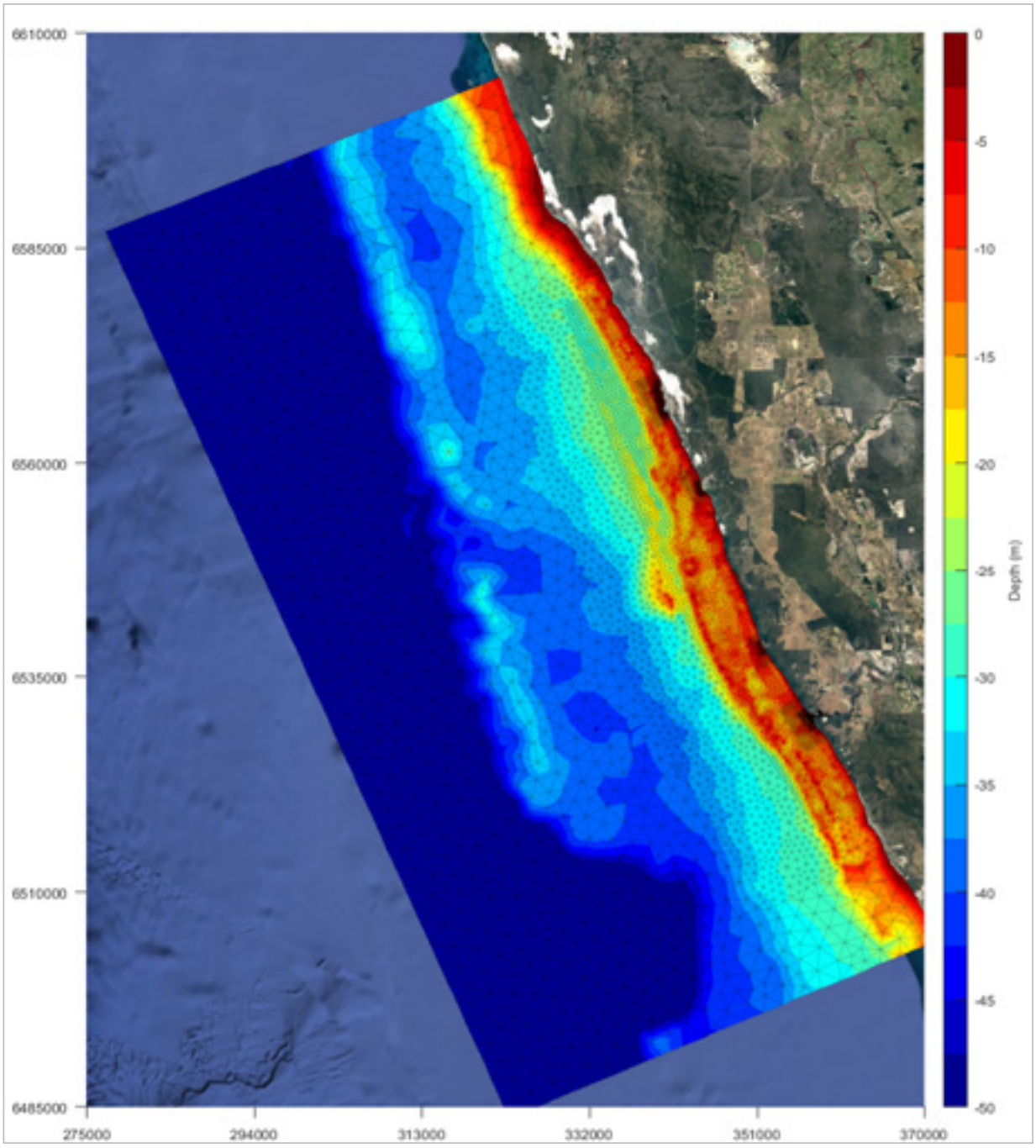


Figure 13: Model Domain and Mesh

The computational triangular mesh of the model is made by sufficiently small cells (~50m near the project site) to resolve the detailed conditions, especially along the Guilderton coastline. The bathymetry was developed using the LiDAR survey data (up to 30m depth) supplied by the Department of Transport (DoT) and Geoscience Australia 250m resolution bathymetry data to fill gaps wherever DoT LiDAR data is not available.

2.3.2.2 Model Calibration

Wave model was calibrated against measurements obtained at Seabird in 2003 (see Figure 14) and at Guilderton in 2021 (Figure 15). Overall, model configuration has been optimised to represent local conditions of the region. Applied wave-breaking parameters in the model are gamma = 0.8 and alpha = 1. Bottom friction is determined based on experience in the study area. The model is considered as suitable for the purpose of CHRMAP study.

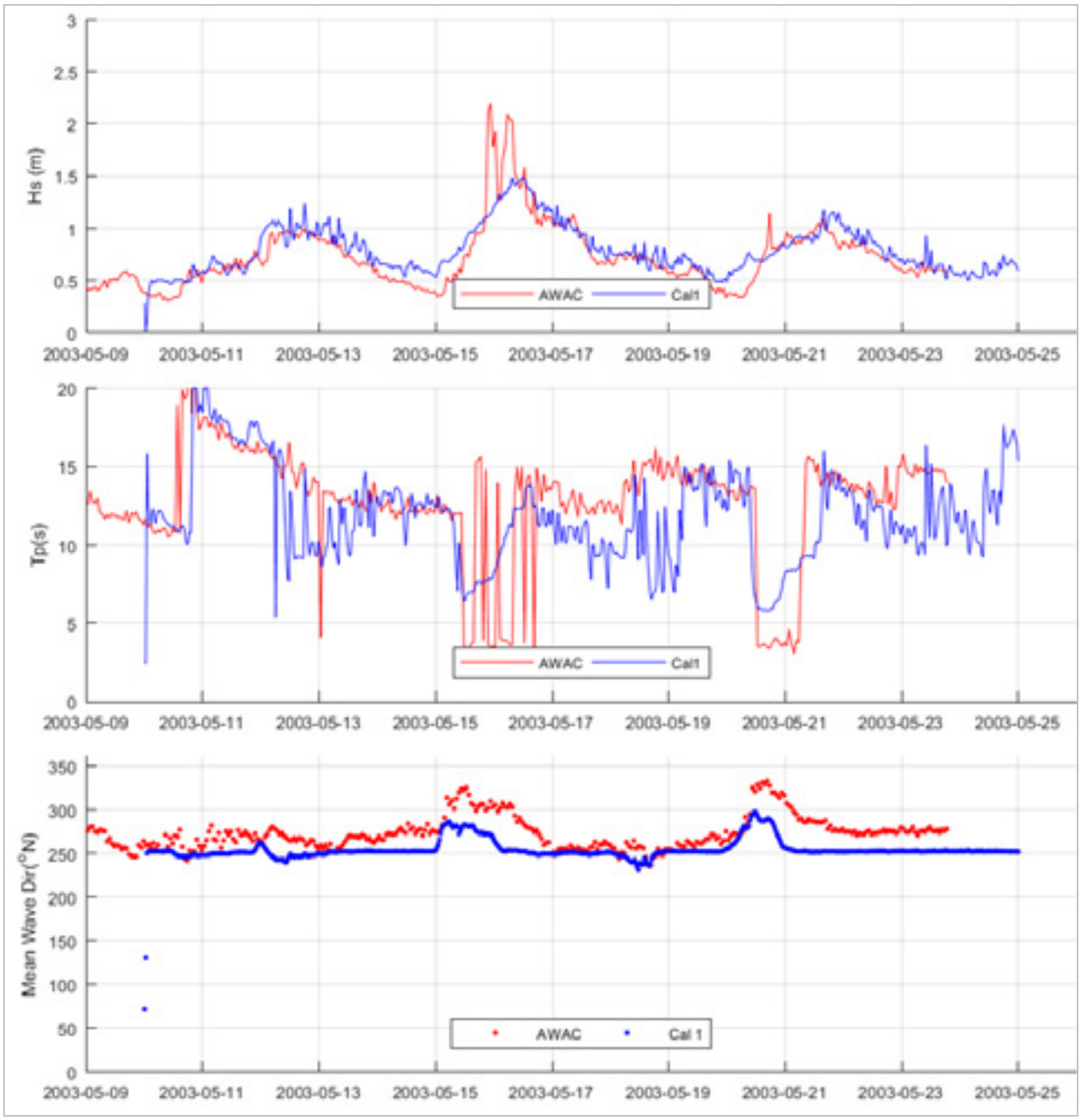


Figure 14: Spectral Wave Calibration (Hs, Tp and Mean Wave Direction) – at Seabird in 2003

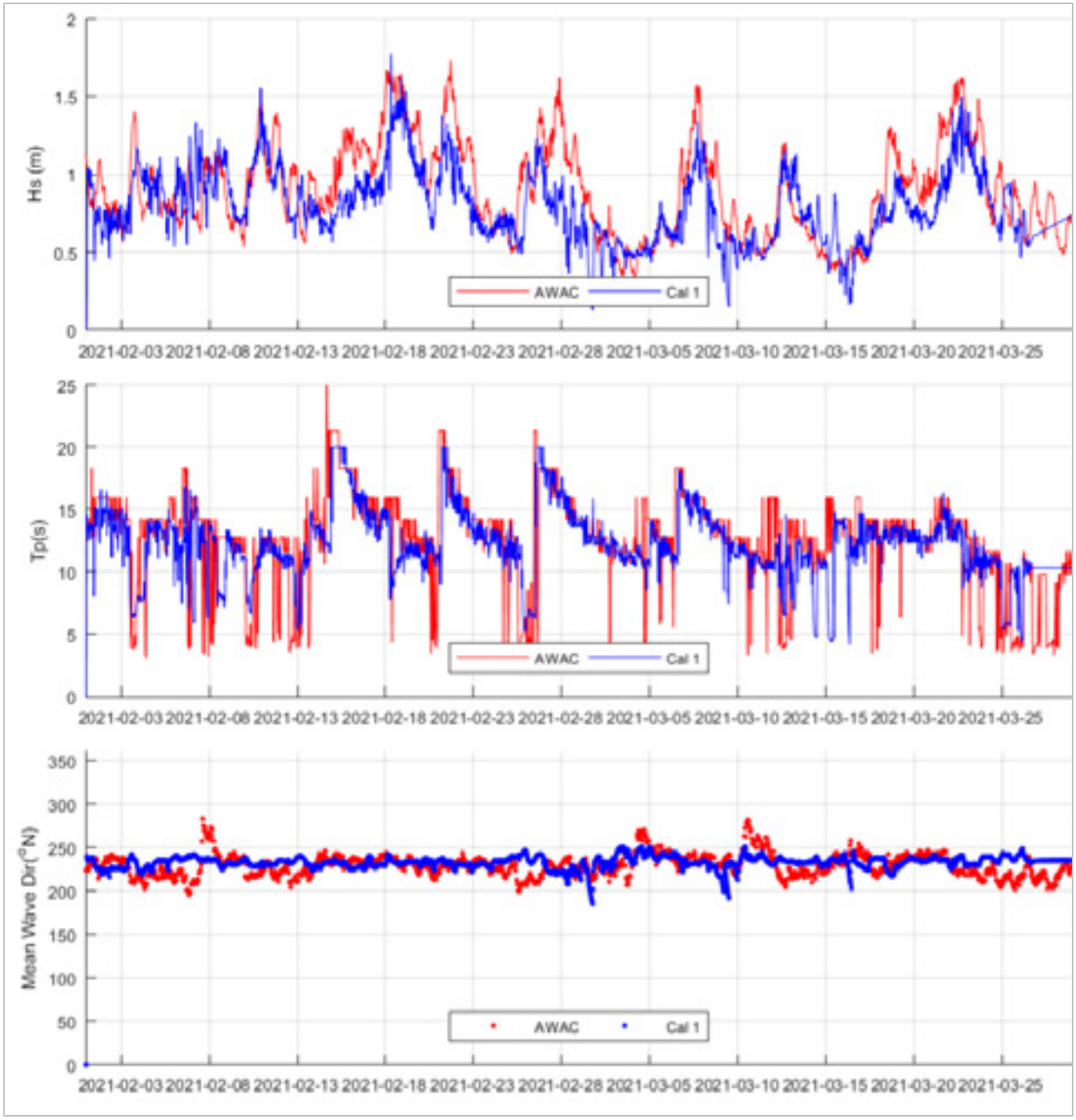


Figure 15: Spectral Wave Calibration (Hs, Tp and Mean Wave Direction) – at Guilderton in 2021

2.3.2.3 Model Scenarios

Water Technology simulated a set of ARI storm events including a 1-year event, a 10-year event, a 25-year event, a 50-year event and a 100-year event. These storms were selected based on their Total Wave Power and potential to cause coastal erosion (MPRA, 2018).

S1 Erosion Allowance

The SBEACH numerical model was developed to calculate short term wave induced erosion (or S1 erosion allowance) and has been utilised in a range of studies including shoreline stability assessments in Western Australia.

Representative beach profiles are determined based on geomorphological features and site inspection outcomes. The profiles extend from about -10m to up to 25m AHD across the beach face. Profile locations are shown in Figure 16.

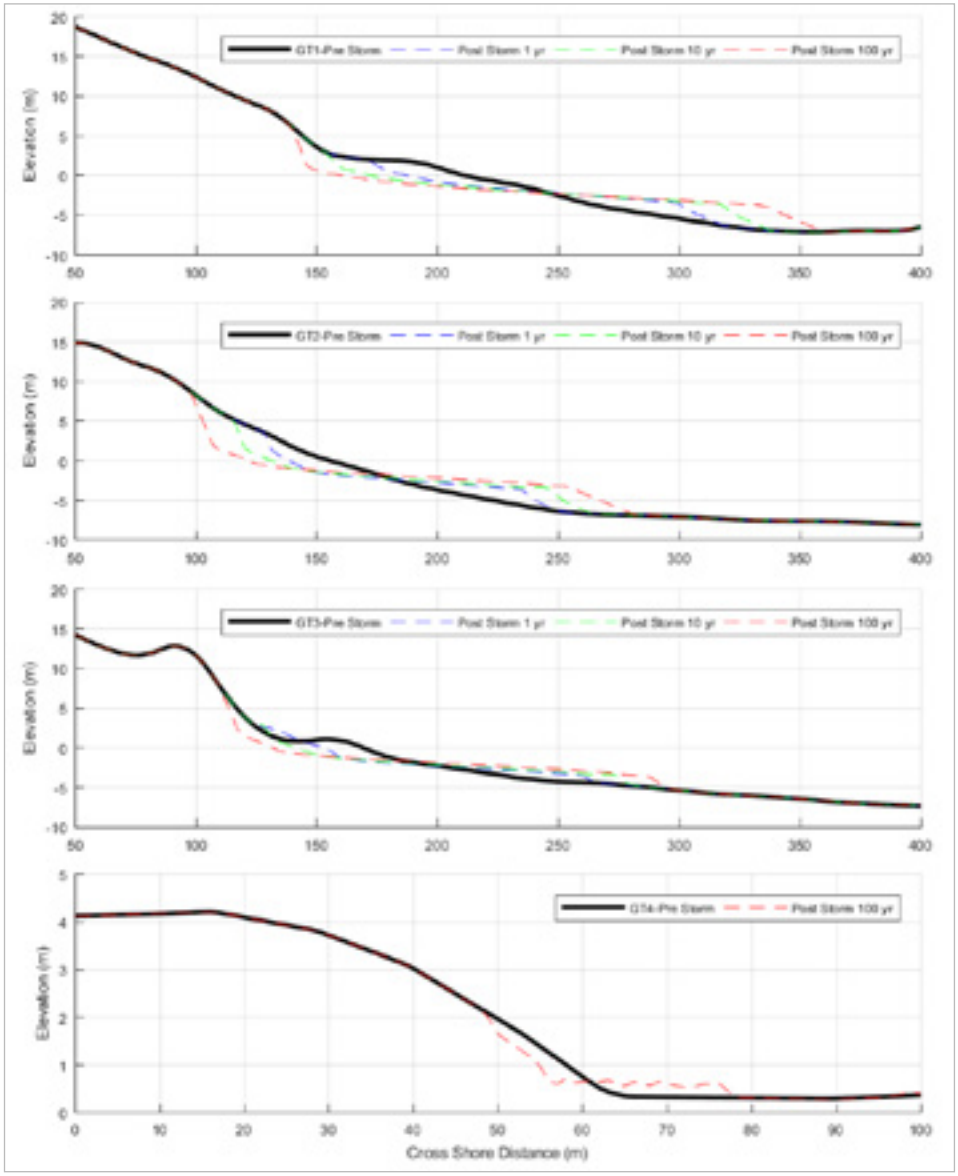


Figure 16: Storm Erosion Model Results (GT1, GT2, GT3 and GT4 profiles)

DoT Lidar data (from ~-30m contour landwards) has been used to generate seabed levels and beach face elevations for each transect. The model does not however incorporate hard sublayers, seawalls, or any other physical controls. Other model settings e.g., sand grain sizes, temperature, transport rate coefficient, transport rate decay coefficient, avalanche slope and surf zone depth are configured as appropriate for the study site. Water Technology has previously undertaken SBEACH calibrations (e.g., Wedge and Grey erosion hazard assessment) and relevant information has been utilised in this project.

Critical inputs utilised for each profile include:

- Digital elevation data from +25m AHD down to -30m AHD offshore
- Time-series of water level from the design events (tide plus surge)
- Time-series of significant wave height (Hs), Peak wave period (Tp) and Wave direction (Wdir)

The S1 storm erosion value was calculated as the maximum horizontal recession measured from the HSD. The modelled S1 erosion allowances for each modelled storm scenarios are presented in Table 6.

- GT1, GT2, GT3 and GT4 are classified as sandy coast where the S1 erosion was estimated using SBEACH model outcomes.
- GT5 is classified as shoreline under physical controls e.g., seawall, boating facilities. All physical controls at the foreshore of Holiday Park are in good condition showing no imminent risk of erosion. No storm erosion is envisaged for this segment of shoreline.
- GT6 is classified as inland riverbank where SPP 2.9 should be applied for assessment of erosion risk.

Table 6: Summary of predicted storm erosion

COASTAL SEGMENT	CLASSIFICATION	S1 EROSION ALLOWANCE (M)		
		1-YEAR STORM	10-YEAR STORM	100-YEAR STORM
GT1	Sandy	6	15	30
GT2	Sandy	10	22	40
GT3	Sandy	3	3	17
GT4	Sandy	0	0	0
GT5	Seawall	0	0	0
GT6	Riverbank	0	0	0

S2 Erosion Allowance

Chronic shoreline movement is estimated through review of available historical shoreline data. The approach adopted is to analyse historical aerial imagery and to use the horizontal change in vegetation line as an indicator for historical shoreline changes. This approach is applicable on natural coastlines where vegetation is free to recede in response to erosion. Areas with common trends are grouped according to their erosion patterns and historic shoreline movement rates.

Historic shoreline movements represent the shoreline movement by coastal processes. DoT archived historic shorelines were reviewed to predict the rate of shoreline movement in the 100-years planning period (Figure 17).



Figure 17: Historic Vegetation Lines (data provided by DoT)

GT1 and GT2 shorelines have been accreting over the past 70 years at a rate of about 0.3m per year. The erosion rate is considered as 0 m per year in this study. This is to account for the uncertainty of future shoreline movement in response to climate change that cannot be represented by historic data.

GT3 has experienced a low rate of erosion at an approximate rate of 0.3m per year. Google satellite images has confirmed that GT3 could be in an erosion zone due to 1) breach of sand bar during extreme flood, 2) wave erosion during oceanic storms. The river mouth has a tendency to head southward. According to discussions with the Shire, this has occurred since the construction of the rock groyne in the 1960s (no reported evidence however).

GT4 has experienced continuous accretion due to deposition of riverine sediment.

At GT5, erosion was found in earlier years; however since the 1990s (the time when the seawall was built) the shoreline has been stable.

At GT6, shoreline variations presented in Figure 17 should not be overinterpreted, as different definitions/approaches may be used to extract the supplied shoreline data. Overall, there is no known severe riverbank erosion reported, as per review of data. For the hazard assessment, GT6 is considered as per SPP 2.9 rather than SPP 2.6.

S3 Erosion Allowance

Along the open coast, rising water levels will cause additional inundation and retreat of the shoreline which is often characterised by Bruun Rule (Bruun 1962). As per SPP 2.6, the shoreline recession is calculated as 100 times the adopted sea level rise value over the defined planning periods for sandy/ mixed coasts. The multiplier of 100 is based on the Bruun Rule (1962) over a mildly sloping shoreline. For this project, the impact of SLR is considered in context with local conditions i.e.:

- Bruun law (1V:100H slope) for open coast, sandy and mixed shoreline
- Bruun law (steeper slope of 1V:12H) for areas within Moore River where SPP 2.6 is applicable.
- Not considered for waterways and river courses.

Table 7: S3 Erosion Allowance due to SLR

	2010	2020	2030	2050	2070	2090	2120
SLR (m)	0	0.04	0.08	0.22	0.42	0.64	0.98
S3 open Coast(m)	0	4	8	22	42	64	98
S3 Moore River (m)	0	0	1	3	5	8	12

Total Erosion Allowance

Total erosion allowance is calculated based on the outcomes of the assessment above:

- GT1 - GT 5, total erosion allowance is calculated as S1+S2+S3+Allowance for Uncertainty (AU in Table 8 below) as per SPP 2.6. For areas classified as physical controls, no allowance is considered.
- for GT6 (or riverbank), a 30 m total allowance has been considered to account for uncertainty of riverbank movement in a 100-year planning period, as per SPP 2.9.

The total erosion allowance is summarised in Table 8.

Table 8: Total Erosion Allowances (m)

ZONE	PRESENT		2030					2050					2070					2090					2120				
	S1	TOTAL	S1	S2	S3	AU	TOTAL	S1	S2	S3	AU	TOTAL	S1	S2	S3	AU	TOTAL	S1	S2	S3	AU	TOTAL	S1	S2	S3	AU	TOTAL
GT1	6	**6**	15	0	8	2	**25**	18	0	22	6	**46**	23	0	42	10	**75**	26	0	64	14	**104**	30	0	98	20	**148**
GT2	10	**10**	22	0	8	2	**32**	26	0	22	6	**54**	31	0	42	10	**83**	35	0	64	14	**113**	40	0	98	20	**158**
GT3	3	**3**	3	3	8	2	**16**	6	9	22	6	**42**	10	14	42	10	**76**	13	20	64	14	**111**	17	29	98	20	**164**
GT4	0	**0**	0	0	1	2	**3**	0	0	3	6	**9**	0	0	5	10	**15**	0	0	8	14	**22**	0	0	12	20	**32**
GT5		**0**					**0**				6	**0**					**0**					**0**					**0**
GT6		**0**				3	**3**				9	**9**				15	**15**				21	**21**				30	**30**

2.4 Coastal Inundation Hazard Assessment

The inundation hazard assessment was completed by Baird in their Gingin CIS report (2020). Extreme water levels based on Baird (2020) are replicated in Table 9 below, including projections of sea level rise.

Table 9: Inundation Levels with Sea Level Rise (based on Baird (2020))

ARI (YEARS)	2010	2020	2030	2050	2070	2090	2120
1	0.7	0.8	0.8	0.9	1.1	1.4	1.7
10	0.9	0.9	1.0	1.1	1.3	1.5	1.9
100	1.4	1.4	1.5	1.6	1.8	2.0	2.4
500	1.8	1.8	1.9	2.0	2.2	2.4	2.8

2.5 Hazard Mapping

Erosion and inundation hazard maps are presented in Figure 18 (erosion hazard lines) and Figure 19 (inundation hazard in 2120). These are also included in Appendix C at larger scale.



Figure 18: Erosion Hazard Map



Figure 19: Inundation Hazard Map (500 yrs. ARI, 2120)

2.6 Asset Identification

Identification of coastal assets and their values is a crucial step toward the development of adaptation options. Coastal assets along the Guilderton foreshore have been identified through review of available information – predominantly Cadastre maps and the community engagement survey. This includes key coastal assets and values that reflect the opinions from local communities and stakeholders.

Assets sharing similar values are grouped as per the recommendation of WAPC (2019), and also in line with the existing Shire CHRMAP (Cardno, 2019), for ease of integration. Categories are listed below, and assets within each group displayed in Table 10.

- Environmental assets such as beach and dune vegetation
- Social assets that have strong community attachment and service
- Economic and infrastructure assets such as residential and commercial properties, utilities that contribute to economy.

Table 10: Coastal Assets and Values

ASSET VALUE CATEGORY	ASSETS AT RISK
Social	• Holiday park • Foreshore reserve & amenity • Car park • Lookout • Beach access • Toilet block and other foreshore facilities.
Environmental	• Beach and Sandbar • Dune vegetation
Economic and Infrastructure (public)	• Road • Boat ramp and boating facilities • Utilities
Economic and Infrastructure (private)	• Residential
Existing Physical Controls	
• Groyne constructed in 1960s, poor condition • Seawall at the foreshore of holiday park, good condition • Boat ramp and other facilities at the foreshore of holiday park	
Existing Planning Controls	
• Various State planning controls as per Shape Urban (2021) • Shire of Gingin Local Planning Strategy • Shire of Gingin Local Planning Scheme No 9 • Shire of Gingin Local Planning Policy 1.2 Foreshore Protection Areas	

SECTION 3. VULNERABILITY ASSESSMENT

3. VULNERABILITY ASSESSMENT

A vulnerability assessment defines the degree of impact coastal hazards are likely to have on coastal assets over the planning timeframe. The vulnerability of coastal assets to coastal hazards is related to its exposure to the hazard, its sensitivity to that exposure, and the ability of the asset to be modified or adapted to manage this exposure. This is displayed diagrammatically in Figure 19; the input components are displayed in blue.

In the sub-chapters below, the asset ratings to the hazards are discussed and a vulnerability rating assigned. Inundation and erosion hazards are considered separately for each of the four coastal townsites. Erosion and inundation hazards are considered for Guilderton first, followed by inundation hazards for Lancelin, Ledge Point and Seabird. Erosion hazards for Lancelin, Ledge Point and Seabird are referenced for viewing within the CHRMAP 2019 by Cardno.

Per asset grouping in Section 2, assets are grouped according to classification for ease of interpretation. Ratings were discussed with the Project Steering Committee to ensure they are reflective of community views.

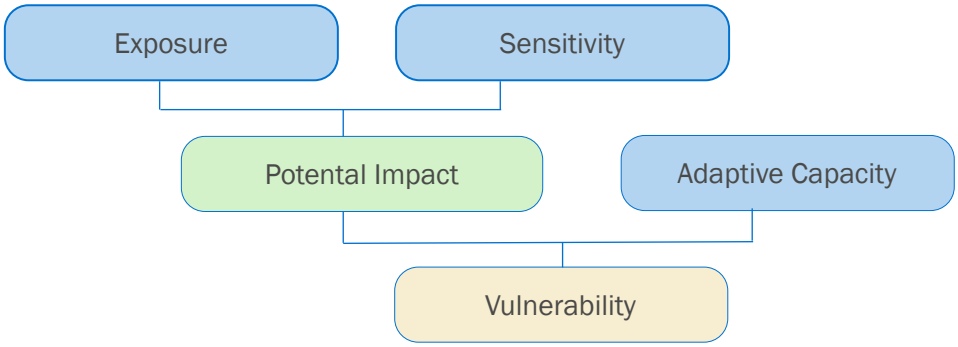


Figure 20: Vulnerability assessment components (reproduced from Allen Consulting, 2005)

Table 11: Exposure / likelihood rating

LIKELIHOOD RATING	DESCRIPTION	ANNUAL EXCEEDANCE PROBABILITY
Almost Certain	Expected to occur in most circumstances	>90%
Likely	Impact to asset shoreline for a given planning timeframe is likely	50-90%
Possible	Impact to asset shoreline for a given planning timeframe is possible	10-50%
Unlikely	Impact to asset shoreline for a given planning timeframe is unlikely	1-10%
Rare	May occur in exceptional circumstances	<1%

3.1 Exposure / Likelihood

The exposure/likelihood of identified assets represents the likelihood of coastal hazards impacting on an asset. That is, the chance of erosion and / or storm surge inundation impacting on existing and future assets and their values (WAPC, 2019). The likelihood scale adopted for this study is presented in Table 11.

Over the years, there has been significant variation in defining the likelihood ratings based on coastal hazard assessment outcomes. The erosion hazard lines (Water Technology, 2021 and Cardno, 2019) were developed based on a number of components, each of which has its own assumptions and degree of uncertainty. For instance, the assessment of S1 erosion risk has considered a few different likelihood storm events which, by themselves, represent their likelihood of occurrence, however such occurrences change over the different planning timeframes. Likelihood of SLR and historic shoreline movement are very difficult to define quantitatively by scientific terms. It is therefore important to adopt a straight-forward approach to transfer the information presented in the coastal hazard maps into likelihood of impact to assets.

Through internal discussion and review, Water Technology has adopted the approach recommended by WAPC (2019) as demonstrated in Figure 21 below for the likelihood of erosion hazard. The likelihood of the current study for erosion is thereby determined by the Table 13.

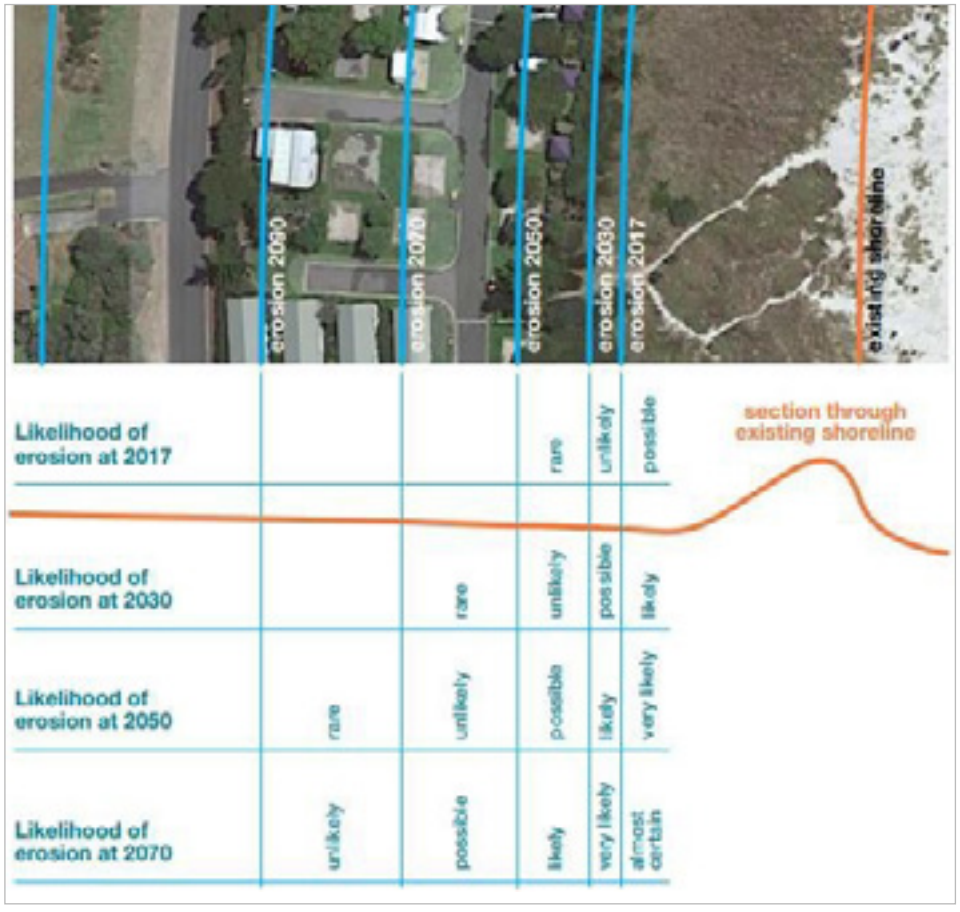


Figure 21: Example of likelihood rating based on erosion hazard lines (adapted from WAPC, 2019)

For the purposes of the inundation assessment, a combination of the 20-year, 100-year and 500-year ARI inundation scenarios was applied. Table 12 presents the probability of each of these events occurring over the planning timeframe. By applying the definitions of the likelihood scale of Table 13, the likelihood of inundation for the current study is presented in Table 14. For each affected asset, the likelihood of all three events was applied to each asset, and the "worst" for each planning timeframe selected for the vulnerability / risk assessment. The inundation likelihood was calculated in this way in particular due to the real risk of inundation for Lancelin. The 20-year ARI event has a much higher likelihood of occurring over the planning timeframe for example (essentially 100% chance of occurring), and this should be accounted for in the risk assessment.

Table 12: Inundation event probabilities over planning timeframes

PROBABILITY	TIMEFRAME			
	PRESENT DAY	2040	2070	2120
20-year ARI	5%	64%	92%	99%
100-year ARI	1%	18%	39.5%	63%
500-year ARI	0.2%	4%	9.5%	18%

Calculation of the probabilities behind the likelihood ratings is extremely complex and simplification is necessary in order to carry out the vulnerability and risk assessments. Any adaptation measures will consider applying triggers before implementation which reduces the risk of this simplification process. For example, a trigger might be reached by an inundation event with certain consequences occurring twice in a given year.

Table 13: Exposure / Likelihood of coastal erosion hazards across the planning timeframe

LIKELIHOOD RATING	LIKELIHOOD OF EROSION					
	2020	2030	2050	2070	2090	2120
HSD-2020	3 - Possible	4 - Likely	5 - Almost Certain	5 - Almost Certain	5 - Almost Certain	5 - Almost Certain
2020-2030	2 - Unlikely	3 - Possible	4 - Likely	5 - Almost Certain	5 - Almost Certain	5 - Almost Certain
2030-2050	1 - Rare	2 - Unlikely	3 - Possible	4 - Likely	5 - Almost Certain	5 - Almost Certain
2050-2070	1 - Rare	1 - Rare	2 - Unlikely	3 - Possible	4 - Likely	5 - Almost Certain
2070-2090	1 - Rare	1 - Rare	1 - Rare	2 - Unlikely	3 - Possible	4 - Likely
2090-2120	1 - Rare	1 - Rare	1 - Rare	1 - Rare	2 - Unlikely	3 - Possible
Beyond 2120	Not assessed					

Table 14: Exposure/likelihood of Inundation hazards across the planning timeframes

TIMEFRAME	PRESENT DAY	2040	2070	2120
20-year ARI Inundation Event	2 - Unlikely	4 - Likely	5 - Almost Certain	5 - Almost Certain
100-year ARI Inundation Event	1 - Rare	3 - Possible	3 - Possible	4 - Likely
500-year ARI Inundation Event	1 - Rare	2 - Unlikely	2 - Unlikely	3 - Possible

3.2 Sensitivity/Consequence

The sensitivity/consequence is an asset's responsiveness to a coastal hazard. This could be a gradual response or a stepped change in response to discrete events (WAPC, 2019). The sensitivity can be applied to the asset itself, or to the asset's function and the criticality of the service it provides (CoastAdapt, 2017). For example, the inundation of a road leading into town would be highly sensitive as this would cut off access to the town.

The consequence ranking presented in Table 15 constitutes the physical impact of the event to the asset, as well as that of the values attributed to it by the success criteria defined earlier in the study. The second column of Table 15 considers the physical impact; columns 3 and 4 refers to potential impact to environmental or community and cultural values and safety of the ommunity.

Table 15: Sensitivity / Consequence ranking

CONSEQUENCE LEVEL	PHYSICAL, ECONOMIC	ENVIRONMENT	COMMUNITY, CULTURE & SAFETY
1 – Insignificant	Minor damage requiring increased maintenance	Negligible to no impact to flora and fauna	Minor instances in which the asset is unable to maintain its services. Short-term inconvenience, <5% community affected
2 – Minor	Damage to assets resulting in restrictions in capability, financial loss of $10,000 to $100,000	Short term loss of flora and fauna. Recovery will be strong	Isolated but noticeable examples of disruption in asset function; <10% community affected
3 – Moderate	Damage to assets resulting in isolated loss of capability, financial loss of $100,000 to $2 million	Medium term loss of flora and fauna. Recovery is likely	General appreciable decline in assets & their function; <25% of community affected
4 – Major	Significant damage to many assets resulting in very limited capability, financial loss of $2 million to $10 million	Long-term damage to flora and fauna. Limited chance of recovery	Severe decline in asset services and corresponding quality of life within the community; <50% of community affected
5 – Catastrophic	Significant damage to most assets resulting in loss of capability, financial loss of over $10 million	Permanent damage to flora and fauna. No chance of recovery	Asset services failure; no chance of repair; >75% of community affected. Long term permanent loss of services

The economic costs associated with the various consequences have been included qualitatively in column 2, however they are assessed in more detail in the cost benefit analysis as part of the adaptation options assessment component (Section 6).

For each hazard, the consequence is assessed against the criteria qualitatively, based on experience of the impacts of coastal erosion and inundation, and the examples presented in the consequence scale.

3.3 Potential Impact (Level of Risk)

Risk level, or potential impact, is calculated as the product of exposure and sensitivity (see Table 16). It provides a classification of the potential impact of coastal hazards on identified assets, which should be determined for each considered planning timeframes. Level of risk is evaluated mainly based on its tolerability (i.e., consequence). Definitions are provided in Table 17.

Table 16: Risk Level (Potential Impact) Matrix as Product of Sensitivity (Consequence) and Exposure (Likelihood)

SENSITIVITY / CONSEQUENCE	EXPOSURE / LIKLIHOOD				
	1 - RARE	2 - UNLIKELY	3 -POSSIBLE	4 - LIKELY	5 - ALMOST CERTAIN
1 - Insignificant	Low	Low	Low	Low	Low
2 - Minor	Low	Low	Low	Medium	Medium
3 - Moderate	Low	Medium	Medium	High	High
4 - Major	Medium	Medium	High	Extreme	Extreme
5 - Catastrophic	Medium	High	Extreme	Extreme	Extreme

Table 17: Risk profile definition

LIKELIHOOD RATING	DESCRIPTION
Low	Tolerable risk. A level of risk that is low and manageable without intervention outside routine asset maintenance.
Medium	A level of risk that may require intervention to mitigate, such as changes to design standards or asset maintenance. Short to medium term action required.
High	A level of risk requiring significant intervention to mitigate in the immediate to short term.
Extreme	Immediate action required to reduce risk to acceptable levels

3.4 Adaptive Capacity

The adaptive capacity is the asset's ability to adjust/adapt to the identified hazard. It is determined based on the potential for the system to be modified to cope with the impacts from coastal hazards. Assets with high adaptive capacity can easily be adapted or one that has some capacity to self-adapt with changing conditions. For instance, beach and dune systems often have higher adaptive capacity than coastal infrastructure and residential land. The scale of adaptive capacity is provided in Table 18. Rating of adaptive capacity is determined by assets/asset groups as well as opinions from the stakeholders and communities.

Table 18: Adaptive capacity

ADAPTIVE CAPACITY	DESCRIPTION
1 - No adaptation required	Potential impact has insignificant effect on asset. Controls are re-established naturally or with ease before more damage would likely occur.
2 - Low	Little or no adaptive capacity. Potential impact would destroy all functionality. Redesign required.
3 - Medium	Small amount of adaptive capacity. Difficult but possible to restore functionality through repair and redesign.
4 - High	Decent adaptive capacity. Functionality can be restored, although additional adaptive measures should still be considered. Natural adaptive capacity restored slowly over time under average conditions
5 - Very High	Good adaptive capacity. Functionality restored easily. Adaptive systems restored at a relatively low cost or naturally over time.

3.5 Vulnerability

Vulnerability is calculated as the product of potential impact (risk level) and the adaptive capacity of an asset (Figure 19 (Figure 22). As per WAPC (2019), four levels of vulnerability are considered in this study which should be assessed for each of the planning timeframes considered by this CHRMAP - Very High, High, Medium and Low.



Figure 22: Vulnerability relationship

Applying the described methodology, assets in all four towns are identified and categorised in the sections below. Exposure level is rated as AC (Almost Certain), L (Likely), P (Possible), U (Unlikely) and R (Rare). Sensitivity is rated as IN (Insignificant), MI (Minor), MO (Moderate), MA (Major) and CA (Catastrophic). Risk / potential impact are rated as EX (extreme), HI (High), ME (Medium) and LO (Low) and vulnerability is rated as as VH (very high), HI (High), MO (Moderate) and LO (Low).

Table 19: Risk Level (Potential Impact) combined with Adaptive Capacity to produce a Matrix of Vulnerability

	ADAPTIVE CAPACITY			
RISK LEVEL	VERY HIGH	HIGH	MODERATE	LOW
LOW	Low	Low	Moderate	Moderate
MEDIUM	Low	Moderate	Moderate	High
HIGH	Moderate	Moderate	High	Very High
EXTREME	Moderate	High	Very High	Very High

An asset with Very High Vulnerability requires adpatation, as the risk is considered intolerable due to its high or extreme risk level and low or moderate adaptive capacity.

An asset with High vulnerability requires adpatation, unless all stakeholders are aware of and willing to accept the risks.

An ssset with Moderate vulnerability may require adaptation, but should certainly be monitored for potential increase to vulnerability.

An asset with Low vulnerability is unlikely to cause impact and is tolerable, although monitoring should be undertaken and adaptation measures may need to be introdiced at a later time.

3.6 Guilderton

Table 20 and Table 21 present the assets predicted to be vulnerable to coastal hazards in Guilderton, as well as their vulnerability / risk level rating. For reference, the predicted erosion hazard lines and inundation extents are presented in Figure 23 and Figure 24 respectively. The asset assignment from LPS 9 is depicted in Figure 25.

3.6.1 Vulnerability to Erosion

Assets under erosion risk at Guilderton:

- Residential land on Gordon Street between Mortimer Street and Anderson Street. Adaptive capacity of residential land to erosion is low. The estimated vulnerability to erosion is high until 2070 and extreme beyond the 50-years planning period.
- Future Development Area. As discussed in Section 2, part of the planned future development area is currently located in Moore River.
- Parks and Recreation areas along both the open coast and the Moore River. These parks and recreation areas correspond to the beach, dune and riverbank which are particularly vulnerable for future climate change. It also includes the informal access road down to Guilderton North Groyne.
- The foreshore area adjacent to the rivers is classified as a Special Control Area labelled “River Environs Management Area”. This area is also under erosion risk.
- Roads adjacent to Moore River e.g., Whitfield Street, Silver Creek Road, Guilderton Road, Mill Road, Moore River Drive. Some sections (e.g., Guilderton Road) are located directly against the low-lying bush lands, for which a site-specific detailed assessment of erosion risk may be required to further investigate and mitigate the erosion risk. This will be listed as an action in the Implementation Plan in the CHRMAP 2023.

3.6.2 Vulnerability to Inundation

Assets under inundation risk at Guilderton:

- Future Development Area. As discussed in Section 2, part of the planned future development area is currently located in Moore River.
- Parks and Recreation areas (mainly beach) and River Management Area along the open coast and along the banks of Moore River. This includes the public foreshore area, car park, boat ramp and finger jetty, although only predicted to be minimally inundated. The remainder of the inundated areas correspond to low-lying bushland adjacent to the riverbanks.
- Whilst Guildford Road itself is not in the inundation hazard zone, the road reserve as defined by LPS 9 is predicted to be inundated, and could be vulnerable to coastal inundation in the 50 to 100-years period.

Table 20: Guilderton Erosion Vulnerability Assessment: Likelihood (exposure), Sensitivity (Consequence), Risk (potential Impact), Adaptive Capacity and Vulnerability

ASSET (ZONE)	EROSION EXPOSURE (AC, L, P, U, R)						SENSITIVITY (IN, MI, MO, MA, CA)				EROSION RISK LEVEL (LO, ME, HI,EX)						ADAPTIVE CAPACITY	EROSION VULNERABILITY (VH, HI, MO, LO)					
	2020	2030	2050	2070	2090	2120	SOCIAL & CULTURAL	ENVIRON-MENTAL	ECON-OMIC	OVER-ALL	2020	2030	2050	2070	2090	2120		2020	2030	2050	2070	2090	2120
River Manage-ment Area	AC	AC	AC	AC	AC	AC	MI	MO	MI	MO	HI	HI	HI	HI	HI	HI	MO	HI	HI	HI	HI	HI	HI
Future develop-ment	AC	AC	AC	AC	AC	AC	IN	IN	IN	IN	LO	LO	LO	LO	LO	LO	VH	LO	LO	LO	LO	LO	LO
General rural							MO	MA	MO	MA							HI						
Parks and recreation	AC	AC	AC	AC	AC	AC	MO	MA	MO	MA	EX	EX	EX	EX	EX	EX	MO	VH	VH	VH	VH	VH	VH
Public use							MA	MO	MA	MA							LO						
Residential	R	R	R	U	P	L	MO	MI	MA	MA	ME	ME	ME	ME	HI	EX	LO	HI	HI	HI	HI	VH	VH
Roads	AC	AC	AC	AC	AC	AC	MA	MI	MA	MA	EX	EX	EX	EX	EX	EX	LO	VH	VH	VH	VH	VH	VH
Tourism							MO	MI	MA	MA							MO						
Town centre							CA	MI	CA	CA							LO						

Almost Certain (AC)
Likely (L)
Possible (P)
Unlikely (U)
Rare (R)

Insignificant (IN)
Minor (MI)
Moderate (MO)
Major (MA)
Catastrophic (CA)

Extreme (EX)
High (HI)
Medium (ME)
Low (LO)

Very High (VH)
High (HI)
Moderate (MO)
Low (LO)

Table 21: Guilderton Inundation Vulnerability Assessment: Likelihood (exposure), Sensitivity (Consequence), Risk (potential Impact), Adaptive Capacity and Vulnerability

ASSET (ZONE)	INUNDATION EXPOSURE (AC, L, P, U, R)				SENSITIVITY (IN, MI, MO, MA, CA)				INUNDATION RISK LEVEL (LO, ME, HI,EX)				ADAPTIVE CAPACITY	INUNDATION VULNERABILITY (VH, HI, MO, LO)			
	2020	2040	2070	2120	SOCIAL & CULTURAL	ENVIRON-MENTAL	ECON-OMIC	OVER-ALL	2020	2040	2070	2120		2020	2040	2070	2120
River Management Area	U	P	AC	AC	MI	MI	MI	MI	LO	LO	ME	ME	HI	LO	LO	ME	ME
Future development	AC	AC	AC	AC	IN	IN	IN	IN	LO	LO	LO	LO	VH	LO	LO	LO	LO
General rural					MI	MI	MO	MO					HI				
Parks and recreation	U	P	AC	AC	MI	MI	MI	MI	LO	LO	ME	ME	HI	LO	LO	ME	ME
Public use					MO	MO	MA	MA					MO				
Residential					MO	MO	MA	MA					MO				
Roads				R	MA	MO	MA	MA				ME	MO				ME
Tourism					MO	MO	MO	MO					MO				
Town centre					MA	MO	MA	MA					MO				

Almost Certain (AC)
Likely (L)
Possible (P)
Unlikely (U)
Rare (R)

Insignificant (IN)
Minor (MI)
Moderate (MO)
Major (MA)
Catastrophic (CA)

Extreme (EX)
High (HI)
Medium (ME)
Low (LO)

Very High (VH)
High (HI)
Moderate (MO)
Low (LO)



Figure 23: Guilderton Erosion Hazard Map (see also Figure 18 and Appendix C)



Figure 24: Guilderton Inundation Hazard Map (500 yrs. ARI, 2120) (see also Figure 19 and Appendix C)



Figure 25: Guilderton Coastal Assets and Asset Type

3.7 Lancelin

Table 22 presents the assets predicted to be vulnerable to coastal inundation in Lancelin, as well as their vulnerability / risk level rating. For reference, the predicted inundation extents for the 500-year ARI for 2120 is reproduced from Baird (2020) in Figure 26. The asset assignment from LPS 9 is depicted in Figure 27.

3.7.1 Vulnerability to Erosion

Refer to Cardno (2019).

3.7.2 Vulnerability to Inundation

The majority of the Lancelin township is at risk of inundation; all asset groups with the exception of General Rural are predicted to have individual assets inundated. The vulnerability of assets commences in the present day and increases over the 100-year planning period.

- The environmental conservation area – dune vegetation west of Casserley Way, has a high inundation vulnerability rating by 2120. From present day there is a medium risk for part of this area.
- The Mixed Business area is predicted to have a high risk by 2120.
- Public purposes/use areas mainly cover services and infrastructure, but also include health services, Shire land, school and aged accommodation. These have an extreme rating by 2120.
- Residential, Roads, Special Use and Town Centre all have an extreme rating by 2120.

Table 22: Lancelin Inundation Vulnerability Assessment: Likelihood (exposure), Sensitivity (Consequence), Risk (potential Impact), Adaptive Capacity and Vulnerability

ASSET (ZONE)	INUNDATION EXPOSURE (AC, L, P, U, R)				SENSITIVITY (IN, MI, MO, MA, CA)				INUNDATION RISK LEVEL (LO, ME, HI,EX)				ADAPTIVE CAPACITY	INUNDATION VULNERABILITY (VH, HI, MO, LO)			
	2020	2040	2070	2120	SOCIAL & CULTURAL	ENVIRON-MENTAL	ECON-OMIC	OVER-ALL	2020	2040	2070	2120		2020	2040	2070	2120
Environmental conservation	R	P	P	AC	MO	MO	MO	MO	LO	ME	ME	HI	MO	ME	ME	ME	HI
General rural					MI	MI	MO	MO					HI				
Mixed business				P	MO	MO	MA	MA				HI	MO				HI
Parks and recreation	U	L	AC	AC	MI	MI	MI	MI	LO	ME	ME	ME	HI	LO	ME	ME	ME
Public purposes/use	R	P	P	AC	MO	MO	MA	MA	ME	HI	HI	EX	MO	ME	HI	HI	VH
Residential	R	P	P	AC	MO	MA	MO	MA	ME	HI	HI	EX	MO	ME	HI	HI	VH
Roads	U	L	AC	AC	MA	MO	MA	MA	ME	EX	EX	EX	MO	ME	VH	VH	VH
Special use	R	U	U	AC	MO	MA	MO	MA	ME	ME	ME	EX	MO	ME	ME	ME	VH
Tourism	U	L	AC	AC	MO	MO	MO	MO	ME	HI	HI	HI	MO	ME	HI	HI	HI
Town centre	R	U	P	AC	MO	MA	MA	MA	ME	ME	HI	EX	MO	ME	ME	HI	VH

Almost Certain (AC)
Likely (L)
Possible (P)
Unlikely (U)
Rare (R)

Insignificant (IN)
Minor (MI)
Moderate (MO)
Major (MA)
Catastrophic (CA)

Extreme (EX)
High (HI)
Medium (ME)
Low (LO)

Very High (VH)
High (HI)
Moderate (MO)
Low (LO)

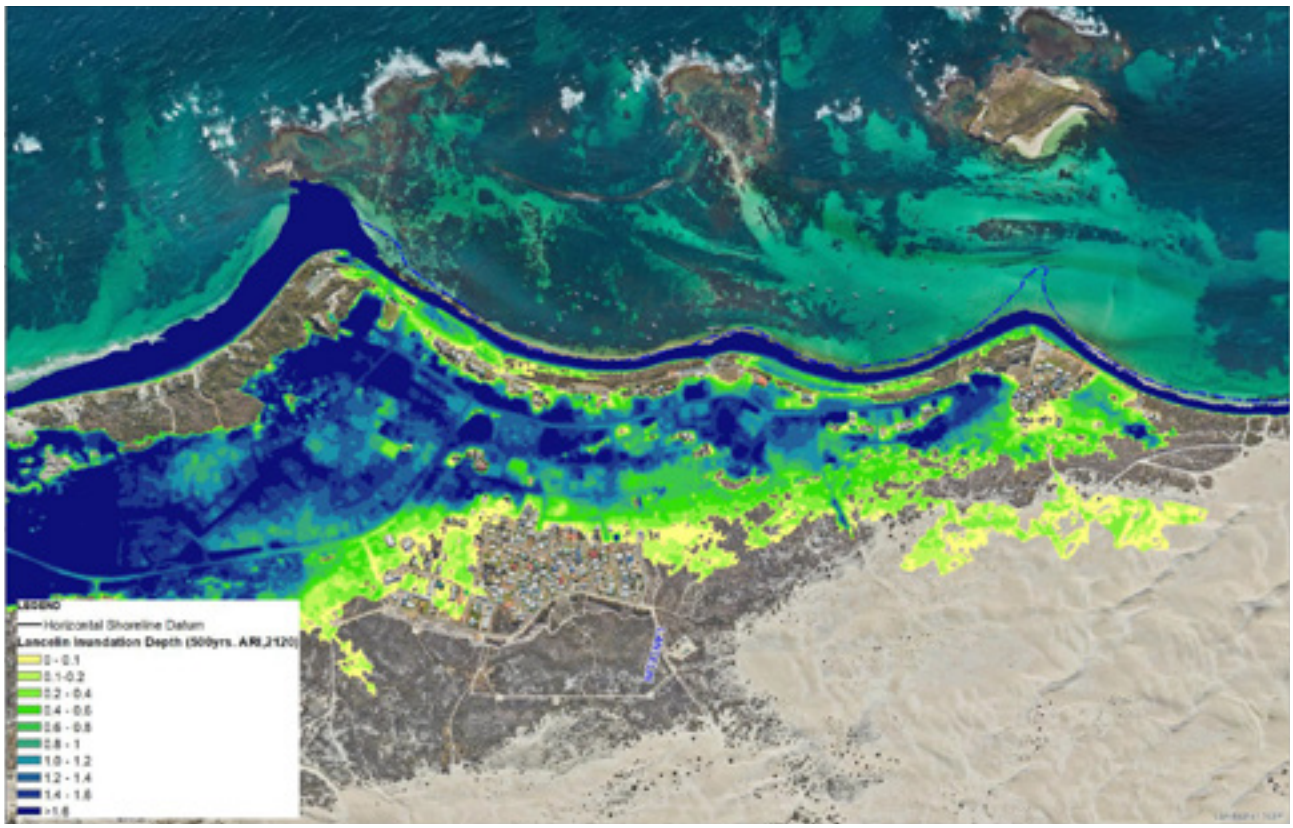


Figure 26: Predicted inundation for Lancelin: 500-year ARI, 2120 (adapted from Baird, 2020)



Figure 27: Lancelin Coastal Assets and Asset Type

3.8 Ledge Point

Table 23 presents the assets predicted to be vulnerable to coastal inundation in Ledge Point, as well as their vulnerability / risk level rating. For reference, the predicted inundation extents for the 500-year ARI for 2120 is reproduced from Baird (2020) in Figure 28. The asset assignment from LPS9 is depicted in Figure 29.

3.8.1 Vulnerability to Erosion

Refer to Cardno (2019).

3.8.2 Vulnerability to Inundation

Assets under inundation risk at Ledge Point:

- Parks and recreation lands adjacent to the beach are vulnerable to inundation hazard, including dune vegetation.
- Beach access points at Jones Street, De Burgh Street and seaward of Robertson Road are predicted to be inundated at their most seaward extents.

Six residential properties along De Burgh Street are immediately adjacent to the inundation hazard zone, however, are not predicted to be inundated.

At Ledge Point, the extent of coastal erosion is greater than the risk of inundation. Adaptation options should be developed focussing on erosion rather than inundation hazard of the shoreline.

Table 23: Ledge Point Inundation Vulnerability Assessment: Likelihood (exposure), Sensitivity (Consequence), Risk (potential Impact), Adaptive Capacity and Vulnerability

ASSET (ZONE)	INUNDATION EXPOSURE (AC, L, P, U, R)				SENSITIVITY (IN, MI, MO, MA, CA)				INUNDATION RISK LEVEL (LO, ME, HI,EX)				ADAPTIVE CAPACITY	INUNDATION VULNERABILITY (VH, HI, MO, LO)			
	2020	2040	2070	2120	SOCIAL & CULTURAL	ENVIRON-MENTAL	ECON-OMIC	OVER-ALL	2020	2040	2070	2120		2020	2040	2070	2120
General rural					MI	MI	MO	MO					HI				
Mixed Business					MO	MO	MA	MA					MO				
Parks and recreation		R	U	U	MI	MI	MI	MI		LO	LO	LO	HI		LO	LO	LO
Public use					MO	MO	MA	MA					MO				
Residential					MO	MO	MA	MA					MO				
Roads					MA	MO	MA	MA					MO				
Special use					MO	MO	MO	MO					MO				
Tourism					MO	MO	MO	MO					MO				
Town centre					MA	MO	MA	MA					MO				

Almost Certain (AC)
Likely (L)
Possible (P)
Unlikely (U)
Rare (R)

Insignificant (IN)
Minor (MI)
Moderate (MO)
Major (MA)
Catastrophic (CA)

Extreme (EX)
High (HI)
Medium (ME)
Low (LO)

Very High (VH)
High (HI)
Moderate (MO)
Low (LO)



Figure 28: Predicted inundation for Ledge Point: 500-year ARI, 2120 (adapted from Baird, 2020)

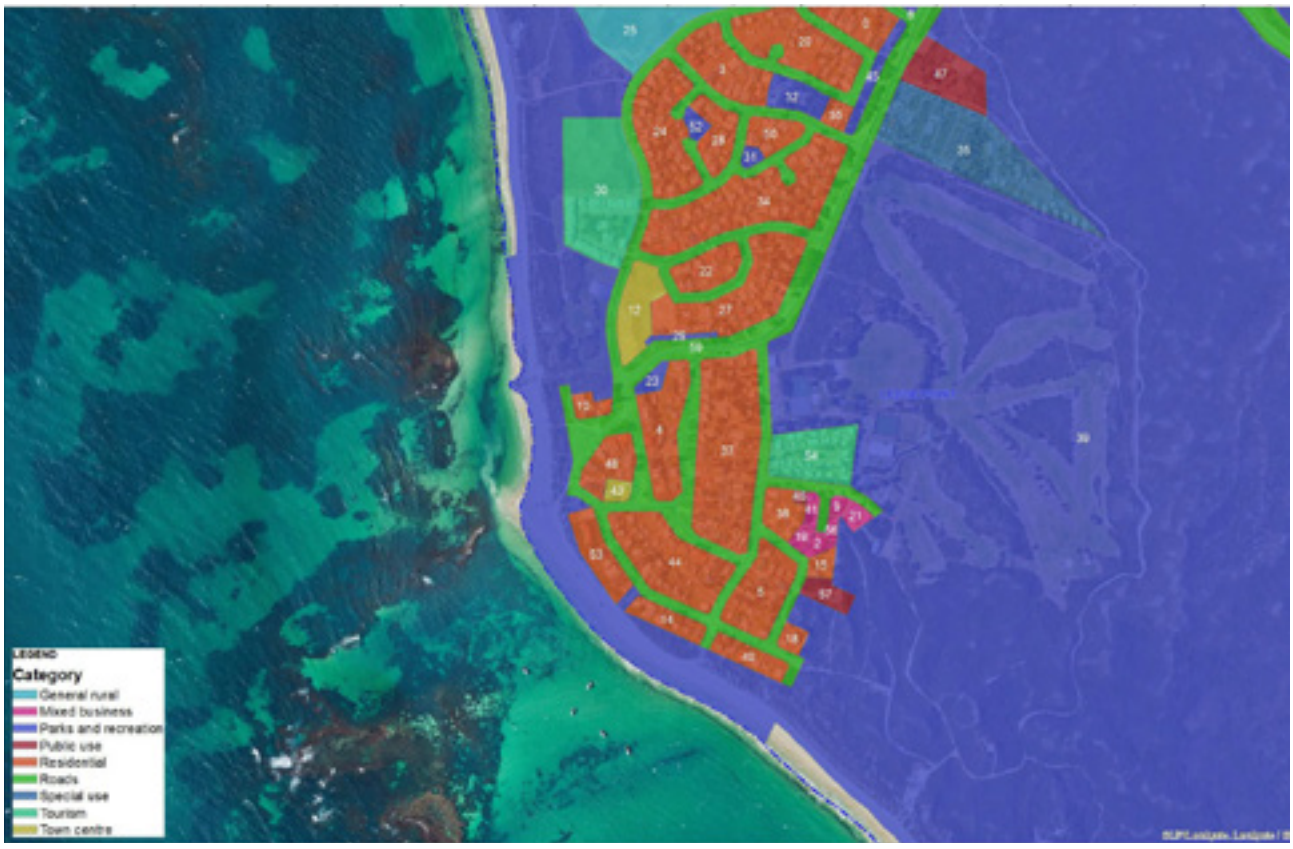


Figure 29: Ledge Point: Coastal Assets and Asset Type

3.9 Seabird

Table 24 presents the assets predicted to be vulnerable to coastal inundation in Seabird, as well as their vulnerability / risk level rating. For reference, the predicted inundation extents for the 500-year Average Recurrence Interval (ARI) for 2120 is reproduced from Baird (2020) in Figure 30. The asset assignment from LPS9 is depicted in Figure 31.

3.9.1 Vulnerability to Erosion

Refer to Cardno (2019).

3.9.2 Vulnerability to Inundation

Assets under inundation risk at Seabird:

- Parks and recreation lands adjacent to the beach are vulnerable to inundation hazard, including the rehabilitated dune above the seawall.
- The end of the retreated Turner Street is located in the close vicinity of the existing seawall which is vulnerable to future inundation

This is flagged purely to ensure LPS 9 is updated to reflect the removal of Turner Street – currently this is still shown.

At Seabird, the extent of coastal erosion is much greater than the risk of inundation. Adaptation options should be developed focussing on erosion rather than inundation hazard of the shoreline.

Table 24: Seabird Inundation Vulnerability Assessment: Likelihood (exposure), Sensitivity (Consequence), Risk (potential Impact), Adaptive Capacity and Vulnerability

ASSET (ZONE)	INUNDATION EXPOSURE (AC, L, P, U, R)				SENSITIVITY (IN, MI, MO, MA, CA)				INUNDATION RISK LEVEL (LO, ME, HI,EX)				ADAPTIVE CAPACITY	INUNDATION VULNERABILITY (VH, HI, MO, LO)			
	2020	2040	2070	2120	SOCIAL & CULTURAL	ENVIRON-MENTAL	ECON-OMIC	OVER-ALL	2020	2040	2070	2120		2020	2040	2070	2120
General rural					MI	MI	MO	MO					HI				
Parks and recreation		R	U	U	MI	MI	MI	MI		LO	LO	LO	HI		LO	LO	LO
Public use					MO	MO	MA	MA					MO				
Residential					MO	MO	MA	MA					MO				
Roads				R	MA	MO	MA	MA				ME	MO				ME
Tourism					MO	MO	MO	MO					MO				
Town centre					MA	MO	MA	MA					MO				

Almost Certain (AC)
Likely (L)
Possible (P)
Unlikely (U)
Rare (R)

Insignificant (IN)
Minor (MI)
Moderate (MO)
Major (MA)
Catastrophic (CA)

Extreme (EX)
High (HI)
Medium (ME)
Low (LO)

Very High (VH)
High (HI)
Moderate (MO)
Low (LO)



Figure 30: Predicted inundation for Ledge Point: 500-year ARI, 2120 (adapted from Baird, 2020)



Figure 31: Ledge Point: Coastal Assets and Asset Type

SECTION 4. RISK EVALUATION

4. RISK EVALUATION

This section assesses available controls that may change the vulnerability rating assigned in Section 3. The erosion assessment considered in Cardno (2019) assigned relevant controls and the review of the assessments is still correct. As such, an assessment of physical controls for Seabird, Ledge Point and Lancelin in this report relates to inundation only. As in Section 3, Guilderton is considered first.

4.1 Planning Controls – All Towns

A summary of relevant planning controls for the study area is provided in Table 25. These controls will be applied / amended during the course of this CHRMAP. The controls apply to any new development within the study area and coastal hazard zones. However, as existing development is currently situated within the coastal hazard zones, these planning controls do not change the vulnerability ratings assigned in Section 3.

4.2 Guilderton

The existing physical controls at Guilderton from a coastal management perspective are the Guilderton North groyne, Guilderton Holiday Park seawall, boat ramps/ landing facilities and current management activities. Where appropriate, these have already been included in the vulnerability assessment. As such, the results remain the same for Guilderton

The bar at the Moore River mouth acts as a control for inundation, however this does not change the vulnerability / risk assessment results as it is a transient control.

4.3 Lancelin

The present-day coastal dune acts as an inundation control for Lancelin. Breaching of this dune has been included in the inundation assessment and, correspondingly the vulnerability assessment. As such, the results remain the same for Lancelin.

4.4 Ledge Point

There are no physical inundation controls in Ledge Point. As such, the results remain the same for Ledge Point.

4.5 Seabird

There are no physical inundation controls in Seabird, noting the existing seawall does not provide any additional inundation control. As such, the results remain the same for Seabird.

4.6 Summary

No changes to the vulnerability results are required: vulnerability results become risk assessment results.

Table 25: Relevant Planning Controls

CONTROL	PRESCRIBED DOCUMENT	COMMENTS
LOCAL PLANNING SCHEME NO.9 (LPS 9)		
Clause 5.2.3 (b) - For those areas within the River Environs Management Area where the Department of Water has identified the flood plain boundary, development will be subject to a minimum habitable floor level of 0.5m above the predicted 1 in 100-year flood level.	LPS 9 SCA 1 – River Environs Management Area	Applies to Guilderton
Clause 5.2.2 - Development approval is required to construct or extend a dwelling or other building, and/or to carry out any other form of development on any land affected by this Special Control Area	LPS 9 SCA 1 – River Environs Management Area	Applies to Guilderton
4.7.4.1 - All coastal development is to comply with the provisions of State Planning Policy 2.6 - State Coastal Planning Policy. 4.7.4.2 - In accordance with section 77(1)(b) of the Planning and Development Act 2005, the provisions of State Planning Policy 2.6 - State Coastal Planning shall apply as if they were part of this Scheme.	LPS 9	SPP 2.6 applies as if it were a part of the scheme This applies to all towns in the study area
Schedule 11 – Tourism Conditions Lot 2 Breton Bay, Seabird – subdivision and development to be in accordance with a structure plan which should provide for, inter alia, protection of environmental values and attributes by ensuring the location, density, scale and nature of all development has regard for the landscape and environmental values of the area, including coastal processes.	LPS 9	Applies to Seabird
LOCAL PLANNING STRATEGY		
All Towns: • Coastal erosion, impact of climate change and sea level rise • Protection/rehabilitation of coastal dune systems Guilderton: • Protection/rehabilitation of coastal dune and Moore River inlet system	Local Planning Strategy, Key Issues Summary 2.3.7.	General advice regarding protection of environmental values
2011 Dept of Planning study - The Coast of the Shires of Gingin and Dandaragan, Western Australia: Geology, Geomorphology and Vulnerability assesses most of the Shire's coast as a low, low to moderate or moderate level of vulnerability to change. The most vulnerable sections of coast were identified as Manakoora Sand Patch and the coast immediately north of Lancelin Island (moderate to high landform vulnerability).	Local Planning Strategy, 2.6.7 Coast	Update required when Shire prepares its next strategy to reflect integrated CHRMAP findings

Table 25: Relevant Planning Controls (Cont'd)

CONTROL	PRESCRIBED DOCUMENT	COMMENTS
LOCAL PLANNING POLICY		
3.1 All structures should be constructed behind the primary dune 3.2 The Council will use a combination of Reservations, zonings and discretion with regard to applications for development 3.4 Unless Council approves otherwise in a particular case a two-storey height limit will apply to all building within this area	Local Planning Policy Statement 1.2 (LPP 1.2) Foreshore Protection Areas	This applies to all towns in the study area Provides general development guidelines including setbacks, building height, pedestrian access and parking in areas where development is permitted in the Foreshore Area
3.1 With the exception of land that has an existing foreshore reserve with a minimum width of 30 metres from the water course, the building line for all development adjacent to a water course shall be 50 metres measured from the top of the bank of the water course 3.3 In the case of rezoning, the Applicant will be required to undertake appropriate scientific investigation to determine the biophysical setback. The determined biophysical setback is to be then included as a Special Control Area No. 1 in the Scheme	LPP 1.4 Foreshore Reserves along Water Courses	This applies to all towns in the study area Protects the margins and foreshores of water courses from future development
MODEL SUBDIVISION CONDITIONS, WESTERN AUSTRALIAN PLANNING COMMISSION		
A notification, pursuant to Section 165A of the Planning and Development Act 2005 is to be placed on the certificate(s) of title of the proposed lot(s). Notice of this notification is to be included on the diagram or plan of survey (deposited plan). The notification is to state as follows: "This lot is located in an area likely to be subject to coastal erosion and/or inundation over the next 100 years from the date this notification is registered." (Western Australian Planning Commission) Situation - If land is proximate to a future coastal hazard as determined in accordance with State Planning Policy 2.6 State Coastal Planning Policy and an endorsed CHRMAP. A shorter timeframe than 100 years may be appropriate where identified in an endorsed CHRMAP.	Western Australian Planning Commission: Planning and Development Act 2005 s.165, SPP 2.6 State Coastal Planning Policy, Planning Bulletin 3 Notification on Titles (Memorials)	The Shire of Gingin has already utilised this mechanism and has an established process for implementing this control

SECTION 5. RISK TREATMENT

5. RISK TREATMENT

SPP 2.6 provides a hierarchy of adaptation pathways to guide decision making in coastal areas for use by planning authorities and development proponents when considering adaptation options to minimise coastal hazard risks at the local level.

The objectives of SPP 2.6 are to:

- ensure that 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 (WAPC, 2006).

The hierarchy, presented in Figure 32, details risk management categories of 'Avoid', 'Planned/ Managed retreat', 'Accommodate' and 'Protect'. It should be noted that the State Government has no obligation to protect private assets from coastal erosion, with the CHRMAP indicating a clear preference against the adoption of 'Protect' as a long-term adaptation pathway. This preference is in accordance with the policy directive in SPP 2.6, the policy guidelines, the CHRMAP Guidelines and the WA Coastal Zone Strategy.

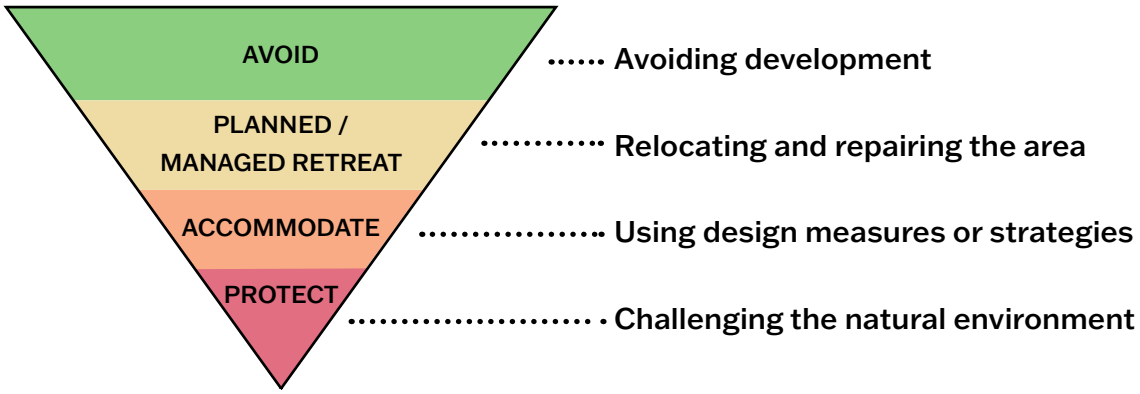


Figure 32: Coastal risk adaptation planning hierarchy adapted from SPP 2.6 (WAPC, 2013a)

Generally, as risk treatment options are selected further down this hierarchy (from avoiding areas with risk to protecting development from those risks), future risk management opportunities will diminish. As such, avoiding the placement of sensitive development within areas that are at risk from coastal hazards provides the most resilience to future risk arising from coastal hazards (WAPC, 2019). Conversely, using protection structures to allow sensitive development within areas that would otherwise be at risk from coastal hazards reduces the flexibility of future decision-makers to address risk arising from coastal hazard (WAPC, 2019).

Further to the risk management and adaptation hierarchy identified in SPP 2.6 and Figure 32, No Regrets and Do Nothing are two risk treatment options that are relevant to the CHRMAP process and have been considered in the risk treatment assessment.

5.1 Avoid



This option aims to avoid the construction of new public and private assets within areas identified to be affected by coastal hazards. The project lifetime of a new asset should be a key consideration in deciding the suitability of locating new assets in coastal hazard areas. For example, the construction of new public assets, such as picnic facilities and public toilets, should be avoided where these assets are likely to be impacted by coastal hazards within the lifetime of the asset. Similarly, the construction of new private assets which are likely to be affected by coastal hazards over their projected lifetimes should not be permitted. The option of avoid can be applied to manage coastal erosion and inundation hazard risks.

5.2 Planned or Managed Retreat



This option aims to relocate or remove assets which are located in hazard areas, in an orderly manner, where hazard risks are likely to be intolerable over relevant planning timeframes. In recognition of the increased risk to assets in the coastal zone, the Department of Planning, Lands and Heritage (DPLH), together with the Western Australian Planning Commission, provides guidance on how to implement a policy of planned or managed retreat through property acquisitions (WAPC, 2019).

Planned or managed retreat is mostly applicable to developed areas, where there is less potential to adapt to coastal hazards through development planning controls, such as setbacks in Greenfield areas. The strategy of retreat is based on social, environmental and economic sustainability, and ties into the SPP2.6 objectives and adaptation hierarchy. It allows for continuing public access to beaches, beach amenity, and the provision of a coastal foreshore reserve.

The CHRMAP Guidelines (WAPC, 2019) suggest a range of mechanisms for achieving managed retreat in developed areas, using compulsory or voluntary acquisition provisions outlined in state legislation. Alternatively, planned or managed retreat can be achieved through the early acquisition and leaseback of private property. This alternative can help to reduce overall implementation costs.

Planned or managed retreat is an option that can be applied to manage coastal erosion and inundation hazards; however, this option requires a significant investment of public resources to fund acquisitions. From a practical perspective, implementation of managed retreat may require the State or Commonwealth to provide the majority of funding to acquire property. Funding programs offered at the State level do not currently provide amounts which facilitate property acquisitions, and there has been no indication to date that this situation will change in the near future. Therefore, landholders and the broader public should be aware of the risks in any decisions they make about purchasing or developing lands in coastal areas.



5.3 Accommodate

This option aims to utilise design and management strategies which render the risks from identified coastal hazards as acceptable. Design and management strategies include: minimum finished floor levels and elevated electrical circuitry, to minimise inundation risks; or, relocatable structures which can be moved to a different location on- or off-site, as shorelines recede, or regular inundation events make the provision of critical services unviable. In this way, the 'Accommodate' option allows landholders to continue to use land until hazard risks become intolerable, while minimising the current and future risk of legal and financial liability for Council.

Accommodate design and management strategies can be facilitated through modifications to local planning frameworks. These modified planning frameworks need to provide clear direction for planning authorities when assessing applications for new development and for affected landholders. Planning frameworks might include the introduction or modification of the following instruments:

- Special control areas, to ensure planning discretion over new development
- Clear development assessment criteria, to ensure that new development gives due regard to coastal processes
- Notifications on title, to inform current and future property owners of hazard risks
- Time or event limited planning permits, to allow the continued use of land until hazards become intolerable

Accommodate is an option that can be applied to help minimise the effect of coastal erosion and inundation hazards on new development and infrastructure. A key concern with the accommodate option, particularly in regard to managing coastal erosion, is that the current State legislative framework means that permanently inundated private land does not become Crown land, unlike in other Australian states (Robb et al 2017, Robb et all 2018). Therefore, where the shoreline is allowed to recede beyond private property boundaries, issues of public access and trespass may arise. This should be a key consideration when assessing the appropriateness of the Accommodate option.

5.4 Protect



This option aims to stabilise the position of the shoreline using hard or soft coastal protection measures such as seawalls, groynes, offshore breakwaters, geotextile sand-containers, sand renourishment and levee banks. Protection is an option that can be applied to manage coastal erosion and inundation hazards.

The adaptation hierarchy considers the construction of new protection measures as the least preferred option of all potential options listed in the hierarchy. Protection measures, particularly hard measures such as rock groynes and seawalls, interfere with local coastal processes and can have detrimental effects on local ecological systems. Protection measures can also inflate property values in hazard areas, create expectations that protection measures will be maintained into the future, and may limit the capacity of future decision makers to change strategies as situations change.

Over the short to medium term, public authorities may need to consider the appropriateness of using interim protection measures to delay shoreline recession. This might be achieved through measures such as geotextile sand containers which can be less costly to remove than rock structures, regular sand renourishment, and revegetating coastal dunes. Where public and private assets are proposed to be constructed inland of interim protection measures, the design life of the protection measure should be a key factor in determining the appropriateness of the proposed asset or development.

5.5 No Regrets

No regrets options cover a period of time where assessments are required or are being undertaken to determine a preferred risk treatment option, prior to implementing specific asset risk management measures. This is particularly pertinent where a more costly or difficult risk treatment option, or better understanding regarding the level of risk to an asset, may be required (WAPC, 2019).

No regret options are cost effective in the current day and provide flexibility for more resilient and appropriate long term management options to respond to coastal hazard risks.

5.6 Do Nothing

This option assumes that all levels of risk are accepted and that no further action will be taken. A Do Nothing option provides the basis for comparison of all other risk treatment options.

A Do Nothing option may also be reflected in reality where the selection of another option (e.g. protect) and the subsequent trade-off considerations are considered unacceptable to the State Government or other funding bodies and is thus not funded. In this case, the selection of an option that is considered unacceptable results in 'nothing happening' despite recommendations in a CHRMAP. This needs to be considered when selecting the most appropriate option to address risk.

5.7 Hierarchy Summary

Maintaining public access to the coast in developed areas is one of the main objectives of SPP 2.6 and identified as a key value of the Shire of Gingin community. As discussed, the current State legislative framework means that where the shoreline recedes beyond private property boundaries, issues of public access and trespass are likely to arise. In this case public authorities have two main adaptation options available to them for preserving public coastal access:

- Planned or Managed Retreat i.e., maintaining a foreshore reserve through public acquisition of private property; or,
- Protect i.e., preventing the shoreline from receding beyond private property boundaries by stabilising the current shoreline position using various protection measures (e.g., rock groynes, offshore breakwaters).

Where public authorities cannot commit to either of these options over the long term, it is likely that public authorities will need to Accommodate, by modifying local planning frameworks to help ensure that new development is appropriately designed and located. Public authorities in this situation may also choose to consider the appropriateness of interim Protection measures to preserve public interests by delaying shoreline recession and minimising the effect of regular nuisance inundation events on existing development and infrastructure.

5.8 Summary for Decision Makers

The points below present a summary of the relevant information for adaptation. It is important to note that there is no law requiring public authorities to provide protection to private property from natural hazards, nor compensation when land is lost due to coastal hazards.

The CHRMAP process aims to minimise coastal hazard risks and maximise beneficial use of the coast.

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



SECTION 6. RISK TREATMENT OPTIONS

6. RISK TREATMENT OPTIONS

6.1 General Options

Table 26 below presents a list of generally available adaptation options suitable for most coastal sites. These relate to both short term and long-term adaptation to coastal hazards in general, not just in relation to planning for climate change impacts. The columns on the right-hand side provide some discussion as to the possibility of the options suitability for the study area and MCA and CBA considerations. Section 7 and Section 8 provide some discussion and selection of these options over the planning timeframe for inundation and erosion.

Whilst the risks and their corresponding adaptation options are assessed separately, triggers to implement the option can be modified to suit the the circumstances at any given point in time, for example, if risks from erosion or inundation are being experienced sooner, a trigger may bring adaptation response forward in time.

Table 26 is adapted from Table 15 in the CHRMAP Guidelines (WAPC, 2019) and Cardno (2019).

Table 26: Available adaptation options (adapted from WAPC, 2019 and Cardno, 2019)

OPTION CATEGORY	OPTION CODE	OPTION NAME	DESCRIPTION	SUITABILITY AND COST CONSIDERATIONS
AVOID	AV	Avoid development	Avoiding new development within the coastal hazard zone and locating assets in areas that will not be vulnerable to coastal hazards	Financial resources will not be required to be spent on risk management
PLANNED OR MANAGED RETREAT	MR1	Leave assets un-protected	Accept loss following hazard event. Only implement repairs to maintain public safety.	Saves financial resources for alternative uses, and allows for retreat that enables natural recession of the shoreline over the long-term
	MR2	Remove / Relocate	Assets located in the hazard zone are permanently removed or relocated.	For residential and commercial property, this option may require voluntary or compulsory acquisition of land, transferrable development rights and land swaps. Enables the social and economic values of assets until such time that the asset needs to be relocated. Can often coincide with asset replacement, and allows the cost of relocation to be shared with the cost of asset replacement. For residential and commercial property, this option may require voluntary or compulsory acquisition of land, transferrable development rights and land swaps
	MR3	Planning controls for managed retreat/ Prohibit expanding existing use rights	Use planning controls to allow continued use of the current infrastructure until such time that impacts arise, but restrict further or new development	This enables existing development and use rights to continue without increasing them, until such time that risk arising from coastal hazards is intolerable. Includes mechanisms for ensuring that the Shire, landowners and prospective buyers are made aware of the risk. Generally applicable where protection of assets is not viable

Table 26: Available adaptation options (adapted from WAPC, 2019 and Cardno, 2019) (Cont'd)

OPTION CATEGORY	OPTION CODE	OPTION NAME	DESCRIPTION	SUITABILITY AND COST CONSIDERATIONS
PLANNED OR MANAGED RETREAT	MR4	Voluntary acquisition	This risk treatment option results in the acquisition of affected properties, on a voluntary basis	This enables removal of private property(s) located within a land use that would otherwise be permitted, to ensure land in the coastal zone is continuously provided for coastal foreshore management, public access, recreation and conservation, and where alternative risk treatment options are not viable for the property and adjacent land. Early acquisition and leaseback could be used as an alternative to help reduce overall costs. May benefit some private landowners more than others
ACCOMM-ODATE	AC1	Design assets to withstand impacts	Design of assets to withstand the impact of inundation, for example, building houses on stilts or raising building pads above the expected inundation levels	This is aimed at retaining existing assets in locations but reducing the consequences of the inundation hazard. It is cheaper to mitigate the impacts with initial design outcomes as opposed to retrofitting (adapting) existing assets in the future
	AC2	Planning controls for accomm-odation	Amend local planning frameworks to require assets to be designed to be able to accommodate hazards	Indicates to current and future landholders that an asset is at risk from coastal hazards over the planning timeframe. and that risk management and adaptation is likely to be required at some stage. Helps owners to make informed decisions about the level of risk they are willing to accept. Low cost option that does not prohibit the use of other management options in the future
PROTECT	**PR1**	Dune care / management	Development of a long-term program for revegetation and rehabilitation of dune system	Program needs to be considered in context of cost of replenishment and resources to undertake actions. Would require continued funding sources.

Table 26: Available adaptation options (adapted from WAPC, 2019 and Cardno, 2019) (Cont'd)

OPTION CATEGORY	OPTION CODE	OPTION NAME	DESCRIPTION	SUITABILITY AND COST CONSIDERATIONS
PROTECT	**PR2**	Groyne	Construct rock groynes along the beach approximately perpendicular to the shoreline to restrict longshore sediment movement and stabilise sections of shoreline. This option is often accompanied by beach nourishment.	Hard protection generally diverts erosion issues elsewhere, such as to the down drift side of a groyne, and can have significant impact on coastal ecosystems when accompanied by beach nourishment. Groynes are not effective as a means of managing short-term storm erosion. Can be expensive and rock sources may not be readily available or affordable. Groynes change the nature and appearance of the coast and can impact walking and beach use. Assessment of this option needs to consider long term maintenance, as this will extend the life of the groyne.
	PR3	Seawall	Construct seawall in front of assets or along length of coastline to protect them from coastal hazards.	Hard protection generally diverts erosion issues elsewhere, such as to beaches either side of, and directly in front of, a seawall. They can also have significant impact on coastal ecosystems Seawalls are expensive and change the nature and appearance of the coast, typically resulting in long term loss of the beach in front. Rock sources may not be readily available or affordable. They need to be accompanied by beach nourishment/ replenishment, which adds to the cost of option. Assessment of this option needs to consider long term maintenance, as this will extend the life of the wall.
	PR4	Nearshore reef/ Breakwater/ Artificial Reef	Construct offshore reef(s) / breakwater(s) or raise existing natural nearshore reef structures to maintain level of protection as sea level rises.	Hard protection generally diverts erosion issues elsewhere. The impacts of these structures are relatively unknown, and untested in the local context. May have significant impact on coastal ecosystems in adjacent areas. Reefs are unlikely to be effective over time as sea levels rise, or the crest would need to be raised in height in response. Are very expensive to design, build and maintain and rock sources may not be readily available or affordable. Assessment of this option needs to consider long term maintenance, as this will extend the life of the structure.

Table 26: Available adaptation options (adapted from WAPC, 2019 and Cardno, 2019) (Cont'd)

OPTION CATEGORY	OPTION CODE	OPTION NAME	DESCRIPTION	SUITABILITY AND COST CONSIDERATIONS
PROTECT	**PR5**	Beach (sand) nourishment	Addition of sand to the beach, dune and/or nearshore area to replace lost material and / or create additional buffer.	This option is a temporary measure and can be more effective in association with other options. The sand may be from an external source or from a nearby part of that coastal area, as such availability of suitable sand sources may be an issue. Where suitable sources are not readily available or a considerable distance away, costs are increased. If the nourishment sand is significantly finer than the existing beach sand the nourishment sand will be lost quickly
NO REGRETS	NR1	Monitoring	Long term baseline monitoring and event-based monitoring following storm erosion events	Monitoring enables assessment of the frequency and severity of events, the impact and consequences on various land uses, to revise risk levels and determine the effectiveness or appropriateness of risk management measures over time. Regular monitoring will support the identification of triggers for risk management measures to be implemented
	NR2	Protection structure audit	Involves undertaking an audit of existing protection structures, to determine their current condition, effectiveness and future protection potential	Depending upon the expected life and future protection from existing protection structures, there may be updates to the hazard estimates. This will flow on to affect other risk treatment options, including implementation of risk management measures
	NR3	Notification on title	Using the Planning and Development Act 2005 and the Land Administration Act 1997 to place a notification on the titles of potentially affected properties.	Indicates to current and future landowners that an asset is likely to be affected by coastal erosion and / or inundation over the planning timeframe. Helps current and future owners make informed decision about level of risk they are / may be willing to accept, and that risk management is likely to be required at some stage within the planning timeframe. Allows vulnerability of asset to hazards to be conveyed to existing and future owners. One means of implementation that is low cost, is through subdivision and development decision making

Table 26: Available adaptation options (adapted from WAPC, 2019 and Cardno, 2019) (Cont'd)

OPTION CATEGORY	OPTION CODE	OPTION NAME	DESCRIPTION	SUITABILITY AND COST CONSIDERATIONS
NO REGRETS	NR4	Emergency evacuation plans	Establishing emergency evacuation management plans where existing assets may be affected by erosion and / or inundation to manage the safety of community and stakeholders	This option is a low-cost option in addressing the consequences of erosion / inundation regarding safety to lives as the impact occurs
DO NOTHING	DN	Do nothing	This is managed retreat at its most basic form. The asset will be lost after a hazard event. Repairs are carried out for public safety purposes only. Take no action. No limitations on development or implementation of adaptation planning. Accept risk	Does not involve any new actions. Where existing levels of risk are low, accepting the risk may be appropriate. However, it may not be appropriate for high-risk locations / assets. The cost of Do Nothing may be substantially greater in the future than the current cost of implementing planning controls. This is because the value of land at risk continues to increase, as does the cost of mitigating recession impacts over time (such as retrofit, or even abandoning lost lands). Further, as the value of land at risk continues to increase over time, implementation of retreat risk treatment options in the future, to ensure land in the coastal zone is continuously provided for coastal foreshore management, public access, recreation and conservation, become increasingly desirable while more difficult to implement

6.2 Risk Treatment Options – Inundation

This section discusses adaptation options identified to respond to inundation hazards for all four coastal towns.

6.2.1 All Towns

It is recommended for all towns to implement adaptation options in the present day that will facilitate flexible adaptation in the future:

- Prevention of further development / limiting existing use rights
    - Introduce 'Special Control Area - Coastal Hazard: Inundation' with a requirement for new development to achieve a minimum finished floor level of 2.8m AHD for habitable areas of buildings. Depending on the nature of development proposed, approval may be time limited or require structures to be removed by a specified date or when a specified trigger is reached (NB: for most townsites, 2.8m AHD will be lower than existing ground level. This measure is most relevant to the foreshore area at Guilderton and in much of Lancelin).
    - Introduce a local planning policy outlining the Shire's requirements for building construction, land fill, and other relevant matters within the Special Control Area, noting requirements will be slightly different for erosion and inundation.
- Avoid development of any new assets in the hazard zone.
    - If they must be located within the hazard zone, they should be designed to withstand the inundation hazard. For example, new buildings to be constructed with permeable lower levels (e.g., a stilt arrangement), and services located above the flood level. This avoids the need to use fill to raise the FFL. Fill is expensive, and also alters the flood flow, which could lead to increased hazards.

6.2.2 Guilderton

In the present day, there is a low risk to assets under inundation for the next 50 years. By 2070, a small area of land adjacent to Moore River could be inundated. At present this is mostly recreational and vegetated land.

As per the above, it is recommended that new assets are avoided in this area. Given the recreational amenity, assets could be located within this zone, however, relocatable structures or structure designed to withstand inundation should be selected.

6.2.3 Lancelin - Present Day

As presented in Section 3.7, many assets are at medium risk of inundation from the present day, due to inundation from the 500-year ARI event. In addition to the options presented in Sections 6 and 7, the following is recommended in the present day for Lancelin:

- Emergency evacuation plans for the affected areas
  - It is noted that access to the town is predicted to be blocked in the event of a hazard: the present day 500-year ARI event.
- Commence investigations to determine options for appropriate longer-term relocation / town scale adaptation.
- Dune restoration / creation
  - Much of the inundation is predicted to occur due to breaching of the dune / gaps in the dune. By strategic vegetation planting, sand fencing and management, the level of inundation may be reduced.
- Investigate effectiveness of improved / additional stormwater management system to deal with excess ocean inundation and prevent inflow into the town.
- Investigate effectiveness of artificial offshore reef to mitigate increased wave energy as a result of sea level rise, noting community engagement identified surfing and use of existing reef is a coastal value.

6.2.4 Lancelin - Future Timeframes

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

6.2.4.1 2040

The modelling has indicated that by 2040, inundation results in most assets being at medium / high risk. This means additional maintenance or repair will be required if significantly inundated. The cost benefit analysis (CBA) conducted for the project (Section 6.6) investigates the timeframe when (if) relocating assets is the most appropriate.

Public, commercial, tourism and residential buildings may need to consider mechanisms for minimising the impact of flood damage. The Shire is not responsible for preventing damage to private assets. Therefore, where relevant, landholders might consider the following measures in their own responses to minimise coastal hazard risk:

- Services moved so as to be located above the recommended FFL
- Commercial stock or important possessions stored above the flood level
- Installation of false (raised) floors
- Use of materials that are water resistant

- Floorplate / wall arrangements to allow flow of water (and therefore minimise damage)
- Building evacuation requirements

The modelling has indicated that by 2040, Lancelin Road / Walker Avenue may be significantly inundated during the 500-year ARI event. Potential modifications to the road / appropriate emergency access and evacuation plans should be complete by this timeframe.

The following planning mechanisms are also recommended:

- Ensure that appropriately zoned land is available for relocation of the town as necessary. Selection and subsequent structure planning of land will be required.
- Amend the provisions (and boundaries, if necessary) of the Special Control Area to manage development in locations at risk of permanent inundation.

6.2.4.2 2070

By 2070 public infrastructure may require significant repair. Relocation may be the more acceptable option by this timeframe. Public, commercial, tourism and residential buildings should consider mechanisms for minimising the impact of flood damage, as per the recommendations in Section 6.2.4.1.

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

6.2.4.3 2120

Under the 2120 predicted sea level rise, the majority of the town is at risk of significant inundation for the 20- year ARI event, i.e. semi-regularly. Relocation of all selected assets should be implemented by this time.

6.2.5 Ledge Point

The predictions for inundation at this time do not indicate the need for adaptation options beyond monitoring of the coastal beach and dune (monitoring of beach levels and vegetation quantity / quality). Consideration should be given to the residential properties along De Burgh Street between Jones and Roe streets, as they are predicted to be immediately adjacent to the inundation hazard zone, but more directly affected by coastal erosion per Cardno 2019.

6.2.6 Seabird

The predictions for inundation at this time do not indicate the need for adaptation options beyond monitoring of the coastal beach and dune (monitoring of beach levels and vegetation quantity / quality).

6.3 Risk Treatment Options – Guilderton Erosion

Erosion adaptation options for Seabird, Ledge Point and Lancelin are discussed in Cardno (2019). This document outlines the erosion adaptation options for Guilderton only.

6.3.1 Guilderton - Present Day

As per the inundation adaptation options, It is recommended to implement adaptation options in the present day that will facilitate flexible adaptation in the future:

- Prevention of further development / limiting existing use rights
    - Introduce 'Special Control Area - Coastal Hazard: Erosion'. Depending on the nature of development proposed, approval may be time limited or require structures to be removed by a specified date or when a specified trigger is reached.
    - Require Notification on Title for all land located seaward of the 100-year hazard line for coastal erosion. This should be made a condition of any approval for development or subdivision/amalgamation of land. The Shire should also negotiate with landholders whose land is not subject to an application for planning approval to place such a notification on the title with their consent.
    - Introduce a local planning policy outlining the Shire's requirements for building construction, land fill, and other relevant matters within the Special Control Area, noting requirements will be slightly different for erosion and inundation.
- Any new assets should avoid the hazard zone.
- Coastal monitoring to regularly document changes to the shoreline and understand system; enables better prediction of management trigger timeframe
- Commence investigations to determine options for appropriate longer-term relocation of affected properties / assets.

6.3.2 Guilderton - Future Timeframes

The modelling has provided an indicative timeframe as to when adaptation will be required. However, it is recommended to employ the use of triggers for adaptation, including for relocation or managed retreat purposes. These are as per those of WAPC (2019).

- Trigger 1: Where the most landward part of the Horizontal Shoreline Datum (HSD) is within S1 of the most seaward point of a development / structure / foreshore reserve area.
    - The recreational and dune area is itself be considered the asset in this case, as per the values and vulnerability assessment.
- Trigger 2: Where a public road is no longer available or able to provide legal access to the property
    - This may occur for Gordon Street between Mortimer Street and Anderson Street.
- Trigger 3: When water, sewage or electricity to the lot is no longer available as they have been removed/decommissioned by the relevant authority due to coastal hazards.

As per the inundation discussion, the management measures discussed above apply in the addition to those discussed below.

6.3.2.1 2030

Amend the provisions (and boundaries, if necessary) of the Special Control Area to limit development in locations at risk of erosion.

Continue to require notification on title as a condition of planning approval and/or on a voluntary basis.

6.3.2.2 2050

Ensure that appropriately zoned land is available for relocation of properties / assets as necessary. Structure planning of the land may be required.

6.3.2.3 2070

Roads adjacent to Moore River (Silver Creek Road, Guilderton Road, Stephens Crescent) may require significant repair or relocation.

Foreshore recreational infrastructure may require significant repair or relocation.

6.3.2.4 2120

Foreshore recreational infrastructure may require significant repair or relocation. Residential properties on Gordon Street may require significant repair or relocation.

SECTION 7. MULTI-CRITERIA ANALYSIS

7. MULTI-CRITERIA ANALYSIS

Successful risk management and adaptation planning requires identification and diligent assessment of suitable options to ensure selection of the best strategy. The chosen option should mitigate risk to an acceptable level whilst maximising the values that were identified as being important to the stakeholders. For the this technical report, the following assessment criteria have been used:

Effectiveness

- Ability for the option to mitigate the coastal hazard risk

Environmental

- Impact on existing native vegetation / dunes / coastal processes
- Includes consideration of:
  - Any construction / clearing impacts
  - Impact of maintenance on the environment

Social

- This considers stakeholder and community impacts, including impact to / on indigenous or historical values

Economic

- This considers the economic impact of the option, and not the cost of the option. Community and stakeholder engagement indicated the impact of coastal hazards to economic prosperity of the towns was a concern. As the towns rely heavily on tourism, this needs to be considered when assessing each adaptation option.

Aesthetic impacts

- The visual appeal of the option
- Consideration of option aesthetics tying into the wider town vision

Future adaptability

- Whether the option is easily adaptable in future
- If the option limits the availability of other options in future

Cost

- Upfront capital costs
- Ongoing maintenance costs

In general, any option that may have detrimental impacts on indigenous or historical values, should have a lower social score along with supplementary notes to indicate the negative interaction. An Aboriginal site with heritage value was identified through the AHIS (DPLH, 2021) covering the town of Guilderton. Information provided by stakeholders is included in the assessment of each value as required. Options are assessed using the multi-criteria assessment (MCA) matrix shown in Table 27, which indicates the rating given to each criterion for a given option and provides the recommendation for pursuing the option.

In most cases it shall be necessary to implement more than one option, and the options selected through the MCA may vary spatially. The results of the MCA for each town are summarised in the sections below.

The MCA results in the 2019 CHRMAP (Cardno, 2019) and this 2023 Technical Report results for Guilderton were tested with community members during workshops in October 2022.

Community members generally supported the MCA results, however a few members observed that they would prefer the 'environment' to be considered as an independant criterion and given more weight in the 2019 CHRMAP (environment was included in a combined criterion with Social Impact in Cardno 2019).

Whilst this would not change the recommended options from Cardno 2019, it is important to recognise the shifting attitudes towards the natural environment since that time.

7.1 Long Term Timeframes

As each document has been prepared at slightly different times, the 100-year timeframe is slightly different.

For the purposes of planning, the difference between the 2090, 2110 and 2120 erosion and inundation timeframes in the 2019 Cardno CHRMAP report, the 2020 Baird CIS Study and the 2023 CHRMAP are negligible and the '100 year' planning horizon is attributed to the 2090 timeframe in all cases. Reviews of the final CHRMAP over the cominig decades should resolve this minor issue.

Table 27: Multi-criteria assessment framework for Shire of Gingin

RATING; SCORE	EFFECTIVENESS	ENVIRONMENTAL IMPACT	SOCIAL IMPACT	ECONOMIC IMPACT	AESTHETIC IMPACT	COST (CAPITAL & ONGOING)	FUTURE ADAPTABILITY	FINAL RECOMMENDATION
Positive; +1 or +2	Expected to be effective	Positive impact; return to more natural coastline	Positive social impact; encourages community development	Positive impact, option improves economic outlook for the town	Positive aesthetics, retains the existing coastline and place recognition	Low or reasonable costs. High-er capital costs accepted if other criteria met	Adaptable, not likely to leave legacy issues	Further Investigation Recommended; Score > 0
Neutral; 0	May or may not be effective, possibly unable to predict	No (or unclear) environmental impact	No discernible social impact; indeterminate net impact	No impact to the town economy	Neutral aesthetic	Moderate costs	May leave legacy issues	Suitability unclear; Score = 0
Negative; -1 or -2	Likely to be ineffective in the short or long term	Potential significant negative impacts, including losing beaches altogether	Negative social impact. May discourage new or existing people from the area	Option could lead to a decrease in the tourism market	Coastline / foreshore appearance negatively altered	High initial or ongoing costs, especially if low likelihood of success	Will create legacy issues	Not recommended; Score < 0

7.1.1 Guilderton

The key messages for both erosion and inundation adaptation options for Guilderton are:

- The options to take forward to the CBA are relocate, limitation of further development, and redesign for inundation (Table 28).
- The relocation costs will be compared to the Do-Nothing approach in the CBA
- A simple protect option of dune revegetation will be investigated to maximise the time before relocation is required.

Table 28: Guilderton Multi-criteria assessment

	Option	Effectiveness	Environment	Social	Economic	Aesthetic	Cost	Future Adaptability	Score / Recommendation	Comment
DO NOTHING	Do Nothing	-2	0	-2	-1	-1	-1	-2	Not recommended (-9)	Not an effective adaptation option and unlikely to be popular with the community. Cost to be investigated further in CBA.
AVOID	Avoid	2	2	1	2	2	2	2	Recommended (13)	For erosion, this mainly applies to the undeveloped land south of the river. Inundation hazards relate to the avoidance of significant development in the river foreshore area. Community will benefit by appropriate foreshore reserve width and access throughout the planning timeframe.
MANAGED RETREAT	Relocate	2	1	-1	1	1	-1	2	Recommended (5)	Effective but costly option. Ensures foreshore reserve retained. May be unpopular with landholders, depending on implementation strategy. Very likely to cost less than protection.
	Prevent Further Development	1	1	-1	0	0	2	1	Recommended (4)	Allows for continued use of the land whilst viable, without creating legacy issues. May be unpopular with landholders.

Table 28: Guilderton Multi-criteria assessment (Cont'd)

	Option	Effectiveness	Environment	Social	Economic	Aesthetic	Cost	Future Adaptability	Score / Recommendation	Comment
ACCOM-MODATION	Notification on Land Titles	1	0	-1	0	0	0	2	Recommended (2)	Likely to be effective at encouraging development outside of hazard zones. Cost shifted from Shire to small number of landholders, likely to be unpopular with those landholders.
	Re-design for Inundation	1	0	1	0	0	1	0	Recommended (3)	Low cost and could be effective at reducing damage costs. Only applicable adjacent to riverbanks, mainly for foreshore recreational infrastructure.
	Re-design for Erosion	1	-1	0	-1	-1	-1	-1	Not recommended (-4)	Expensive and intrusive to construct. Private asset protection may have detrimental impacts on adjacent assets.
PROTECT	Dune Re nourishment	0	1	1	-1	0	-2	-1	Not recommended (-2)	Expensive with lower confidence in effectiveness. Creates legacy issues for future.
	Dune revegetation for erosion hazard	1	1	1	1	1	-1	0	Recommended (4)	Relatively simple measure to maximise the stability of the existing dunes. In particular, this applies to the extent of beach seaward of the main beach access car park and boardwalk
	Seawall	1	-2	-2	-2	-2	-2	0	Not recommended (-10)	For erosion hazard. Expensive option, not realistic due to the elevation of the existing dune, and potential terminal erosion issues at the crest, the river mouth and the northern end of the structure. Not required for significant period of time.
	Groyne	-1	0	0	-1	0	-1	0	Not recommended (-3)	For erosion hazard. A groyne could potentially assist locally with boat launching, but would not be appropriate as an erosion mitigation option to combat the coastal hazards from the impacts of climate change. Groynes can lead to downdrift erosion issues if not designed and constructed appropriately.

7.1.2 Lancelin

All suggested options are recommended for further investigation, with the exception of Do Nothing and Artificial Offshore Reef. Do Nothing will however be costed in the CBA in order to compare to the other options.

The options recommended in Cardno (2019) match those in this report (shown in Table 29), with the exception that Cardno 2019 recommended investigating the suitability of groynes and seawall as erosion mitigation options. As these are not considered effective at managing the combined impacts of erosion and inundation, they are now discounted. Cardno (2019) also highlighted the importance of commencing the managed retreat process immediately. All recommendations should be progressed in parallel.

The implementation of an artificial offshore reef (or collection of reefs) does not appear to be a suitable protection option to reduce the possibility of dune breaches for Lancelin. The largest dune breach zone in the southern end of the townsite is around 700m long, which would require a very large offshore breakwater or numerous smaller structures (in both cross-shore and along-shore dimensions) in order to attenuate a significant amount of wave energy. This would be prohibitively expensive and have a high probability of detrimental effects to adjacent coastline, requiring artificial renourishment in perpetuity or managed retreat for the affected area(s). In addition, surf reefs often have different characteristics to artificial reefs due to the desired outcomes. If construction of a large artificial reef for dune protection were to be pursued by the Shire, then collection of local wave measurements and rigorous morphological modelling of the proposed design is recommended.

Table 29: Lancelin Multi-criteria assessment - Inundation Options Only

	Option	Effectiveness	Environment	Social	Economic	Aesthetic	Cost	Future Adaptability	Score / Recommendation	Comment
	Do Nothing	-2	-1	-2	-2	-1	-1	-2	Not recommended (-10)	Not an effective adaptation option and unlikely to be popular with the community. Cost to be investigated further in CBA.
AVOID	Avoid	0	1	1	1	0	1	2	Recommended (6)	Foreshore is predominantly already developed so this option is not applicable for the majority of the town, except for the conservation reserve and undeveloped dune in the south of the town. Avoiding development in this environmentally sensitive area is viewed positively. The area of undeveloped land outside the inundation zone is limited.

Table 29: Lancelin Multi-criteria assessment - Inundation Options Only (Cont'd)

	Option	Effectiveness	Environment	Social	Economic	Aesthetic	Cost	Future Adaptability	Score / Recommendation	Comment
MANAGED RETREAT	Relocate	2	1	-1	0	1	-1	2	Recommended (4)	Effective but costly option. Likely to apply for the majority of the township. May be unpopular depending on implementation strategy. Costs will be compared against Protect in the CBA. If not implemented well, a lack of planning certainty could also result in a negative social outcome, especially as a lack of certainty could lead to a lack of insurability.
	Prevent Further Development	1	1	-1	0	0	2	1	Recommended (4)	Allows for continued use of the land whilst viable, without creating legacy issues. May be unpopular with landholders.
ACCOM-MODATION	Notification on Land Titles	1	0	-1	0	0	0	2	Recommended (2)	Likely to be effective at encouraging development outside of hazard zones. Likely to be unpopular with landholders.
	Emergency Plans	-1	0	1	0	0	2	0	Recommended (2)	Not effective or future facing in terms of asset adaptation, but necessary to have as a town and design is low in cost.
	Re-design for Inundation	1	0	1	0	0	1	0	Recommended (3)	Low cost and could be effective at reducing damage costs. Potentially delays relocate option.
PROTECT	Dune Restoration / Creation	1	1	1	1	1	-2	-1	Recommended (2)	Relatively simple measure to maximise the height and stability of the existing dunes. This may reduce the level of inundation / delay the inundation issue within the town. If undertaken without renourishment, simply through re-vegetation and sand fencing, it limits the creation of legacy issues for the future.
	Stormwater Management	1	1	1	0	0	-1	0	Recommended (2)	May delay / reduce the level of inundation. If designed and implemented appropriately it may limit legacy issues.
	Artificial Offshore Reef	0	-1	1	-1	1	-2	0	Not recommended (-2)	Expensive option with significant risks, even with extensive design evaluation. Unlikely to protect for the full planning timeframe, and could also lead to additional erosion. Potential impacts on common recreational activities such as fishing and surfing.

7.1.3 Ledge Point

The predictions for inundation at this time do not indicate the need for adaptation options beyond monitoring of the coastal beach and dune (monitoring of beach levels and vegetation quantity / quality). Erosion adaptation options were assessed in Cardno (2019). This included avoid, managed retreat, planning controls, dune maintenance, investigating the use of groynes / seawall in some areas as an erosion mitigation option. These options do not impede the inundation assessment shown in Table 30, and vice versa. The erosion issue is the more critical issue at Ledge Point, and that implementation plan detailed in Cardno (2019) should be followed.

Table 30: Ledge Point Multi-criteria assessment - Inundation Options Only

	Option	Effectiveness	Environment	Social	Economic	Aesthetic	Cost	Future Adaptability	Score / Recommendation	Comment
DO NOTHING	Do Nothing	1	0	0	0	0	0	0	Recommended (1)	Inundation is not predicted to be a hazard during the planning timeframe. Do Nothing excludes the recommended continued monitoring of the coastal beach and dune (monitoring of beach levels and vegetation quantity / quality).
AVOID	Avoid	0	0	0	0	0	0	0	Not recommended (0)	This does not apply in this town as development exists across the study area
MANAGED RETREAT	Relocate	0	0	0	0	0	0	0	Not recommended (0)	Continued monitoring of the coastal beach and dune to determine if this option is required.
	Prevent Further Development	0	0	0	0	0	0	0	Not recommended (0)	Continued monitoring of the coastal beach and dune to determine if this option is required.

7.1.4 Seabird

The predictions for inundation at this time do not indicate the need for adaptation options beyond monitoring of the coastal beach and dune (monitoring of beach levels and vegetation quantity/quality). Erosion adaptation options were assessed in Cardno (2019). This included avoid, managed retreat, planning controls, dune maintenance, investigating the use of groynes/seawall in some areas as an erosion mitigation option. These options do not impede the inundation assessment shown in Table 31, and vice versa. The erosion issue is the more critical issue at Seabird, and that implementation plan detailed in Cardno (2019) should be followed.

Table 31: Seabird Multi-criteria assessment - Inundation Options Only

	Option	Effectiveness	Environment	Social	Economic	Aesthetic	Cost	Future Adaptability	Score / Recommendation	Comment
DO NOTHING	Do Nothing	1	0	0	0	0	0	0	Recommended (1)	Inundation is not predicted to be a hazard during the planning timeframe. Do Nothing excludes the recommended continued monitoring of the coastal beach and dune (monitoring of beach levels and vegetation quantity / quality).
AVOID	Avoid	0	0	0	0	0	0	0	Not recommended (0)	This does not apply in this town as development exists across the study area
MANAGED RETREAT	Relocate	0	0	0	0	0	0	0	Not recommended (0)	Continued monitoring of the coastal beach and dune to determine if this option is required.
	Prevent Further Development	0	0	0	0	0	0	0	Not recommended (0)	Continued monitoring of the coastal beach and dune to determine if this option is required.

SECTION 8. COST BENEFIT ANALYSIS

8. COST BENEFIT ANALYSIS

8.1 Analysis Approach

The purpose of the Cost-Benefit Analysis (CBA) as part of this CHRMAP is to further examine the selection of adaptation options through economic analysis. In the previous section, potential adaptation options have been assessed against a range of criteria, including expected lifetime cost (score only). Options that may require significant financial investment and scored positively in the MCA have been included in this CBA. A rigorous assessment of costs and benefits for each option will assist with preferential selection and potentially uncover any poor financial assumptions included in the MCA. This analysis will also ensure that a selected adaptation option is economically defendable. The CBA has only addressed physical options (e.g., flood damage to property, the cost of seawalls, groynes, or other protection structures, etc.). Indirect costs that another user might consider to be a loss are not considered. For example, costs associated with SCA title notifications, emergency planning, development restrictions were not considered.

The cost-benefit of each option is presented in net present value (NPV) terms. NPV is a standard economic analysis to compare options with time-variable costs and benefits. It allows for the adjustment of all future economic considerations to present day dollars for a more direct comparison. This relates to the time-value of money, as planned expenses in the future are, in a sense, cheaper than equivalent costs today, because the money required for a future expense could be spent elsewhere today to provide value over time (i.e., it can be invested now to generate a return). An expense that occurred today could not be invested elsewhere. In this case, all our cashflows are costs, so options with a lower net present cost are considered better investments from a financial standpoint.

The real discount rate (expected inflation adjusted) chosen for this project was 7% based on similar assessments (Baird, 2018, APH, 2018). Sensitivity analysis was also performed with discount rates of 5% and 9%. The discount rate essentially converts all future costs back to today's dollar value for comparison (in the NPV).

For example, a project with a cost of $1 million per year for 10 years would discount to an NPV of roughly $7.5 million, whereas a project that only has a single outlay of $10 million in 10 years' time would have an NPV of roughly $5.4 million, both discounted at 7%. A project that costs $10 million today would have an NPV of $10 million. This example shows the importance of when a cost is realised.

Real estate is a special case as this asset class historically appreciates at a higher rate than inflation. For the purpose of this analysis, we assume that real estate will appreciate at a real rate of 3.5%. This is a reasonable assumption based on Australia-wide market trends from 1980 to 2015 (RBA, 2015). This difference is only applied if the entire residential asset value is assumed lost, i.e.: through erosion. Commercial assets, construction costs, and all flood repair costs are assumed to increase at the expected inflation rate and therefore no adjustment is required in the analysis.

The CBA has been performed over a 100-year period, designed to match the project planning period. It should be noted that the uncertainty around the CBA estimates and assumptions made grows with time. Estimates beyond 2040 should be viewed as indicative trends only. Long-term adaptation pathways should always be monitored and updated over time.

8.2 Existing Asset Valuation Method

In order to adequately compare the cost of different adaptation pathways we first must estimate the total value of assets at risk if an erosion or inundation event were to occur. This will form the asset value component of the Do Nothing strategy. The cost estimates for erosion damage and inundation damage are performed separately, with the erosion damage taking precedent (i.e.: if an asset suffers both erosion damage and inundation during an epoch then the erosion damage will be used, typically 100% of the asset value for built assets). The cost estimation for each risk type is described next. Note that these cost estimates are concept level estimates only, intended for general comparison and not a detailed evaluation of expected damage.

8.2.1 Erosion Damage

Storm erosion typically undermines the structural footing of an asset rendering it unsafe and unsuitable for further habitation or use. For this reason, the full value of an asset is assumed to be lost when the erosion hazard line reaches the footprint of an asset. For residential assets we have applied a value based on the gross rental value supplied by the Shire. For public assets we have applied the value supplied by the Shire of Gingin (if available). For private assets or any other asset with no valuation supplied we have applied value estimates based on the gross rental value (supplied by the Shire). Erosion damage for small roads (road removal) was estimated at $600/m and carpark removal was estimated at $100/m^2.

8.2.2 Inundation damage

Inundation damage can be difficult to estimate because an asset may only suffer partial damage and not total write-off. This damage is dependent on the asset type and flood depth, with minor damage usually occurring when flood levels are below the finished floor level (FFL), and major damage occurring when flooding exceeds the FFL. Water Technology has significant experience estimating flood damage from a range of coastal and urban environmental flood studies which will be applied to this project. Damage estimates are calculated by piecewise-linear interpolation of the flood tables (depth-dependent damage curves) described next. There are separate damage curves for residential property and commercial/public property, with commercial/public property divided into five damage classes.

Detailed FFL is not supplied for this project and so it is assumed that the average residential FFL is 0.3m above the average block elevation. This means that damage estimates for flood depths up to 0.3m follow the below-floor flood curve, and damage estimates for flood depths over 0.3m follow the above-floor flood curve. The residential flood curves supplied show the total cost estimate per residence flooded. The depth-dependent damage rates per residence are shown in Table 32. Vacant blocks were assumed to not incur any damage from temporary inundation events.

Table 32: Residential damage curve per residence flooded. Note the damage rates assume the FFL is at 0.3m depth

DEPTH FLOODED (M)	DAMAGE ($)
0.0	$0
0.05	$0
0.26	$6,144
0.4	$64,348
0.9	$79,954
1.8	$108,042
2.1	$117,406
10.3	$143,901

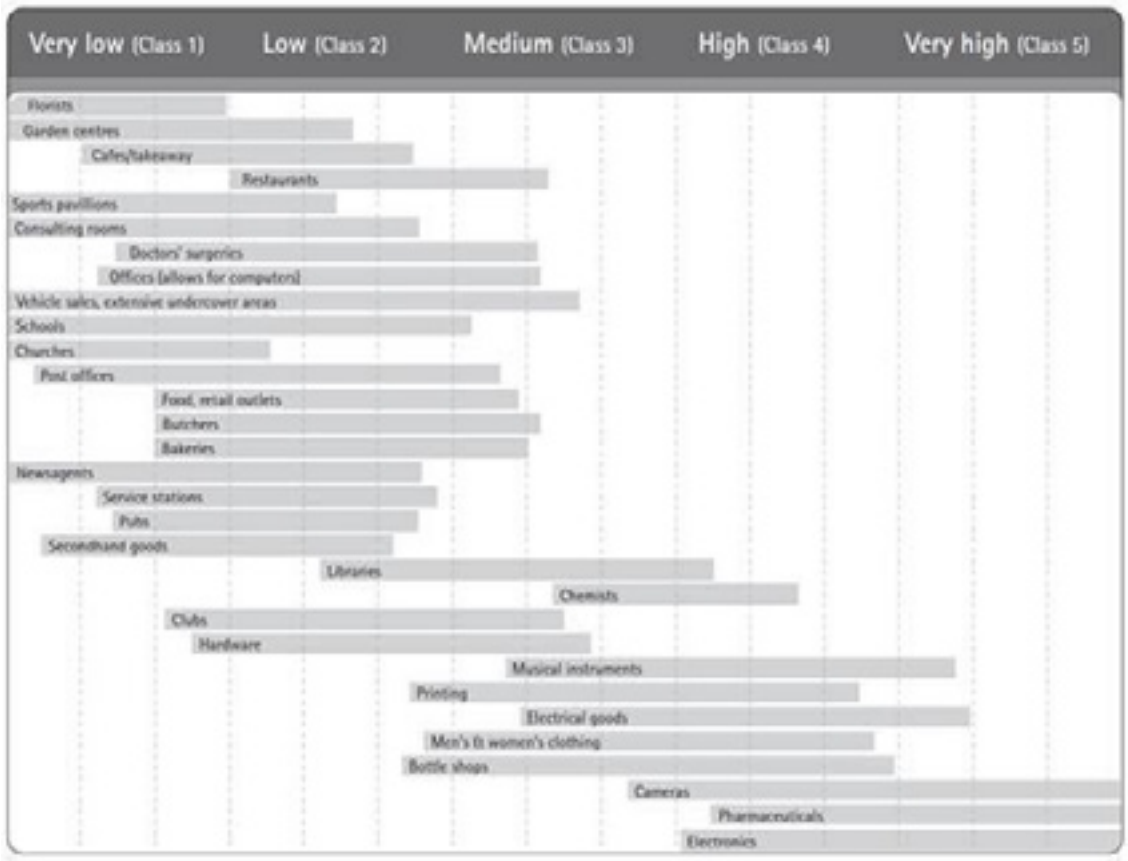


Figure 33: Commercial damage classes (reproduced from D.I.Smith and M.A.Greenaway, 1992)

Commercial and public flood damage estimates have been performed for each affected asset using Figure 33 and Table 33. Commercial and public assets were not assumed to have an extra 0.3m FFL elevation above the average block elevation. Asset class was determined based on Figure 33 for typical assets, with the majority of commercial assets assigned to Class 1 or 2. Notable exceptions were the police station, ambulance depot, and the medical centre (Class 3). No assets were deemed to be Class 4 or 5.

Table 33: Commercial damage curves per unit area flooded for each class (determined from Figure 33)

DEPTH FLOODED (M)	DAMAGE ($/M²)		
	CLASS 1	CLASS 2	CLASS 3
0	$0	$0	$0
0.25	$7	$16	$34
0.75	$41	$83	$163
1.25	$86	$172	$345
1.75	$140	$283	$565
2	$168	$337	$674
10	$168	$337	$674

8.3 Existing Valuation Asset Results

8.3.1 Guilderton Erosion

The total estimated value of residential and commercial assets at risk of erosion damage by 2120 was $8 million for Guilderton (2021 dollars). All of these potential losses occur beyond 2070, with the majority of assets at risk between 2090 and 2120 (Table 34).

Using these estimates of when the damage is expected to occur, the calculated NPV for Guilderton reduces to $570,000 using a 7% discount rate. There is very large uncertainty in these estimates due to the significant time between now and the expected loss date. The sensitivity analysis using a 9% discount rate gave an NPV of $150,000, while the sensitivity analysis using a 5% discount rate gave an NPV of $2.4 million.

This analysis suggests erosion mitigation projects with an NPV of $570,000 or less are likely to be economically viable. Given the timing of the expected losses it is unlikely that any major protection works would be viable at present.

Note that the Guilderton NPV appears less “discounted” when compared to Lancelin, because erosion damage assumes total asset loss and house prices are assumed to appreciate at a higher rate than inflation. For flood damage in Lancelin the asset is only repaired, not lost, with repair costs expected to stay in line with inflation.

Table 34: Guilderton inundation cost summary for existing residential, commercial, and public assets

ASSET TYPE / TOTAL COST	DAMAGE AT EPOCH (2022 DOLLARS)			
	PRESENT DAY	2040	2070	2120
RESIDENTIAL & COMMERCIAL				$7 mil
PUBLIC (REMOVAL OF ROADS AND CARPARK)				$1,040,000
TOTAL				$12.04mil
NPV* 7%				$570k
(9%, 5%)				($150k, $2.4 mil)

8.3.2 Lancelin Inundation

A significant number of assets are at risk of inundation for the Lancelin townsite. No existing assets were identified as at risk of inundation for the other towns. The resulting estimates of inundation in 2022 dollars are summarised in Table 35. Public assets such as roads, drainage, parks, and reserves were not expected to be damaged by temporary standing water inundation events.

The net present value (NPV) of flood damage will vary depending on the year the flood occurs. This is a complex and unquantified variable. Here the NPV was calculated under the assumption the flood occurred in the epoch year. The expected damage increases at each epoch due to sea level rise, but the NPV (the discounted cost) decreases due to the long timescales. Note there are many possible sources of uncertainty that are not captured by the NPV sensitivity analysis. The NPV will be used in comparison with protection options in the following sections.

The net present value (NPV) of flood damage if the flood occurs in the present day for the Lancelin townsite is estimated at $23 million using a 7% discount rate (no discount for the present day). This suggests that if the flood was expected to occur in 2021, adaptation options costing up to $23 million could be considered viable. If the flood was not expected to occur until 2070, however, the NPV is estimated to be $1.5 million, with a sensitivity $0.6 to $3.7 million. This suggests that adaptation works with a NPV of $1.5 million or less are expected to be economically viable and works greater than $3.7 million are highly unlikely to be viable.

Without more information on the potential for dune breaches to occur this study must assume that a 500-year ARI event would result in flooding of the town. It is recommended that a detailed risk assessment and adaptation cost estimation study be undertaken. This is beyond the scope of this project and will be listed in the CHRMAP recommendations for further investigation.

Table 35: Lancelin inundation cost summary for existing residential, commercial, and public assets

ASSET TYPE / TOTAL COST	DAMAGE AT EPOCH (2022 DOLLARS)			
	PRESENT DAY	2040	2070	2120
RESIDENTIAL	$20 mil	$25 mil	$33 mil	$47 mil
COMMERCIAL / PUBLIC	$3.1 mil	$4.1 mil	$7.2 mil	$17 mil
TOTAL	$23 mil	$29 mil	$40 mil	$64 mil
NPV* 7%	$23 mil	$8 mil	$1.5 mil	$80k
(9%, 5%)	($23 mil, $23 mil)	($5.6 mil, $11.5 mil)	($0.6 mil, $3.7 mil)	($13k, $500k)

8.4 Summary of Assets at Risk

Table 36: Guilderton erosion assets at risk by 2120

CATEGORY	ASSET TYPE	EXTENT / QUANTITY
PUBLIC	Moore Estuary Lookout Carpark	4,400m²
	Coastal foreshore reserve	0.2km²
	Roads	~1km
RESIDENTIAL	Property	15

Table 37: Lancelin inundation notable assets at risk by 2120

CATEGORY	ASSET TYPE	EXTENT / QUANTITY AT 2120
PUBLIC	Multi-purpose health centre	1.5m at 100%
	Lancelin Primary School	1.2m at 100%
	Police Station	1.1m at 100%
	Ambulance Depot	0.9m at 100%
	Lancelin Hall	1.6m at 100%
	Community & Visitor Centre	1.4m at 100%
Private	Residential	640 (536*)
	Aged care facility 2 Atkinsons Way	1.4m at 100%
	Aged care facility 131 Gingin Rd	1.1m at 100%
	Block with IGA, Café, Bakery, etc.	1.4m at 100%
	Lancelin North End Caravan Park	1.3m at 95%

*Residential blocks with at least 0.3m depth of flooding and at least 60% of block area inundated.

8.5 Adaptation Options Costing and Discussions

As per Section 6.2, inundation specific adaptation options are carried through from the MCA for Seabird and Ledge Point. The erosion issue is the more critical issue for these towns, and the implementation plan detailed in Cardno (2019) should be followed.

8.5.1 Guilderton

As per the MCA, the options for consideration in the CBA are relocate, limitation of further development, and redesign for inundation. In this section, the relocation costs are compared to the Do Nothing approach. In addition, a simple protect option of dune revegetation will be investigated to maximise the time before relocation is required. The two management units are:

- MU1 – Guilderton Foreshore
- MU2 – Moore River Foreshore

In this report, adaptation options are placed in context of their management unit.

8.5.1.1 Relocate (MU1)

Table 36 presents the assets that may require relocation over the planning timeframe. These are all located in MU1. The predictions indicate the residential properties would not require relocation until 2070, depending on erosion trends and the foreshore reserve allowance so as to maintain public access.

The Moore Estuary lookout car park would need to be relocated. Other roads can simply be removed, depending on their use as access to properties and services.

A plan for the relocated properties should be developed. In this instance, Do Nothing holds greater risks than a Relocate plan in terms of safety and public education / relations.

Given the long timeframes involved, relocation triggers should be identified rather than a relocation time. The Shire should develop a public foreshore reserve allowance. Regular monitoring can be performed, and once assets are deemed to encroach on the foreshore reserve, relocation should be triggered. The foreshore reserve may be different for the open coast and estuary foreshore. An SCA should be established for high-risk zones to ensure that properties are not redeveloped close to (within a certain number of years of) the projected relocation time, based on monitoring of shoreline regression.

8.5.1.2 Limitation of Further Development

This has no direct costs so is not considered within the CBA.

8.5.1.3 Re-Design for Inundation (MU2)

The re-design for inundation relates to the Moore River foreshore areas (MU2), as per Section 6.2 – Risk Treatment Options - Inundation. There are no specific costs for this. Recommend undertaking redesign at end of asset life as required.

8.5.1.4 Dune Management (MU1)

A simple protect option of dune revegetation in MU1 is investigated in this section to maximise the time before relocation is required. Best practice dune and foreshore management should include dune revegetation and monitoring programs and this is recommended as a standard approach, rather than considering it a true “protect” strategy.

Table 38 summarises the recommended approach and provides costs. Given this management technique does not in any way guarantee the relocate option is not required, the costs listed allow a more qualitative comparison. Certainly, without adequate dune and foreshore management, erosion would occur at a faster rate.

he existing dune north of the river mouth, approximately 300m in length, has sparse to medium density of vegetation. Whilst not known concretely, it is thought that this dune is recovering from historic erosion mainly caused by storm activity and exacerbated by human disturbance, based on our review of historical aerial imagery. Over time, as the beach access became more formalised, the dune appears to recover.

It is recommended that continued beach access management combined with community education be undertaken to maximise the success of the dune revegetation. Costs for revegetation of this area are provided in Table 38.

There is also increased damage in the vicinity of the three beach access points to the north. It is recommended that the Hopkins Street beach access be closed, and the remaining three beach access paths are formalised to limit pedestrian access to sensitive areas of the dune. Vegetation should recover in the areas adjacent to these access points if access is limited.

Table 38: Guilderton dune management actions

MANAGEMENT ACTION	DESCRIPTION	QUANTITY	COST ESTIMATE
Dune revegetation	300m length coastline immedi-ately north of river mouth Sand matting and native vegetation planting (installed)	1-2 plants per 2m² 10,500m²	Approx. $60k de-pending on plant density
Rationalise and formalise beach access	Close the Hopkins Street beach access and formalise three other beach access paths to limit pedestrian access to dune vegetation. Vegetation should recover in areas adjacent to these access points, if access limited	Approx. 300m of fencing (estimate)	$18k

8.5.1.5 River Mouth Management (MU1)

It is recommended that the Shire limit the movement of the river mouth to the north as much as is practical. This is based on the historic beach erosion coincident with outflows to the north. While this may impact the HSD location to the south of the estuary, there are no existing built assets in this area.

8.5.1.6 Coastal Protection Structures

The assets at risk in Guilderton are spread between the open coast and the estuary. Given the NPV cost of $850k and the long timeframe until risk is predicted to be high, no coastal protection structures are considered economically viable. This can be re-assessed closer to the expected loss date. For the present day, Relocation or Do Nothing are better options than protection, as the cost of protection would be greater than the asset value. In addition, Relocation will have less potential negative impacts to the foreshore.

8.5.2 Lancelin

The modelling to date indicates the majority of Lancelin is at risk of inundation. The adaptation options of Relocate, Prevent Further Development, Notification on Land Titles, Emergency Plans and Re-design for Inundation are selected for implementation, and are not considered in the CBA. Cardno (2019) defined management units (MUs) for Lancelin: LA1-4. These are referenced during the discussions below.

8.5.2.1 Stormwater Management (all MUs)

This option was originally considered as some form of low (~0.5m) wall in place of dune fencing at the landward edge of the dunes, at key locations along the coast where coastal inundation pathways were identified in Baird (2020). However, ongoing discussions with the Shire indicate that inundation issues already exist in the present day. This is connected to rainfall-induced stormwater pooling, due to a combination of inadequate stormwater drainage infrastructure, and a high groundwater table. Since the source of the inundation would then be from the land as well as the ocean, this simple wall approach would not be appropriate.

As such, it is recommended that a detailed investigation be undertaken, including groundwater modelling, surface water modelling (from rainfall), as well as the ocean water levels under a variety of storm conditions and planning timeframes. Such a study, at up to approximately $200,000 ex-GST, would enable a clear understanding of when the flood events may become untenable for the town, and also if there are feasible Protect style adaptation options that could delay the requirement for relocation. In this way, the Shire and community may have longer to develop the relocation plan, or at the very least have a clearer understanding of what the plan looks like.

It is not possible to cost a potential protect option in this category as it depends on a number of factors that have not yet been quantified. The cost of a $200,000 study however, compared to the $23 million present day Do Nothing estimate, indicates this study would be of significant benefit to the adaptation process.

8.5.2.2 Dune Restoration/ Creation (all MUs)

This option aims to harness best practice dune management to minimise coastal inundation at key locations of the Lancelin coast currently vulnerable to coastal hazards. The option described here relates purely to inundation mitigation. All actions defined here will need to be tied into erosion adaptation options. This option does not prevent the implementation of other options in future, so is considered appropriate under SPP 2.6.

The inundation maps identify areas where the dune is susceptible to breaching, leading to the inundation maps presented in Baird (2020). Investigation of these sites indicates that there is the potential to reduce the inundation likelihood by rehabilitating and encouraging dune growth in some of these areas.

The following is recommended:

- The majority of the existing dune vegetation seems to be low grasses and shrubs. If it is possible without damaging existing vegetation, plant or replant larger varieties into the existing spread, using endemic species only. This may encourage additional sand capture and naturally raise the height of the dunes. This is recommended:
  - Dune between Desert Rd & Hawcroft Place (LA4)
  - Dune between Miragliotta St and Shell Street (LA3)
  - Dune along the length of Cunliffe Street, in particular south of Timothy St (LA2)
- The removal of coastal road immediately landward of dune, between Desert Road and the beach car park at Hinchcliffe Road (LA4). Revegetation of the area once road is removed, in particular north of Wood Street, with sand fencing to create height. Encourage larger plants rather than grasses.
- In line with Cardno (2019), long-term managed retreat of Grace Darling Park, the sea rescue building etc (LA1) and revegetate. Encourage the establishment of a larger dune which may reduce the inundation pathway.
- In addition to the study recommended to investigate the stormwater management, local dune surveys should be undertaken as well as a detailed geomorphology study so as to better define the vulnerable areas (all MUs). In turn, this will allow greater confidence that such revegetation measures will be successful.

Table 39 provides a summary of the recommended actions, including some approximate costs. These are high level estimates which should be updated once survey and the geomorphological study are undertaken. Table 40 provides a summary of the expected costs for the recommended additional investigations. In total, an estimate of $1.25 million could be spent that may provide delays in the managed retreat option. Again, compared to the $23 million present day Do Nothing estimate, this indicates these measures may be of significant benefit to the adaptation process.

Table 39: Lancelin dune management actions

MANAGEMENT ACTION	DESCRIPTION	QUANTITY	COST ESTIMATE
Dune revegetation / re-habilitation LA4	Removal of coastal road between Desert Road & Hinchcliffe Road, rehabilitate and revegetate dune	12,000m² 1-2 plants per 2m² 2 rows sand fencing Matting	$310k
Promote dune growth LA2-4	Dune between Desert Rd & Hawcroft Place (LA4)	4,200m² 1 plant per 5m²	$6.8k
	Dune between Miragliotta Street & Shell Street (LA3)	30,000m² 1 plant per 5m²	$48k
	Dune along the length of Cunliffe Street, in particular south of Timothy Street (LA2)	60,000 m² 1 plant per 5m²	$96k
Rehabilitate dune through managed retreat (LA1)	Rehabilitate Grace Darling Park to dune vegetation Beach front site access road removed and replaced with extension of Carl Street	8,000m² total area 1-2 plants per 2m² 2 rows sand fencing Matting	$250k removal $150k reveg. $400k total cost
APPROX DUNE MANAGEMENT COSTS			**$900,000**

Table 40: Lancelin investigations: all MUs

INVESTIGATION	APPROX. COST ESTIMATE
Stormwater Management	$200k
Geomorphological Investigation	$100k
Local surveys	$ 50k
APPROX INVESTIGATION COSTS	**$350,000**

SECTION 9. ADAPTATION RECOMMEN-DATIONS

9. ADAPTATION RECOMMENDATIONS

9.1 Overarching Recommendations

All assets within the study area become more vulnerable over time. This requires consideration of other management and adaptation planning options that may be relevant to all assets. This section summarises the key strategic planning, statutory planning, and policy or governance interventions that the Shire will need to implement regardless of the proposed adaptation options chosen per area or asset. These instruments are particularly useful for implementing Accommodate and Planned or Managed Retreat options.

Recommendation 1: Special Control Areas

Amend the local planning scheme to introduce a Special Control Area (SCA) over all land identified as being at risk of coastal erosion and/or inundation. The SCA would be delimited by the position of either the 2120 coastal processes setback line or the inundation extent of the 500-year ARI event in the year 2120, whichever is the more landward.

An SCA is a planning layer that applies in addition to the underlying zoning and land use permissibility of the land. It identifies planning controls that apply in addition to any other requirements relevant to the underlying zone. An SCA can facilitate land use changes and development control within that area.

An SCA should be applied to relate specifically to land subject to coastal processes (as recommended in WAPC, 2019).

Each SCA is allocated a number and depicted on the LPS Map.Each SCA is allocated a number and depicted on the LPS Map.

WAPC (2019) provides draft amendment text including the purpose, objectives and provisions for SCAs (see below). The purpose of the SCA is to provide guidance as to the appropriate scope of land use and development to be permitted within a coastal erosion and inundation hazard risk area.

Its objectives would be:

- To ensure land in the coastal zone is continuously provided for coastal foreshore management, public access, recreation and conservation.
- To ensure public safety and reduce risk associated with coastal erosion and inundation.
- To avoid inappropriate land use and development of land at risk from coastal erosion and inundation.
- To ensure land use and development does not accelerate coastal erosion or inundation risks; or have a detrimental impact on the functions of public reserves.

- To ensure that development addresses the Shire of Gingin CHRMAP prepared in accordance with SPP 2.6.
- The SCA would include additional provisions such as:
- All proposed development within the SCA requires approval - this would include development that would not ordinarily require development approval under the LPS.
- Approval to be issued on a temporary or time limited basis - the applicant could later apply for a further approval, which could be granted if the risk from coastal processes was still considered acceptable.
- Referral of applications - any planning application should be referred to the Department of Transport, the Western Australian Planning Commission and any other relevant authority for advice and comment on the coastal risk.
- Minimum finished floor levels and/ or other development standards - 2.8 metres AHD has been identified as the appropriate minimum finished floor level (FFL).

An SCA could begin to introduce rezoning of the vulnerable lands including private property to a foreshore reserve (where it is currently zoned).

It is recognised that this recommendation has the potential to cause concern amongst the community, especially for landowners, which is a natural response from citizens trying to protect property values. However, it must be noted that there is no obligation on Government to compensate land lost due to erosion, and it is much more proactive for the Shire to identify land at risk in the future and take appropriate action. For landowners who may be considering purchasing or developing lands, it is important to note that they should not assume any funds will be forthcoming to support future retreat.

(Options: MR3 - Planning controls for managed retreat / Prohibit expanding existing use rights, AC3 - Planning controls for accommodation).

Recommendation 2: Coastal / Waterway Local Planning Policy

Prepare / update a local planning policy (LPP) to clarify the Shire's attitude and expectations in relation to coastal development within an identified area, including the type of permanent or temporary assets it is prepared to accept within the coastal reserve and/or on land subject to coastal processes.

LPPs are prepared and adopted according to the provisions in Part 2 Division 2 of the Deemed Provisions of LPS 9. The Shire may prepare an LPP in respect of any matter related to the planning and development of the Scheme area. The LPP may apply to a particular class or classes of matter specified in the policy and may apply to the whole of the Scheme area or to parts specified in the policy.

An LPP can provide more detail and guidance on what sort of development would be acceptable and will also assist the Council in making planning decisions on coastal development requiring the exercise of discretion. For example, on land at risk of erosion within the life of a proposed development the LPP may encourage use of structures that can be disassembled and / or transported should erosion come within a specified distance of the structure.

The policy would identify the Council's intention to require notifications on title as a condition of development approval.

The Shire has two LPPs that deal with coastal and waterway development and management – LPP 1.2 Foreshore Protection Areas and LPP 1.4 Foreshore Reserves along Water Courses. These LPPs should be updated or a new LPP should be prepared by the Shire to reflect these recommendations.

(Options: MR3 - Planning controls for managed retreat / Prohibit expanding existing use rights, AC3 - Planning controls for accommodation).

Recommendation 3: Notifications on Title

All freehold land identified as being at risk of impact from coastal processes should have a notification placed on its certificate of title/s to make the owner and future landholders aware of the potential for the land to be impacted.

Section 165 of the Planning and Development Act 2005 enables a local government or public authority to place a notification on the certificate of title of land to make owners and future owners of land aware of being within or proximate to a future coastal hazard as determined in accordance with SPP 2.6 and an endorsed CHRMAP that may affect the use and enjoyment of the land. The process requires the written consent of the landholder and payment of a fee, so it is usual for the requirement for placement of a notification to be a condition of development or subdivision approval. However, placement of a notification on the title does not have to be tied to an application and could take place at any time with owner consent.

Current wording recommended by the WAPC and in accordance with SPP 2.6 is as follows:

"This lot is located in an area likely to be subject to coastal erosion and/or inundation over the next 100 years from the date this notification is registered."

With regard to the above wording, the WAPC notes that a shorter timeframe than 100 years may be appropriate where identified in an endorsed CHRMAP.

(Options: MR3 - Planning controls for managed retreat / Prohibit expanding existing use rights, AC3 - Planning controls for accommodation NR3 - Notification on title).

Recommendation 4: Local Planning Strategy – Investigation Area

The Shire is in the process of preparing its Local Planning Strategy, which provides an excellent opportunity to identify the vulnerability in this study area in the strategic planning framework.

This will help to guide ongoing planning and development in the area, and provide an important signal to landowners and developers that the land in the study area has associated risks. This is an important first step to including known vulnerability in the statutory planning framework.

(Options: MR3 - Planning controls for managed retreat / Prohibit expanding existing use rights, AC3 - Planning controls for accommodation).

Recommendation 5: Purchase of Property Investigation

As noted in Recommendation 2, it is suitable to begin contemplating the gradual increase of the foreshore reserve in the vulnerable zone in the medium term. Such a decision could potentially result in an obligation on the Shire to acquire lands under current legislation (Injurious Affection).

It is recommended that the Shire investigate, as an alternative, the opportunity to acquire land as it become available on the public market. Such property could then be converted to a leasable asset and continue to be utilised up to the time when the risk becomes likely/very likely. Lease clauses may include immediate relocation of tenants. This option would result in a more flexible approach to adaptation over time, with assets being the long term responsibility of the Shire rather than private landowners.

(Options: MR3 - Planning controls for managed retreat).

Recommendation 6: Shire Infrastructure Asset Planning

It is recommended that the Shire ensure that all future infrastructure assets placed in the vulnerable zone either be sacrificial or have a design life that ensure the asset will be redundant before the risk becomes almost certain. This can be done through the Shire's Asset Management Planning either spatially or via a database.

This will ensure that hard assets such as seating, pathways, toilets, playgrounds etc, as well as soft assets such as landscaping, be developed in such a way as to continue enjoyment of the coastal zone for as long as possible whilst also reducing or removing the risk associated with assets.

An asset management pathway should enable:

- Progressively relocate non-critical assets (MR2) away from the coastal hazard zone once they reach the end of asset life or replace assets with suitably durable and/or sacrificial infrastructure.
- Plan for the relocation of critical service infrastructure outside of the coastal hazard zone once they reach the end of asset life, or at a minimum, modify the service infrastructure asset so that it does not run parallel to the coastline and can be progressively removed when exposed to intolerable risk levels.

Investigate opportunities for leaseback of land and land swaps in the context of planned and managed retreat. Seek legal advice regarding the basis of agreements with landholders and whether opt-ins can be time constrained.

(Options: MR3 - Planning controls for managed retreat, NR2 - Protection structure audit).

Recommendation 7: Resilience Planning and Monitoring

A number of the at-risk assets could include management options that are already ongoing Shire management processes. This includes sand nourishment, and dune rehabilitation and protection.

Ongoing dune rehabilitation will be subject to securing grants, which the Shire can continue to apply for, support and manage.

These options were the preferred options across all criteria. This aligns with community preferences for more natural options.

It is recommended that the Shire develop a system of assessment for priority resilience planning, which may include an ongoing schedule, as well as an event response criteria and action plan. This plan should include or should form part of a monitoring plan which should address the entire study area. It is also recommended that the Shire use this plan to support ongoing grant applications through grant bodies such as Coastwest. The development of this plan may be supported by the Federal Coastal Management Plan Assistance Program or the State Coastal Management Plan Assistance Program.

(Options: NR2 - Monitoring).

Recommendation 8: Sand and Rock Source Investigation

A number of the at-risk assets include possible sand nourishment (importing sand from elsewhere) as a management option, however, it is acknowledged that the availability of sand for nourishment is not well understood.

Similarly, but for armour rock suitable for building coastal management structures, some options require rock which needs to be fit for purpose. .

It is recommended that the Shire undertake a sand availability analysis to determine the capacity of local sand supplies, including the feasibility of both terrestrial and marine sand sources, and an analysis of the availability of such rock suitable for marine works, with suitable density, quarry yields, close location and tolerable costs. Potential environmental impacts should be considered in both studies, as well as any approvals required

(Options: PR1-5 - all Protect Options are supported by this recommendation).

Recommendation 9: Emergency Management Plan

Notwithstanding any of the above recommendations it is also recommended that the Shire prepare emergency management plans to cover unexpected events, significant coastal erosion and / or inundation and resulting emergency asset repair or removal. This plan could be undertaken in line with Recommendation 7 and include resilience planning and monitoring activities.

The development of an emergency management plan may be supported by the Federal Coastal Management Plan Assistance Program or the State Coastal Management Plan Assistance Program.

(Option: NR4 - Emergency evacuation plans).

Recommendation 10: Coastal Management Strategy

A Coastal Management Strategy (CMS) is currently being prepared and is an important mechanism to increase the protective capacity of the natural dune system and should address:

- The requirements of SPP2.6 and its supporting documentation
- The findings of the Shire of Gingin CHRMAP (2023)
- Potential environmental issues such as biodiversity and environmental impacts, and detail a weed management strategy for the coastline
- Findings of Asset Management Plans as appropriate
- Include recommendations for closing excess beach access points, ensuring appropriately fenced and signed paths, signage for dune repair and clear signage for 4-wheel drive access and permissibility
- Include recommendations for an education strategy for coastal and environmental management, and work to inform the community about coastal planning and hazards. The education strategy should also include appropriate on-ground signage and information for beach access, camping and 4-wheel driving, where applicable.
- Monitoring for impacts of 4WD vehicles (where applicable) and general beach access on nesting habitats and migratory bird species in dune areas
- The need for a bush fire management plan for the dune and coastal areas

Options: MR2 - Remove/Relocate, AC1 - Revegetate, PR1 - Dune care / Sand management PR2 - Beach nourishment, NR1 - Monitoring, NR2 - Protection structure audit).

Recommendation 11: Other Instruments

Other instruments may be useful for implementing adaptation options. These include:

- Restrictive Covenants, which can be used to restrict present and future landholders from constructing protection structures and, to internalise the risk of building in inherently hazardous locations.
- Special Area Rates, which can be used to ensure that the costs associated with protection options are equitably distributed across beneficiaries.
- The requirement for a structure plan could be considered, setting out development provisions and planning controls consistent with SPP 2.6 for vulnerable areas with new development / subdivision proposed.
- Implementation of an internal procedure at the Shire of Gingin, to provide a note to settlement agencies when they seek a property report linked to the sale of land (settlement agencies typically request these and they include details of rates paid, outstanding issues, approved development etc). This would elevate the potential impact to the prospective purchaser, ensuring that later planning controls are not a surprise.

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

(Options: MR3 - Planning controls for managed retreat).

9.2 Area Based Recommendations

This section describes the recommended adaptation actions proposed for the areas which are identified at risk. Recommendations are provided for individual assets as appropriate.

This section introduces the concept of 'triggers'. Triggers are an indicator of increasing risk to an asset and are consistent with the 'S1' factor from SPP 2.6 – the extreme storm erosion factor, which was established for the study area in Cardno 2019 and confirmed in this project.

9.2.1 Flexible Adaptation

It should be noted that the CHRMAP policy preferences the most flexible adaptation pathways; the pathways that provide for the broadest possible decision making at the time when a decision becomes necessary.

For this reason, recommended options favour Avoid and Planned Retreat where these are available. Notwithstanding, when an avoid or retreat option is recommended, many other options remain valid. This is the direct benefit of preferencing more flexible adaptation options, because it retains the greatest possible decision making available for a later time when the trigger has been met.

Regardless of the recommended option, planning should continue to be undertaken on all valid options until the point a decision is to be made. Every option recommended remains subject to detailed design and investigation, which will confirm the specific design and design life, the likely impacts to adjacent areas and detailed costings.

The risk treatment recommendations outlined in Section 6.6.1 provide a number of tasks that can be undertaken independent of the area or asset based recommendations – this will contribute to providing greater levels of certainty regarding particular options.

This CHRMAP will also require regular review, at which time the recommended pathways should again be considered. It is recommended that future reviews be undertaken comprehensively, for the whole of the Shire of Gingin coastline, where this is possible.

9.2.2 Risk Management Pathways

This section describes risk management options and the pathways for the four coastal townsites and the associated triggers for risk management measures to be established. These management pathways provide the Shire with a decision-making strategy pathway that is made up of a sequence of decision points over time and at the appropriate time. This will allow the Shire to be responsive to changing circumstances over time and decisions can be planned, prioritised and prepared for.

Cardno 2019 details adaptation pathways for Lancelin, Ledge Point and Seabird. The 2023 CHRMAP project reviewed these pathways in the context of the impact of inundation risks outlined in the CIS Stdy by Baird (2020) and any coastal changes that have occurred since document publication.

It has confirmed that inundation risks apply to Lancelin and Guilderton and that inundation impacts for Ledge Point and Seabird are negligible enough not to impact existing pathways detailed in the Cardno 2019 .

The sub-sections below outline the adaptation pathways for sections of the coastal areas for the four townsites. These coastal areas reference Cardno 2019 management units (MUs) for Lancelin, Ledge Point and Seabird.

Each coastal section includes;

- Key vulnerable asset identification to erosion for all sections and inundation for Guilderton and Lancelin sections
- Existing or proposed management pathway summary (depending on whether it reflects Cardno 2019 or this 2023 CHRMAP assessment)
- A visual representation of what the management options could look like
- The risk management (adaptation) pathway

The MCA results and management options were tested with the community in Community Panel workshops and stakeholder meetings. Community members supported the MCA results and largely supported the recommended management options in the short term. In the longer term, community members also supported some management options that scored neutrally in the MCA.

9.2.3 Guilderton

Key vulnerable assets to erosion in Guilderton are:

- Residential land (Gordon Street) – high vulnerability in current day, extreme vulnerability by 2090
- Roads (Gordon Street, Edward Street) – extreme vulnerability in current day
- Parks and Recreation land (Moore River front car park and foreshore area) – extreme vulnerability in current day
- River management area – high vulnerability in current day

Key vulnerable assets to inundation in Guilderton are:

- Roads (Gordon Street, Edward Street) – extreme vulnerability in 2120 (none prior)

The recommended management actions for Guilderton are:

- Avoid further development
- Remove / relocate
- Planning controls for retreat
- Planning controls to accommodate risk
- Emergency plans and controls
- Revegetate dune

At present day, the Shire can action the following:

- Prevention of further development / limiting existing use rights
- New assets to avoid hazard zones (erosion & inundation)
- Coastal monitoring to regularly document changes and improve system understanding - reference Adaptation Triggers
- Commence update to the Special Control Area
- Commence investigations for relocation
- Dune revegetation

By 2030, it is recommended that the Shire action the following:

- Continue Notifications of Title and development restrictions
- Monitor for Adaptation Triggers
- Appropriate Foreshore Management

The first asset requiring removal on the open coast will be a section of Gordon Street. Access to properties closest to the coast may then be from Fraser St or the remaining length of Gordon Street. If the private properties in this area become within 40 m of the HSD their relocation should be triggered.

For relocation of assets along Gordon Street, it is recommended the adaptation trigger be where the most landward part of the Horizontal Shoreline Datum (HSD) is within 40 metres of the most seaward point of the foreshore reserve area. In this way, public access will be maintained.

For the public car park, this can be within 40 metres of the most seaward point of the car park, as it serves to access the foreshore reserve area. Depending on the condition of the beach access stairs / boardwalk, this trigger may need to be flexible and revised over time.

Along with the measures previously noted, by 2050 it is recommended that the Shire be prepared with appropriately zoned land available for relocation of properties / assets.

By 2070 roads adjacent to Moore River may require significant repair or relocation and foreshore recreational infrastructure may require significant repair or relocation. The Shire should continue previously noted measures.

It is likely by 2120 that some residential properties on Gordon Street will be impacted and may require relocation.

The Guilderton adaptation pathway is at Table 41. Figure 34 visualises management actions spatially.

Table 41: Guilderton Adaptation Pathway

<table>
<tr><th colspan="3">PATHWAYS & ACTIONS</th></tr>
<tr><td>Undeveloped areas</td><td colspan="2">Avoid
AV - Avoid further development</td></tr>
<tr><td rowspan="3">Developed areas</td><td>Managed Retreat
MR1, MR3 - Leave assets unprotected, Implement planning controls to prevent new development</td><td rowspan="3">Managed Retreat
MR2 - Remove/relocate assets</td></tr>
<tr><td>Accommodate/No regrets (until approximately 2070)
AC1, AC2, NR3, NR4 - Implement planning controls (SCA) for designing to accommodate risk,
Notification on Certificate of Title, Implement emergency management plans</td></tr>
<tr><td>Protect
PR1 - Dune care/management</td></tr>
<tr><td>Minor infrastructure</td><td colspan="2">Managed Retreat
MR1, MR2 - Leave assets unprotected, Remove/relocate minor infrastructure as it becomes damaged, irreparable or unsafe</td></tr>
</table>



Figure 34: Guilderton Adaptation Management Actions

9.2.4 Lancelin

For the purpose of this technical assessment, the Lancelin area has been broken down into Lancelin North (LA3 and LA4 in Cardno 2019, Lancelin Centre (LA2 in Cardno 2019) and Lancelin South (LA1 in Cardno 2019).

9.2.4.1 Lancelin North (LA3 and LA4)

Key vulnerable assets to inundation in Lancelin North are:

- Beach – very high vulnerability by 2070
- Residential – high vulnerability by 2030, very high vulnerability by 2070
- Coastal / dune vegetation – very high vulnerability by 2070
- Hotel, restaurant and Endeavour Tavern – high vulnerability by 2070
- Caravan park north – high vulnerability by 2070

The following assets were also identified in Cardno 2019 (erosion), and are referenced here for information only (NB: some assets that are vulnerable to inundation are also vulnerable to erosion).

- Beach – very high vulnerability by 2070
- Residential – high vulnerability by 2030, very high vulnerability by 2070
- Coastal / dune vegetation – very high vulnerability by 2070
- Hotel, Restaurant and Endeavour Tavern – high vulnerability by 2070
- Caravan Park north – high vulnerability by 2070

The recommended management actions for Lancelin North are:

- Avoid further development
- Planning controls for retreat
- Planning controls to accommodate risk
- Emergency plans and controls
- Dune care / sand management
- Stormwater Management

The Lancelin North adaptation pathway is at Table 42. Figure 35 visualises management actions spatially.

Table 42: Lancelin North (LA3 and LA4) Adaptation Pathway

<table>
<tr><th colspan="3">PATHWAYS & ACTIONS</th></tr>
<tr><td>Undeveloped areas</td><td colspan="2">Avoid
AV - Avoid further development</td></tr>
<tr><td rowspan="3">Developed areas</td><td>Managed Retreat
MR3 - Implement planning controls to prevent new development</td><td rowspan="3">Managed Retreat
MR2 - Remove/relocate assets</td></tr>
<tr><td>Accommodate/No regrets
NR3, NR4 - Notification on Certificate of Title, Implement emergency management plans to accommodate risk</td></tr>
<tr><td>Protect
PR1 - Dune care/management</td></tr>
<tr><td>Minor infrastructure</td><td colspan="2">Managed Retreat
MR1, MR2 - Remove/relocate minor infrastructure as it becomes damaged, irreparable or unsafe</td></tr>
</table>

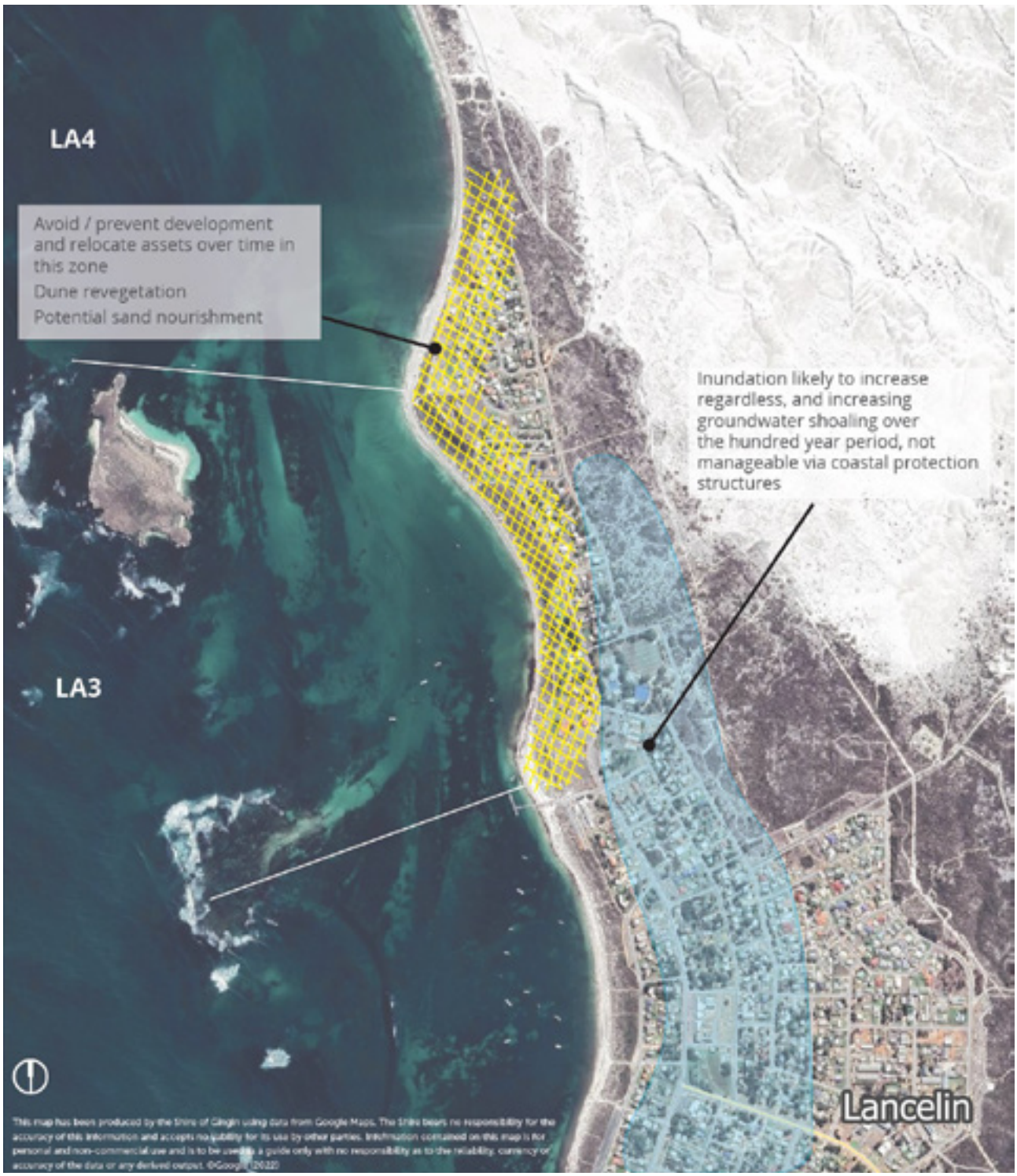


Figure 35: Lancelin North (LA3 and LA4) Adaptation Management Actions

9.2.4.2 Lancelin Centre (LA2)

Key vulnerable assets to inundation in Lancelin Centre are:

- Residential - High vulnerability by 2040, extreme vulnerability by 2120
- Cunliffe Street and adjacent roads - extreme vulnerability by 2040
- Tourism - High vulnerability by 2040
- Town centre - High vulnerability by 2070, extreme vulenrability by 2120

The following assets were also identified in Cardno 2019 (erosion), and are referenced here for information only (NB: some assets that are vulnerable to inundation are also vulnerable to erosion).

- Residential – high vulnerability by 2070, very high vulnerability by 2110
- Cunliffe Street – high vulnerability by 2110
- Beach – high vulnerability by 2070, very high vulnerability by 2110
- Coastal / dune vegetation – high vulnerability by 2070, very high vulnerability by 2110
- Jetty – high vulnerability by 2070
- Light industrial, cafe - high vulnerability by 2110

The recommended management actions for Lancelin Centre are:

- Avoid further development
- Planning controls for retreat
- Planning controls to accommodate risk
- Emergency plans and controls
- Dune care / sand management
- Stormwater Management

The Lancelin Centre adaptation pathway is at Table 43. Figure 35 visualises management actions spatially.

Table 43: Lancelin Centre (LA2) Adaptation Pathway

<table>
<tr><th colspan="3">PATHWAYS & ACTIONS</th></tr>
<tr><td>Undeveloped areas</td><td colspan="2">Avoid
AV - Avoid further development</td></tr>
<tr><td rowspan="3">Developed areas</td><td>Managed Retreat
MR3 - Implement planning controls to prevent new development</td><td rowspan="3">Managed Retreat
MR2 - Remove/relocate assets</td></tr>
<tr><td>Accommodate/No regrets
NR3, NR4 - Notification on Certificate of Title, Implement emergency management plans to accommodate risk</td></tr>
<tr><td>Protect
PR1 - Dune care/management</td></tr>
<tr><td>Minor infrastructure</td><td colspan="2">Managed Retreat
MR1, MR2 - Remove/relocate minor infrastructure as it becomes damaged, irreparable or unsafe</td></tr>
</table>



Figure 36: Lancelin Centre (LA2) Adaptation Management Actions

9.2.4.3 Lancelin South (LA1)

Key vulnerable assets to inundation in Lancelin South are:

- Sea Rescue and Grace Darling Park – high vulnerability by 2040, extreme vulnerability by 2120
- Caravan Park south – high vulnerability by 2040

The following assets were also identified in Cardno 2019 (erosion), and are referenced here for information only (NB: some assets that are vulnerable to inundation are also vulnerable to erosion).

- Sea Rescue and Grace Darling Park – very high vulnerability by 2070
- Caravan Park south - high vulnerability by 2070, very high vulnerability by 2110
- Coastal/ dune vegetation – medium vulnerability by 2070
- Beach – low vulnerability over the hundred-year horizon
- Car park (Back Beach) – low vulnerability over the hundred-year horizon

The recommended management actions for Lancelin South are;

- Avoid further development
- Planning controls for retreat
- Planning controls to accommodate risk
- Emergency plans and controls
- Dune care / sand management
- Stormwater Management

The Lancelin South adaptation pathway is at Table 44. Figure 37 visualises management actions spatially.

Table 44: Lancelin South (LA1) Adaptation Pathway

<table>
<tr><th colspan="3">PATHWAYS & ACTIONS</th></tr>
<tr><td>Undeveloped areas</td><td colspan="2">Avoid
AV - Avoid further development</td></tr>
<tr><td rowspan="3">Developed areas</td><td>Managed Retreat
MR3 - Implement planning controls to prevent new development</td><td rowspan="3">Managed Retreat
MR2 - Remove/relocate assets</td></tr>
<tr><td>Accommodate/No regrets
NR3, NR4 - Notification on Certificate of Title, Implement emergency management plans to accommodate risk</td></tr>
<tr><td>Protect
PR1 - Dune care/management</td></tr>
<tr><td>Minor infrastructure</td><td colspan="2">Managed Retreat
MR1, MR2 - Remove/relocate minor infrastructure as it becomes damaged, irreparable or unsafe</td></tr>
</table>



Figure 37: Lancelin South (LA1) Adaptation Management Actions

9.2.4.4 Lancelin Overall

At present day, the Shire can action the following:

- Prevention of further development / limiting existing use rights
- New assets to avoid hazard zones (erosion & inundation)
- Commence groundwater study
- Coastal monitoring to regularly document changes and improve system understanding - reference Adaptation Triggers
- Commence inclusion of a Special Control Area in the Local Planing Scheme (if not already progressed)
- Commence investigations for relocation
- Commence technical investigations; dune revegetation if deemed suitable

It is noted that Lancelin's drinking water comes from the Lancelin Water Reserve, an unconfined superficial groundwater formation. This is located adjacent to the town of Lancelin, and extends to the north and east. This needs to be considered during the relocate planning process, as well as the recommended groundwater study.

As part of the relocate process, the Shire will need to consider other utility related issues.

If the dune revegetation measures indicate they may be successful, then these should be carried out as soon as possible.

By 2030, it is recommended that the Shire action the following:

- Continue Notifications of Title and development restrictions
- Monitor for Adaptation Triggers
- Appropriate Foreshore Management

Along with the measures previously noted, by 2050 it is recommended that the Shire be prepared with appropriately zoned land available for relocation of properties / assets.

Beyond 2050, the Shire will need to continue to monitor and review triggers and action relocation planning.

9.2.5 Ledge Point

Assets have limited vulnerability to inundation in Ledge Point. For the purpose of this report, the tables and figures below reflect the recommendations from Cardno 2019 (and are general in nature).

Key vulnerable assets in Ledge Point are:

- Holiday Village – high vulnerability by 2070, very high vulnerability by 2110
- Residential – high vulnerability at current day, very high vulnerability by 2030 or very high vulnerability by 2070 (location specific)
- Key Biscoyne Park – very high vulnerability by 2110
- Coastal / dune vegetation – very high vulnerability by 2110
- Beach – high vulnerability by 2070 & 2110
- Car park and road (De Burgh Street) – high vulnerability by 2110, very high vulnerability not shown in the 100-year horizon
- Roads – high vulnerability by 2070, very high vulnerability by 2110
- Foreshore recreation areas – high vulnerability by 2110, very high vulnerability not shown in the 100 year horizon

At present day, it is recommended that the Shire continue monitoring of the coastal beach and dune (monitoring of beach levels and vegetation quantity / quality), in conjunction with the erosion risk management pathway stipulated in Cardno 2019.

The Ledge Point adaptation pathways are at Table 45, Table 46 and Table 47. Figure 38, Figure 39 and Figure 40 visualise management actions spatially, with Figure 40 illustrating potential impacts of a groyne option.

Table 45: Ledge Point (LP1 and LP4) Adaptation Pathways

PATHWAYS & ACTIONS		
Undeveloped areas	Avoid AV, MR3 Implement planning controls to prevent new development and intensification of development in the Coastal foreshore reserve	
Developed areas	Accommodate/Managed Retreat AC1, MR3 Implement planning controls and emergency plans to accommodate coastal risk	
Minor infrastructure	Protect PR1 Dune care and sand management	Managed Retreat MR1, MR2 Remove minor infrastructure as it becomes damaged, irreparable and/or unsafe

Table 46: Ledge Point (LP2) Adaptation Pathway

PATHWAYS & ACTIONS		
Undeveloped areas	Avoid AV, MR3 Implement planning controls to prevent new development and intensification of development in the Coastal foreshore reserve	
Developed areas	Protect PR3 Protection by groyne	Managed Retreat MR2 Remove assets as their risk becomes intolerable
Minor infrastructure	Managed Retreat MR1, MR2 - Remove / relocate minor infrastructure as it becomes damaged, irreparable or unsafe	

Table 47: Ledge Point (LP3) Adaptation Pathway (Cardno 2019)

PATHWAYS & ACTIONS		
Undeveloped areas	Avoid AV, MR3 Implement planning controls to prevent new development and intensification of development in the Coastal foreshore reserve	
Developed areas	Accommodate AC1, MR3 Implement planning controls and emergency plans to accommodate coastal risk	Managed Retreat MR2 Remove assets as their risk becomes intolerable
Minor infrastructure	Managed Retreat MR1, MR2 - Remove / relocate minor infrastructure as it becomes damaged, irreparable or unsafe	



Figure 38: Ledge Point North (LP3 and LP4) Adaptation Management Actions



Figure 39: Ledge Point South (LP1 and LP2) Adaptation Management Actions

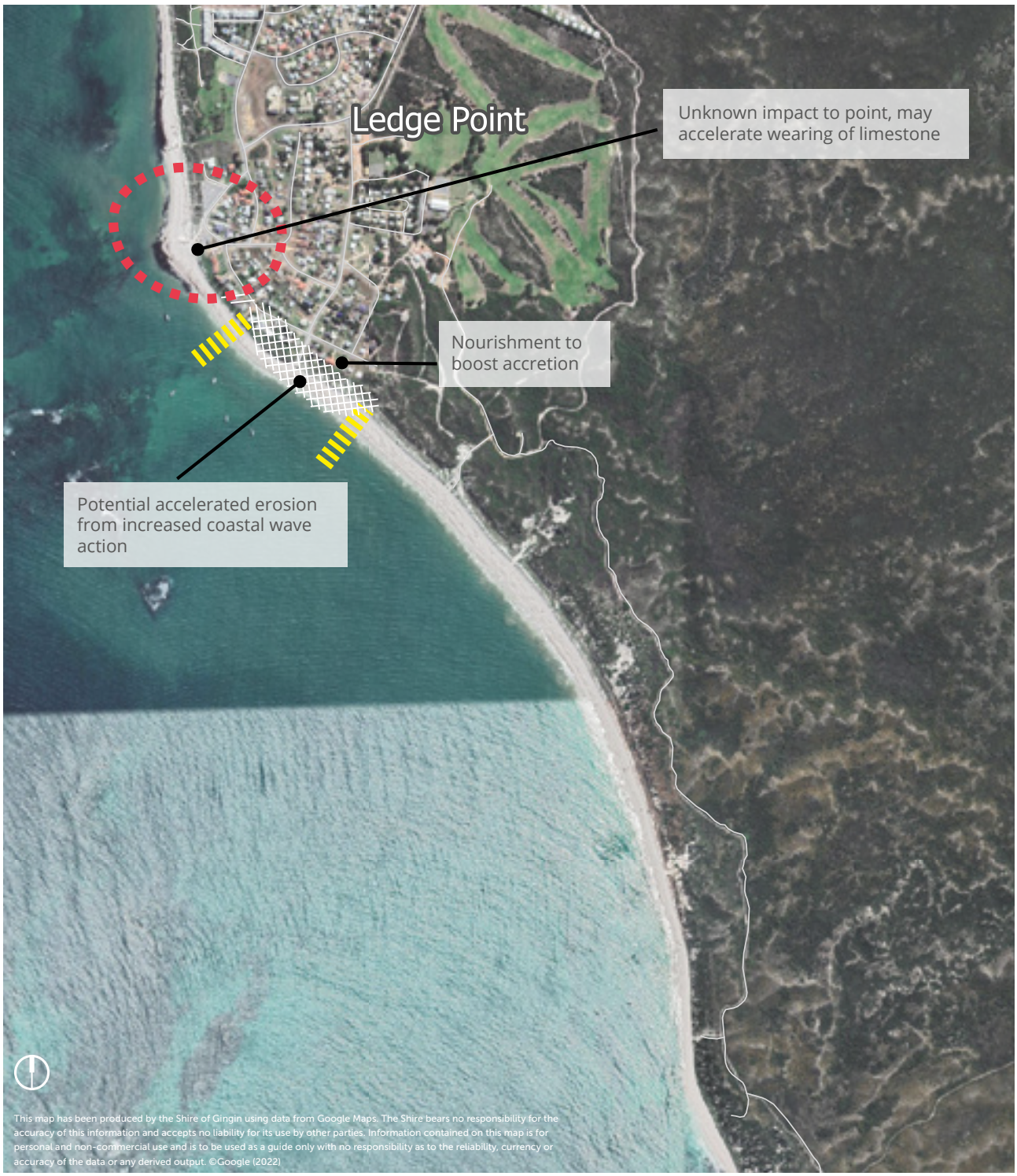


Figure 40: Ledge Point (LP2) Adaptation Management Actions - Protect Option

9.2.6 Seabird

Assets have limited vulnerability to inundation in Seabird. For the purpose of this report, the tables and figures below reference the recommendations from Cardno 2019 (and are general in nature).

Key vulnerable assets in Seabird North are:

- Beach – high vulnerability by 2030, very high vulnerability not shown in the 100-year horizon
- Caravan Park (Seabird Private) – very high vulnerability by 2070
- Coastal / dune vegetation – high vulnerability by 2070, very high vulnerability by 2110
- Tavern – high vulnerability by 2110, very high vulnerability not shown in the 100-year horizon

The recommended management actions for Seabird North are:

- Avoid further development
- Planning controls for retreat
- Planning controls to accommodate risk
- Emergency plans and controls
- Dune care / sand management

Key vulnerable assets in Seabird South are:

- Beach – high vulnerability by 2030, very high vulnerability by 2070
- Residential - very high vulnerability in current day
- Coastal / dune vegetation – high vulnerability by 2030, very high vulnerability by 2070
- Car parks and roads – high vulnerability by 2030, very high vulnerability not shown in the 100 year horizon

The recommended management actions for Seabird South are:

- Avoid further development
- Planning controls for retreat
- Planning controls to accommodate risk
- Emergency plans and controls
- Dune care / sand management

At present day, it is recommended that the Shire continue monitoring of the coastal beach and dune (monitoring of beach levels and vegetation quantity / quality), in conjunction with the erosion risk management pathway stipulated in Cardno 2019.

The Seabird North adaptation pathway is at Table 48 and the Seabird South adaptation pathway is at Table 49. Figure 41 and Figure 42 visualise management actions spatially.

Table 48: Seabird North (SE2) Adaptation Pathway (Cardno 2019)

PATHWAYS & ACTIONS		
Undeveloped areas	Avoid AV, MR3 Implement planning controls to prevent new development and intensification of development in the Coastal foreshore reserve	
Developed areas	Protect AC1, AC2, PR1 Implement planning controls and emergency plans to accommodate coastal risk and dune care and sand management	Managed Retreat MR2 Remove assets as their risk becomes intolerable
Minor infrastructure	Managed Retreat MR1, MR2 Remove minor infrastructure as it becomes damaged, irreparable and/or unsafe	

Table 49: Seabird South (SE1) Adaptation Pathway (Cardno 2019)

PATHWAYS & ACTIONS		
Undeveloped areas	Avoid AV, MR3 Implement planning controls to prevent new development and intensification of development in the Coastal foreshore reserve	
Developed areas	Protect PR5 Protection by seawall	Managed Retreat MR2 Remove assets as their risk becomes intolerable
Minor infrastructure	Managed Retreat MR1, MR2 Remove minor infrastructure as it becomes damaged, irreparable and/or unsafe	



Figure 41: Seabird North (SE2) Adaptation Management Actions - Managed Retreat



Figure 42: Seabird South (SE1) Adaptation Management Actions - Managed Retreat

SECTION 10. SUMMARY

10. SUMMARY

This section provides a summary of the adaptation pathways proposed to respond to erosion and inundation in Guilderton and for inundation in Lancelin, Ledge Point and Seabird (although it also identifies actions required for erosion in Lancelin, Ledge Point and Seabird that reflect Cardno 2019).

Table 50 summarises the individual recommendations, highlights responsibility, the relevant trigger and the required timeframe. The timeframes used are immediate (now), short term (within 10 years), medium term (10-50 years) and long term (beyond 50 years). All timeframes for asset actions are approximate, as the trigger point is the key determinant of action.

With regard to cost, it should be noted that each individual option would require a detailed cost assessment based on final design / source material.

Protection measures should not be implemented if maintenance schedules cannot be adhered to, as this places undue risk on future populations. Likewise, the identified triggers should be subject to ongoing monitoring and review.

In the first instance, monitoring should be in accordance with the Monitoring Plan which can be found at Chapter 11. However, regular review of the overarching hazard models should also occur. It is recommended that the Shire continue to monitor changes in international scientific understanding, and maintain a working relationship with the DPLH as well as the DoT's Coastal Infrastructure Business Unit in this regard.

A review of immediate actions recommended in the CHRMAP should be undertaken within 2 years to confirm progress. A full review should be undertaken within ten (10) years and in conjunction with ongoing reviews of the Shire's Local Planning Strategy and Local Planning Scheme.

Table 50: Summary of Gap Assessment Technical Report Recommendations

NO.	RECOMMENDATION	RESPONSIBILITY	TRIGGER	TIMEFRAME
1	Local Planning Scheme – Special Control Area (all MUs)	Planning	Local Planning Strategy review or Scheme amendment	Immediate
2	Coastal Waterway Local Planning Policy for Shire (all MUs)	Planning and Environment	2026	Short
3	Notifications on Title (all MUs)	Planning	Ongoing	Ongoing
4	Local Planning Strategy update (investigation area)	Planning	2024	Short
5	Purchase of Property Investigations (Lancelin, Guilderton, Seabird)	Corporate services	2025	Short
6	Shire Infrastructure Asset Audit (all MUs). Update Asset database to incorporate end of life date to facilitate future management of assets (all MUs)	Infrastructure and Environment	Ongoing	Ongoing
7	Resilience Planning including monitoring (in some cases immediate)	Infrastructure and Environment	Ongoing	Ongoing
8	Sand and Rock Source Investigation	Infrastructure and Environment	2025	Short
9	Emergency Management Plan (all MUs)	Infrastructure and Environment	2025	Short
10	Prepare a Coastal Management Strategy	Infrastructure and Environment	2023	Immediate
11	Avoid further development in hazard zones (all towns)	Corporate services	2023	Immediate/ Ongoing
12	Prepare a 'Developing on the coast in the Shire of Gingin' Fact Sheet	Corporate services	2023	Immediate
13	Stormwater Management Study for Lancelin	Infrastructure and Environment	2023	Immediate
14	Detailed Risk Assessment and Adaptation Cost Estimation Study for Lancelin	Corporate services	2023	Immediate
15	Dune Restoration - strategic vegetation planting, sand fencing and management (all MUs)	Infrastructure and Environment	2023	Short/ Ongoing

Table 50: Summary of Gap Assessment Technical Report Recommendations (Cont'd)

NO.	RECOMMENDATION	RESPONSIBILITY	TRIGGER	TIMEFRAME
16	Shire Internal Procedure – Settlement Agent Note and real estate agent letter	Corporate services and Planning	2023	Immediate
17	Annual Beach Profile Surveys	Infrastructure and Environment	Ongoing	Ongoing
18	Rates Levy Investigation – Potential Protection Structures (Lancelin, Seabird, Guilderton)	Corporate services	2027	Short
19	Update 4WD Strategy	Infrastructure and Environment	2027	Short/ Ongoing
20	Rationalise and Formalise Pedestrian Access Paths (all MUs)	Infrastructure and Environment	2027	Short
21	Managed Retreat Planning Lancelin (all MUs)	Corporate services	2030	Short/ Ongoing
22	River Mouth Management for Guilderton (G-MR)	Infrastructure and Environment	Ongoing	Ongoing
23	Managed Retreat Planning Ledge Point (LP2, LP3)	Corporate services	2035	Medium
24	Managed Retreat Planning Seabird private caravan park (S2) and Residential Properties and Roads (S1)	Corporate services	2035	Medium
25	Managed Retreat planning Guilderton - residential properties on Gordon Street, roads (Gordon Street, Edwards Street) and the Moore River front car park and foreshore area	Corporate services	2040	Medium
26	Redesign for inundation for Guilderton (G-MR)	Infrastructure and Environment	As new assets are proposed	Medium
27	Review all lease land and ensure condition of lease provide for coastal hazard management; include notice on property file	Corporate services	2023	Immediate
28	Progress Review	Major Projects	2025	Short
29	CHRMAP Review – Comprehensive	Major Projects	2030	Short

*These items for erosion not inundation and technically not included in this report.

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11. REFERENCES

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APPENDICES

APPENDIX A

COMMUNITY VALUES CARDNO 2019



Please help us understand what you value about the Lancelin coast, where do you like to work, rest and play?

Legend

- Recreational
- Enviromental
- Commercial
- Infrastructure
- Civic
- Heritage
- Threatened Flora, Fauna; Ecological Communities

Our Coastal Values

Lancelin

11 Harvest Terrace, West Perth,
WA, 6005, Australia
Phone: +61 8 9273 3888 Web: www.cardno.com

Data Source: Department of Parks & Wildlife (2017) Threatened and Priority Flora/Fauna Database. Search for Lancelin accessed on 8 May 2017. Prepared by the Species and Communities Branch for Cardno for the Shire of Gingin CHRMAPS.

SHIRE OF GINGIN

DATE	DRAWING NO	ISSUE
25/05/17	LA-003	DRAFT



Please help us understand what you value about the Lancelin coast, where do you like to work, rest and play?

Legend

- Recreational
- Enviromental
- Commercial
- Infrastructure
- Civic
- Heritage
- Threatened Flora, Fauna; Ecological Communities

Our Coastal Values

Ledge Point

SHIRE OF GINGIN

11 Harvest Terrace, West Perth,
WA, 6005, Australia
Phone: +61 8 9273 3888 Web: www.cardno.com

Data Source: Department of Parks & Wildlife (2017) Threatened and Priority Flora/Fauna Database. Search for Ledge Point accessed on 8 May 2017. Prepared by the Species and Communities Branch for Cardno for the Shire of Gingin CHRMAPS.

DATE	DRAWING NO	ISSUE
25/05/17	LA-004	DRAFT



Please help us understand what you value about the Lancelin coast, where do you like to work, rest and play?

Legend

- Recreational
- Enviromental
- Commercial
- Infrastructure
- Civic
- Heritage
- Threatened Flora, Fauna; Ecological Communities

Our Coastal Values

Seabird

11 Harvest Terrace, West Perth,
WA, 6005, Australia
Phone: +61 8 9273 3888 Web: www.cardno.com

Data Source: Department of Parks & Wildlife (2017) Threatened and Priority Flora/Fauna Database. Search for Seabird accessed on 8 May 2017. Prepared by the Species and Communities Branch for Cardno for the Shire of Gingin CHRMAPS.

SHIRE OF GINGIN

DATE	DRAWING NO	ISSUE
25/05/17	LA-005	DRAFT

APPENDIX B – HAZARD MAPPING

(see page 551 of the main report)

APPENDIX D

Appendix D - CHRMAP Integration Project Phase 2 Engagement Summary Report

GINGIN COASTAL HAZARD RISK MANAGEMENT ADAPTATION PLANNING (CHRMAP) INUNDATION INTEGRATION PROJECT

ENGAGEMENT SUMMARY REPORT



SHAPE URBAN

EXECUTIVE SUMMARY

The Shire of Gingin (the Shire) is experiencing growth as a result of its lifestyle, the environment and its proximity to Perth. Its coastal areas are subject to erosion and inundation risks, which will have a significant impact on its communities over time.

The Shire's existing Coastal Hazard Risk Management and Adaptation Plan (CHRMAP; 2019) identifies coastal erosion risks and challenges to the Lancelin, Ledge Point and Seabird townsites, but does not include risks and challenges to the Guilderton townsite or inundation risks and challenges for the four coastal townsites.

The purpose of the Gingin CHRMAP Inundation Integration project is to prepare an integrated and updated CHRMAP for the coastal townsites of Lancelin, Ledge Point, Seabird and Guilderton. The CHRMAP will be updated to:

- Include the coastal erosion risks and challenges to the Guildertown townsite;
- Incorporate the recently completed Gingin Coastal Inundation Study (CIS) for the four townsites by Baird (July 2020); and
- Update risks, challenges and proposed adaptation measures since the CHRMAP and CIS were prepared.

A public facing summary CHRMAP document will also be prepared for the local community that is easy to read and understand.

A critical part of this project is the engagement with the local community and relevant stakeholders. Given the coastline's susceptibility to coastal erosion, extreme weather events and climate change risks, the stakeholder engagement for the project has been shaped to facilitate an understanding of coastal challenges, hazards and risks, understand how the community values assets along the coastline and the value they place on protection for those assets, and to select appropriate adaptation strategies to respond to the risks.

The community's values will help inform the management actions and adaptation strategies for the use and protection of the management units that make up the Shire's coastal zone.

This engagement summary report summarises the online engagement undertaken to inform about the community about coastal risks and processes and to collect community coastal values coastal values for the four coastal townsites workshops undertaken for the Lower Coastal Region (Guilderton and Seabird) in Guilderton on 31 July 2021, and for the Upper Coastal Region (Ledge Point and Lancelin) in Lancelin on 1 August 2021. This workshop report will be updated as engagement for the project progresses and the community values are translated into coastal assessments, trade-offs, risks and adaptation approaches.

We thank all those who were involved in generating these values via the online engagement platform (Social Pinpoint), social media or email, and through the workshopping processes.





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1.0 INTRODUCTION

1.1 BACKGROUND

The Shire of Gingin (the Shire) is experiencing growth as a result of its lifestyle, the environment and its proximity to Perth. The Shire's four coastal townsites - Lancelin, Ledge Point, Seabird and Guilderton - are subject to erosion and inundation risks, which will have a significant impact on its communities over time.

The Shire prepared a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) in 2019 which identifies coastal erosion risks and challenges to the Lancelin, Ledge Point and Seabird Townsites. However, the CHRMAP does not include risks and challenges to the Guilderton townsite or inundation risks and challenges for any of the four coastal townsites.

In 2020, the Shire commissioned BAIRD to undertake a Coastal Inundation Study (CIS) for its four coastal townsites.

Now, the Shire is looking to integrate and update existing coastal work - the Gingin CHRMAP Inundation Integration project will:

- Update the 2019 CHRMAP to include coastal erosion risks and challenges to the Guilderton townsite;
- Update the 2019 CHRMAP to include the CIS by Baird; and
- Update risks, challenges and proposed adaptation measures for the remaining three coastal townsites since the CHRMAP and CIS were prepared.

An easy-to-read summary CHRMAP document will also be prepared for the local community so the CHRMAP is simple to digest and understand.

A critical part of this project is the engagement with the local community and relevant stakeholders.

Given the coastline's susceptibility to coastal erosion, extreme weather events and climate change risks, the preliminary stage of stakeholder engagement for the project has been shaped to raise awareness of the project and understand how the community values assets along the coastline and ensure that concerns and aspirations along the coastline are understood.

This information will help inform the selection of appropriate adaptation strategies to respond to the coastal risks in later stages of the project.

This report details the online engagement and workshops undertaken in the preliminary engagement stage.

This report will continue to be updated as more engagement work is undertaken.

1.2 ENGAGEMENT ACTIVITIES

The engagement activities for this stage of the project included:

- use of an interactive project tool (Social Pinpoint) to answer CHRMAP value survey questions and pin values and comments spatially on a project map;
- two community workshops in Guilderton and Lancelin to discuss coastal processes, map community values for the four coastal Townsites and have preliminary discussions about the criteria to assess possible adaptation options; and
- stakeholder meetings.

Preliminary engagement was based on the four coastal townsites:

- Lancelin
- Ledge Point
- Seabird
- Guilderton (Figure 1 refers).



Figure 1 - Gingin CHRMAP Inundation Integration Study Area

1.3 PURPOSE OF THE REPORT

The purpose of this report is to summarise the stakeholder engagement process undertaken through the preliminary engagement phase. It includes activities undertaken, the information presented and modes of engagement.

The report details feedback received. All individual responses from the online engagement are detailed through the report and all comments from the community values workshops can be found unedited in the Appendices section of this report.

1.4 ENGAGEMENT SUMMARY

The preliminary stage of engagement sought to raise awareness of the project, identify community values and ensure concerns and aspirations for the four coastal townsites was understood.

Stakeholders could visit an online project page with a mapping tool and survey. They could drop pins and comment on activities they valued and their locational preferences for these activities on the mapping tool.

Participants could also respond to a survey and provide any other feedback on how they use the different areas of the coastline. The survey and mapping tool was open from 31 May 2021 to 22 August 2021.

The project team received 38 values survey responses, 6 'pins' were placed on the map and 25 documents were downloaded. The documents available for stakeholders to download were a Coastal Adaptation Infographic created for the project and State Planning Policy 2.6 - Coastal Planning (SPP 2.6). The Coastal Adaptation Infographic can be found at Appendix B..

Stakeholders were further engaged through the following:

- Social media posts
- Key briefings with the Project Steering Group (PSG) including administrative and elected members from the Shire, the Department of Planning, Lands and Heritage and the Department of Transport
- Briefings to key staff members and Executive Management at the Shire.

21 people attended the Guilderton and Lancelin workshops.

In total more than 30 participants contributed to this stage of engagement, with an approximate reach of more than 300 local community members and organisations.

The community's values and other stakeholder feedback received will be used to inform the development of adaptation options for the four coastal townsites along the coastline.

The project team will also be looking to schedule targeted meetings with identified key stakeholders as part of the next engagement stage.

This report will be updated with these outcomes and the outcomes of additional engagement as the project progresses.


BEACH ACCESS
TRACK
NO
PARKING

2.0 PRELIMINARY FEEDBACK

2.1 ONLINE ENGAGEMENT

Online engagement is measured by splitting the level of interaction into three groups; aware, informed and engaged.

Aware

The total number of participants aware of the project through the online engagement tools can be measured by the number of people that viewed at least one page of the website relating to the project. 1,529 participants visited at least one page of the project online.

Informed

Of those who were aware, a smaller group were informed further about the project. This can be measured by the number of interactions with the pages. These people numbered 307.

Engaged

The total who contributed or engaged by using one of the tools was 38. From these, 38 engaged contributors submitted a total of 16 survey responses and six (6) pins were placed.

Other

Additional online engagement for the project included 25 document downloads from the Social Pinpoint project page. Downloadable material included a Coastal Adaptation Infographic (at Appendix B) and SPP 2.6.

2.2 CHRMAP SURVEY

The community told the project team that the coastal foreshore areas are important to them for many recreation, social and cultural reasons.

A survey was set up to understand the importance of each of the four coastal townsite study areas to the community for a range of activities, and the community's values around these.

The CHRMAP survey asked the community seven questions about how they use and value the coastal areas, how they value different adaptation responses, and their relationship to the coastal townsites.

One of the questions asked respondents how they used the beach or foreshore areas.

Two additional questions asked respondents about their age and gender.

A total of 16 participants responded to the survey. All participants responded to all the questions in the survey.

The following section summarises the responses to the survey questions.

CHRMAP SURVEY

Q1 - Within the Shire of Gingin which beach or foreshore area do you visit/use the most?

The 16 responses were spread between Guilderton and Lancelin. Guilderton is the most common area with 10 votes.

Whilst not selected by the 16 people who completed the survey, it is assumed that this is related to the individuals who responded, rather than a specific lack of use of the Ledge Point or Seabird area.

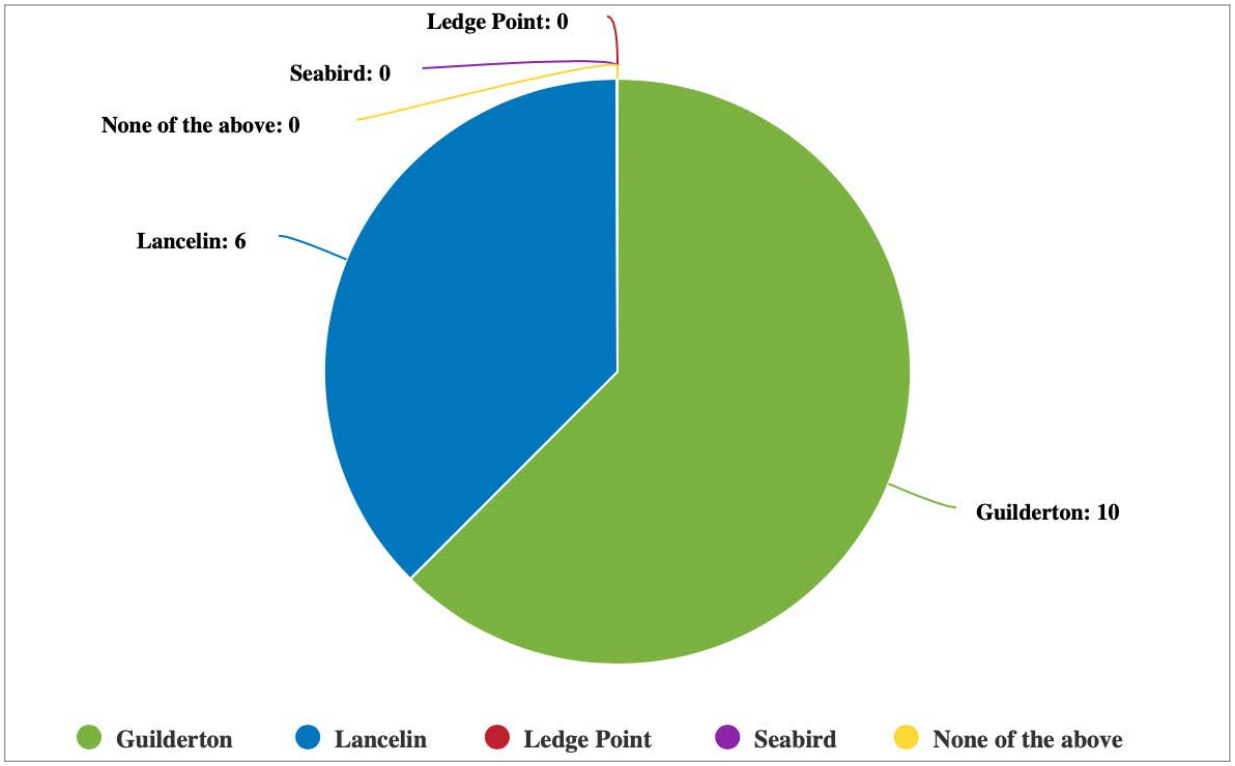


Figure 2 - Question 1

Q2 - How often do you visit the beach or foreshore area?

The frequency of visitation to the beach varied.

Seven of the 16 respondents visit the beach or foreshore area daily, three visit weekly, five visit monthly and one visits occasionally.

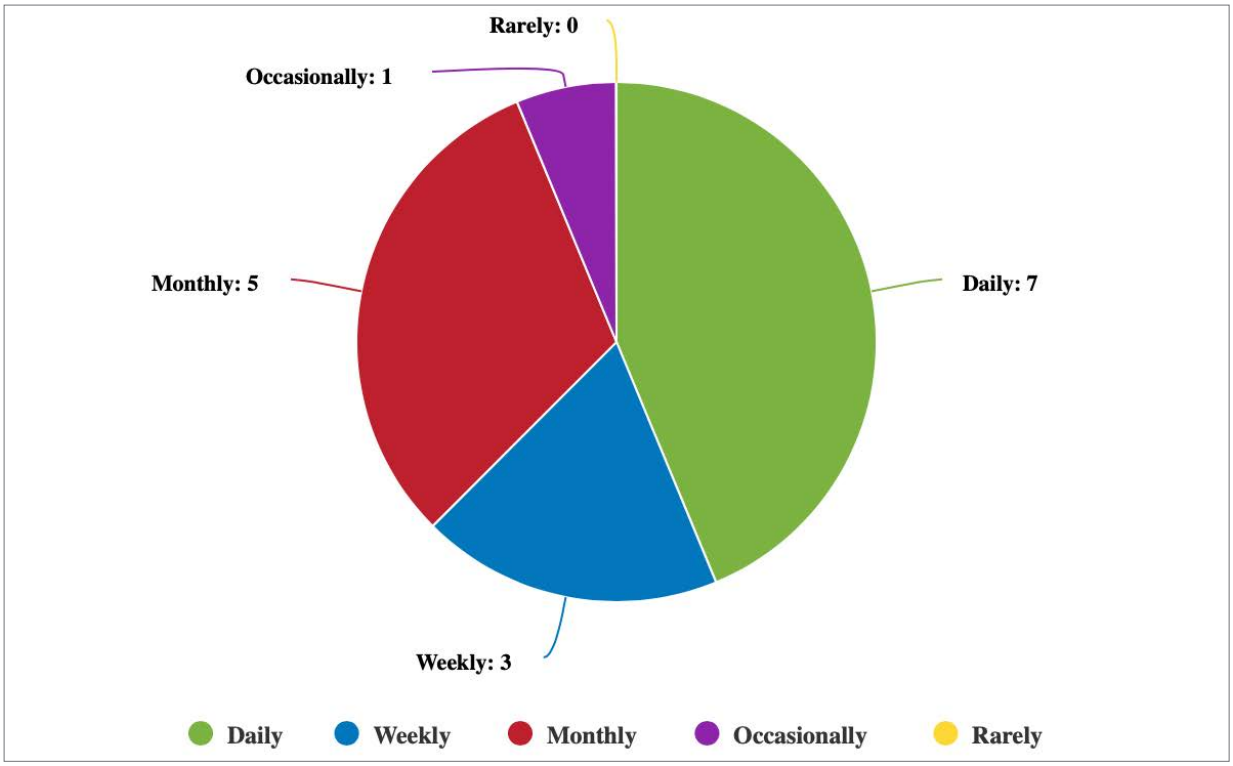


Figure 3 - Question 2



Q3 - What do you use the beach or foreshore area for?

People were able to select multiple options regarding what they use the beach or foreshore areas for.

Walking was the most popular use with 15 votes, following by swimming with 14 votes. Watching the sunset was the next most popular activity with 12 votes.

Wildlife watching and fishing each scored 8 votes, with boat launching coming in closely behind that with 7 votes.

The beach and foreshore areas are used for a variety of reasons, as depicted in Figure 4 below.

One person said they used the beach or foreshore area for their guest house events such picnics and wedding events.

One stakeholder commented that they wished there was public art or activities at the beach as a tourist attraction (to post online and help promote the area), something like the Locks of Love at Pont des Arts in Paris, night lights for nocturnal life and musical markets or concerts in summers.

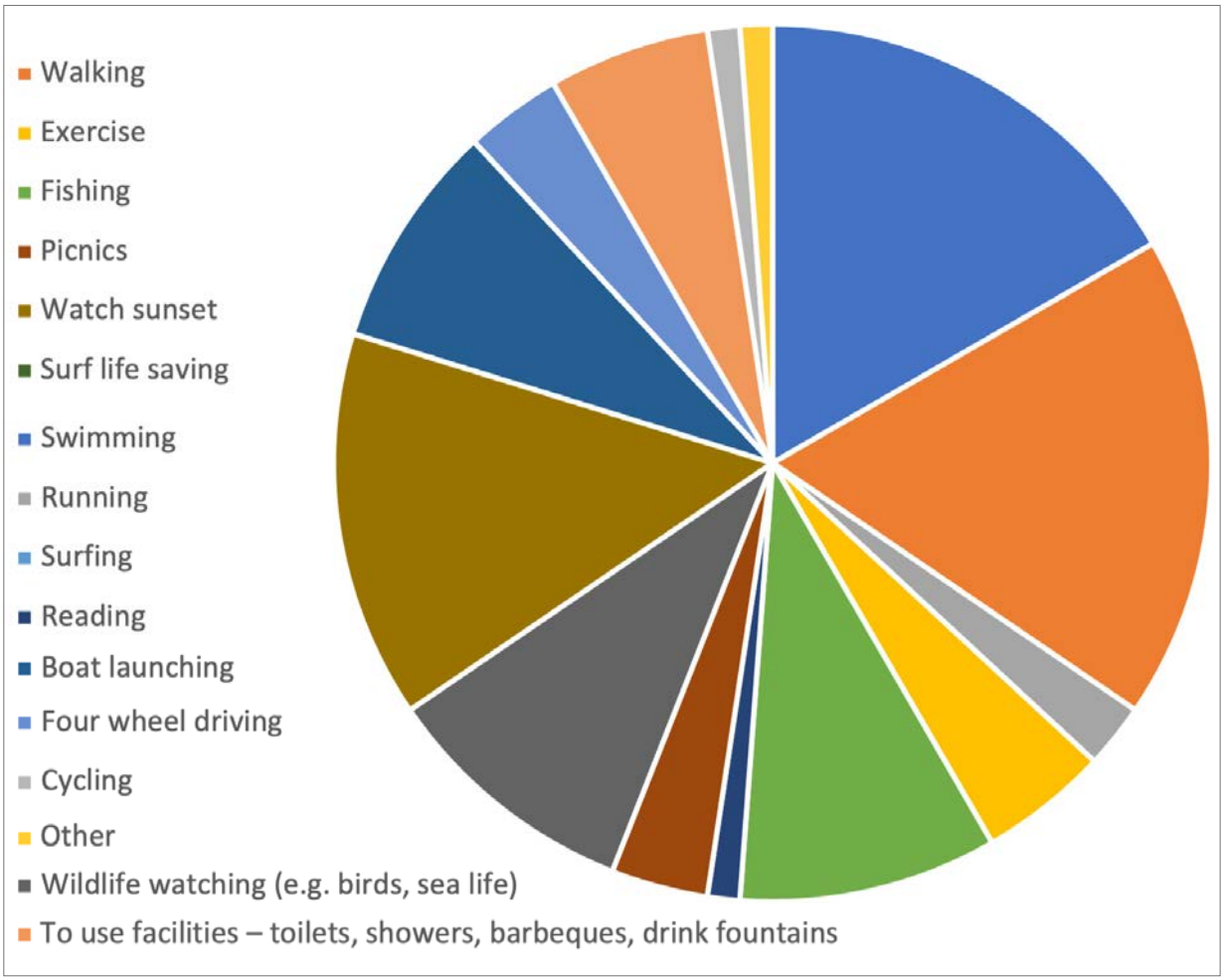


Figure 4 - Question 3

Q4 - On the scale below, how do you value the following?

Participants were asked to value a range of activities and opportunities along the coastline.

There was strong agreement from all participants for all activities and opportunities as per Figure 5 below.

Four (4) people strongly disagreed with the 'Retention of natural landscapes, not interrupted by human-made structures', while five (5) people agreed or strongly agreed.

'Conservation of heritage sites' and 'Preserving the natural environment and ecological systems' had a higher number of neutral responses than the other activities and opportunities.

The remaining activities and opportunities had an Agree/Strongly agree trend.

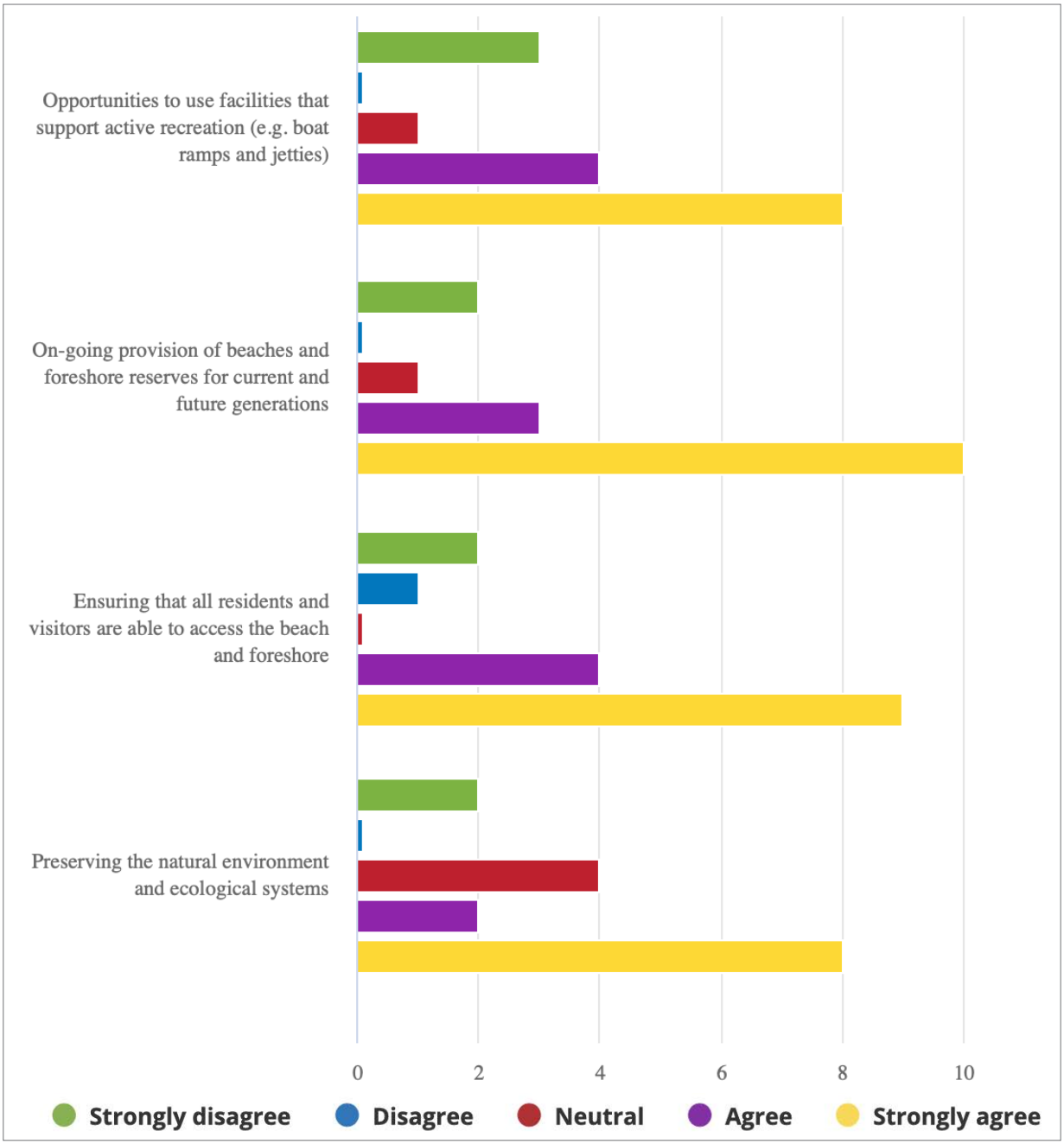


Figure 5 - Question 4

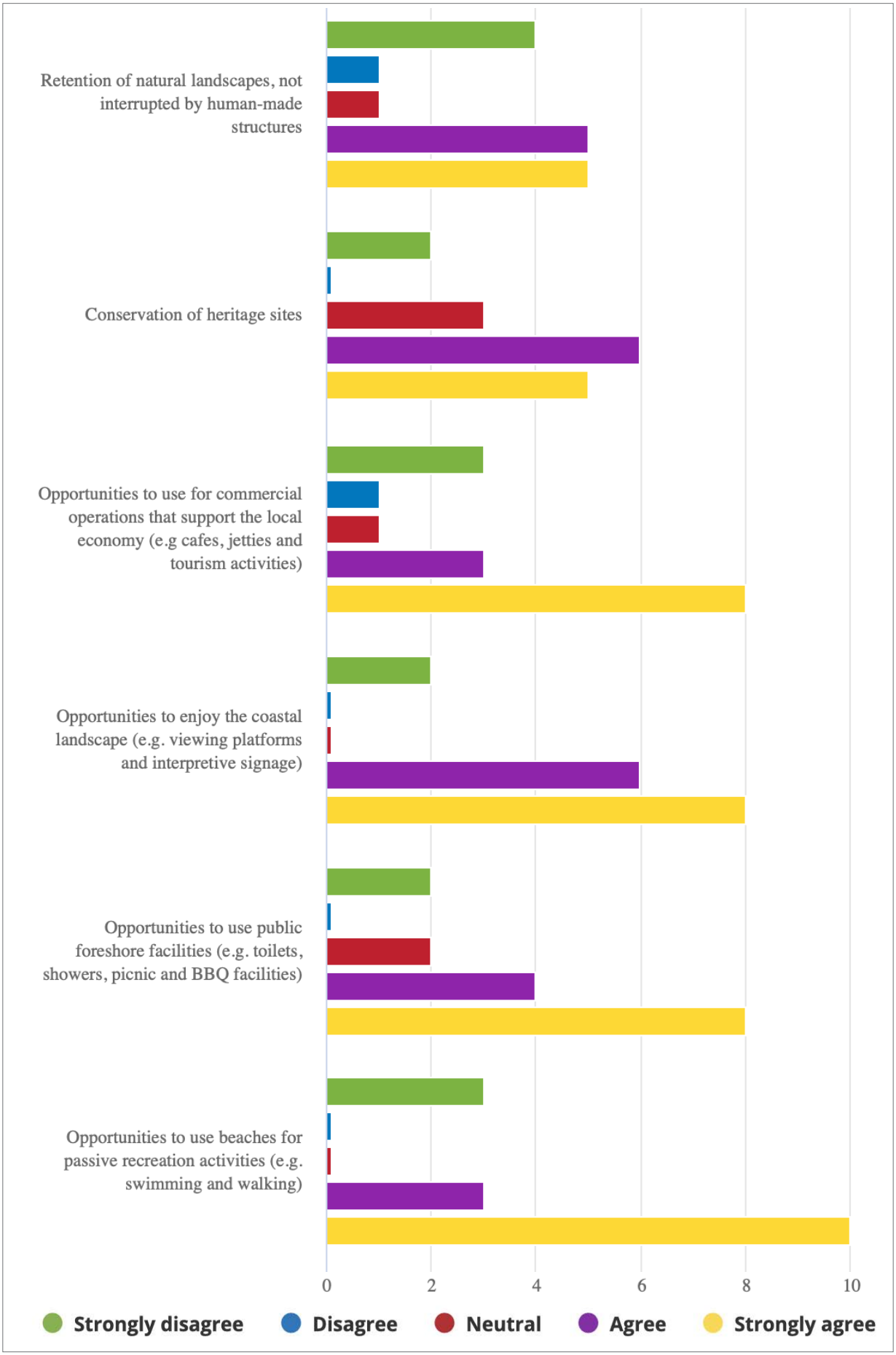


Figure 5 - Question 4, continued...

Q5 - On the scale below, how do you feel about the following options for coastal management?

Question five asked participants to value a selection of coastal management options.

'Preserving dunes, revegetating foreshore reserves and do not remove beach wrack (seaweed) to lower the risk of coastal erosion' and 'Private landowners should be informed about the risk of erosion when purchasing or developing in hazard areas' received strong 'Strongly agree' responses from participants.

'Landowners should also be allowed to protect their property where they have demonstrated there will be not impact on the adjoining coast' also received a strong 'Agree' vote.

The remaining responses are generally well spread between Strongly disagree and Strongly agree.

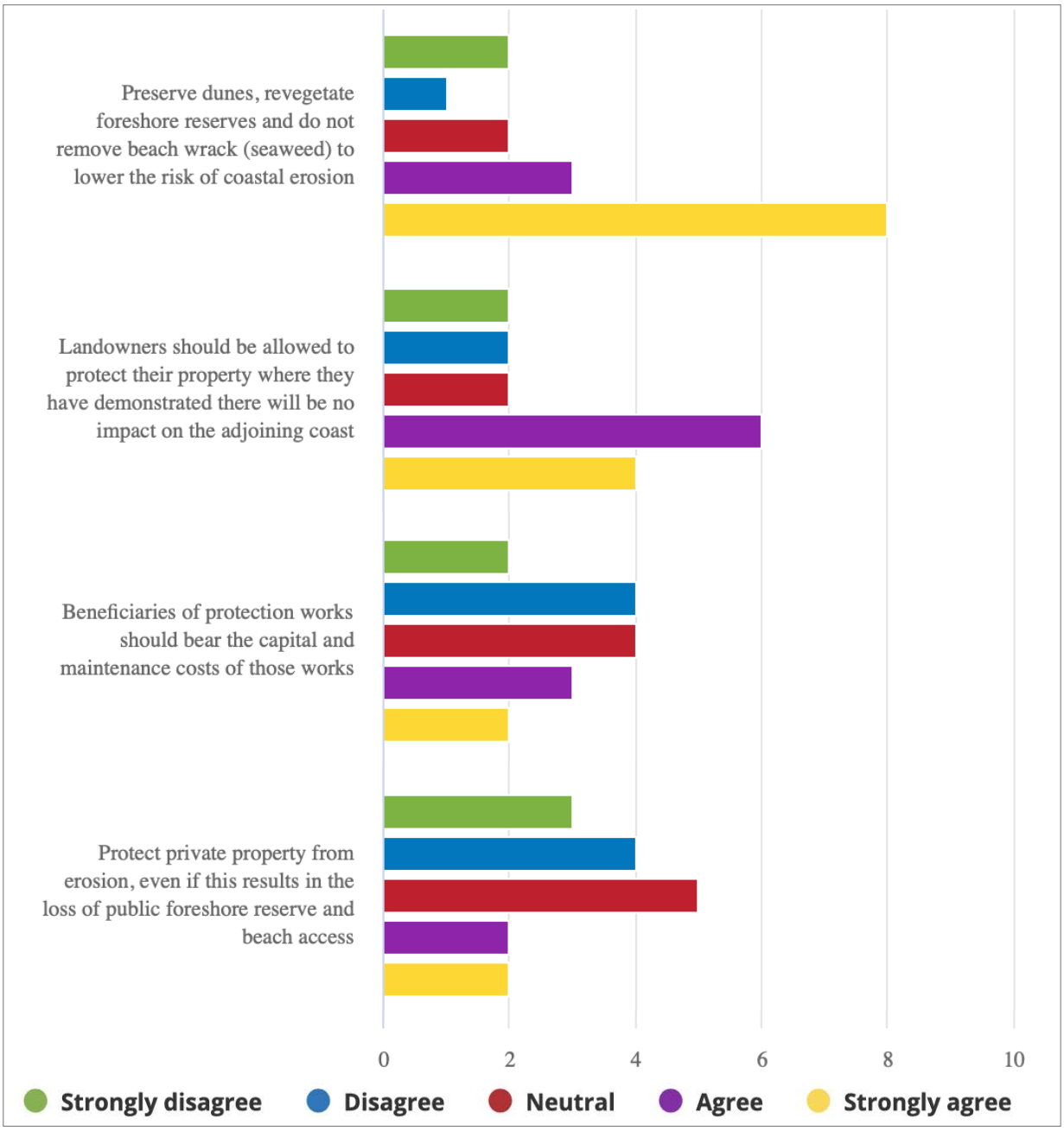


Figure 6 - Question 5

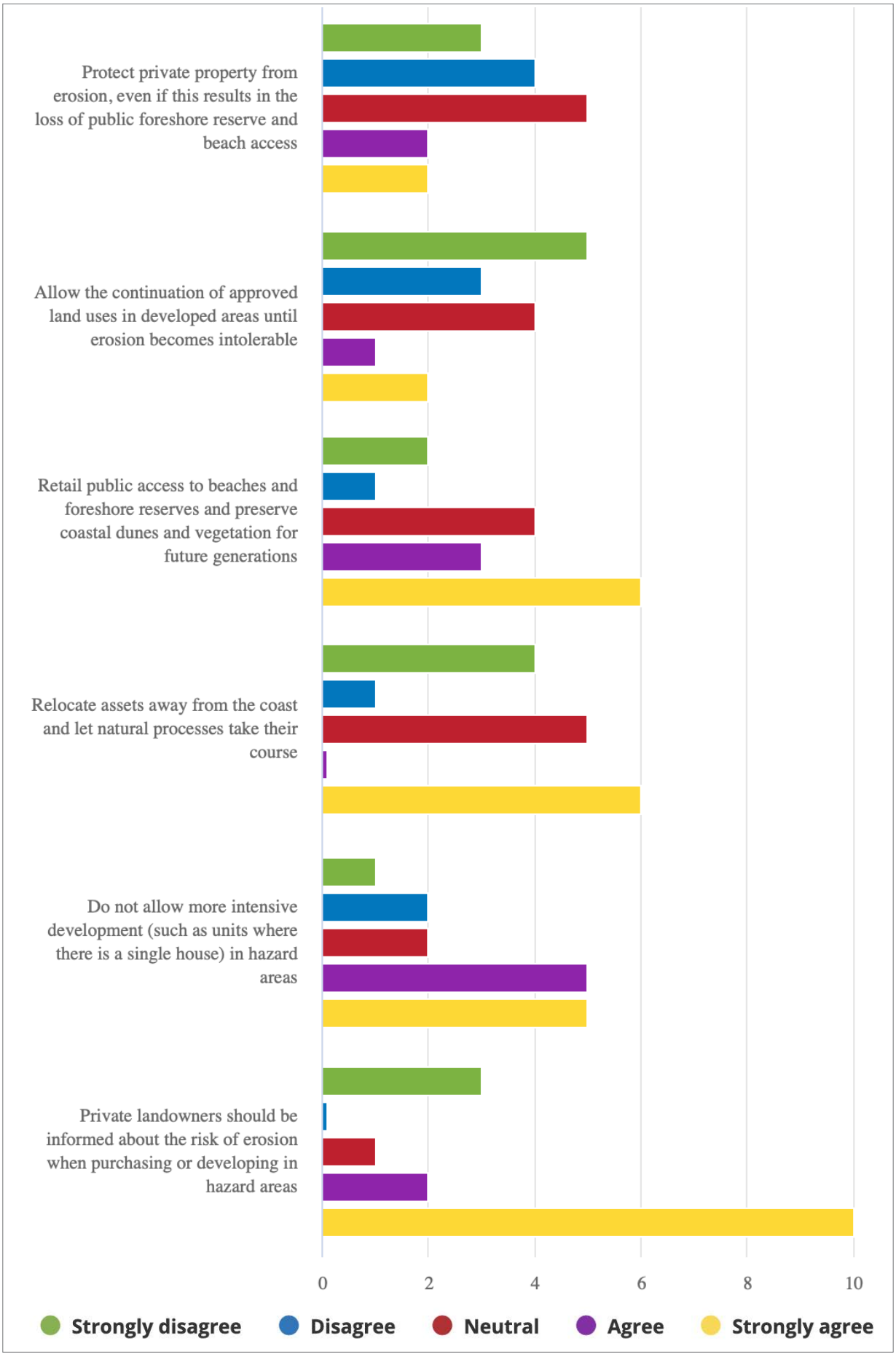


Figure 6 - Question 5, continued...



Q6 - Which coastal town do you live in or own property in?

To contextualise the responses, participants were asked which coastal town they live in or own property in.

Eight (8) respondents were from Guilderton, five (5) were from Lancelin, three (3) selected 'None of the above' and one (1) chose 'More than one town'.

None of the respondents lived in Seabird or Ledge Point.

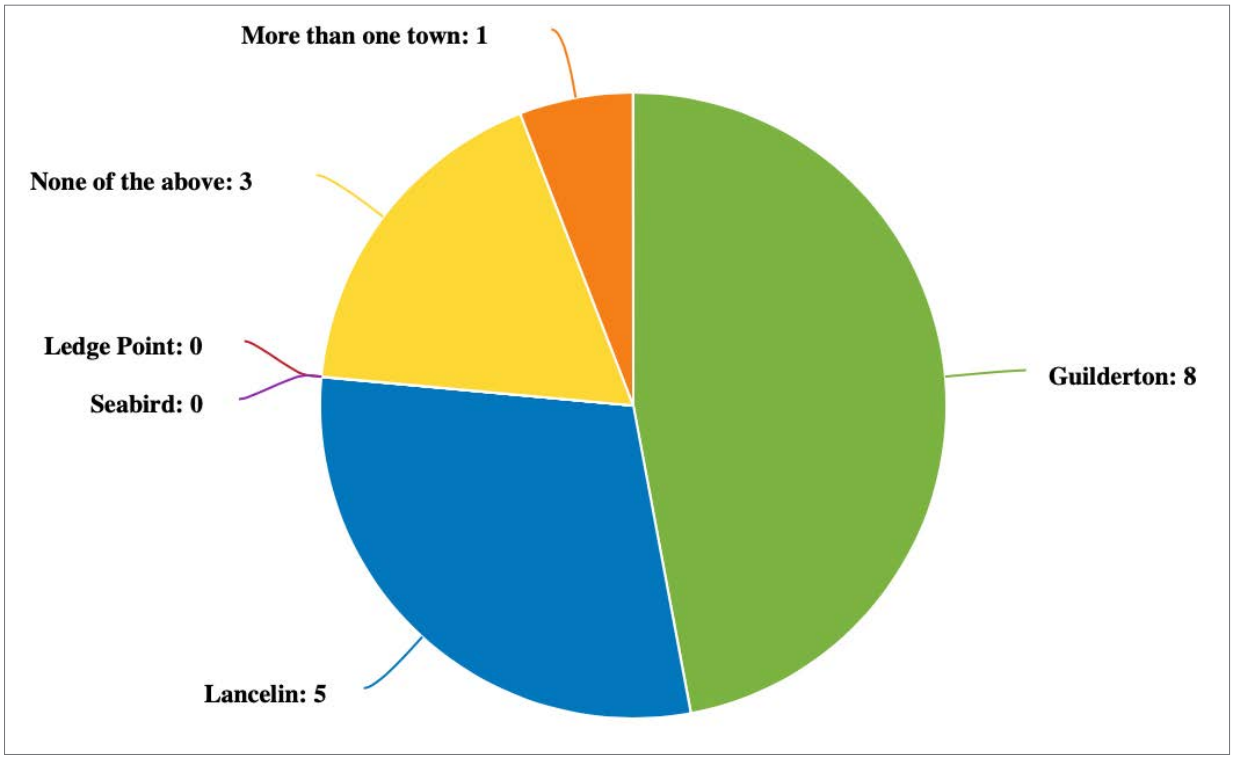


Figure 7 - Question 6

Q7 - Which best describes you?

Participants were asked about their interests in the area (business or property). They could select multiple options to respond to this question.

16 respondents are landowners/occupiers, one (1) is a business owner and two (2) are employees at local businesses.

Based on the responses, it should be noted that those people who selected that they were employees at a local business likely live in one of the four coastal townsites.

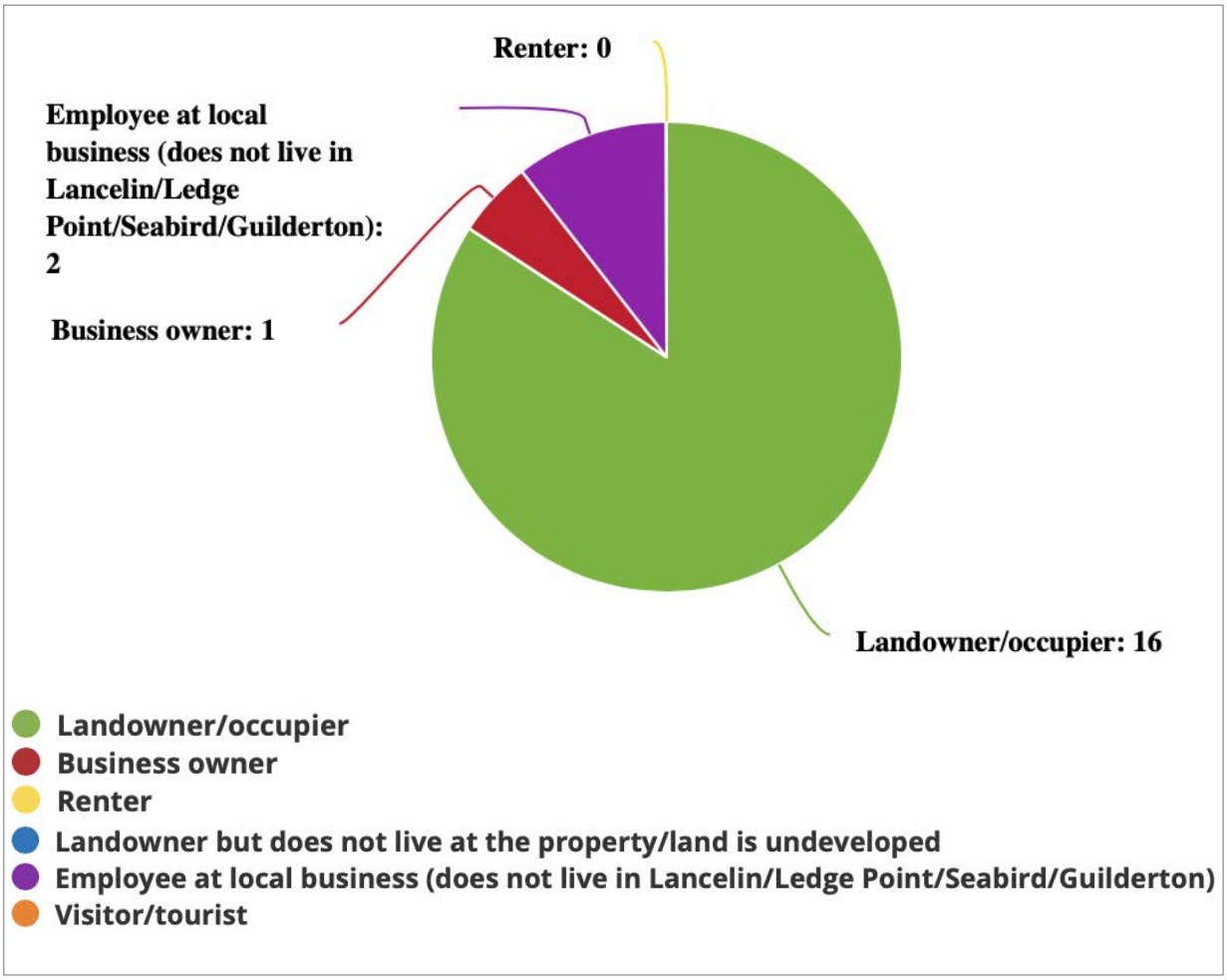


Figure 8 - Question 7

Q8 - How would you describe yourself?

10 survey respondents were female and six (6) respondents were male.

Q9 - What age bracket applies to you?

10 respondents were 56+ years old.

14 respondents were 46+ years old.

The remaining two respondents were from the 26-35 age bracket and 36-45 age bracket.

This sample is representative of the demographic population in the four coastal townsites.

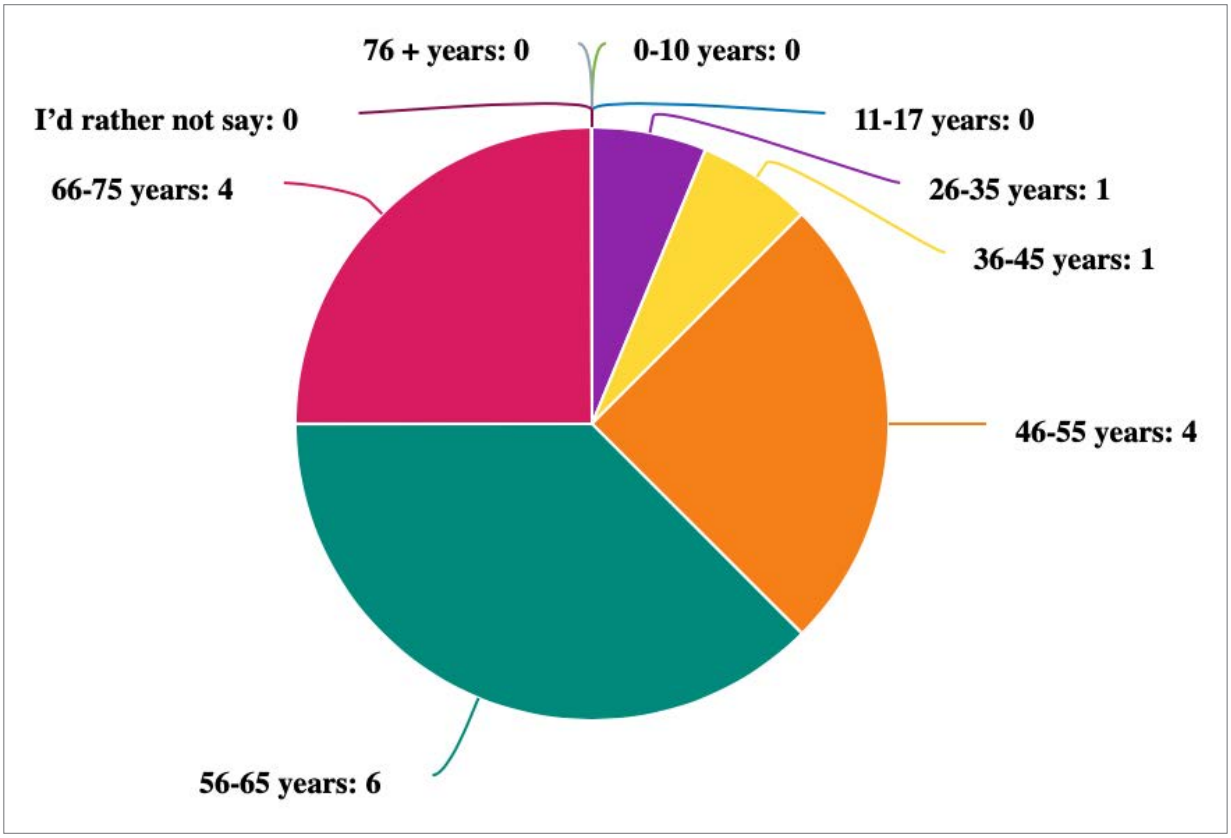


Figure 9 - Question 9

2.3 MAP AND COMMENTS

Respondents had the choice to place a 'pin' on a map provided on the project page and make a comment regarding that location.

Figure 10 illustrates the web portal mapping tool comments received. It shows where feedback was provided across a number of themes represented by the pin options.

The pins related to the following five category options:

- Water based activities (e.g. swimming, boating, surfing, windsurfing, fishing)
- Beach based activities (e.g. four-wheel driving)
- Foreshore based activities (e.g. walking, running, picnics, bbqs, watching sunset)
- Nature based activities (e.g wildlife watching, enjoyment of coastal vegetation)
- Something else/other (please describe).

Six (6) comments were 'pinned' to the map.



Figure 10 - Interactive online mapping tool

These comments are:

a beautiful area especially for younger children to enjoy the easy walks and is well used unfortunately car parking is at a premium after 9.30 in the mornings. Also paths require regular maintenance and more rubbish bins are needed

2 months ago Like +1 Dislike

Conducting Recreational Skippers Ticket Assessments

2 months ago Like Dislike

the river is a perfect place for children and older adults to swim in safety. Unfortunately over the years more and more power boats are ignoring the yellow marker buoys and cutting through children playing to pull up on the limited shoreline. This was evident during the last few years of swimming lessons when even paddle eg canoes were cutting through the closed off area for lessons

2 months ago Like +1 Dislike

I am aware of the erosion taking place all around our coastline & wish to assist in any form to try & protect it the best way forward. Climate change is one issue that I am very aware of & concerned about. I myself are doing what I can to help the planet. Carbon emissions, recycling in many forms, protecting water ways, clean up coastline when on the beach & river, protecting flora & fauna etc.

2 months ago Like Dislike

Swimming, sunset picnics, dog walking, 4wd, walking

2 months ago Like Dislike

Dog walking, picnics & swimming

2 months ago Like Dislike

Comments received relate to:

- How and where people use the beach (walking, dog walking, picnics, swimming, four wheel-driving, boating assessments)
- A desire to see regular maintenance of paths and more rubbish bins
- Safety issues around conflicting swimming and boating activities
- Concerns around climate change and erosion and a desire to address this through cleaning up the coastline and river and protecting flora and fauna.



3.0 WORKSHOPS

Two community workshops were held in Phase Two of the project - the Community and Stakeholder engagement phase.

The first workshop was held at the Guilderton Community Hall on Saturday 31 July 2021, with community members from the Lower Coastal Region (Guilderton and Seabird) invited to attend. The second workshop was held at the Lancelin Sporting Complex on Sunday 1 August 2021, with community members from the Upper Coastal Region (Lancelin and Ledge Point) invited to attend.

The workshops provided community members with the opportunity to let the project team know their concerns, establish and record their coastal values for the region, and to start a discussion about potential adaptation options and some of the potential trade-offs.

At the Guilderton workshop, attendees were also provided with new information about coastal risks given the previous CHRMAP does not cover Guilderton.

At both workshops attendees learned or were reminded about CHRMAPs and inundation for their relevant region.

Each workshop was three and a half hours long.

3.1 WORKSHOP FORMAT

The workshops opened with an introduction to the project and what a CHRMAP is, a commitment to participants about what they would be able to influence in the project process, and what they would be doing in the workshops. Facilitation was undertaken by Shape Urban and Water Technology spoke to the coastal information.

The project team provided a background to the project and described the Shire's coastline and its vulnerabilities, reminded participants about the coastal planning that has already been undertaken, and the gaps that now needed to be considered (context).

Workshop participants were provided with the following remit:

"*The CHRMAP needs to establish adaptation options for coastal planning on the coastline including Lancelin, Ledge Point, Seabird and Guilderton*

In that context, what values and assets are critical to maintain and how can we best balance the needs and expectations of all community members, including social, environmental and economic values?"

The workshops comprised three activities:

1. **Establishing coastal values** - workshop participants were asked to identify values important to them on a map at their table. At the end of this exercise participants presented their established values back to the group.
2. **Prioritising values** - the project team presented SPP 2.6 and the CHRMAP Guidelines' adaptation hierarchy to participants after the first activity. Using this information, participants were then asked to identify the values they had mapped that were of particular importance to them and to note what characteristics made it highly valued to them. Participants were provided with a template to record these characteristics and comments.

3. **Criteria for assessment** - once participants had a better understanding of values and adaptation options, they discussed a multi-criteria assessment (MCA) process and the identified criteria that might be used to assess adaptation options. Participants were provided with a template and asked to consider how they might measure success against various decision making criteria. At the end of this exercise, there was a discussion about why participants had scored criteria the way they had.

Workshop participants worked in groups for these activities.

After the three activities and discussions, the workshops concluded. Participants were advised what the next steps in the process would be and how they could be involved.

Section 3.3 discusses the outcomes of each of the activities. Activities are broken down into responses for each coastal townsite (Guilderton, Seabird, Lancelin and Ledge Point).

The presentation given at the workshops is at Appendix C.

3.2 WORKSHOP ATTENDEES

There were four workshop attendees at the workshop in Guilderton and 17 attendees at the workshop in Lancelin (with a total of 21 attendees at the two workshops).

Workshop attendees included:

- Residents (landowners)
- Local business employees
- The project team (facilitator and coastal specialist)
- The Shire (client).

3.3 WORKSHOP OUTCOMES

3.3.1 Establishing and prioritising coastal values

Workshop participants were advised of the online engagement feedback (Section 2.0 refers).

They were also reminded of the values collected for the 2019 CHRMAP for Lancelin, Ledge Point and Seabird (Appendix A refers these values), and that this CHRMAP integration inundation process would collect coastal values for the first time for Guilderton.

Participants were then asked to consider what the coastal values for the townsites were. Participants were asked to consider what was important to them and to place a mark on each location or asset of value in the marked 'Coastal zone' of the map on their tables.

Participants were then introduced to the Western Australian State Planning Policy 2.6 - Coastal Planning (SPP 2.6) hierarchy of adaptation options, which are as follows:



These options and the hierarchy of controls were explained to workshop participants as follows:

- Avoid – Options which aim to eliminate the risk of coastal hazards by avoiding development
- Managed Retreat – Options which progressive retreat/relocate development
- Accommodation – Options which seek to enhance assets to cope with the temporary impacts
- Protection – Options which seek to artificially protect the coast.

Following this, participants moved on to the next activity. Using the values they had mapped in the previous activity, participants were asked which values are of particular importance to them and to note the characteristics that made them highly valued.

Characteristics provided to participants in template form were Physical, Appearance, Access, Use or Other. The 'Other' column allowed participants to note other characteristics that made a particular value important to them.

Coastal values that were mapped for the four coastal townsites and the reasons stated by participants are:

3.3.1.1 Guilderton

- Silver Creek (inland section of the Moore River) for fishing and swimming (#1)
- Moore Rivermouth Beach parking - workshop participants discussed that this was of high value to be able to access the beach, but that it filled up and was paid parking (which could be a disincentive to visiting the beach) (#2)
- Sand boarding at the Guilderton Sand Dunes (#3)
- Boat launching at the Guilderton North Groyne (although noting that it was usually good going out but not so good coming back in) (#4).

Other comments post-it noted to the map referenced that Guilderton is under pressure for tourism growth (Yanchep train, Indian Ocean Drive) and that there is a 200 lot subdivision approved or proposed, with the impact of this not clearly known.

The mapped values for Guilderton are at Figure 11.

3.3.1.2 Seabird

- Tourism is important for the Lower Coastal Region - it supports the community (#1)
- The Seabird Tavern for its pub views (#1)
- The ability to launch boats (access point) from the caravan park site (#6)
- Boat launching - it would be nice to have a proper boat launching facility at Seabird, the current location is okay in the morning but the wind in the afternoon makes it dangerous (#2)
- A proposed breakwater (#3)
- Great kids play area (#4)
- The beach In the northern section of the Seabird coastline - very important to families and kids and is a regionally accessed beach (#5).

Other comments related to the Residential zone in place to accommodate future growth in Seabird and that there is only a single access route to Guilderton, which has redundancy implications in the event of a bush fire.

The mapped values for Seabird are at Figure 12.



Figure 11 - Coastal values exercise for Guilderton

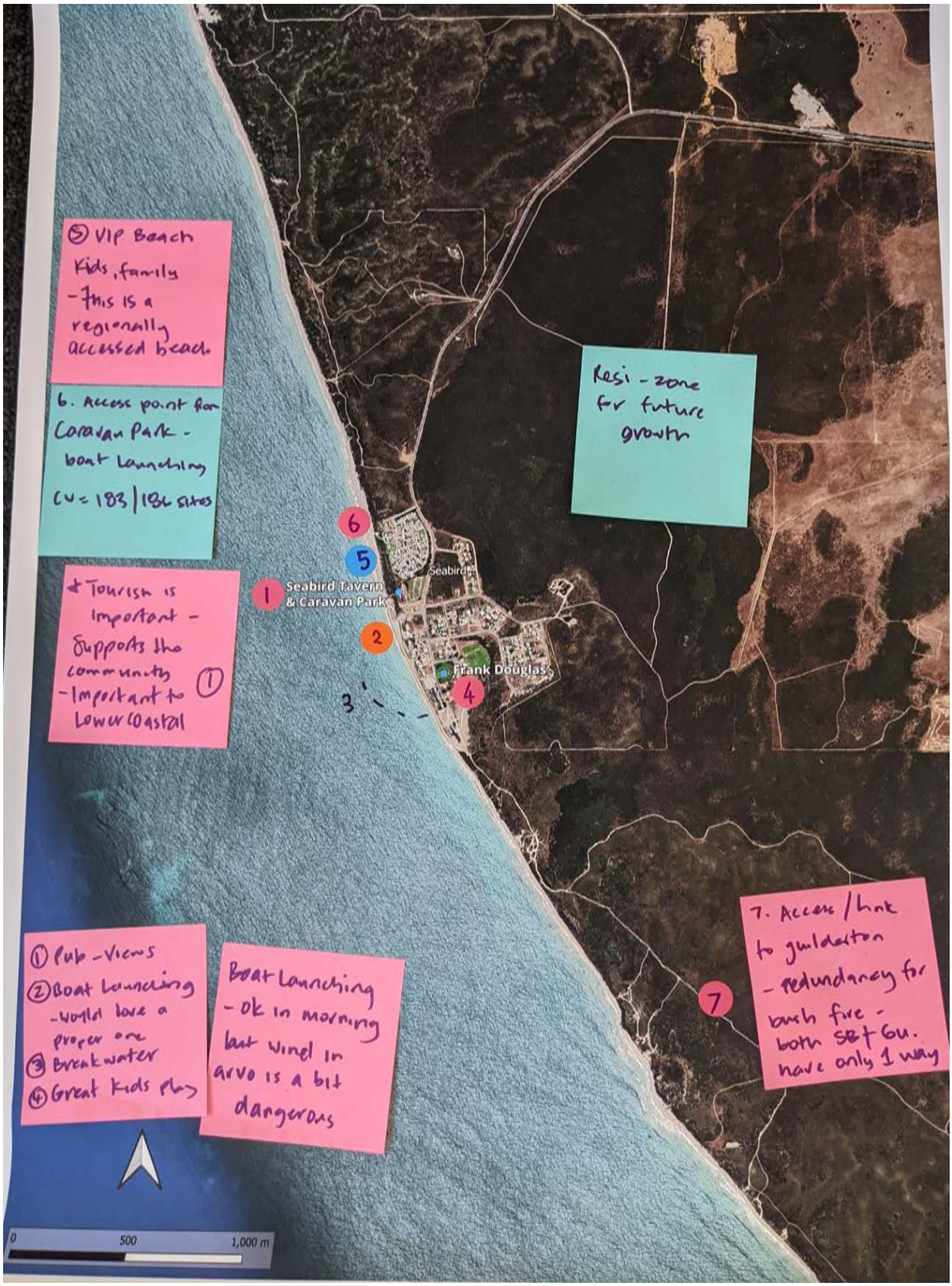


Figure 12 - Coastal values exercise for Seabird

3.3.1.3 Lancelin

Workshop 1

- Fishing, swimming, windsurfing and surfing at back beach (#1)
- Calm beach behind the island, and erosion (#2)
- Good swimming near the lookout at the northern end of Lancelin

These mapped values for Lancelin are at Figure 13.

Workshop 2

- Back Beach for walking, fishing, swimming, wind surfing, surfing, picnics, dog walking (#1) - views over the Indian ocean, unspoilt beaches and good access to the beach
- The Lookout (#2)
- The calm waters between Lancelin and Edwards Islands Nature Reserve (#3)
- Main Break surfing reef (#3), South Passage reef (#4) and Hole in Wall surfing reef (#5) - unique, with people driving from Perth for the day to surf at these locations - access varied to the three locations - for Main Break (#3) requires parking near residential lots and having to unload surfing gear from cars
- Noticeable erosion on the beach (#6 - erosion is causing steep drop-offs where the dunes are high. Some paths are preventing access to the beach and there is a loss of ability to walk on the beach as a result
- North Point (#7) is good for swimming, picnics and dog walking - it has views over the Indian Ocean, unspoiled beach and no vehicles on the beach. It was noted that there could be better pathways to the beach and that these places were used for physical and mental wellness.
- (#7) A comment noted that the Point has disappeared, with water now encroaching the car park and based on the boardwalk/ disabled access - there have been recent improvements
- Radio Tower (#8) for volunteer marine rescues - there are boat views in any weather from the building described as 'iconic' by participants - it is important as it contributes to the safety of boats
- Grace Darling Park (#8) - has park and toilets, sunset views, but is slowly eroding, exposing sharp rocks which impacts water sports at the beach and damages feet - this is a well known area for wind/ kite surfing due to the natural reefs and should be protected at all costs
- Town Beaches (#8 to #9) are also good for swimming, picnics, dog walking - it has views, an unspoiled beach and is used for four wheel driving - there is good access to the beach. The front dunes offer protection but Edwards Island Point (#10) is the weak point that needs protection - the foredunes must be protected and allowed to flourish particularly Edwards Island Point - four wheel driving should be restricted here
- Jetty Beach (#9) is good for boat launching and fishing for the family (with kids)
- The islands (#10 and #15) are home to birds and access should be controlled to them
- French Reef (11) for swimming, picnics, dog walking - with views over the Indian Ocean, unspoilt beach and four wheel drive access - good access to the beach

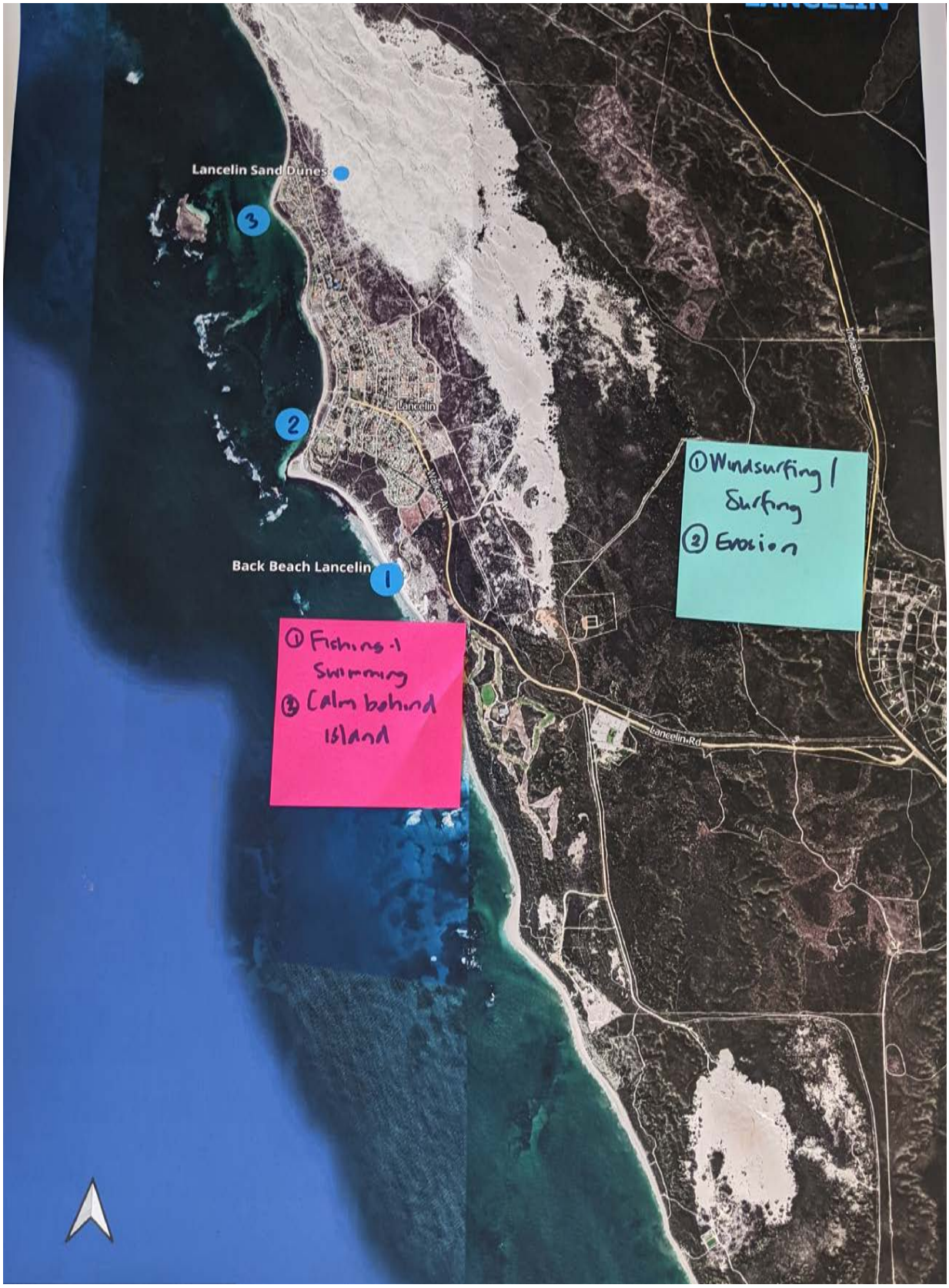


Figure 13 - Coastal values exercise for Lancelin (Workshop 1)

- The Cunliffe Street houses (12) - used as holiday homes for generations. In recent times, the Shire has imposed memorials on title for dwellings within the 2019 CHRMAP - significant impact to individual residents
- Lancelin Sand Dunes (#13) - comments were made that continued sand mining is not protecting the natural cycle of sand blown from the ocean and that the beautiful vista is being gradually spoilt which has been Lancelin's historic 'monument' for the community and tourists alike
- Back Beach south of Edwards Island (#14) is valued but there is erosion from four wheel driving
- Dune mining (#15) - upsets the natural east west winds that replenish the dunes - there is a massive environmental impact on the physical environment as a result of granting this mining lease
- Threatened Ecological Communities (#16) should be preserved and protected
- Seagrass beds (#17) - important - particularly in front of Grace Darling Park (#8)
- Four wheel driving - comments were made about the beaches needing to be policed due to vehicles driving and disrupting sand on beaches where four wheel driving is not permitted and there is Shire imposed signage in place
- Lancelin townsite and coastal views - risk to roads to access the townsite as it is only 1 metre above sea level. This will impact homes, use of beaches for pleasure and recreation.

These mapped values for Lancelin are at Figure 14.

3.3.1.4 Ledge Point

No comments were made regarding Ledge Point at any workshop.

3.3.1.5 Summary

The workshops identified some key coastal values and views for the townsites - namely:

- Beaches for activities like walking, exercise, sunset watching, views, picnics, fishing, surfing, swimming, four wheel driving - calm areas for swimming were particularly valued along the coastline
- Participants wanted to see access improvements at various beaches
- Four wheel driving has very divergent views - some participants wanted to see it controlled or restricted in locations where they believed it was impacting natural coastal processes, locations or wildlife, while some wanted access to be maintained. One recommendation was for access to be kept open but to transition this to the northern beaches (i.e. rationalisation of four wheel drive locations) which would support ongoing tourism but allow for control of where this occurred.
- Beach areas and beach parks for things like kids play areas and recreation were greatly values
- Boat launching - both valued and desired along the coast
- Environmental protection - TECs, seagrass, other was highly values
- Lancelin sand mining - participants spoke about the detrimental impact in has on the natural cycle that protects the coastlines and commented on the gradually declining sand dunes as a result.

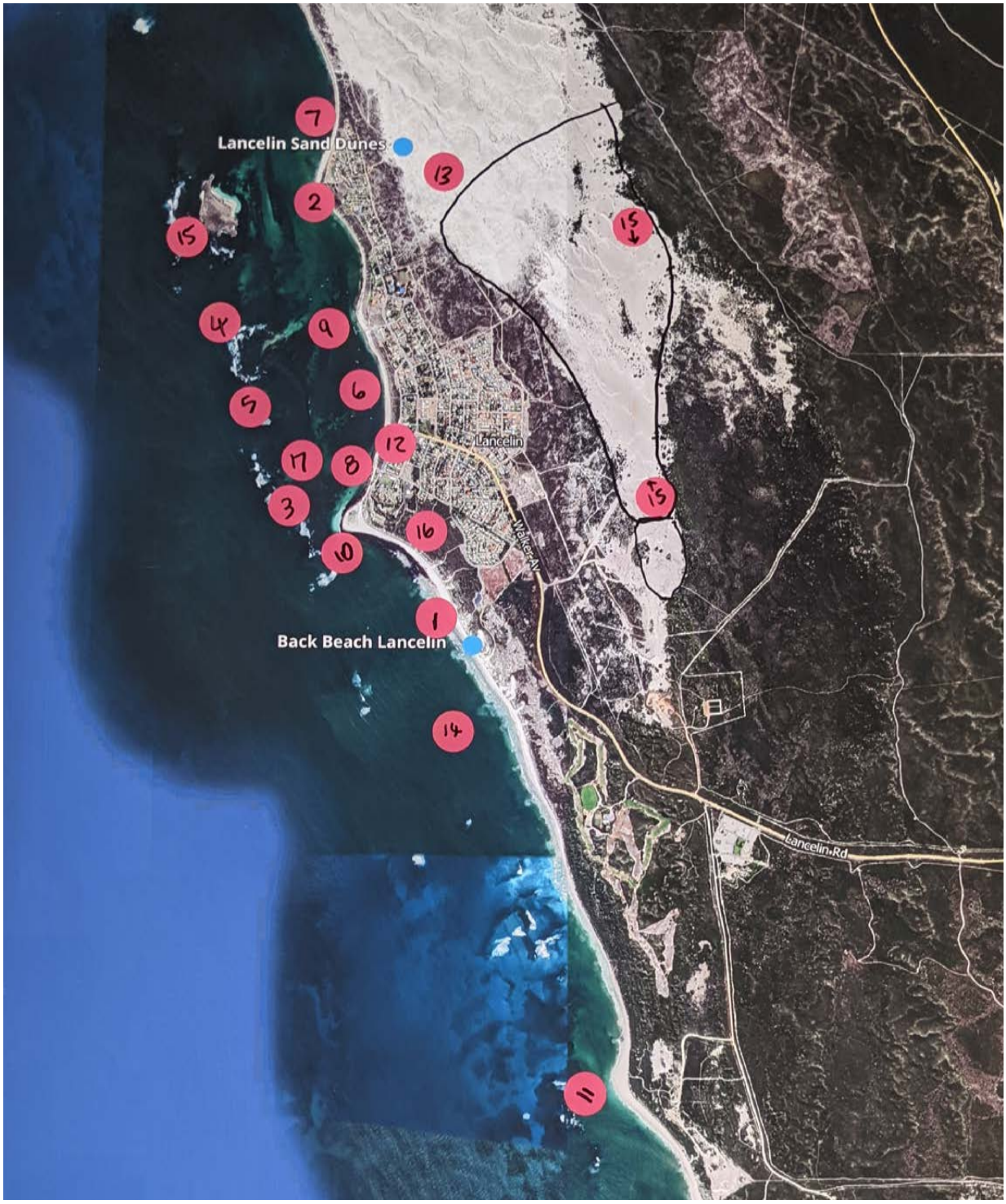


Figure 14 - Coastal values exercise for Lancelin (Workshop 2)

These reasons *why* workshop participants value various features provide better understanding and insight to assess what assets have the greatest need or priority for adaptation and management.

3.3.2 Criteria for Assessment

Once workshop participants had a better understanding of values and adaptation options, the project team discussed some of the criteria that are typical in assessing adaptation options for coastal assets.

These criteria have been identified from numerous studies and research of possible impacts on the coast. The criteria include things like cost, property impact and effectiveness.

The project team explained a Multi Criteria Assessment (MCA) process and then described each of the identified criteria.

Participants were reminded that some of the adaptation options can be very expensive. They were asked if they would change how much influence one criterion had over decision making if the cost was borne by themselves or the beneficiary.

The participants were then invited to discuss the criteria and consider how they would 'measure' success against a selection of criteria using a scale of 1 to 5 (where 1 is an outcome that would not be considered successful and 5 would be an outcome that is considered successful).

The criteria for discussing were:

- **Capital cost** - how much it costs us to build something up front (in todays' $)
- **Maintenance cost** - how much it costs us to keep maintaining something over 100 years (in todays' $)
- **Environmental impact** - the damage/ loss of beach, vegetation, seagrass, fauna habitat and erosion in adjacent areas
- **Social impact - property** - where private property is affected and may be lost or damaged, may have a restriction placed on use and a number of private properties may be impacted
- **Social impact - communal** - this relates to things like loss of ability to walk on the beach, enjoy vistas or have access to car parks, loss of parkland and footpaths, and loss of assets such as cafes, surf life saving clubs, etcetera
- **Reversibility** - once chosen, other options are off the table or very difficult to implement or highly reversible, and sets expectation/ ties future community to the decision/ costs
- **Effectiveness** - speaks to things like short term options being suitable for minor protection or options being untested/ unclear about effectiveness or well tested and understood to work to reduce risk.

Whilst this is a complex and difficult discussion, the workshop participants provided a wealth of feedback. The feedback about success measures can be seen in Table 1, whilst additional comments, direction and discussion is noted from page 38.

CRITERIA	SCORING				
	1 (NOT SUCCESSFUL)	2	3	4	5 (SUCCESSFUL)
Capital Cost	High cost (except if it meets other criteria) Choose a cheaper option with less chance of success				Minimising capital cost Pay a bit more now e.g. sandbags for a better outcome and less money to pay on maintenance [not unanimous]
Maintenance Cost	Greater than or equal to 10% of the capital costs over the lifetime High costs that keep occurring i.e. sand washing away		Willing to accept reasonable maintenance		Less than or equal to 2% of the capital costs over the lifetime/low maintenance No impact
Environmental Impact	Significant impact High Losing beaches altogether - erosion all the way up the coast	Minor impact	Impacts away from town (north)		No impact at all Low No Impact
Social Impact - Property	Any properties lost (>1)				Built properties to be preserved

Table 1 - Workshop Criteria Outcomes

	SCORING				
Social Impact - Communal	Losing a park - big asset especially in front of properties High impact No beaches/parks, tourism areas, parking, accommodation etc Public losing access to beaches and banning 4wd access	Losing beach access to vehicles e.g. one long seawall with only limited access etc	Lose some seating, footpaths etc but not big assets		Preserved, zero loss of assets over time Low impact or improvement
Reversibility	Making a mistake that cant be reversed				Something that helps trial and test and can be removed easily Highly desirable outcome [to be reversible]
Effectiveness	Not sure or not effective Doing the same thing over and over again and not working		Will probably work but may be time limited or too slow to implement		Will definitely work if done in time
Economical	Impacts the towns economy				Benefits the towns economy (or no degradation)

Table 1 - Workshop Criteria Outcomes (cont'd)

The following sections show the feedback given via additional comments, direction and discussion on each of the criteria. One comment was a general comment - 'above all we want something done - no more new plans'

3.3.2.1 Capital Cost

Comments about Capital cost included:

- It should not to be a differentiator - the cost of the best option will be what is necessary to spend.
- Capital cost and maintenance cost be considered together.
- Not important
- Tetra pods
- Memorials on all houses oceanfront and stop houses from selling in future
- Needs to be cost effective and not impact rates, insurances to a huge degree

One of the respondent groups noted that an unsuccessful outcome would be that locals pay and maintain the adaptation option, whilst a successful outcome would be 'Government Pays + Maintains'.

3.3.2.2 Maintenance Costs

Comments about Maintenance cost included:

- Must be less than 2% of capital cost pf life of infrastructure
- Needs to be a moderate annual cost to maintain and who is responsible to maintain

3.3.2.3 Environmental Impact

Comments about Environment included:

- Losing beaches altogether - erosion all the way up coast
- Lancelin washed away - Gingin Road shops are than Cunliffe Street so shops would flood
- More education of how visitors can affect the environment

3.3.2.4 Social Impact - Property

Comments about Social Impact - Property included:

- Private properties to be effected may need further consideration
- Commercial property can be moved
- Loss of beach front properties would be terrible
- Singling out individual properties with memorials to fix shires solution [sic]
- Loss of beach front properties would be terrible

There was also a specific comment about design - 'property to suit'

3.3.2.5 Social Impact - Communal

Comments about Social Impact - Communal included:

- Public losing access to beaches and banning 4x4 access

3.3.2.6 Reversibility

Comments about Reversibility included;

- Concept designs require reversibility
- Needs to be reversible as previous attempts have failed
- This criteria is not as important as capital investment and planning.

3.3.2.7 Effectiveness

Comments about Effectiveness included;

- Must be better than 75% effective
- Emphasis on effectiveness
- Needs to be effective and thoroughly studied

3.3.2.8 Prioritisation

The participants were also invited to provide comment about the relative importance of one criteria against the other. Only two participants concluded this task with clear direction, with one indicating the following prioritisation:

1. Environmental Impact
2. Social Impact - Property
3. Social Impact - Communal
4. Effectiveness
5. Reversibility
6. Capital Cost
7. Maintenance Cost

The other participant prioritised Capital Cost, Social Impact - Property and Effectiveness as the most important (equally), Social Impact - Community as second most important, Maintenance Cost as not as important and Environmental Impact and Reversibility as the least important.

Further investigation into the priority of various criteria will occur over the next stages to provide suitable weighting to each criteria. This will need to be tested again with the community.

3.3.3 Responsibility

Each workshop concluded with a final discussion regarding who would be responsible for funding and maintaining adaptation works. The participants provided some feedback that adds nuance to this issue, as follows:

- Bad [outcome] - locals pay and locals maintain
- Needs to be cost effective and not impact rates/insurances/ to a huge degree
- Good [outcome] - government pays and maintains
- Needs to be a moderate annual cost to maintain and who is responsible to maintain

Another issue which attracted much attention was the matter of memorials being placed on titles in the vulnerable zone. One affected property owner suggested that the process was unclear as well as inequitable with regard to how the memorials are implemented.

Some consideration should be given to how owners might be impacted by memorials or other land use and property title instruments.

CONCLUSION

The engagement undertaken to date provides a strong understanding of what the community values in each of the four townsites along the coastline.

The multi-engagement approach has allowed for a thorough investigation of community values at different sections of the coastline.

There was strong alignment from stakeholders on the following values:

- Beaches along the coastline for activities like walking, exercise, sunset watching, views, picnics, fishing, surfing, swimming and four wheel driving
- Access to beaches and improvements to access at various beaches
- Coastal erosion is occurring and there is a need to protect the values and assets at these locations
- Protection of threatened ecological communities (TECs), seagrass and coastal vegetation generally
- Sand boarding at dunes
- Opposition to sand mining at Lancelin Sand Dunes due to the detrimental impact in has on the natural cycle that protects the coastlines and the gradually declining sand dunes.

It was recognised that activities such a four wheel driving will need to be balanced with the need for protection of dunal ecosystems and vegetation on beaches along the coast, with many participants recognising the impacts of some of our recreation activities on the fragile coastline.

When tasked with considering criteria, participants were able to differentiate on all of the criteria in some way. It is notable that the most difficult criteria to differentiate on is the impact on property, where the measurement for an unsuccessful outcome and a highly successful outcome is a very narrow margin. This indicates an understanding that the loss of property would be extremely challenging, notwithstanding that other criteria might be positively achieved.

The introduction by one group of 'economic impact' as a criteria is also interesting - pointing to the recognised importance of protecting the local economy to attract and retain residents and tourists alike.

All of the discussion and direction regarding the criteria, and the ranking of criteria, will help the project team in developing a suitable draft multi-criteria analysis process.

At the same time, the introduction of coastal adaptation options, the criteria to assess these options, and preliminary discussions about what weight each criteria should hold at the workshops introduced the local community to the complexity of the decision that have to made to protect the values they love. This includes costs, lifetimes of adaptation options, impacts, and other trade-offs like private versus public asset protection.

In the following stages, the feedback provided will enable the development of a robust assessment process in line with the community feedback, with a further opportunity for the community to influence outcomes later in the project.



NEXT STEPS

This engagement summary report summarises the preliminary engagement undertaken with the community to understand community values for the four coastal townsites, which included online engagement and workshops in Guilderton and Lancelin.

The community's values and other stakeholder feedback received will be used to inform the development of adaptation options for the four coastal townsites along the coastline.

The project team will also be looking to schedule targeted meetings with identified key stakeholders as part of this preliminary engagement stage.

This report will be updated with these outcomes and the outcomes of additional engagement as the project progresses and the community values are translated into coastal assessments, trade-offs, risks and adaptation approaches.



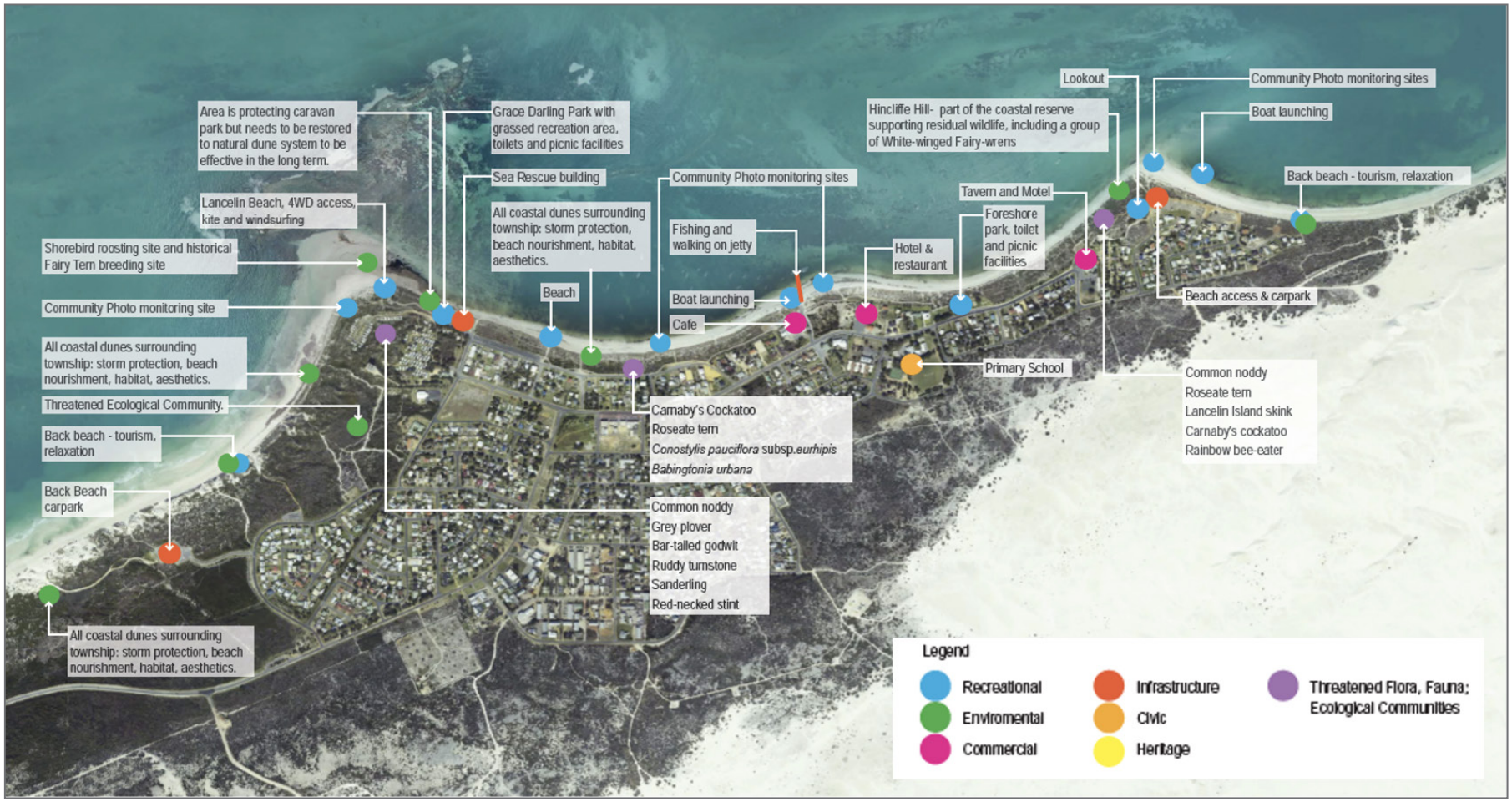
APPENDICES

- Appendix A: 2019 CHRMAP Coastal Values for Lancelin, Ledge Point and Seabird
- Appendix B: Coastal Adaptation Infographic
- Appendix C: Workshop Presentation

APPENDIX A

APPENDIX A - 2019 CHRMAP COASTAL VALUES FOR LANCELIN, LEDGE POINT AND SEABIRD

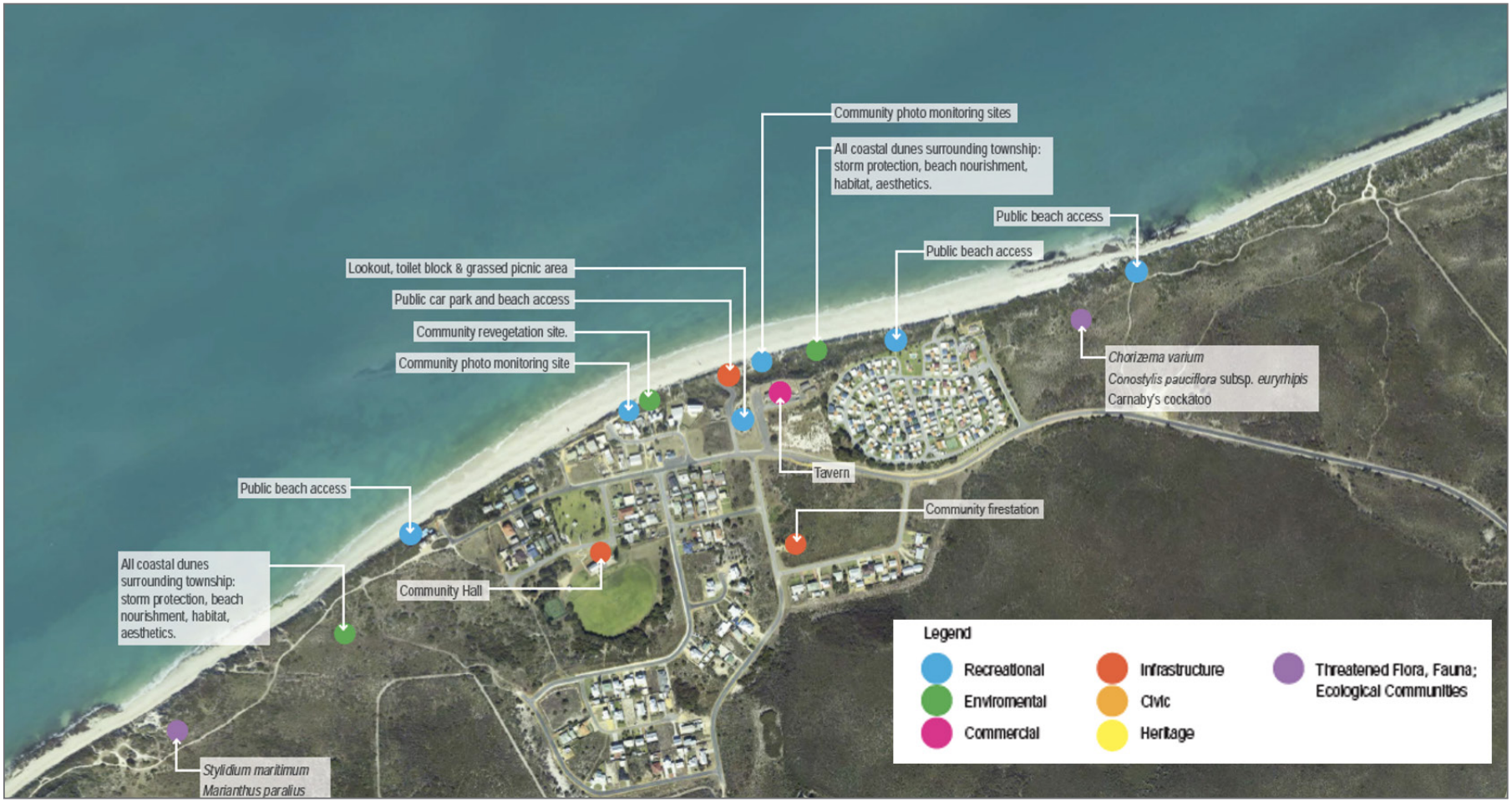
2019 CHRMAP COASTAL VALUES FOR LANCELIN



2019 CHRMAP COASTAL VALUES FOR LEDGE POINT



2019 CHRMAP COASTAL VALUES FOR SEABIRD



APPENDIX B

APPENDIX B - COASTAL ADAPTATION INFOGRAPHIC

APPENDIX B - COASTAL ADAPTATION INFOGRAPHIC

COASTAL PROCESSES AND PLANNING

The coastline is constantly changing from storm events, sea level rise and human modifications and as it changes it can impact the infrastructure (e.g. footpaths, roads, houses, beach access, services) in the coastal zone and how the coast can be used.

So we can continue to use and enjoy the coast, we need to understand the coastal hazards (such as erosion, accretion and inundation) and the risks.

Once we understand the coastal hazards and risks, we can determine what the best way to respond. The response options (also known as coastal adaptation options) are:



A Coastal Hazard Risk Management Adaptation Plan (CHRMAP) will help us to understand the coastal hazards and risks in the short, medium and long term so that we can plan for the future.

'erosion' refers to shoreline movement where the shoreline shifts landward reducing the width of a coastal foreshore reserve and/or the distance to a fixed feature on the adjoining land.

'accretion' refers to shoreline movement where the shoreline shifts seaward increasing the width of a coastal foreshore reserve and or the distance to a fixed feature on the adjoining land.

'inundation' means the flow of water onto previously dry land. It may either be permanent (for example due to sea level rise) or a temporary occurrence during a storm event.



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APPENDIX B - COASTAL ADAPTATION INFOGRAPHIC

COASTAL ADAPTATION - AVOID

Avoid is to not allow new development to occur in areas that have been identified to be affected by coastal hazards.

Where this option is achievable, it is the preferred option over 'planned/managed retreat', 'accommodate' and 'protect'.









Option types and description

- **Avoid new development in areas that are currently un-developed that are impacted by coastal hazards.**
- **Avoid further development in existing areas, that are impacted by coastal hazards.**

Long-term measure

Low cost option

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APPENDIX B - COASTAL ADAPTATION INFOGRAPHIC

COASTAL ADAPTATION - PLANNED / MANAGED RETREAT

Planned or managed retreat is relocating or removing things which may be at intolerable risk of damage from coastal hazards.

Where 'avoid' is not achievable, this option the preferred option over 'accommodate' and 'protect'.







Source: https://www.homestratosphere.com/houses-built-on-stilts/



Option types and description

- **Leave assets unprotected and accept they may be lost in hazard events.**
- **Remove and relocate assets from coastal hazards.**
- **Remove protection structures that allow the coastline to return to a natural state.**

Long-term measure

Medium cost option

APPENDIX B - COASTAL ADAPTATION INFOGRAPHIC

COASTAL ADAPTATION - ACCOMMODATE

Accommodate is to use design measures and/or management strategies that make the risks from coastal hazards more acceptable.

Where 'avoid' and 'planned/managed retreat' are not achievable, this option is the preferred option over 'protect'.









Option types and description

- Design assets (either new or modify existing) to withstand impacts of hazards.
- Beach system maintenance and enhancement (e.g. beach scraping or back passing)
- Dune system maintenance and enhancement (e.g. track access management, dune blowout controls, revegetation, sand fencing)
- Nearshore system maintenance and enhancement (e.g. increasing seagrass density)
- Sand nourishment (placement of sand on beach, dune or nearshore)
- Beach dewatering.(lowering ground water table)

Medium-term measure

High cost option

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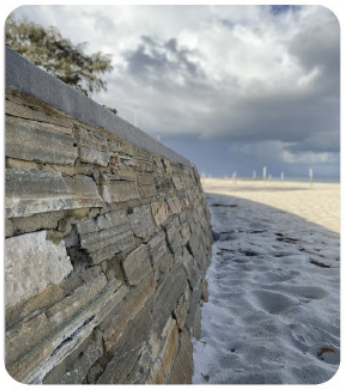
APPENDIX B - COASTAL ADAPTATION INFOGRAPHIC

COASTAL ADAPTATION - PROTECT

Protect is to undertake works that will preserve the foreshore reserve, public access, public safety and significant property and infrastructure.

This option should only be applied where 'avoid', 'planned/managed retreat' and 'accommodate' can not be achieved.









Option types and description

- Offshore structures (e.g. artificial reefs/shoals
- Offshore structure (detached breakwaters/ headlands)
- Nearshore structures (e.g. breakwaters/ headlands)
- Nearshore structures (groynes)
- Levees/dykes
- Seawalls/revetments
- Storm surge barriers
- Upgrade existing protective structures

Short-medium term measure

High cost option

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APPENDIX C

APPENDIX C - WORKSHOP PRESENTATION

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GINGIN COASTAL HAZARD RISK MANAGEMENT ADAPTATION PLANNING (CHRMAP)

"Our Coast, Our Journey"

S+U
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Welcome

Your team

Shire of Gingin:

Meredith Taylor

Consultant Team:

Shape Urban - Anna Kelderman

Water Technology – Joanna Garcia-Webb

we're here to help

every question is a good question

we want to hear from you – you are running this!

Welcome

A spot of housekeeping....

- Mobile Phones
- Bathrooms
- Emergency procedures
- We will be taking photos/recordings - let me know if you do not want us to use photos of you in our reporting
- Be COVID safe - try and keep distance from others, use the hand sanitiser, hold on to your pen until you leave and please make sure you practice good hygiene if sneezing!
- Write it down!

Introductions

Where do you live?

What brings you here today – concerns, ideas, knowledge to share?

CHRMAP…

What on earth is a CHRMAP??

- Coastal Hazard Risk Management Adaptation Plan
- Hard to say…
- Char-map, croomp, cher-map, adaptation plan

So…What will you influence?

- Better understanding of community values (more measureable)
- Through your values and identification of important criteria, the preferred option for each at-risk asset
- Future engagement activities – what else you need to know, want to hear etc

What are we doing today?

- Discussing coastal processes, risks and hazards (context)
- Understand community values
- Getting a better idea of key issues and concerns
- Considering the criteria to assess management options



Tips

- Be curious. Ask questions. Learn as much as you can
- Keep an open mind – listen to others
- Focus on the remit – there are many factors
- Remember that you are here as a citizen, to take into account what is best for the whole community; think about everyone
- Listen to each other. Work together.
- If something isn't working for you let us know – it is important you are able to contribute

What are we doing?

Background

The Shire of Gingin's coastline is vulnerable to natural coastal processes such as waves, storms and sea level rise, and to the changes that people make to the coastline (buildings, hard coastal structures and dune/beach changes).

As the coastline begins to change, it can impact the infrastructure and assets in the 'coastal zone' and how the coast can be used.

The Shire has already done some coastal planning…

- In 2019 Cardno prepared a CHRMAP for **Lancelin, Ledge Point and Seabird** - examined erosion risks and adaptation options
- In 2020 Baird prepared an Inundation study for **Lancelin, Ledge Point, Seabird and Guilderton**
- Other coastal studies, including those relating to existing physical controls – seawall, groyne, current management activities

Background

Pieces of the puzzle need to be consolidated:

- Risk assessment and adaptation options for **Guilderton**
- Reviewing the risk assessment and adaptation options including the Inundation study for **Lancelin, Ledge Point and Seabird**
- Consideration of any changes since the previous studies were done

Background

The Shire will combine the studies so we have a single, comprehensive understanding of how our coastline will be impacted in the future, and how we can plan for and manage these changes

(= integrated CHRMAP)

Our Remit

The CHRMAP needs to establish adaptation options for coastal planning on the coastline including Lancelin, Ledge Point, Seabird and Guilderton

In that context, what values and assets are critical to maintain and how can we best balance the needs and expectations of all community members, including social, environmental and economic values?

How are we doing it?

CHRMAP…

A strategic plan to meet *coastal hazard challenges…*

- Identifies vulnerable public and private assets
- Aims to preserve community values for current & future generations
- Informs community and decision makers
- Required under *State Planning Policy 2.6 – Coastal Planning*

A plan for the next 100 years

CHRMAP...

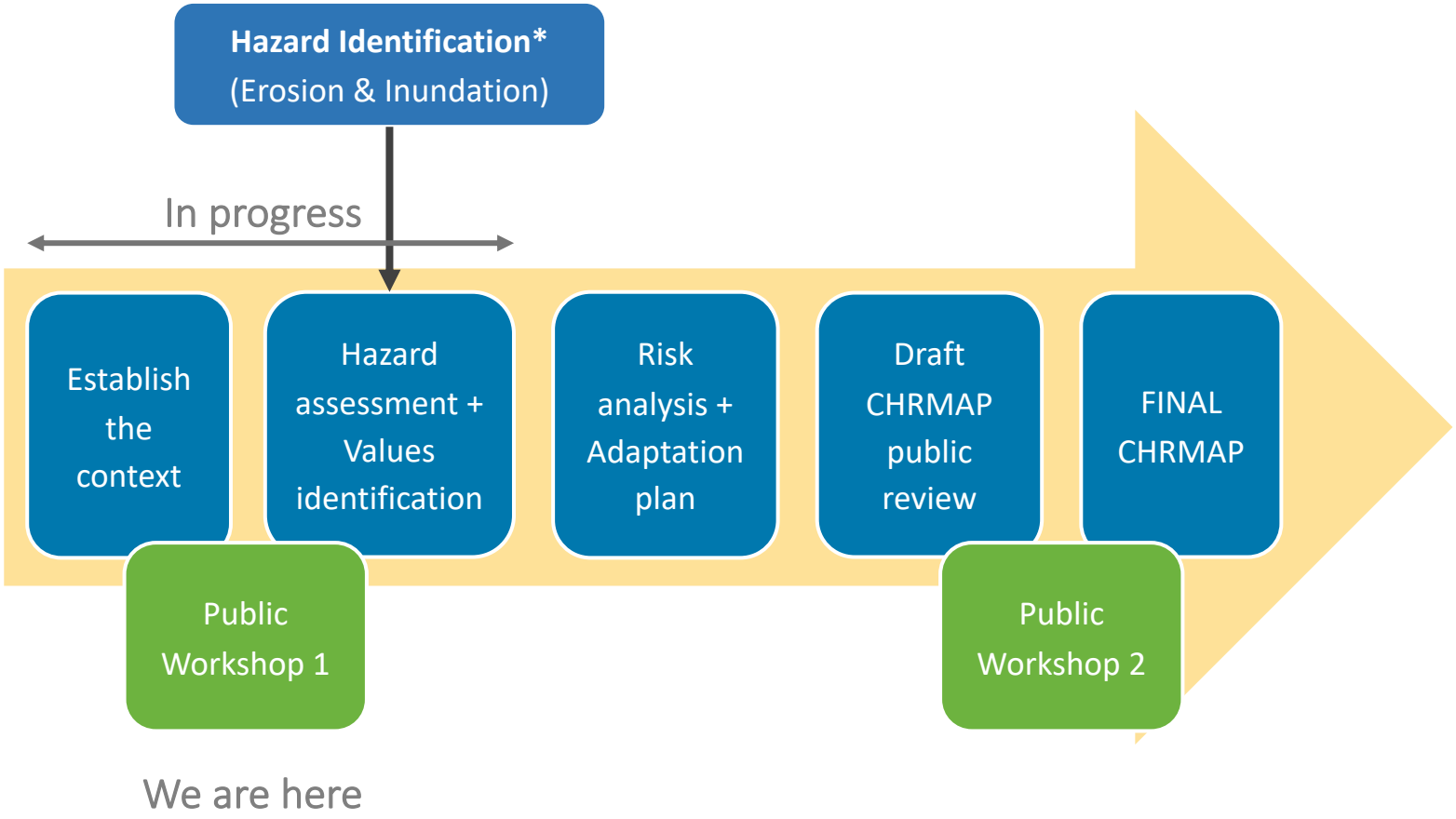
The key components of a CHRMAP are:

- Understanding the local environment and community values
- Assessing how much things can cope with the impact of climate change
- Identifying the risks (likelihood of an event occurring and the consequences of that event occurring)
- Analysing the findings and evaluating the management options (multi-criteria assessment)
- Identifying the adaptation options
- Identifying funding options, monitoring and review of frameworks

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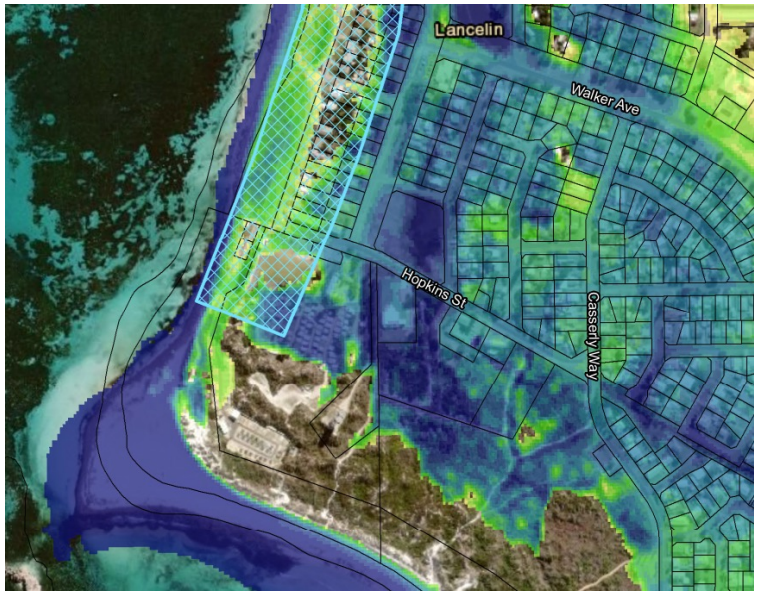
CHRMAP...


Hazard Identification*
(Erosion & Inundation)
In progress
Establish the context
Hazard assessment + Values identification
Risk analysis + Adaptation plan
Draft CHRMAP public review
FINAL CHRMAP
Public Workshop 1
Public Workshop 2
We are here

Coastal hazard challenges

The key challenges on the coast are **erosion** and **inundation**



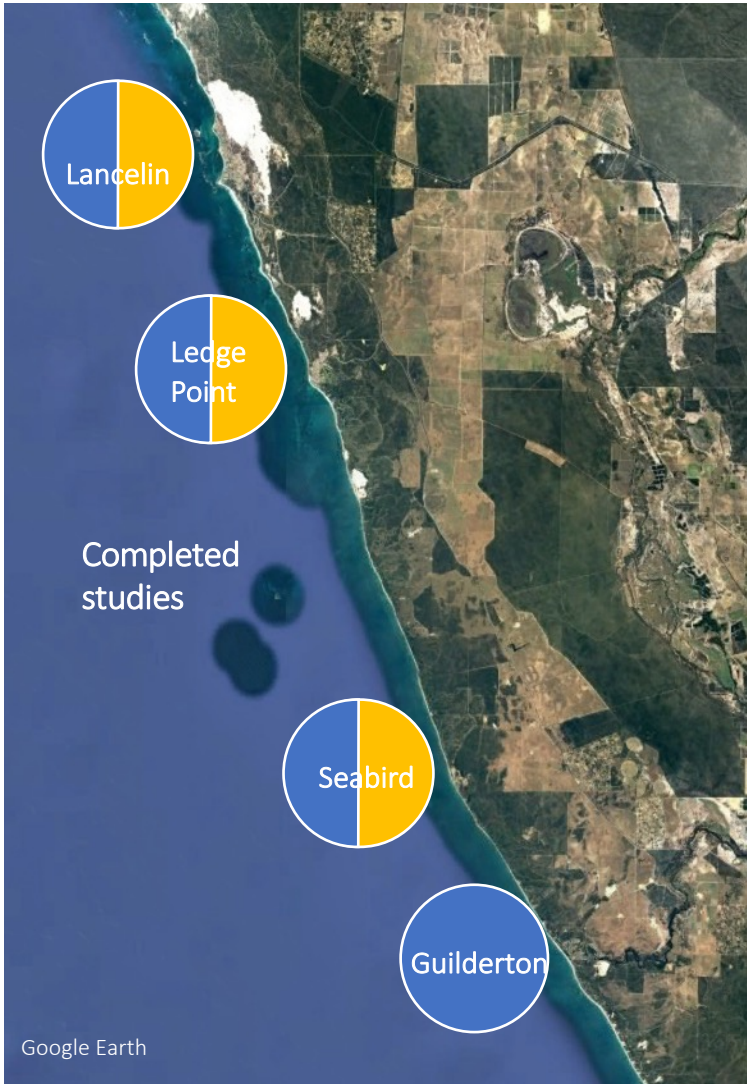


Predicted Sea Level Rise will increase impacts of both!

Hazard Identification

Predicting the *risk* of **erosion** + **inundation** with sea level rise

- Already completed by others
  - Except erosion at Guilderton (*in progress*)
- Gingin's **low lying sandy coast** is susceptible to changing conditions
- Hazard mapping indicates the **zone of risk** – not the predicted future shoreline!



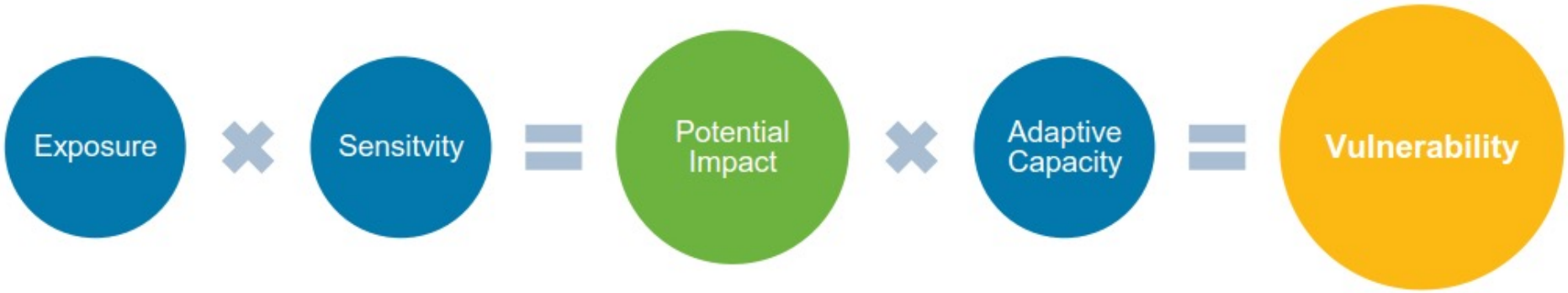
Risk



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Vulnerability



Sea Level Rise

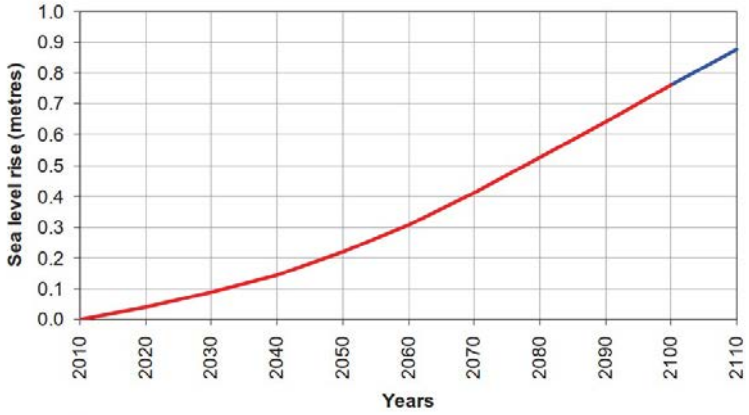
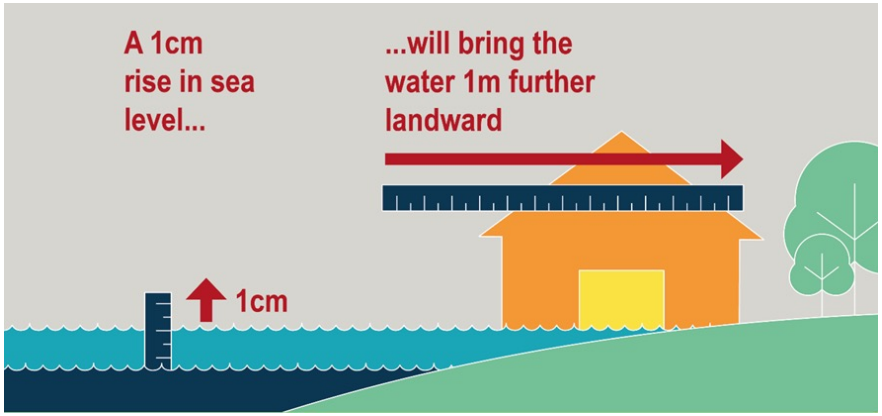


Figure 16 - Recommended allowance for sea level rise in coastal planning for WA (red line SRES scenario A1FI 95th percentile after Hunter (2009), normalised to 2010, blue line continuation of scenario to 2010)



Key Issues – Lancelin

- Potential for minor flooding of more than 100 homes during an extreme event (500-yr storm) today
  - Frequency of flooding events increases as sea levels rise → **500-yr storm becomes the 20-yr storm**
- Dunes act as a natural levee **at present**
  - The pressure on the dunes will **increase** (SLR), while their ability to withstand will **decrease** (erosion)



Baird: 500-yr ARI at present

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Key Issues – Lancelin

Erosion summary (previously completed by MRA, 2016)

- Caravan park may be at risk by 2030
- Some properties may be at risk by 2070
- Majority of coastal properties currently closest to the coast will be under threat by 2110
    - Assumes no future active management
    - Dunes not expected to provide flood protection by 2070, but could be breached much earlier



Key Issues – Ledge Point

- Inundation may reach 1.9 m above mean sea level (500-yr storm)
  - 2.8 m AHD by 2120
  - Minimal inundation impact on existing assets
- Sea level rise will increase frequency of extreme high-water levels which will intensify erosion along the coast



Key Issues – Ledge Point

Erosion summary (previously completed by MRA, 2016)

- Houses south of cusp at high risk (De Burgh St)
- Assets north of groynes at risk by 2070
  - Legacy issue for groynes
    - Potential for increased erosion north of groynes



MRA: Erosion risk by 2070

Key Issues – Seabird

- Inundation may reach 1.7 m above mean sea level (500-yr storm)
  - 2.6 m AHD by 2120
  - Minimal inundation impact on existing asset
- Sea level rise will increase frequency of extreme high-water levels which will intensify erosion along the coast



Key Issues – Seabird

Erosion summary (previously completed by MRA, 2016)

- Area north of the existing seawall at risk of erosion
  - Seawalls can increase erosion for adjacent coastlines
- Legacy issue for seawall
  - Do we keep the wall forever?
  - What if we lose the beach?
    - Seawalls reflect wave energy, increasing local erosion (loss of beach)

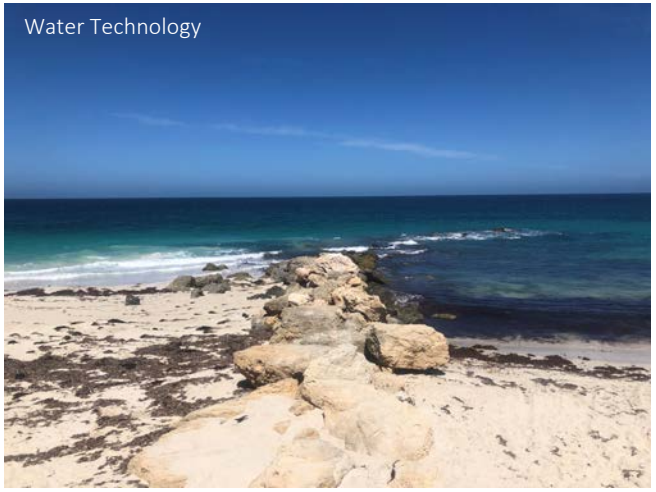


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Key Issues – Guilderton

- Highly mobile river mouth can exacerbate erosion
  - Erosion reported south of river mouth – site of potential residential development
- Guilderton groyne depreciation
  - Erosion between river and groyne may change

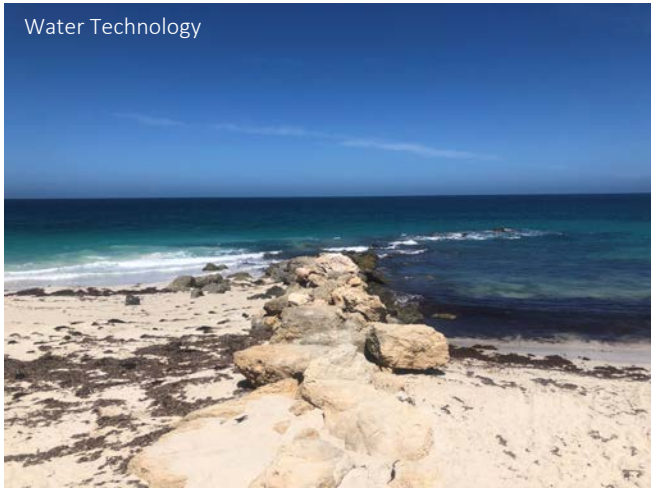




Key Issues – Guilderton

- Riverbank may be sensitive to extreme events
  - Area near coast may erode if storm breaches sandbar
- Inundation may reach 1.8 m above mean sea level (500-yr storm)
  - Minimal impact on existing assets





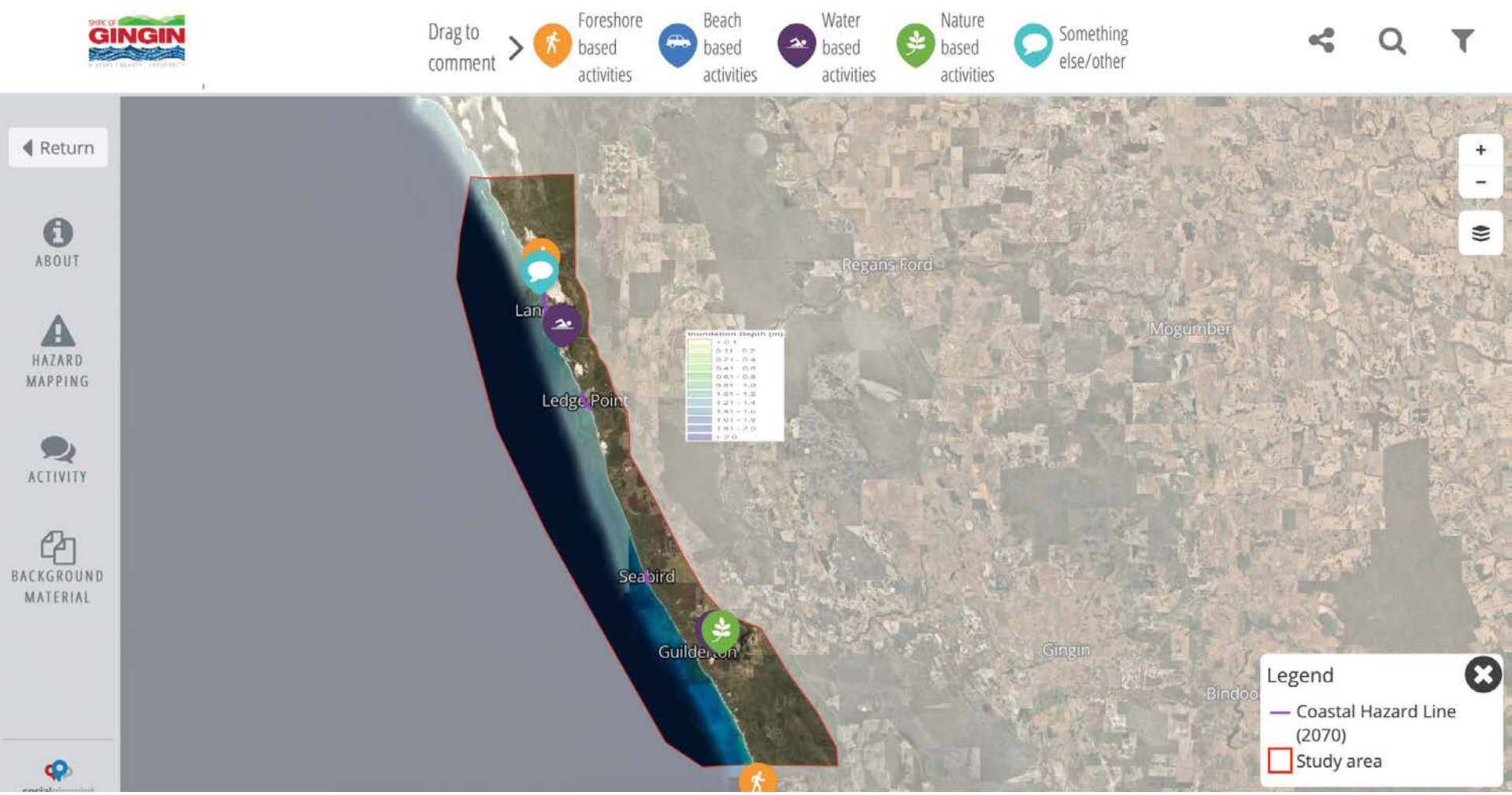
SHIRE OF GINGIN
HISTORY | BEAUTY | PROSPERITY

Q&A

S+U
SHAPE URBAN

Values – what have you previously said…

Online portal - current



What did you say?

Web portal	244 Unique Users	22 Unique stakeholders	6 Comments	31 Survey Responses	6 'Pins' dropped

Other	~6 Facebook Comments

What did you say?



What did you say?

Swimming, sunset picnics, dog walking, 4wd, walking

Start a discussion

a month ago Like Dislike

the river is a perfect place for children and older adults to swim in safety. Unfortunately over the years more and more power boats are ignoring the yellow marker buoys and cutting through children playing to pull up on the limited shoreline. This was evident during the last few years of swimming lessons when even paddle eg canoes were cutting through the closed off area for lessons

Start a discussion

a month ago Like +1 Dislike

I am aware of the erosion taking place all around our coastline & wish to assist in any form to try & protect it the best way forward. Climate change is one issue that I am very aware of & concerned about. I myself are doing what I can to help the planet. Carbon emissions, recycling in many forms, protecting water ways, clean up coastline when on the beach & river, protecting flora & fauna etc.

Start a discussion

a month ago Like Dislike

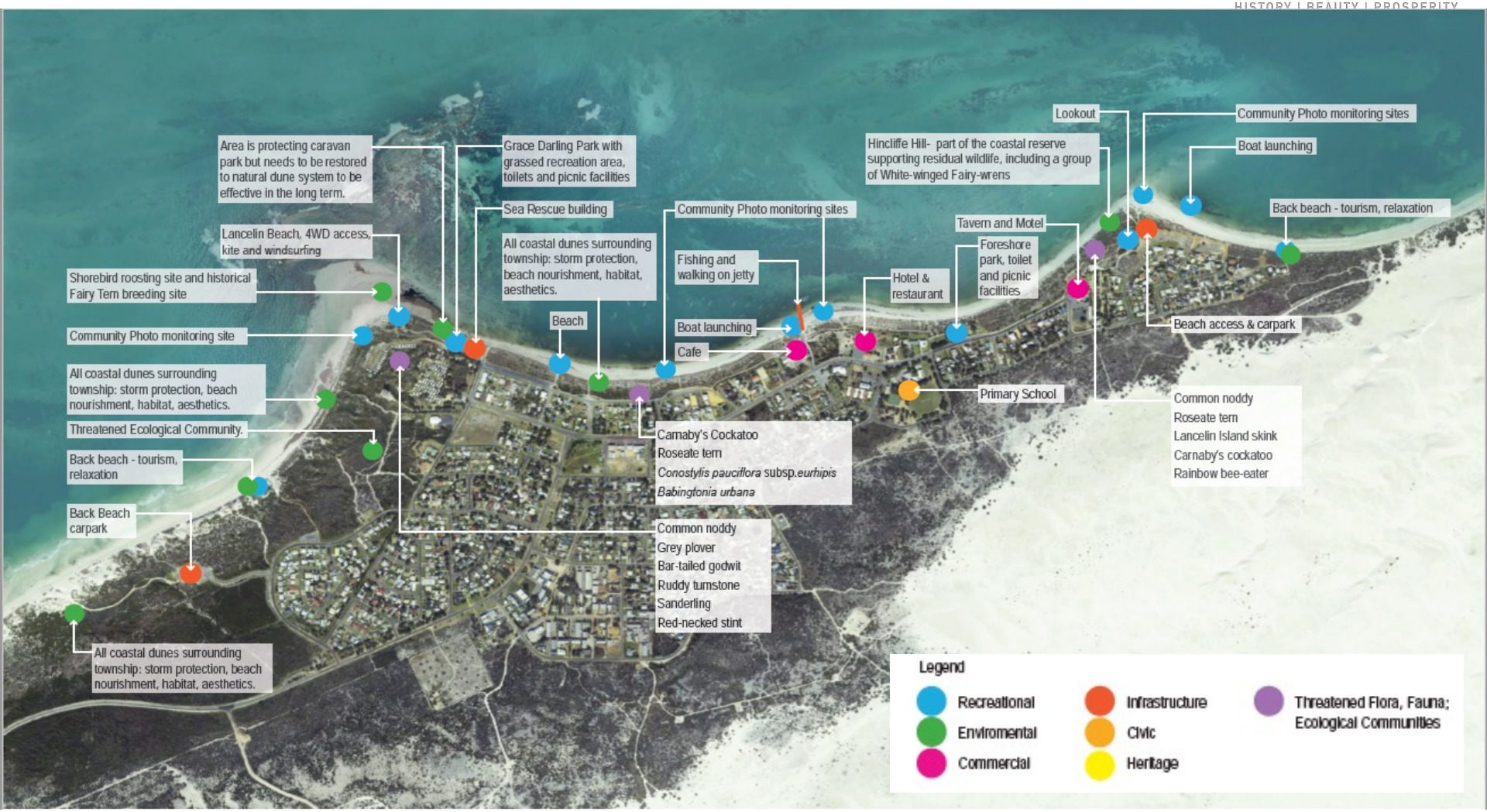
a beautiful area especially for younger children to enjoy the easy walks and is well used unfortunately car parking is at a premium after 9.30 in the mornings. Also paths require regular maintenance and more rubbish bins are needed

Start a discussion

a month ago Like +1 Dislike

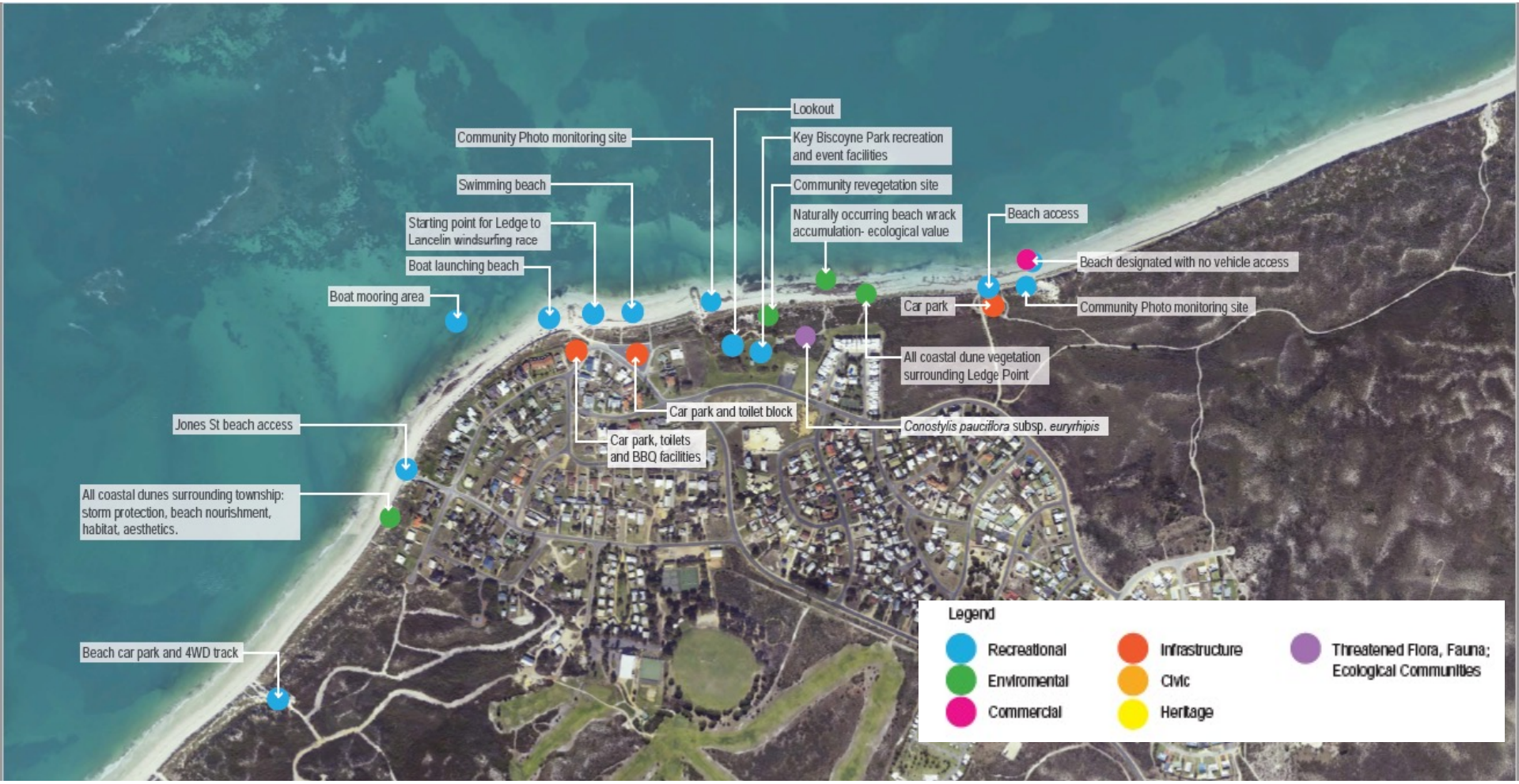
What did you say previously?
(2019)

CHRMAP 2019 values – Lancelin



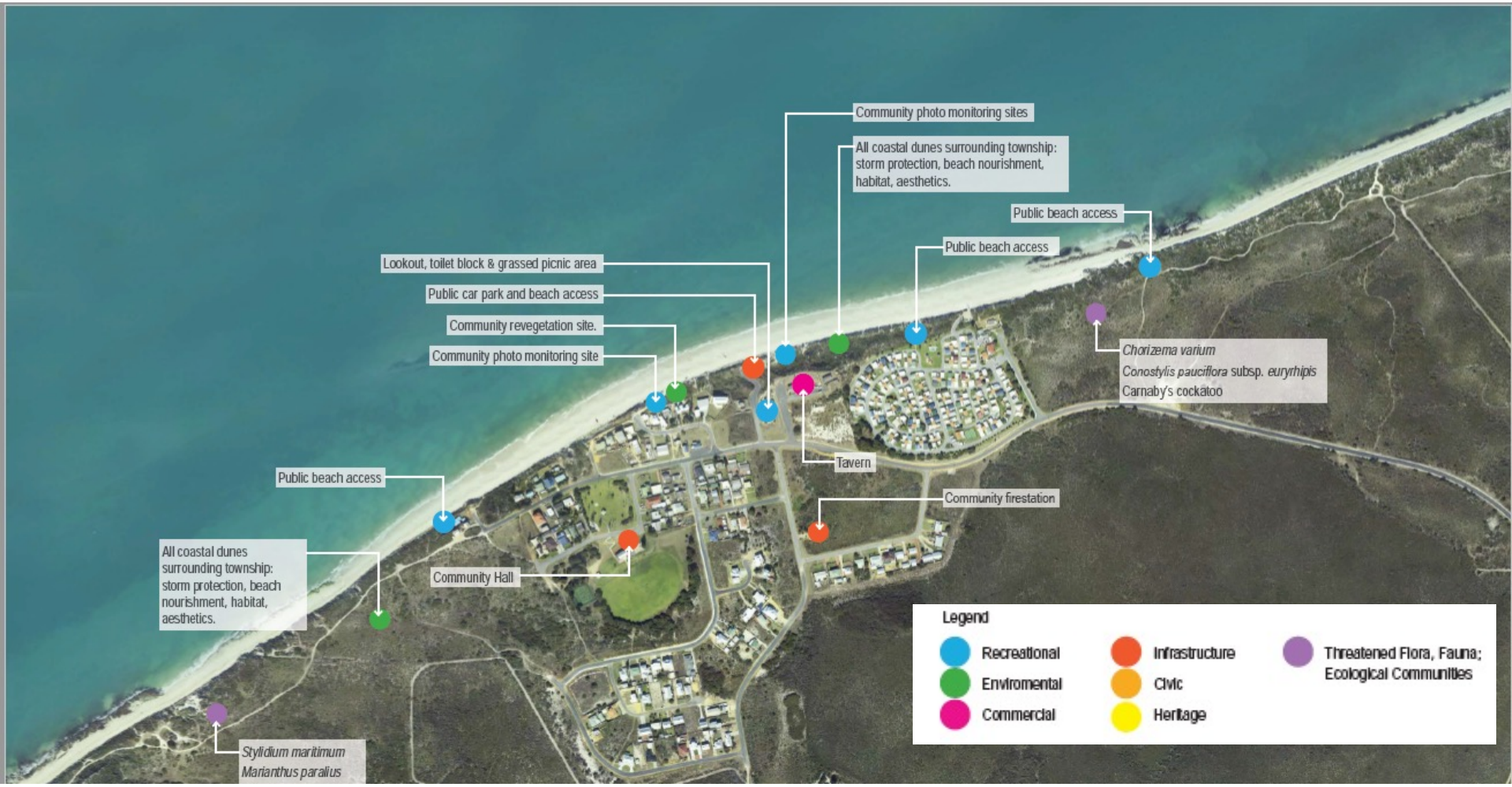
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CHRMAP 2019 values – Ledge Point



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CHRMAP 2019 values – Seabird



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And Guilderton?

Starting now...

Task 1

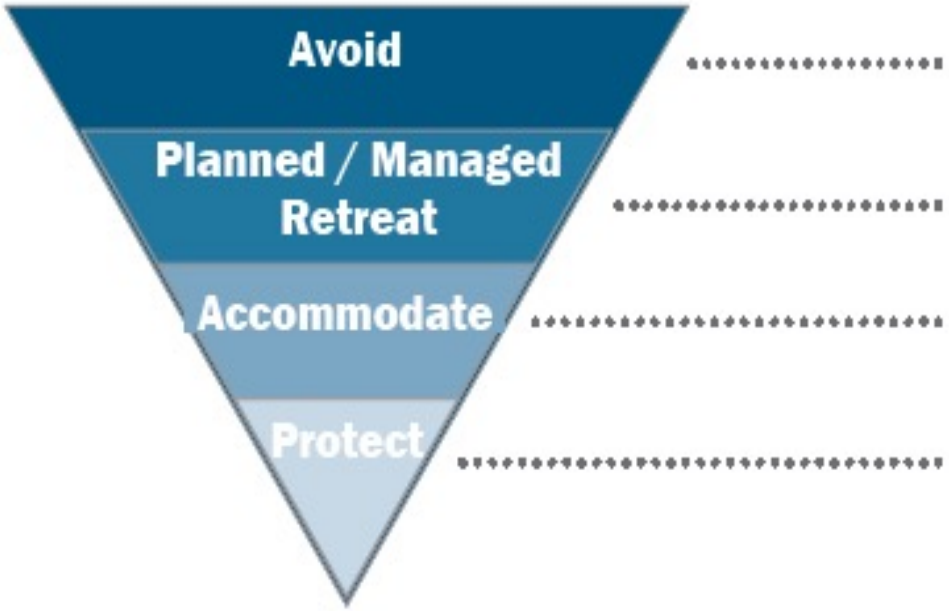
What are our coastal values?

1. Look at the map on your table
2. What is important to you?
3. Sticky dot each location/asset/other of value in the marked ‘Coastal zone’)
4. Sticky dots are colour themed – the page on your table will explain the colours

+ present back

Group Work

Adaptation Options



Avoiding development

Relocating or removing things

Using design measures or strategies

Challenging the natural environment

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Adaptation Options

Hierarchy of Controls:

- **Avoid** – Options which aim to eliminate the risk of coastal hazards by avoiding development
- **Managed Retreat** – Options which progressive retreat/relocate development
- **Accommodation** – Options which seek to enhance assets to cope with the temporary impacts
- **Protection** – Options which seek to artificially protect the coast

Adaptation Options







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Task 2

With that introduction to coastal processes and adaptation options, let's focus in on the mapped values....

1. Of the values mapped on your table, what is of particular importance to you?
2. Using the template on your table, tell us the characteristics that make it highly valued to you
3. Feel free to add other characteristics!

+ present back...

Group Work

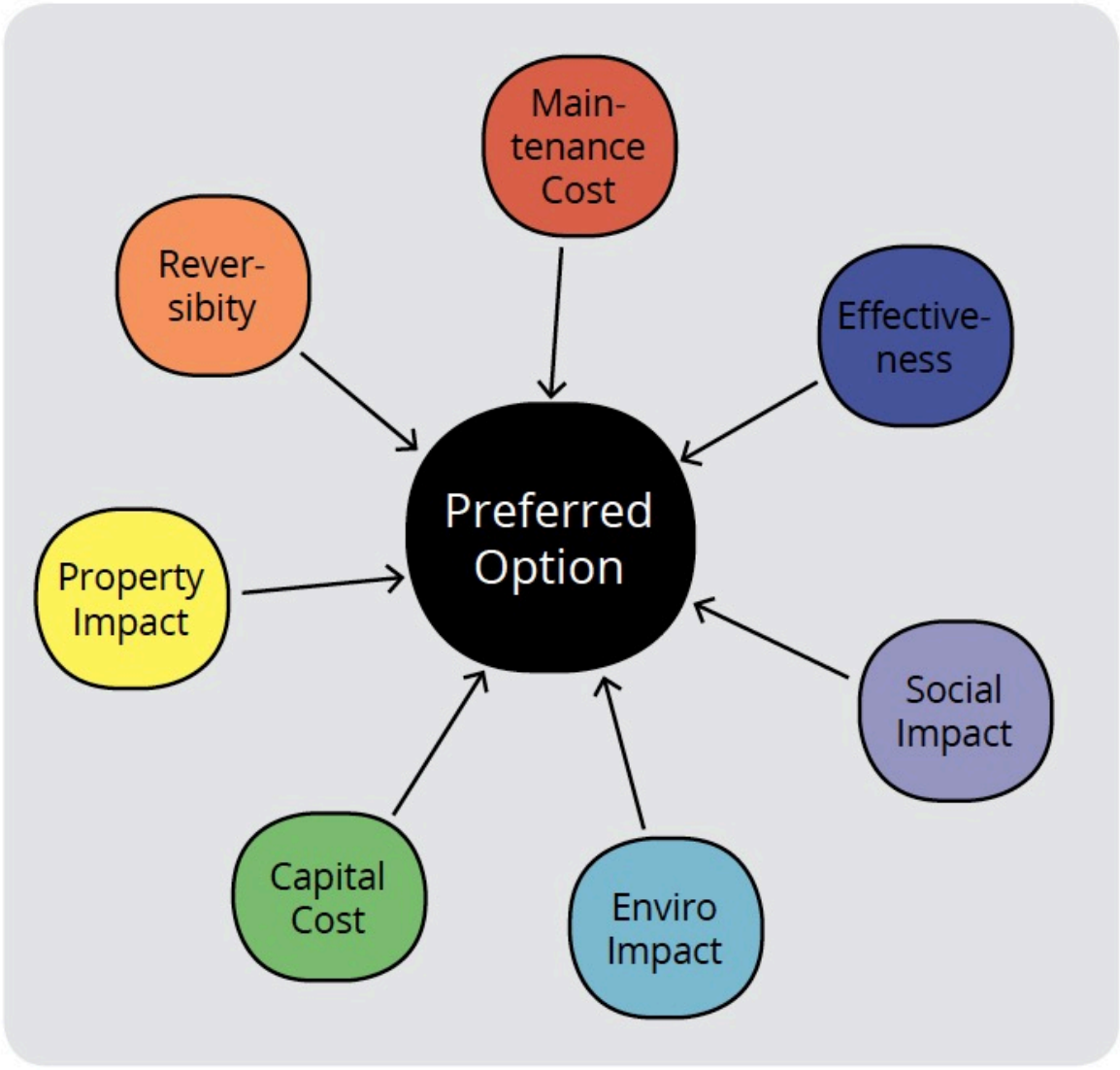
Criteria...

Now we have a better understanding of values and adaptation options, let's discuss criteria....

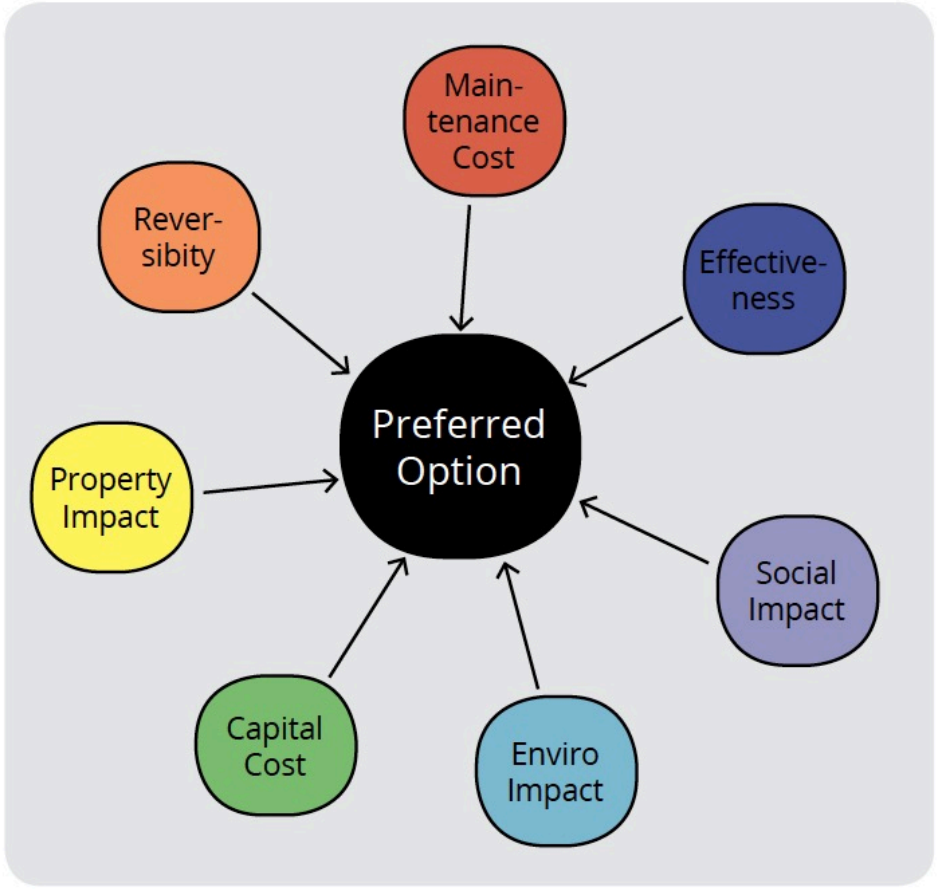
We have studied and researched possible impacts on the coast and have identified criteria for how we might assess adaptation options.

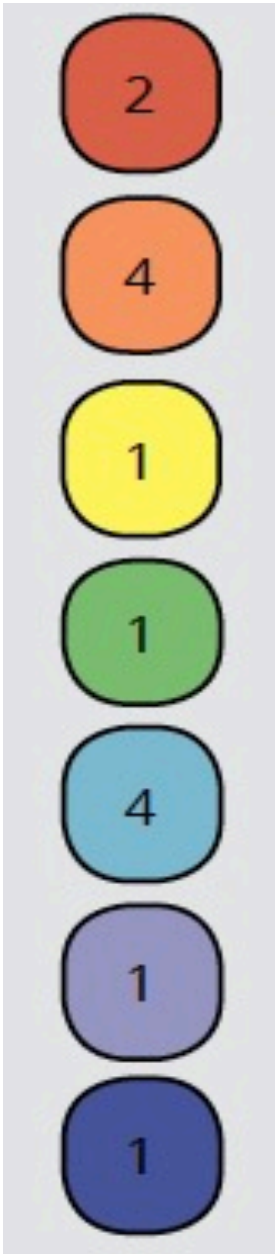
Things like cost, property impact, effectiveness – these are all criteria

What is Multi- Criteria Assessment?



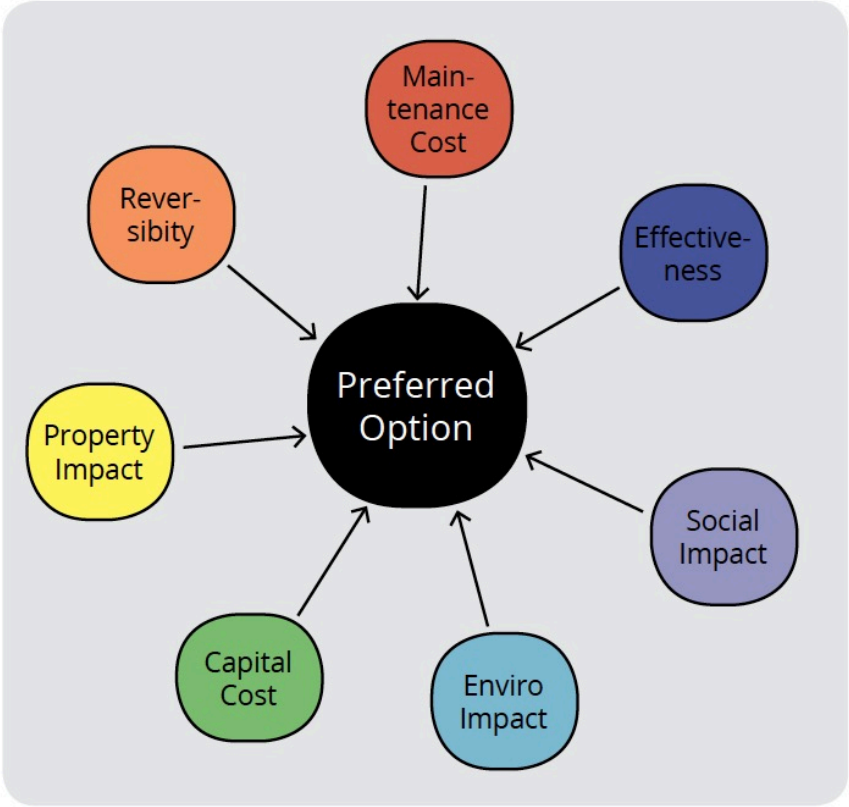
Option 'X'

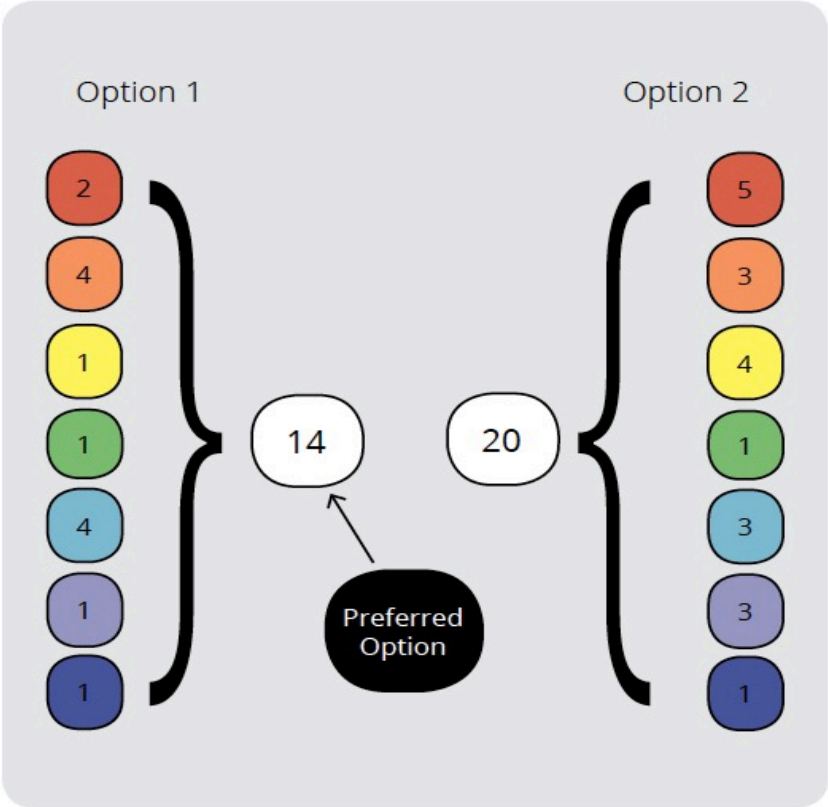




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Main-
tenance
Cost
Rever-
sibity
Effective-
ness
Preferred
Option
Property
Impact
Social
Impact
Capital
Cost
Enviro
Impact


Option 1
Option 2
2
4
1
1
4
1
1
14
20
5
3
4
1
3
3
1
Preferred
Option

Capital Costs

- How much it costs us to build something up front (in todays' $)

Maintenance Costs

- How much it costs us to keep maintaining something over 100 years (in todays' $)

Environmental Impact

- Damage/loss of beach, vegetation, seagrass, fauna habitat
- Erosion in adjacent areas

Social Impact - Property

- Private property is affected and may be lost or damaged
- May have restriction placed on use
- Number of private properties impacted

Social Impact - Communal

- Loss of ability to walk on beach, enjoy vistas, access to car parks
- Loss of parkland, footpaths
- Loss of assets such as cafes, Surf Life Saving Club etc

Reversibility

- Once chosen, other options are off the table or very difficult to implement OR highly reversible
- Sets expectation/ties future community to the decision/costs

Effectiveness

- Short term options suitable for minor protection
- Untested/unclear how effective
- Well tested and understood – works to reduce risk

Break...

Scoring

How would you score these criteria?

(Comparing a technical view to the community's expectation)

REMEMBER - A HIGH SCORE IS WHERE AN OPTION WOULD DO VERY WELL AGAINST THE CRITERIA

Discussion...

Are all these criterion equal?

Should all these criterion have equal affect on the assessment of options?

Discussion...

These options can be very expensive.

Would you change how much influence one criterion had over decision making if the cost was borne by you?

Or if it was borne by the beneficiary?

Wrap-up

Next Steps...

Thank you!!



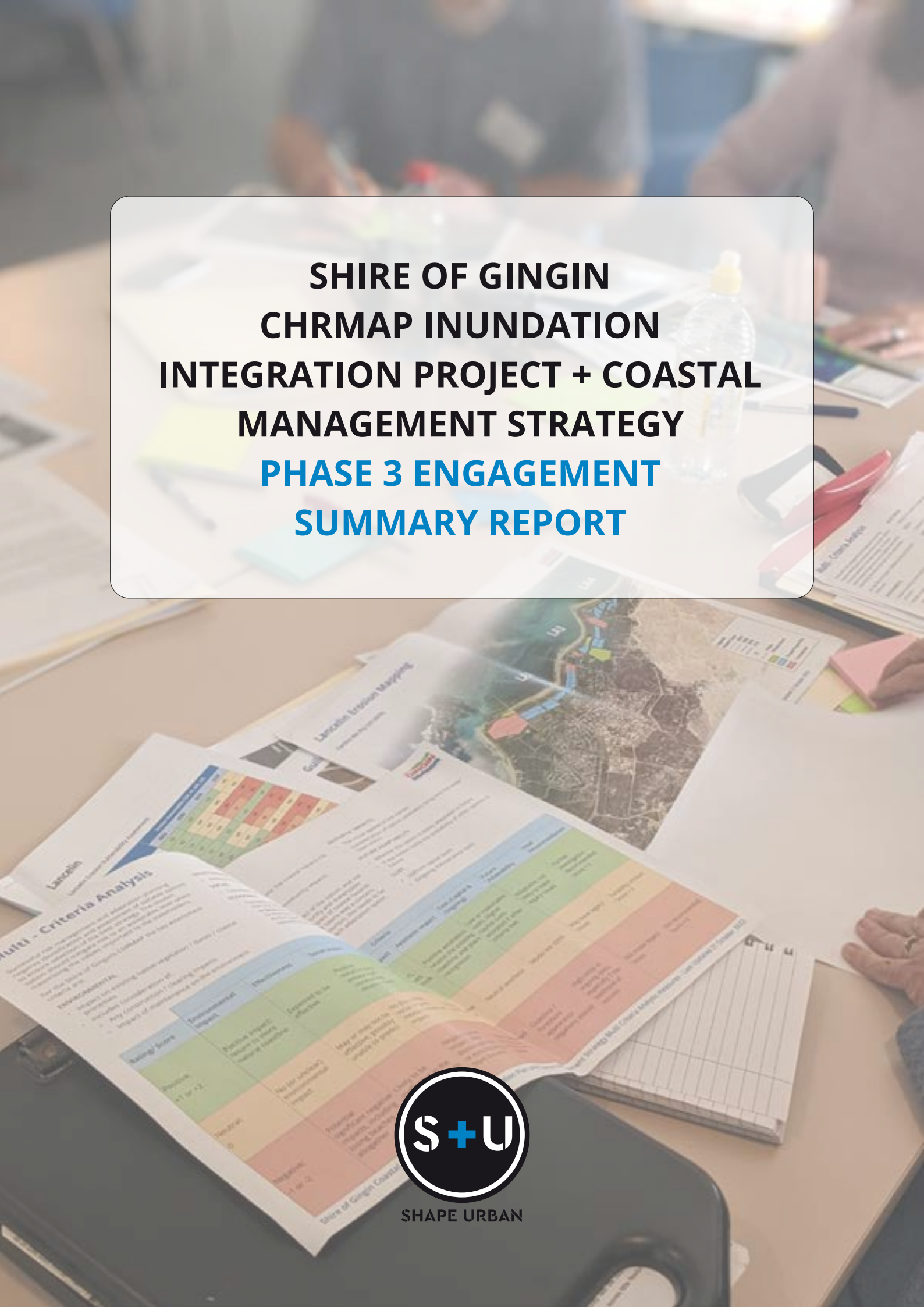


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APPENDIX E

Appendix E - CHRMAP Integration Project + Coastal Management Strategy Phase 3 Engagement Summary Report

SHIRE OF GINGIN
CHRMAP INUNDATION INTEGRATION PROJECT + COASTAL MANAGEMENT STRATEGY
PHASE 3 ENGAGEMENT
SUMMARY REPORT



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ACKNOWLEDGEMENT

Shape Urban acknowledge the Yued Nyoongar People as traditional custodians of the land on which we have worked for this project. We recognise their cultural heritage, beliefs and relationship to the land, which continue to be important to the Yued Nyoongar People today.

We pay our respects to Elders past and present, and to the land which they have cared for.

This document has been prepared with the support of many people from the Shire of Gingin community. We wish to acknowledge the community for your contributions.

DISCLAIMER

This document has been prepared by Shape Urban for the purpose of summarising the outcomes of the community and stakeholder consultation undertaken for Phase 3 of the Shire of Gingin CHRMAP Inundation Integration project (the CHRMAP) and to inform the development of the Coastal Management Strategy (CMS).

This report forms part of a broader suite of documents for the Shire of Gingin CHRMAP and the CMS.

DOCUMENT CONTROL

Shire of Gingin CHRMAP Inundation Integration project + Coastal Management Strategy - Phase 3 Engagement Summary Report

NO.	AUTHOR	REVIEWED BY	DATE	PURPOSE
1	K Yang	A Chhabra	5/12/22	Draft for review
2	A Chhabra	A Kelderman	17/01/23	For Client review
3				



EXECUTIVE SUMMARY

The Shire of Gingin's coastal areas of Lancelin, Ledge Point, Seabird and Guilderton are subject to erosion and inundation risks, which will have a significant impact on its communities over time.

The Shire has prepared a number of coastal management plans to respond to these risks and is now finalising this work to form a 'blueprint' for implementing management actions, including updating planning framework documents, requesting funding from the Department of Transport for priority management actions, and undertaking budgeting for coastal management works.

Engagement for this stage comprised Community Panel workshops and stakeholder meetings, with information communicated via a website project page at https://getinvolved.mysocialpinpoint.com.au/shire-of-gingin-coastal-planning, via the Shire's Facebook page and local community newsletter, and by direct letters and email contact.

The engagement undertaken for this stage of the Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) Inundation Integration project provides the project team with a confirmation of community values and the Community Panel members' preferred management options for the four coastal towns overall for both the short to medium term and long term.

The engagement also provided the community with the opportunity to learn about the Multi Criteria Assessment (MCA) process, criteria and scoring, and to review and confirm proposed scores from technical experts.

It also allowed community members to recognise that each of the proposed adaptation options in the State Planning Policy 2.6 - State Coastal Planning Policy (SPP 2.6) hierarchy has pros and cons, and that selection comprises a complex comparison of benefit, cost, who pays, how options impact established community values and the negative consequences of various options e.g. loss of beach in front of seawalls and scouring at the terminus of a seawall.

Table 1 summarises the polling results for preferred management options for sections of the coast by the Community Panel. It shows a general consensus/ agreement with the 2019 CHRMAP or draft consultant team recommendations, where:

Green = recommended option that scored well across most criteria;

Yellow = options that score neutrally and require investigation; and

Red = score negatively and are not recommended.

In the short term, there was general support for the recommended options by panel members, with the exception of the groynes preferred at Seabird North.

Non-physical controls were not voted on (for either Gingin coastal zones overall or Lancelin overall).

In the long term, panel members supported the options recommended by the technical team for Lancelin Centre, Seabird North and Guilderton. but preferenced options that require additional investigation for Lancelin South, Ledge Point (North and South) and Seabird South.

For Lancelin North panel members preferenced an option that was not recommended by the technical team because it is not assessed to be effective in managing the coastal hazards.

It should be noted that 'Remove / Relocate' was recommended for Lancelin Overall in the long term, which contradicts the recommendations for Lancelin North, Centre and South individually.

The community's confirmed values, feedback and shared information, and preferred short to medium and long term management option preferences will help refine the adaptation pathways to be outlined in the CHRMAP.

The next step is submission of the draft CHRMAP to the Shire for endorsement of advertising, where the community will be able to provide further feedback on the information and recommendations contained within the CHRMAP report.

TABLE 1 POLLING RESULT - MANAGEMENT OPTIONS WITH THE HIGHEST VOTE

MAP AREAS	OPTIONS WITH THE HIGHEST VOTE	
	SHORT & MEDIUM TERM	LONG TERM
All Coastal Zones	There were no votes for this proposition	
Lancelin North	Recommended Options	Nearshore reef / breakwater
Lancelin Centre	Recommended Options	Recommended Options
Lancelin South	Recommended Options	Beach nourishment Groynes
Lancelin Overall		Remove/Relocate*
Ledge Point North	Recommended Options	Seawall
Ledge Point South	Recommended Options	Beach nourishment Seawall
Seabird North	Groynes	Recommended Options
Seabird South	Recommended Options	Groynes
Guilderton	Recommended Options	Recommended Options



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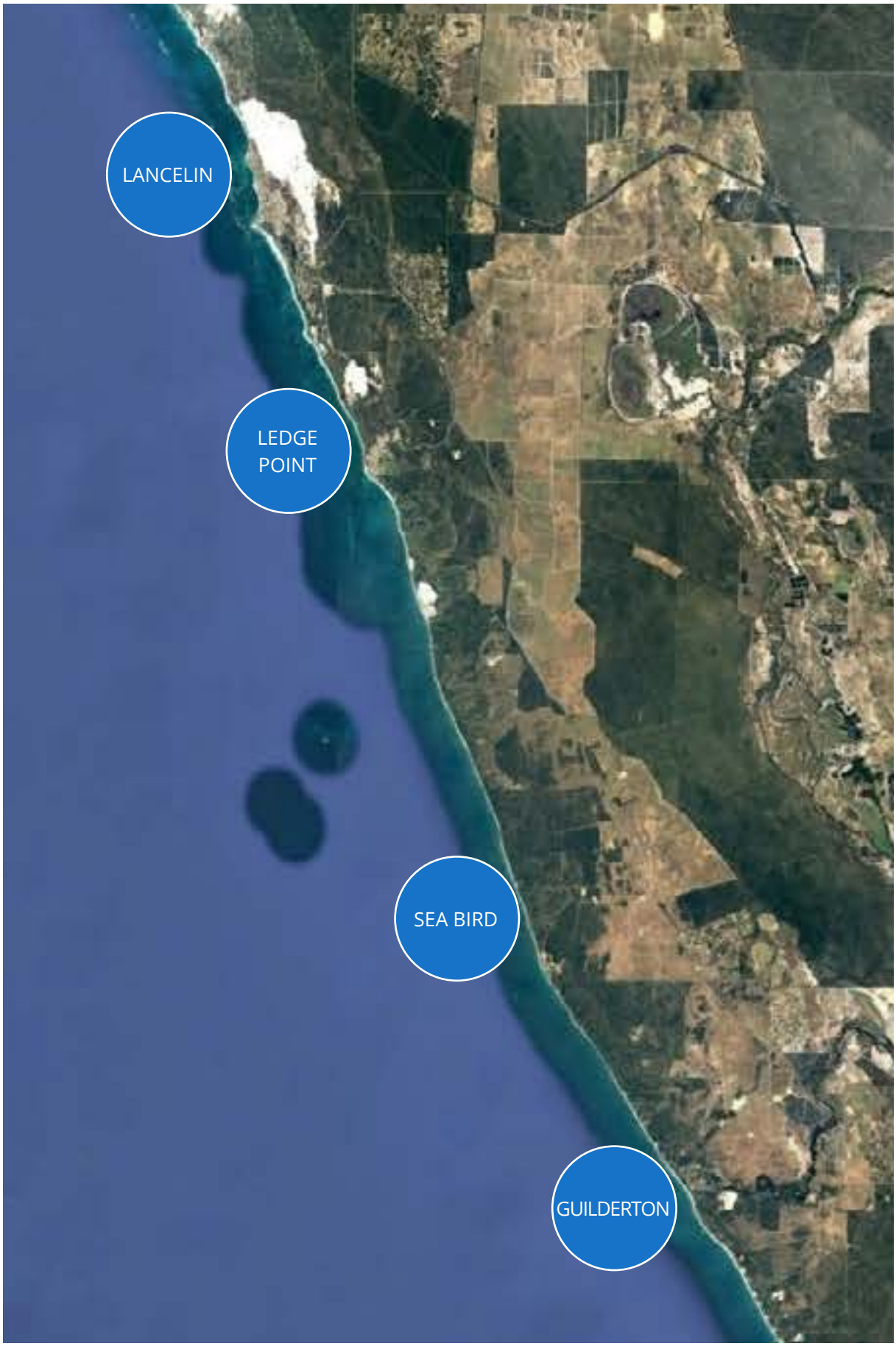


FIGURE 1 GINGIN CHRMAP INUNDATION INTEGRATION STUDY AREA

1 INTRODUCTION

1.1 BACKGROUND

The Shire of Gingin's coastal areas of Lancelin, Ledge Point, Seabird and Guilderton are subject to erosion and inundation risks, which will have a significant impact on its communities over time.

The Shire has prepared a number of coastal management plans to respond to these risks. As part of the Shire's coastal hazard risk management adaptation planning, a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) was prepared for the Lancelin, Ledge Point and Seabird townsites by Cardno in 2019 and the Gingin Coastal Inundation Study (CIS) was prepared for all four coastal towns by Baird (July 2020).

These plans identify coastal erosion risks and adaptation and implementation pathways for the Lancelin, Ledge Point and Seabird townsites, and inundation risks and challenges for the Lancelin, Ledge Point, Seabird and Guilderton townsites.

However, they do not consider erosion risks and management responses for Guilderton or the combined erosion risks and management responses for inundation and erosion in the four townsites per the WA State Government's CHRMAP Guidelines (2019).

The CHRMAP Inundation Integration project will accordingly:

- Update the 2019 CHRMAP to include coastal erosion risks and adaptation and implementation pathways for the Guilderton townsite;
- Review adaptation pathways presented in the 2019 CHRMAP;
- Include the Gingin CIS for the four townsites by Baird (July 2020);" "
- Develop adaptation and implementation pathways;
- Develop an integrated CHRMAP document that includes all this information; and
- Develop a public facing summary CHRMAP document for the local community that is easy to read and understand.

A Coastal Management Strategy (CMS) is also being prepared. The CMS will build on the outcomes and recommendations of the updated CHRMAP and previous coastal studies. It will detail information about the coastal zone, including flora and fauna and the Shire's owned or managed assets, relevant to planning and management of the coastline.

Figure 2 depicts the coastal management planning that has been undertaken for Gingin to inform the 'blueprint' for the Shire's management of the coastline. This includes the community and stakeholder engagement that forms part of the current CHRMAP Inundation Integration and CMS projects.

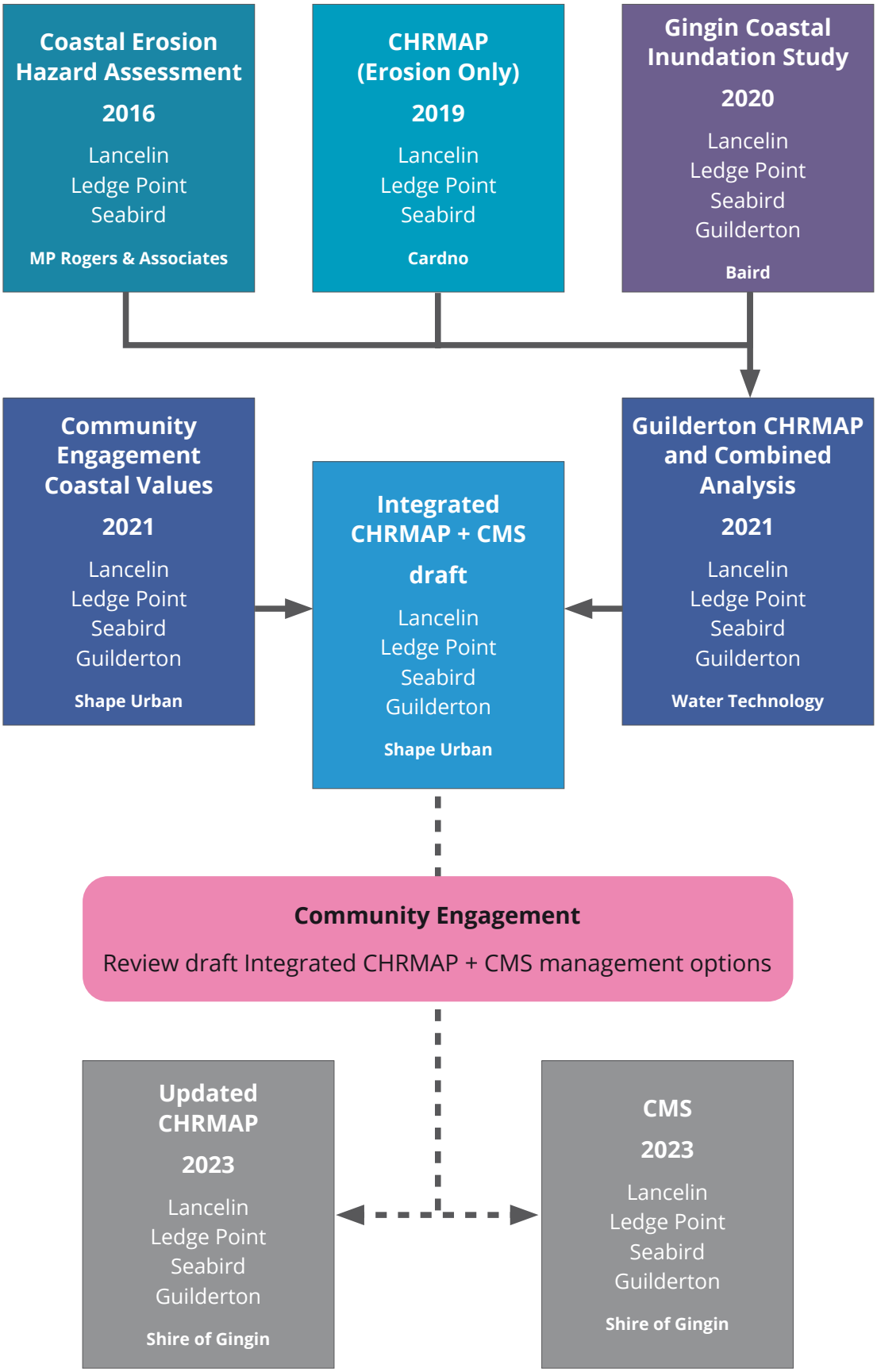


FIGURE 2 PREVIOUS REPORTS AND CURRENT ACTIONS

1.2 PURPOSE OF THE REPORT

The CHRMAP Guidelines (2019) outline seven stages for CHRMAP development - see Figure 3. Stages 2 and 5 and the final public advertising of the reporting comprise stakeholder engagement.

This report summarises the engagement undertaken in Stage 5 - Risk treatment. The community and stakeholders were asked to 'ground truth' and confirm established values, investigate qualitative criteria used in the multi-criteria analysis (MCA) process and the MCA assessment prepared by the project team and through previous studies, and to examine trade-offs of management options.

This report summarises the processes, information presented, modes of engagement and the outcomes.

An engagement summary report was also prepared at the end of Stage 2 - Risk Identification (see Figure 2 Community Engagement Coastal Values 2021).

These summaries of community and stakeholder values and of risk treatment considerations are being used to inform refinement of the draft CHRMAP and development of the CMS.

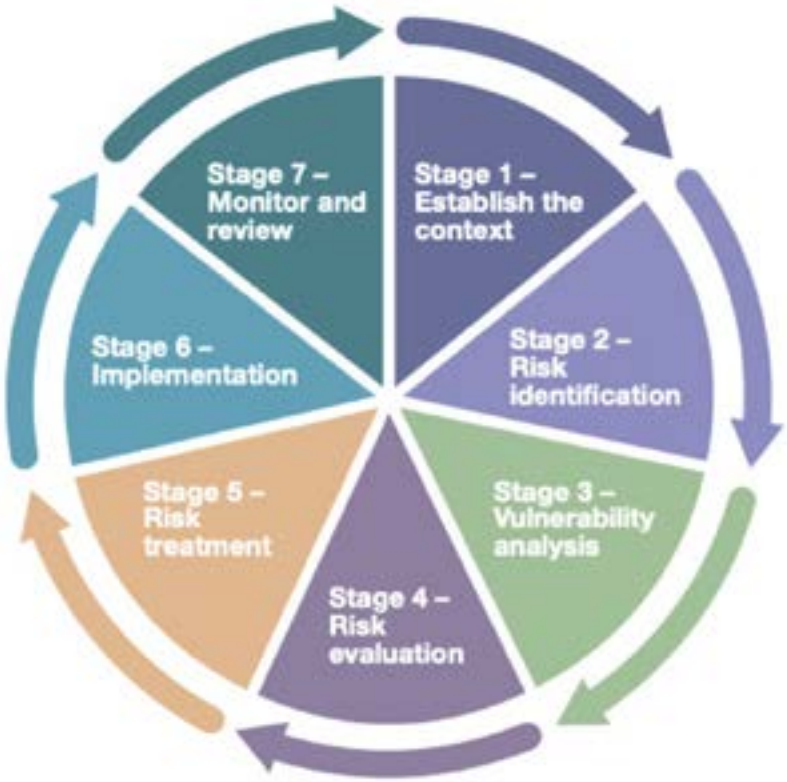


FIGURE 3 CHRMAP STAGES PER THE CHRMAP GUIDELINES (WAPC, 2019)

1.3 ENGAGEMENT PURPOSE

A critical part of this project is engagement with the local community and relevant stakeholders.

In mid-2021, initial community and stakeholder engagement was completed to enable the project team to understand community values when assessing adaptation strategies to respond to the coastal risks. This engagement also helped to re-confirm values that had been identified during preparation of the 2019 CHRMAP (Cardno).

Since then, technical assessments have been completed and a draft integrated CHRMAP developed.

The Stage 5 engagement process aims to facilitate an understanding of coastal challenges, appropriate adaptation strategies, implications and trade-offs and how the community may be affected, cognisant of the earlier stated values.

Specific engagement objectives are to:

- Inform the community and stakeholders about coastal hazards, the adaptation options selected to respond to the impacts of the hazards over time, and what this means for different community members
- Invite the community to bring their local knowledge, expertise and lived experience to the process and give them adequate opportunity to understand the complexities in coastal planning and trade-off considerations the Shire Council needs to make
- Explain the Shire's responsibilities and capacity to respond to coastal hazards and management options
- Confirm community values along the coastline
- Ensure that stakeholder advice and recommendations are incorporated into the decisions to the maximum extent possible
- Ensure that engagement is fair, equiTable, transparent and honest. It is fundamental that engagement be undertaken in a way that allows the informed community to work with the project team, using their local knowledge.

The deliberative engagement comprised a Community Panel process and targeted meetings with affected landowners in Lancelin and other community members who nominated to speak with the project team.

The engagement approach was aligned with the framework of the Shire's strategic planning framework and the CHRMAP process.

This is in accordance with the WA State Government's coastal planning policy framework - State Planning Policy No. 2.6 - State Coastal Planning Policy (SPP 2.6) and the CHRMAP Guidelines.

2 ENGAGEMENT ACTIVITIES

2.1 COMMUNITY PANEL

This phase of engagement involved establishing a Community Panel which would meet for two workshops. Nominations were open between 8 September and 19 October 2022 and community members could nominate to be a part of the process online by completing a survey on the Social Pinpoint project website or in-person at the Shire offices.

A total of 33 nominations were received. One nomination opted out of the process before it commenced due to other commitments. Members involved a cross section of the community from Lancelin, Ledge Point, Seabird and Guilderton, as well as those from further afield with an interest in the coast. Nominations were received from businesses, residents and ratepayers with an interest in and surrounding the coastal areas.

One member advised that they were unable to attend the first session and nominated an alternative community group member who attended both sessions.

There were accordingly a total of 33 panel members who formed the Community Panel. Councillors and Shire staff members attended the two workshop sessions.

Due to illness and other commitments, neither workshops had all members present.

The Community Panel engagement was held on:

- 22 October 2022 10:00am – 3:00pm: Coastal context, coastal values discussion, technical findings
- 29 October 2022 10:00am – 3:00pm: Review criteria used to assess management options, test findings and conclusions.

Three panel members were identified to undertake a vignette presentation to give different local perspectives on their values and use of the coast during the first workshop session.

2.2 STAKEHOLDER MEETINGS

Community members were invited to request a meeting with the project team, via letter at the commencement of this stage. Alternatively, this option was also available on the online project page. Community Panel members could also request a meeting.

The project team met with three stakeholders/ stakeholder groups - the Lancelin Caravan Park, the Seabird Progress Association, and a combined group of Elders from the Yued Noongar community who represent the Traditional Owners of the area.

There has also been follow up phone meetings with two members of the Community Panel.



3 COMMUNICATION METHODS

For this stage of the project, information was communicated in the following ways:

3.1 LETTERS

The Shire sent general invitation letters to all community members in the four coastal towns and in Gingin. They also sent more targeted letters to affected landowners in Lancelin.

3.2 ONLINE PROJECT PAGE

A website project page was established at the commencement of Stage 2 using the 'Social Pinpoint' platform was used as the primary location for all project information. This included project timeframes, forms for the Community Panel or to be kept informed, hazard mapping for the four townsites and community values from Stage 2, key documents and links, frequently asked questions (FAQs) and common terms used in the project.

3.3 DIRECT CONTACT

Community Panel members were communicated directly via email to provide information relating to the workshops.

3.4 COMMUNITY PANEL WORKSHOPS

Project information was shared at the two Community Panel workshops on the 22nd and 29th of October 2022.

3.5 STAKEHOLDER MEETINGS

Individual meetings were undertaken with community members and community reference group representatives as requested. The meetings provided the project team with the opportunity to share project information and get feedback on values and the viable adaptation options for the four towns, focussed on more specific locations and issues.

3.6 SOCIAL MEDIA

Social media, specifically the Shire's Facebook page, was used to promote the project website and opportunities to be involved.

3.7 OTHER

The Shire published a Council to Community newsletter article on 5 October 2022. The article promoted the project website and how the community could get involved in the project.

Relevant Shire staff and Councillors were also provided with communication packages at launch of engagement regarding how staff or Councillors could assist the process.

The Shire also sent local schools a letter and an interactive activity for school children to undertake, however there was no response to this activity.



4 COMMUNITY PANEL WORKSHOPS

Community Panel processes provide members time to understand detailed technical background information, the complex nature of coastal risk management planning and the potential trade-offs that need to be considered when managing and balancing multiple elements.

Panels provide members with a forum to discuss issues and allow the project team to draw on local knowledge and enhance community voice in decision making processes and outcomes. They also build community understanding of decision-making processes and requirements.

4.1 SCHEDULED PROGRAM

Community panel members were invited to two days of workshops. Each workshop was five hours long with the following focused discussions:

- 22 October 2022 from 10:00am – 3:00pm at the Lancelin Sporting Complex - Coastal context, coastal values discussion, technical findings
- 29 October 2022 from 10:00am – 3:00pm at the Guilderton Community Hall - Review criteria used to assess management options, test findings and conclusion

4.2 WORKSHOP ATTENDANCE

Day 1 workshop attendance:

- 26 Community Members
- Three Councillors
- Two Shire Staff
- Three Consultant team

Day 2 workshop attendance:

- 23 Community Members
- One Councillors
- Two Shire Staff
- Three Consultant team

4.3 WORKSHOP FORMAT

The workshops were facilitated by the project team and included the following typical format:

- Presentation and findings from the project team;
- Discussion forums; and
- Interactive activities.

On the first day, the project team focused on providing panel members with the remit for the project (addressing coastal management in the most equiTable way to ensure future generations can enjoy the coastlines), technical information on coastal processes, management options and actions and the criteria for the multi-criteria assessment process.

The Day 1 agenda comprised:

- Introduction and Background
- Coastal processes, hazards and risks – CHRMAP process and CMS process
- Local Perspectives
- Funding Options and Remit
- Present Coastal Values from Initial Engagement Outcomes
- Present all available Management Options and Actions
- Introduce MCA


BUSSELTON
JETTY SWIM

The first day included local perspective vignettes from three panel members to provide the broader group with different perspectives on the coastlines.

The vignettes reflected values based on environmental protection, four-wheel driving with a focus on natural vegetation management and clean up of beaches and a property owner and part time resident.

Day 1 presentation slides are at Attachment A.

On the second day, the project team described the MCA undertaken by the consultant project team for panel review, presented a series of recommended coastal management options and sought feedback from panel members about their preferred short term and long term coastal actions for each of the four towns.

The material presented was incredibly complex, with source data from all four previous studies (MP Rogers and Associates 2016, Cardno 2019, Baird 2020, Shape Urban 2022). Through this process panelists were able to observe the complex assessment undertaken for delivering and MCA.

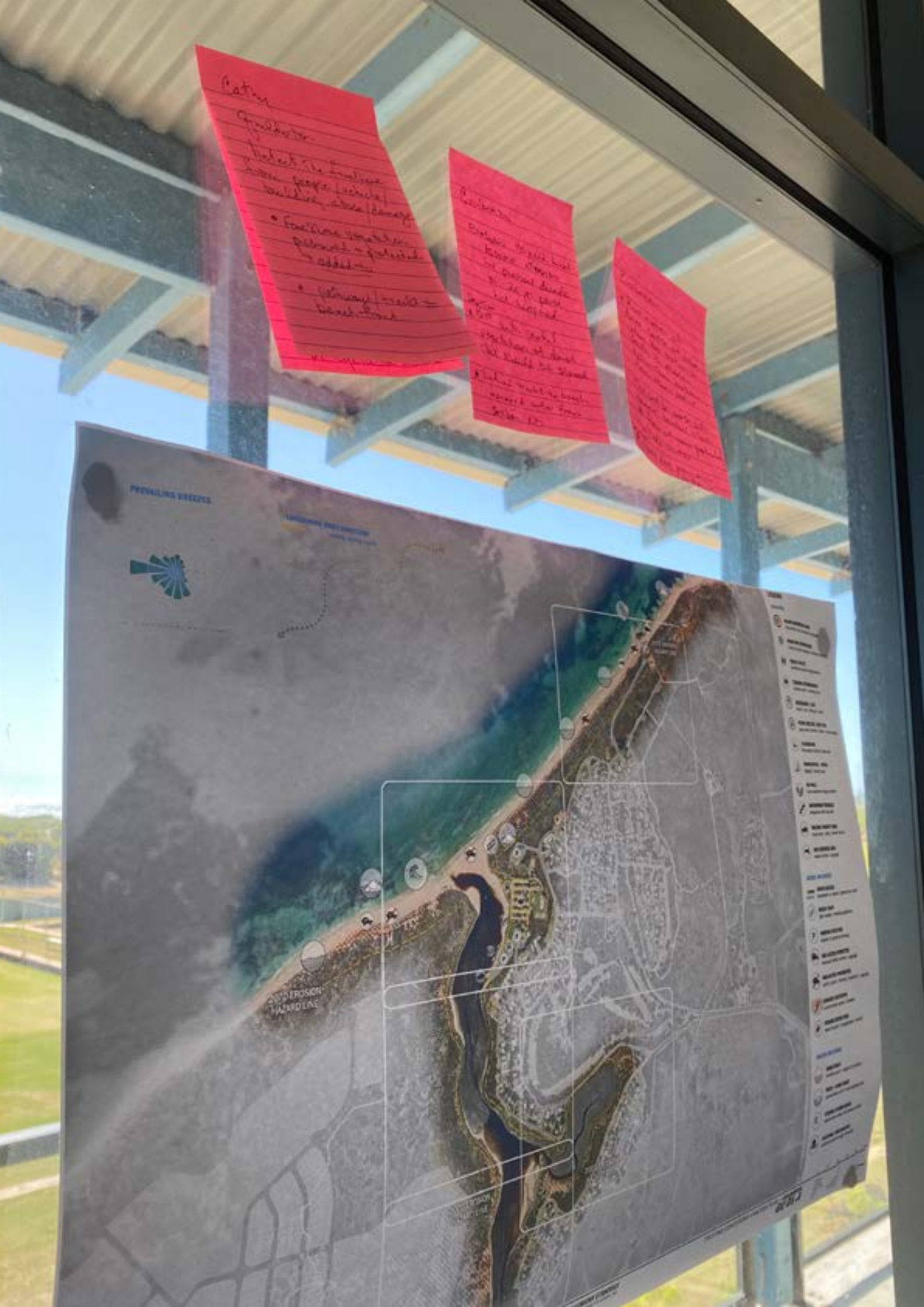
For the preference task, panel members were presented with all viable proposed management options as well as a few additional options requested by community members through the development of the CHRMAP and previous engagement meetings and workshops.

There were two interactive activities, with Task 1 undertaken in Table groups and Task 2 undertaken individually.

The Day 2 agenda was:

- Recap: Feedback from Day 1
- Task 1: Panel review of MCA scores and process undertaken by the consultant project team
- Present the draft management options
- Task 2: Panel review of draft management options for coastal sections
- Task 3: Panel consideration of all draft proposed options and selection of preferred short term and long term options

The Day 2 presentation slides are at Attachment C.


PREVAILING BREEZES
EROSION HAZARD LINE

4.4 WORKSHOP OUTCOMES

This section summarises both days' workshop proceedings, activities and key outcomes or workshop notes. A full list of comments from Day 1 is at Appendix B and at Appendix D for Day 2.

DAY 1: COASTAL CONTEXT, COASTAL VALUES DISCUSSION, TECHNICAL FINDINGS		
AGENDA	**ACTIVITIES**	**KEY WORKSHOP NOTES OR ISSUES**
Coastal processes, hazards and risks – CHRMAP process and CMS process • The role of the CHRMAP and CMS • The key issues for each of the coastal towns: - Lancelin: erosion, inundation, groundwater - Ledge Point: erosion - Seabird: erosion - Guilderton: erosion	**EXERCISE: What are the key issues?** Panel members were asked to note any surprises or impacts for each townsite. A full list of comments by panel members is at Appendix B	• Participants asked about the accuracy of using 0.9m for Sea Level Rise (SLR). Specifically, they questioned if the 0.9m was still relevant or accurate. The project team advised they would review this and share findings at the workshop two • A panel member asked about the underlying rock at Seabird and the seawall's impact on adaptation option efficiency • Panel members noted the incorrect zoning of a site in Lancelin (circled pink in Figure 4) and a site in Seabird (circled pink in Figure 5)
Funding Options Funding sources, allocation, availability, prioritisation and what this means for the various coastal locations along the WA coast was presented. The presentation slides are at Appendix A	Discussion	Group discussion about the State Government coastal planning policies and prioritisation of community benefit, including absence of legal obligation for the State Government to fund protection of private assets within the coastal zone



FIGURE 4 ZONING INCONSISTENCY - LANCELIN



FIGURE 5 ZONING INCONSISTENCY - SEABIRD

DAY 1: COASTAL CONTEXT, COASTAL VALUES DISCUSSION, TECHNICAL FINDINGS		
AGENDA	**ACTIVITIES**	**KEY WORKSHOP NOTES OR ISSUES**
A Local Perspective Three 10-minute presentations from local community panel members to showcase different perspectives of coastal use and activity	• Owner occupier who runs the Friends of Lancelin Coast group • Shire property owner and member of Wilbinga Shacks Crew (4WD group) • Property owner and regular visitor to Lancelin	• The importance of letting the dunes grow out to protect the coast • Need for collective care of bushland and to work with 4WD organisations. • Noted absence of adequate ranger patrolling of the area. • Suggested getting involved with the Wilbinga Shacks crew - group can be accessed at https://www.facebook.com/groups/wilbinga/ • Observed the sense of amazement at being able to live so close to the coast. • Noted changes along the coast e.g. Locations where 4WDing is restricted but recognition of the need for this
Q&A	Discussion	• The need for beach dune management • 4WD is a tourism driver to be encouraged, but think visitors should be given information about coastal vulnerability and protection • Discussion about the stormwater / drainage issue in North Lancelin
Present Values from Previous Engagement	NA	NA

DAY 1: COASTAL CONTEXT, COASTAL VALUES DISCUSSION, TECHNICAL FINDINGS		
AGENDA	**ACTIVITIES**	**KEY WORKSHOP NOTES OR ISSUES**
Management Options and Actions Introduction to SPP 2.6's hierarchy of adaptation options (see Appendix A), what each means and the trade-offs for each (benefits and constraints)		• There was a discussions about how a plan for managed retreat (at Seabird) would work - one suggestion was for the use of notifications on title which identify a possible relocation option (link current and relocation areas), with the option to acquire the relocated land at a nominal fee • Prioritising revegetation and rehabilitation of dunes • A panel member noted that Ledge Point was only going to lose one road and suggested that government buy properties there • The use of an artificial reef/ tombolo was raised as a protection option (this has previously been raised in this project's engagement) - project members noted this option is costly, does not provide appropriate protection and has unknown side effects • The use of proprietary product 'tetrapods' was also questioned as a protection option (operating similarly to artificial reef)
MCA and Criteria used in MCA Participants introduced to the MCA process and criteria used in a coastal MCA	NA	NA

DAY 2: REVIEW CRITERIA USED TO ASSESS MANAGEMENT OPTIONS, TEST FINDINGS AND CONCLUSION		
AGENDA	**ACTIVITIES**	**KEY WORKSHOP NOTES OR ISSUES**
Recap: Feedback from Day 1 Including response to the Day 1 questions about sea level rise and Seabird underlying material	NA	• Sea level rise – clarification that the 0.9m level that was previously established by the Department of Transport (DoT) was on a worst case basis. Since then there has been an increasing trend and 0.9m is tracking as a best case scenario - the project team confirmed its suitability for currently use • Rock at Seabird (plus seawall) – the project team clarified that the DoT had undertaken basic geotechnical investigations in 2002 and that the 2016 study by MP Rogers and Associates had considered this. The team clarified that if the seawall was included in the assessment, the hazard lines would only move slightly, with erosion impacts further north
Observations Participants were asked for their observations after the Day 1 workshop and whether they had additional feedback to provide	**EXERCISE: What is the feedback** Panel members noted thoughts and observations on post-it notes. The complete list of comments is at Appendix D	• Concern about a lack of funding for Gingin due to the low population numbers • Observation about conflict in interests of beach front residents and the broader community who use the beach

DAY 2: REVIEW CRITERIA USED TO ASSESS MANAGEMENT OPTIONS, TEST FINDINGS AND CONCLUSION		
AGENDA	**ACTIVITIES**	**KEY WORKSHOP NOTES OR ISSUES**
MCA Criteria + Process • Panel members were reminded about the criteria used in coastal MCAs and the MCA process • Panel members were shown an example of a MCA assessment in the 2019 CHRMAP • Panellists were asked to review the consultant project team's MCA scores (Task 1)	**TASK 1 : Review the MCA** • Panel members were asked to review the scores and also asked if any criteria had been missed • Panel members were asked to write any suggestions or notes on post-it notes for the team	• Groups largely agreed with the scoring results for the four coastal townsites, however it was noted that the Seabird scoring in the 2019 CHRMAP should consider the revegetation option more positively • Panel members suggested that the 'tourism impact' has too much weight in the scoring • Panel members provided feedback/ review comments - general, for Lancelin and for Guilderton. These are at Table 2, Table 3 and Table 4 respectively. Hand-written comments on the Guilderton MCA are at Figure 6.
Draft Options Analysis Draft options for each of the coastal townsites were presented, and the pros and cons of each. Presentation included options suggested by panellists that are not considered technically suitable or effective.	**TASK 2: Polling Preferred Short- and Long-Term Options** Options for different coastline sections were presented - members used blue and orange dots to vote for their preferred short term and long term options	See Section 4.5 for panel member questions about the options and their voting results

TABLE 2 MCA REVIEW COMMENTS - GENERAL

MCA FOR SHIRE OF GINGIN'S CHRMAP
AESTHETIC IMPACTS Technical issues are confusing Inundation independent of erosion doesn't make sense Social vs Economic Individual cost vs community cost
ECONOMIC Economic Impact: Tourism focus is too overweighted if tourism (in some communities) actually negatively impacts environment, social and aesthetic impacts on existing community. Every consideration should not always be for the sake of the tourism to use when it may cause more harm than good!! Economic 2 Performance more important than cost
SOCIAL Social 2 Rights of individual vs rights of community
COST "cost" should be perhaps "value". ie. How much is spent vs how effective it is. A "red" capital cost may still be the only viable option. Assured funding source of on-going cost & impact on local community (rates?)
EFFECTIVENESS Effect 2 Long or short term? Need to ensure that the short/long term. No discrimination between short and long term. eg. A cheap, easy, but "ugly" short term option may be still worth doing to buy more time.
ENVIRONMENT Enviro 2

TABLE 3 MCA REVIEW COMMENTS - LANCELIN

MCA FOR LANCELIN
* Change 'planning' to 'Town Planning'
L1: MR2 = MR3: should be considered together
L1: AC1: Environmental - social impact should be considered separately. Environmental -> green Social -> amber
L1: PR3: Effectiveness -> Red Reversability/adaptability -> Red Environ/social impact -> Red Recommendation --> investigate/NR
L2: MR2: possibly amber/red
L2: MR3: Environmental --> green social --> red
L2: PR3: same as L1

TABLE 4 MCA REVIEW COMMENTS - GUILDERTON

MCA FOR GUILDERTON
Avoid further roads too close to shoreline - North of town potutienl (*potential*) Avoid future develop too close too foreshore & river (South)
Residential - prob not going to effect current homes (100 yrs) but future buildup need to be setback. ie north & south of township.
Future develop * Must set better/longer SETBACKS to reduce/negate 'loss' at assets developed.
[PROTECT] *Dune reveg. *groyne - would protect beach area SOUTH of groyne & protect 'rock' outcrop above beach area & therefore road access. - Rock wall alongside river needs continued maintenance as does 'wall' below walkway from caravan park to main beach. - protect beach erosion by 'boat' launching as presently happens. - not sure of effect on north beach access by 4wd, fisher
Inundation - rocky point just north of groyne - beach used v.v. reg by fisherman to go north of this point to fish at 'reef'. - also parking area & access around 'groyne' area beach.
* Maybe the track to the beach at Fraser St needs to be 'closed'. AND maybe beach access (lower track) from top carpark.
ASSETS under risk? - alongside Gordon between Mortimer & Anderson * Road needs protection to preserve theses homes. - at least re-veg requires serious & continued action & protection
River Management - EXTREME more appropriate because - environ - social - economic River is major asset of township
Managed Retreat - Caravan Park - Public ablution block (coast) - Public ablution block (Silvercreek)

FIGURE 6 PANEL MEMBERS REVIEW COMMENTS ON THE GUILDERTON MCA

Table 1-2 MCA for Guilderton

Option Category	Option	Effectiveness	Environment	Social	Economic	Aesthetic	Cost	Future Adaptability	Score / Recommendation	Comment
Avoid	Avoid	2	2	1	2	2	2	2	Recommended (13)	For erosion, this mainly applies to the undeveloped land south of the river ✓ Inundation hazards relate to the avoidance of significant development in the river foreshore area ✓ Community will benefit by appropriate foreshore reserve width and access throughout the planning timeframe
Managed Retreat	Do Nothing	-2	0	-2	-1	-1	-1	-2	Not recommended (-9)	Not an effective adaptation option and unlikely to be popular with the community. Cost to be investigated further in CBA.
	Relocate	2	1	-1	1	1	-1	2	Recommended (5)	Effective but costly option. Ensures foreshore reserve retained. May be unpopular with landholders, depending on implementation strategy. Very likely to cost less than protection.
	Prevent Further Development	1	1	-1	0	0	2	1	Recommended (4) too low	Allows for continued use of the land whilst viable, without creating legacy issues. May be unpopular with landholders.
Accommodation	Notification on Land Titles	1	0	-1	0	0	0	2	Recommended (2)	Likely to be effective at encouraging development outside of hazard zones. Cost shifted from Shire to small number of landholders, likely to be unpopular with those landholders.
	Re-design for Inundation	1	0	1	0	0	1	0	Recommended (3)	Low cost and could be effective at reducing damage costs. Only applicable adjacent to river banks, mainly for foreshore recreational infrastructure.
	Re-design for Erosion	1	-1	0	-1	-1	-1	-1	Not recommended (-4)	Expensive and intrusive to construct. Private asset protection may have detrimental impacts on adjacent assets.
Protect	Dune Renourishment	0	1	1	-1	0	-2	-1	Not recommended (-2)	Expensive with lower confidence on effectiveness. Creates legacy issues for future.
	Dune revegetation	1	1	1	1	1	-1	0	Recommended (4)	Relatively simple measure to maximise the stability of the existing dunes. In particular, this applies to the extent of beach seaward of the main beach access car park and boardwalk.
	Seawall	1	-2	-2	-2	-2	-2	-1	Not recommended (-10)	Expensive option, not realistic due to the elevation of the existing dune, and potential formation of erosion issues at the creek, the river mouth and the northern end of the structure.
	Groyne	-1	0	0	-1	0	-1	0	Not recommended (-3)	A groyne could potentially assist locally with boat launching, but would not be appropriate as an erosion mitigation option to combat the coastal hazards from the impacts of climate change. Groynes can lead to downdrift erosion issues if not designed and constructed appropriately.

1.2 Guilderton

The following key messages for both erosion and inundation adaptation options:

- The options to take forward to the CBA are relocate, limitation of further development, and redesign for inundation.
  - The relocation costs will be compared to the Do Nothing approach in the CBA.
  - Re-design for inundation relates to the foreshore areas, as per Section **Error! Reference source not found.**
- A simple protect option of dune revegetation will be investigated to maximise the time before relocation is required.

MORE NEEDED JUST NORTH of ESTUARY.

RIVER FORESHORE / ESTUARY

4.5 DRAFT OPTIONS ANALYSIS

Draft options for sections of the four town's coastlines were placed on walls and the project team discussed the various options and trade-offs for each section, before asking panel members to vote individually for their preferred short to medium term management option (blue sticky dot) and their preferred long term management option (red sticky dot).

Questions / discussions during this activity were:

- **Tourism impact in Gingin** - how to manage the implications of a retreat adaption option on this
- **Economic impact** - if fear mongering is created it will have an impact on tourism and an economic impact, and that these things need to be balanced with the best option for that section
- **Retreat at Lancelin** - inundation due to a storm event may happen much faster, with project team confirmation that one CHRMAP recommendation will be to undertake a groundwater investigation for Lancelin.
  A question was also prompted about the costs and funding for the approximately 1000 properties in Lancelin that would need to retreat and that a coordinated approach would be required.
- **Groyne at Ledge Point** - trade off considerations and impacts of a groyne on adjacent areas
- **Seawall at Seabird** - funding restrictions on maintenance creating legacy issues for the Shire and the present day cost (capital and operational) of building and maintaining the seawall being outside of Shire's budget capacity. The project team clarified that capital cost and operation cost were combined into the single cost criteria to ensure consideration of maintenance of structure into the future for any protection structures. Discussion was also had about the loss of beach as an impact of seawalls
- **Seabird Caravan Park / Strata** - great that future planning is happening, but how can current enjoyment of the beach continue? I.E. solutions over the next 15 to 20 years
- **Existing groyne at Guilderton** - the role of the existing groyne and possible impacts of replacing it with a new one (adaptation and trade offs such as erosion)

The polling results summary at Table 5 shows a general consensus/ agreement with the 2019 CHRMAP or draft consultant team recommendations, where:

Green = recommended option that scored well across most criteria;

Yellow = options that score neutrally and require investigation; and

Red = score negatively and are not recommended.

It should be noted that there were fewer votes for the long term management options.

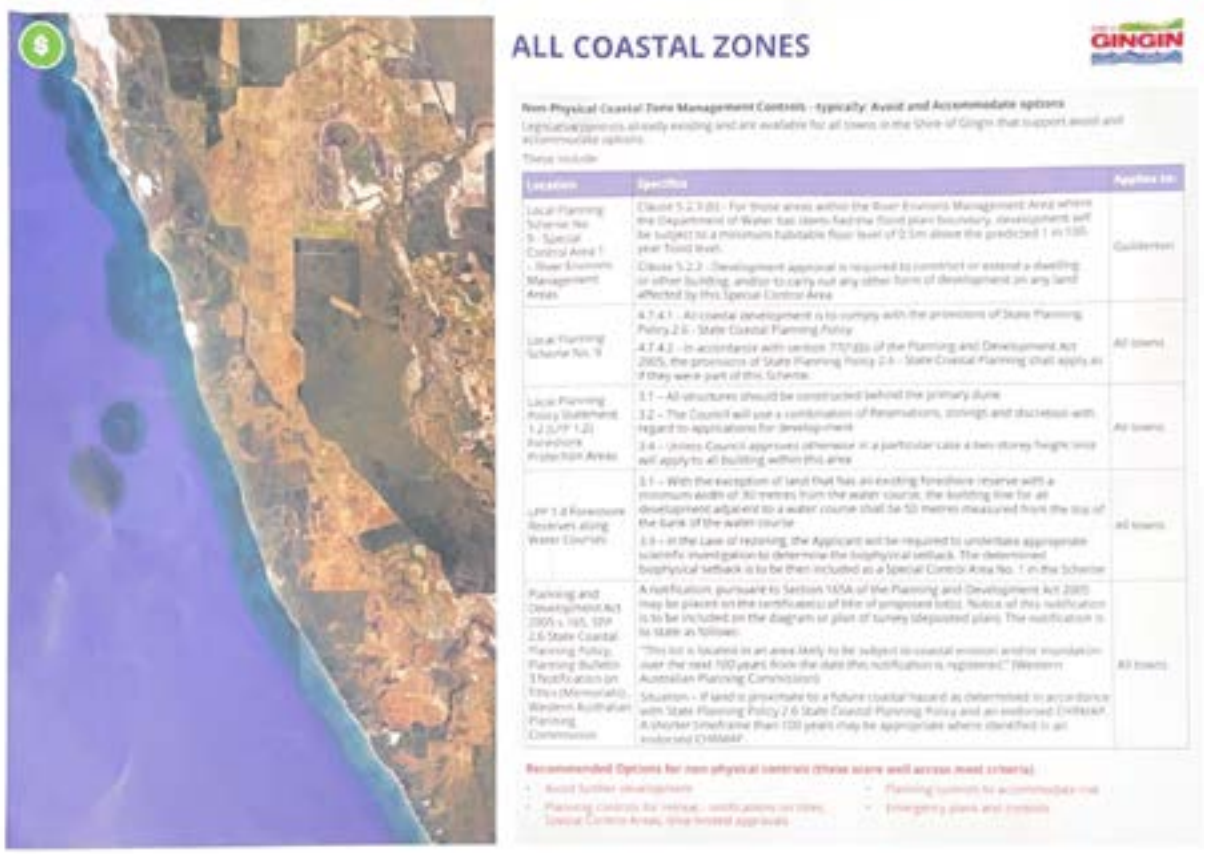
The mapping sub-sections that follow include:

- Mapped adaptation options across the top of the page;
- A description of key vulnerable assets;
- The existing or proposed pathway (per 2019 CHRMAP or draft consultant project team MCA results); and
- The Community Panel votes (options and cost, vote counts and individual commentary if provided).

The original Options Analysis pages are at Appendix F.

TABLE 5 POLLING RESULT - MANAGEMENT OPTIONS WITH THE HIGHEST VOTE

MAP AREAS	OPTIONS WITH THE HIGHEST VOTE	
	SHORT & MEDIUM TERM	LONG TERM
All Coastal Zones	There were no votes for this proposition	
Lancelin North	Recommended Options	Nearshore reef / breakwater
Lancelin Centre	Recommended Options	Recommended Options
Lancelin South	Recommended Options	Beach nourishment Groynes
Lancelin Overall		Remove/Relocate
Ledge Point North	Recommended Options	Seawall
Ledge Point South	Recommended Options	Beach nourishment Seawall
Seabird North	Groynes	Recommended Options
Seabird South	Recommended Options	Groynes
Guilderton	Recommended Options	Recommended Options



4.5.1 All Coastal Zones

Non-Physical Coastal Zone Management Controls - typically: Avoid and Accommodate options

Legislative controls are already existing and available for all towns in the Shire of Gingin that support avoid and accommodate options.

These include:

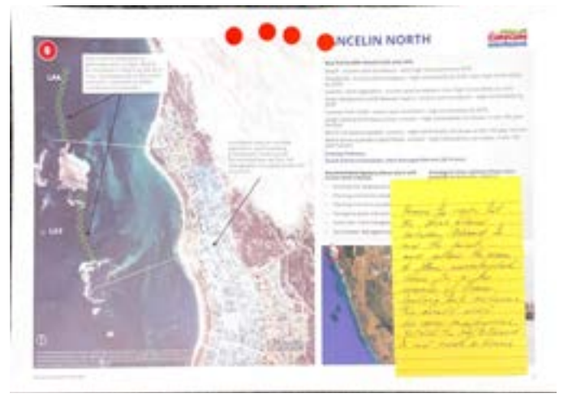
LOCATION	APPLIES TO
Local Planning Scheme No. 9 - Special Control Area 1 – River Environs Management Areas	Guilderton
Local Planning Scheme No. 9	All towns
Local Planning Policy Statement 1.2 (LPP 1.2) Foreshore Protection Areas	All towns
LPP 1.4 Foreshore Reserves along Water Courses	All towns
Planning and Development Act 2005 s.165, SPP 2.6 State Coastal Planning Policy, Planning Bulletin 3 Notification on Titles (Memorials) , Western Australian Planning Commission	All towns

The complete list with specific controls is in the Options Analysis at Appendix F.









4.5.2 Lancelin North

Key Vulnerable Assets (LA3 and LA4)

- Beach - erosion and inundation - Very High Vulnerability by 2070
- Residential - erosion and inundation - High vulnerability by 2030, Very High Vulnerability by 2070
- Coastal / dune vegetation - erosion and inundation)- Very High Vulnerability by 2070
- Hotel, Restaurant and Endeavour Tavern - erosion and inundation - High Vulnerability by 2070
- Caravan Park north - erosion and inundation - High Vulnerability by 2070
- Gingin Road and Primary school - erosion - High Vulnerability not shown in the 100 year horizon
- Beach Car park (unselaed) - erosion - High Vulnerability not shown in the 100 year horizon
- Beach access (Lancelin Island Point) - erosion - High Vulnerability not shown in the 100 year horizon

Existing Pathway

Avoid and Accommodate, then Managed Retreat OR Protect

Magnitude of Cost

$ Considerable $ High $ Very High

Community Panel Votes for Preferred Management Options

MANAGEMENT OPTIONS MAP SHOWN	COST	VOTES COUNT		ADDITIONAL COMMENT (POST-IT NOTES)
		SHORT & MEDIUM TERM	LONG TERM	
Recommended Options (these score well across most criteria): • Avoid further development • Planning controls for retreat • Planning controls to accommodate risk • Emergency plans and controls • Dune care / sand management • Stormwater Management	$	**11**	3	Important to bolster these front beach dunes in protection against inundation.
Investigate these options (these score neutrally across most criteria): • Beach nourishment • Groynes	$	0	3	
Investigate these options (these score neutrally across most criteria): • Beach nourishment • Seawall	$	4	0	
Not recommended (these score neutrally across most criteria, but negatively on Cost) • Nearshore reef / breakwater	$	0	**4**	Remove the rocks that the Shire placed between Edwards Is and the point. and allow the ocean to flow unrestricted leave for a few seasons if Grace Darling Park returns the result which be very [...] Extend the reef to Edwards Is create as Marina







4.5.3 Lancelin Centre

Key Vulnerable Assets (LA2)

- Residential - inundation - High vulnerability by 2040, Extreme Vulnerability by 2120
- Residential - erosion - High vulnerability by 2070, Very High Vulnerability by 2110
- Cunliffe Street and adjacent roads - inundation - Extreme Vulnerability by 2040
- Cunliffe Street - erosion - High Vulnerability by 2110
- Beach - erosion - High Vulnerability by 2070, Very High by 2110
- Coastal / dune vegetation erosion - High Vulnerability by 2070, Very High by 2110
- Jetty - erosion - High vulnerability by 2070
- Light industrial, cafe - erosion - High vulnerability by 2110
- Tourism - inundation - High vulnerability by 2040
- Town centre - inundation - High vulnerability by 2070, Extreme by 2120

Existing Pathway

Avoid and Accommodate, then Managed Retreat OR Protect

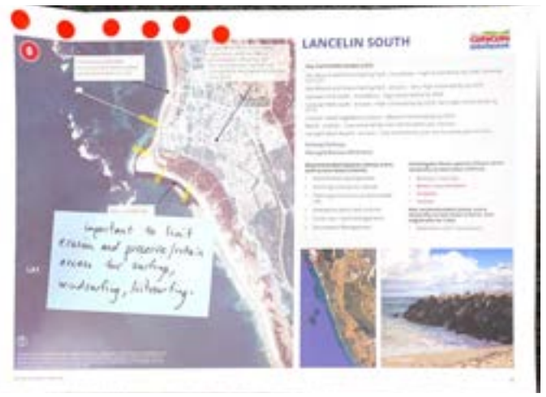
Magnitude of Cost

$ Considerable $ High $ Very High

Community Panel votes for Preferred Management Options

MANAGEMENT OPTIONS MAP SHOWN	COST	VOTES COUNT SHORT & MEDIUM TERM	VOTES COUNT LONG TERM	ADDITIONAL COMMENT (POST-IT NOTES)
Recommended Options (these score well across most criteria): • Avoid further development • Planning controls for retreat • Planning controls to accommodate risk • Emergency plans and controls • Dune care / sand management • Stormwater Management	$	**9**	**9**	
Investigate these options (these score neutrally across most criteria): • Beach nourishment • Seawall	$	2	3	
Not recommended (these score neutrally across most criteria, but negatively on Cost) • Nearshore reef / breakwater	$	5	0	









4.5.4 Lancelin South

Key Vulnerable Assets (LA1)

- Sea Rescue and Grace Darling Park - inundation - High Vulnerability by 2040, Extreme by 2120
- Sea Rescue and Grace Darling Park - erosion - Very High Vulnerability by 2070
- Caravan Park south - inundation - High Vulnerability by 2040
- Caravan Park south - erosion - High vulnerability by 2070, Very High Vulnerability by 2110
- Coastal / dune vegetation erosion - Medium Vulnerability by 2070
- Beach - erosion - Low vulnerability over the hundred year horizon
- Car park (back beach) - erosion - Low vulnerability over the hundred year horizon

Existing Pathway

Managed Retreat OR Protect

Magnitude of Cost

$ Considerable $ High $ Very High

Community Panel votes for Preferred Management Options

MANAGEMENT OPTIONS MAP SHOWN	COST	VOTES COUNT SHORT & MEDIUM TERM	VOTES COUNT LONG TERM	ADDITIONAL COMMENT (POST-IT NOTES)
Recommended Options (these score well across most criteria): • Avoid further development • Planning controls for retreat • Planning controls to accommodate risk • Emergency plans and controls • Dune care / sand management • Stormwater Management	$	**14**	3	this is not a long term solution. buys time only.
Investigate these options (these score neutrally across most criteria): • Beach nourishment • Groynes	$	0	**6**	important to limit erosion and preserve/retain access for surfing, windsurfing, kitesurfing.
Investigate these options (these score neutrally across most criteria): • Remove / relocate • Beach nourishment • Seawall	$	4	0	
Not recommended (these score neutrally across most criteria, but negatively on Cost) • Nearshore reef / breakwater	$	1	2	



Long Term Existing Pathway - Managed Retreat

4.5.5 Lancelin Overall

Key Vulnerable Assets (LA1)

- Sea Rescue and Grace Darling Park - inundation - High Vulnerability by 2040, Extreme by 2120
- Sea Rescue and Grace Darling Park - erosion - Very High Vulnerability by 2070
- Caravan Park south - inundation - High Vulnerability by 2040
- Caravan Park south - erosion - High vulnerability by 2070, Very High Vulnerability by 2110
- Coastal / dune vegetation erosion - Medium Vulnerability by 2070
- Beach - erosion - Low vulnerability over the hundred year horizon
- Car park (back beach) - erosion - Low vulnerability over the hundred year horizon

Key Vulnerable Assets (LA2)

- Residential - inundation - High vulnerability by 2040, Extreme Vulnerability by 2120
- Residential - erosion - High vulnerability by 2070, Very High Vulnerability by 2110
- Cunliffe Street and adjacent roads - inundation - Extreme Vulnerability by 2040
- Cunliffe Street - erosion - High Vulnerability by 2110
- Beach - erosion - High Vulnerability by 2070, Very High by 2110
- Coastal / dune vegetation erosion - High Vulnerability by 2070, Very High by 2110
- Jetty - erosion - High vulnerability by 2070
- Light industrial, cafe - erosion - High vulnerability by 2110
- Tourism - inundation - High vulnerability by 2040
- Town centre - inundation - High vulnerability by 2070, Extreme by 2120

Key Vulnerable Assets (LA3 and LA4)

- Beach - erosion and inundation - Very High Vulnerability by 2070
- Residential - erosion and inundation - High vulnerability by 2030, Very High Vulnerability by 2070
- Coastal / dune vegetation - erosion and inundation)- Very High Vulnerability by 2070
- Hotel, Restaurant and Endeavour Tavern - erosion and inundation - High Vulnerability by 2070
- Caravan Park north - erosion and inundation - High Vulnerability by 2070
- Gingin Road and Primary school - erosion - High Vulnerability not shown in the 100 year horizon
- Beach Car park (unselaed) - erosion - High Vulnerability not shown in the 100 year horizon
- Beach access (Lancelin Island Point) - erosion - High Vulnerability not shown in the 100 year horizon

Community Panel votes for Preferred Management Options

MANAGEMENT OPTIONS MAP SHOWN	COST	VOTES COUNT		ADDITIONAL COMMENT (POST-IT NOTES)
		SHORT & MEDIUM TERM	LONG TERM	
Investigate these options (these score neutrally across most criteria): • Remove / relocate Challenges in delivering retreat include finding a suitable location. Unallocated Crown Land impacts much of the available land, as does the presence of basic raw materials and a water source protection area.	$	0	**9**	

Magnitude of Cost

$ Considerable $ High $ Very High



4.5.6 Ledge Point North

Key Vulnerable Assets (LP 3 and LP4)

- Holiday Village - erosion - High Vulnerability by 2070, Very High Vulnerability by 2110
- Residential - erosion - Very High Vulnerability by 2070
- Key Biscoyne Park - erosion - Very High Vulnerability by 2110
- Coastal / dune vegetation - erosion - Very High Vulnerability by 2110
- Beach - erosion - High Vulnerability by 2110, Very High Vulnerability not shown in the 100 year horizon
- Car park and road (De Burgh St) - erosion - High Vulnerability by 2110, Very High Vulnerability by 2070 not shown in the 100 year horizon

Existing Pathway

Avoid / Accommodate

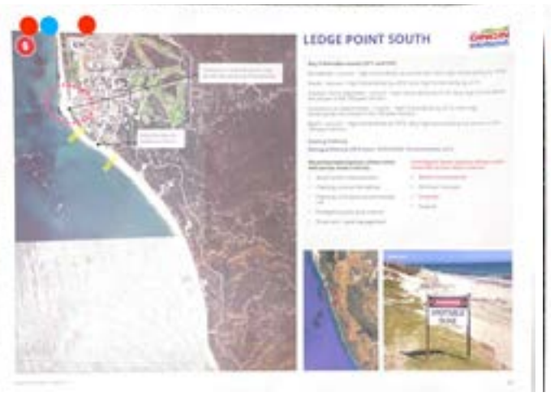
Magnitude of Cost

$ Considerable $ High $ Very High

Community Panel votes for Preferred Management Options

MANAGEMENT OPTIONS MAP SHOWN	COST	VOTES COUNT SHORT & MEDIUM TERM	VOTES COUNT LONG TERM	ADDITIONAL COMMENT (POST-IT NOTES)
Recommended Options (these score well across most criteria): • Avoid further development • Leave unprotected (where undeveloped) • Planning controls for retreat • Planning controls to accommodate risk • Emergency plans and controls • Dune care / sand management	$	**8**	4	
Investigate these options (these score neutrally across most criteria): • Groynes (refurbish)	$	2	1	
Investigate these options (these score neutrally across most criteria): • Seawall	$	0	**8**	







4.5.7 Ledge Point South

Key Vulnerable Assets (LP 1 and LP2)

- Residential - erosion - High Vulnerability at current day, Very High Vulnerability by 2030
- Roads - erosion - High Vulnerability by 2070, Very High Vulnerability by 2110
- Coastal / dune vegetation - erosion - High Vulnerability by 2110, Very High Vulnerability not shown in the 100 year horizon
- Foreshore recreation areas - erosion - High Vulnerability by 2110, Very High Vulnerability not shown in the 100 year horizon
- Beach - erosion - High Vulnerability by 2070, Very High Vulnerability not shown in the 100 year horizon

Existing Pathway

Managed Retreat OR Protect (LP2) Avoid / Accommodate (LP1)

Magnitude of Cost

$ Considerable $ High $ Very High

Community Panel votes for Preferred Management Options

MANAGEMENT OPTIONS MAP SHOWN	COST	VOTES COUNT SHORT & MEDIUM TERM	VOTES COUNT LONG TERM	ADDITIONAL COMMENT (POST-IT NOTES)
Recommended Options (these score well across most criteria): • Avoid further development • Leave unprotected (where undeveloped) • Planning controls for retreat • Planning controls to accommodate risk • Emergency plans and controls • Dune care / sand management	$	**11**	4	
Investigate these options (these score neutrally across most criteria): • Beach nourishment • Groynes	$	1	2	
Investigate these options (these score neutrally across most criteria): • Beach nourishment • Seawall	$	0	**7**	









4.5.8 Seabird North

Key Vulnerable Assets

- Beach - erosion - High Vulnerability by 2030, Very High Vulnerability not shown in the 100 year horizon
- Caravan Park (Seabird Private) - erosion - Very High Vulnerability by 2070
- Coastal / dune vegetation - erosion - High Vulnerability by 2070, Very High Vulnerability by 2110
- Tavern - erosion - High Vulnerability by 2110, Very High Vulnerability not shown in the 100 year horizon

Existing Pathway

Managed Retreat OR Protect

Magnitude of Cost

$ Considerable $ High $ Very High

Community Panel votes for Preferred Management Options

MANAGEMENT OPTIONS MAP SHOWN	COST	VOTES COUNT SHORT & MEDIUM TERM	VOTES COUNT LONG TERM	ADDITIONAL COMMENT (POST-IT NOTES)
Recommended Options (these score well across most criteria): • Avoid further development • Planning controls for retreat • Planning controls to accommodate risk • Emergency plans and controls • Dune care / sand management	$	8	5	
Investigate these options (these score neutrally across most criteria): • Groynes	$	**9**	5	
Investigate these options (these score neutrally across most criteria): • Seawall	$	5	6	
Existing Pathway • Managed Retreat	$	1	**8**	







4.5.9 Seabird South

Key Vulnerable Assets

- Residential (houses and land) - erosion - Very High Vulnerability in current day
- Beach - erosion - High Vulnerability by 2030, Very High Vulnerability by 2070
- Coastal / dune vegetation - erosion - High Vulnerability by 2030, Very High Vulnerability by 2070
- Carparks and roads - erosion - High Vulnerability by 2030 Very High Vulnerability not shown in the 100 year horizon

Existing Pathway

Managed Retreat OR Protect

Magnitude of Cost

$ Considerable $ High $ Very High

Community Panel votes for Preferred Management Options

MANAGEMENT OPTIONS MAP SHOWN	COST	VOTES COUNT SHORT & MEDIUM TERM	VOTES COUNT LONG TERM	ADDITIONAL COMMENT (POST-IT NOTES)
Recommended Options (these score well across most criteria): • Avoid further development • Planning controls for retreat • Planning controls to accommodate risk • Emergency plans and controls • Dune care / sand management	$	**13**	4	
Investigate these options (these score neutrally across most criteria): • Seawall	$	1	4	
Investigate these options (these score neutrally across most criteria): • Groynes	$	6	**11**	







4.5.10 Guilderton

Key Vulnerable Assets

- Residential (Gordon Street) - erosion - High Vulnerability in current day, Extreme Vulnerability by 2090
- Roads (Gordon Street, Edward Street) - erosion - Extreme Vulnerability in current day, inundation - Extreme Vulnerability in 2120 (no vulnerability until 2120)
- Parks and Recreation (Moore River front car park and foreshore area) - erosion - Extreme Vulnerability in current day, inundation - no vulnerability in the hundred year period
- River management area - erosion - High Vulnerability in current day

Existing Pathway

Avoid / Accommodate, then Managed Retreat OR Protect

Magnitude of Cost

$ Considerable $ High $ Very High

Community Panel votes for Preferred Management Options

MANAGEMENT OPTIONS MAP SHOWN	COST	VOTES COUNT SHORT & MEDIUM TERM	VOTES COUNT LONG TERM	ADDITIONAL COMMENT (POST-IT NOTES)
Recommended Options (these score well across most criteria): • Avoid further development • Remove / relocate • Planning controls for retreat • Planning controls to accommodate risk • Emergency plans and controls • Revegetate dunes	$	15	13	
Not recommended: • Seawall	$	0	0	
Not recommended: • Groynes	$	0	5	

GUILDERTON



Key Vulnerable Assets

Residential (Gordon Street) - erosion - High Vulnerability in current day, E… Vulnerability by 2090

Roads (Gordon Street, Edward Street) - erosion - Extreme Vulnerability in c… inundation - Extreme Vulnerability in 2120 (no vulnerability until 2120)

Parks and Recreation (Moore River front car park and foreshore area) - erosion - … Vulnerability in current day, inundation - no vulnerability in the hundred year perio…

River management area - erosion - High Vulnerability in current day

Proposed Pathway

Avoid / Accommodate, then Managed Retreat OR Protect

Recommended Options (these score well across most criteria):

- Avoid further development
- Remove / relocate
- Planning controls for retreat
- Planning controls to accommodate risk
- Emergency plans and controls
- Revegetate dunes

Not recommended

- Groynes
- Seawall






GREG H

4.6 COMMUNITY PANEL WORKSHOP SUMMARY

4.6.1 Day 1

Day 1 of the panel provided a significant quantum of information and prompted a number of panel members to consider very long term implications of the coastal hazards being proposed. Progressive commentary was provided by panellists, recognising the trade-offs and challenges in an incredibly proficient fashion.

Panellists provided suggestions ranging across the SPP 2.6 adaptation hierarchy, including retreat, albeit in a qualified manner.

4.6.2 Day 2

The feedback from the Community Panel after Day 1 was a consistent feeling of being better informed about the specific coastal processes affecting the Shire. Panellists raised concern about the lack of funding availability for coastal management for a Shire the size of Gingin.

Panel members largely agreed with 2019 CHRMAP scoring and the draft scoring by the consultant project team.

In the short term, there was largely support for the recommended options, with the exception of the Seabird North management unit (groynes).

In the long term, panel members supported the recommended options for Lancelin Centre, Seabird North and Guilderton.

However, panellists preferred neutral scoring options for Lancelin South, Lancelin Overall, Ledge Point (overall) and Seabird South, and preferred an option which was not recommended (offshore breakwater) for Lancelin North.

It should be noted that fewer panel members voted for long term management options, leading some recommendations having very low scores comparatively.

4.6.3 Overall Observations

Some of the recommended options from the panel will be difficult to achieve in isolation. For example, the long term recommended options for Lancelin South, Centre and North differ, despite each management unit impact the other. For these situations a collective adaptation response will need to be selected, and the three recommended options (offshore breakwater, retreat, groynes) will need to be assessed objectively.

Throughout, panel members acknowledged their uncertainty about how to achieve responsible, viable management options, noting the rights of individuals versus collective good.

Notwithstanding their pragmatic participation, panellists provided an emblematic response to the challenges experienced by the project team on similar projects; that is, that it is complex to consider the recommended hierarchy of SPP 2.6 when it is in the context of one's own home, business and community. When this is the case, decision making is much harder.

4.6.4 Feedback from Community Panel Members

Community Panel members provided the project team with information pertaining to the coast after Day 1 and Day 2. This information included:

- The Wilbinga Conservation Park proposal
- The Wilbinga Conservation Park Recreation Master Plan
- A letter to the Shire CEO requesting action to address the imminent risk to the Lancelin Volunteer Mariner Rescue Tower (dated post Day 1 workshop)
- An email about the land valuations for properties in the Seabird townsite
- An email about observed 4WD and beach access works at Lancelin post Day 1 workshop (photographs at Appendix G)
- Feedback on general adaptation options from a panel member at Appendix H
- Photographs of the ocean breach into the carpark from Edwards Island Point through a 4WD access point during a storm in August 2021 and the 10m wide regular 4WD access track to Edwards Island Point - it was also noted that there was significant damage to Edwards Island Point and destruction of half a metre of foredune 50m north of Grace Darling Park. The submitted photographs are at Appendix I.

5 KEY STAKEHOLDERS

The project team met with a number of stakeholders who were directly engaged or who requested meetings. Meetings were hold online and over the phone.

Yued Noongar Elders

A meeting was held at the Shire offices with six Elders of the Yued Noongar people of the area; the Traditional Owners. The meeting explored historical knowledge, stories of flooding and important areas to consider the in the region.

The Elders provided historical context for the river mouth at Guilderton, including a number of floods. Also discussed was the complicated history of the Moore River and New Norcia settlements, leading to layering of knowledge of country in the area.

Elders requested that any future planning of storytelling or art be subject to suitable heritage advice, and suggested the Cultural Advice Council model (as part of the South West Settlement process this may be strengthened).

Specific opportunities discussed included:

- Telling the story of Phillip Jackamarra and parent Yoroba and Utonga from the Woodbridge area - the direct lineage of Yued people
- Telling the story of the attempt to get the children out of the settlement at New Norcia and ending up on Wadjemup (prison
- Stories of an historical land purchase
- Research partnerships
- Artwork or signage with appropriate history
- Introduce an Indigenous Ranger program

The Elders expressed a desire to use the CHRMAP and Coastal Management Strategy process to begin to heal and fix wrongs.

Elders suggested no additional tracks be permitted and 4-wheel driving be limited.

Lancelin Caravan Park

The owners were provided with a summary of the Community Panel presentation. They advised that they had observed coastal changes happening and were building new cabins 1.1 to 1.2m above ground level with awareness of a 700mm groundwater level.

They also advised the project team members that they already use succulent cuttings from pruning around the property to help stabilise the foredunes and had observed a quick take up of vegetation growth. The indicated they would like to continue this practice with the agreement of the Shire

The owners noted that land values have changed in the last five years which they attributed to the awareness of coastal vulnerability. However, they also noted people were buying into the area again.

Seabird Progress Association

Members of the project team met with the President and ex-President of the Seabird Progress Association (SPA), following the President's Community Panel workshop attendance.

The SPA described their involvement in previous coastal planning, speaking to the ~$100,000 contribution to the Seabird seawall and $20,000 to an engineering study

The project team clarified the project scope and confirmed that the recommended management actions for Seabird in the 2019 CHRMAP have not been affected by inundation considerations.

SPA advised disagreement with the 2019 CHRMAP recommendations and a desire to achieve a protect option for Seabird (seawalls) for both Seabird North and Seabird South.

The SPA queried what the pathway for managed retreat would look like, with the project team clarifying that the managed retreat pathway requires investigation, with few national examples readily available for case studies. The team noted that the WA state government would need to make decisions on how to deliver this pathway if selected.

The project team members also discussed the Benefit Distribution Analysis (BDA) that was being undertaken for the proposed options and how this would inform decision making and funding. The SPA acknowledged that BDA informed decisions might help resolve the existing conflict about how to prioritise management options and funding for locations.

Warburton Group

The project team were contacted by the Warburton Group to provide details of the coastal modelling supporting the CHRMAP process. The project team provided details as requested and no further liaison occurred.

Private Landowner - Seabird

The project team liaised with a private landowner at Seabird with interest in the challenge of coastal hazards and potential retreat plans, providing additional supporting information regarding land valuation and ownership of the Seabird strata site that was previously identified as a caravan park.

6 CONCLUSION

The engagement undertaken for this stage of the CHRMAP Inundation Integration project has provided the project team with a confirmation of community values.

It has equally enable the Community Panel members' to provide feedback on the preferred management options for the four coastal towns and overall for both the short to medium term and long term.

The engagement also provided the community with the opportunity to learn about the MCA process, criteria and scoring, and to review 'expert' results and question or confirm these.

It also allowed community members to understand that each of the proposed adaptation options in the SPP 2.6 hierarchy has pros and cons, and that selection needs to consider broad benefit, costings and who pays, how options impact established community values and the negative consequences of various options e.g. Loss of beach in front of seawalls and scouring on either side of the seawall.

In the short term, there was general support for the recommended options by panel members, with the exception of a preference for groynes at Seabird North.

In the long term, panel members supported the recommended options for Lancelin Centre, Seabird North and Guilderton, and wanted neutral scoring options (beach nourishment, groynes, remove/ relocate, seawall) for Lancelin South, Lancelin Overall, Ledge Point (North and South) and Seabird South.

It was noted that fewer panel members voted for long term management options, and this may reflect the complexity of the long term nature of these considerations.

7 NEXT STEPS

The community's confirmed values, feedback and shared information, and preferred short to medium and long term management option preferences will help refine the adaptation pathways to be outlined in the CHRMAP.

The next step is submission of the draft CHRMAP to the Shire for endorsement of advertising, where the community will get another opportunity to provide feedback on the information and recommendations contained within the CHRMAP report.



8 APPENDICES

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APPENDIX A

APPENDIX A: WORKSHOP PRESENTATION SLIDES DAY 1

APPENDIX B

APPENDIX B: DAY 1 POST-IT NOTES

INITIAL THOUGHTS – EXERCISE 1	LOCATION (where relevant)
Dune erosion at Main Beach Ledge Point	Ledge Point
Speeders on Main Beach	Ledge Point
Preservation + future utilisation of coast line / amenity	
Retaining the awesome recreational access to the beaches while managing erosion to dunes/vegetation	
Mitigating inundation & minimising dune & vegetation degradation	
Identify foreshore replenishment process	
Preserving built environment	
Keep town alive ongoing	
Maintain tourism	
Preserve flora/fauna & human interaction	
Vegetation Reference Shark Bay (*Denham) foreshore = Protection + Tourism	
Financial – Imfrastried (*illegible*) Protect foredunes	Lancelin
Social cohesion Long term solution Impacts of the wall Time to find solutions	Seabird
Protect vegetation River challenges Buildings too close	Guilderton
Front row rentals dune destruction	
Locking outdoor enthusiasts out instead of helping in management	

INITIAL THOUGHTS – EXERCISE 1	LOCATION (where relevant)
Loss of amenities Beach – Parks – Building Siltation of bay Lack of action	
1) Inaction 2) Loss of coastal foreshore & amenity	
Nothing will get done in time	
Council inaction Or Applying today's thinking to tomorrow's siltation	
Concern: not having a long term view or solution that will make a difference	
Degradation by uncontrolled 4WD activity (Tony J)	Ledge Point
Erosion	Ledge Point
Development too close to dunes	
4WD access	Ledge Point

OTHER COMMENTS – MAPS ON WALLS	MAP LOCATION
LANCELIN	
Emergency management plan	NR4
Revegetation of main beach dunes and limit and modify access paths/ roads to reduce inundation risks	AC/PR
No LAN	PMR1
OK	PMR2
Works – BAU (business as usual)	PMR3
Not cost effective	PMR4
Demolish old Sea Rescue Tower Relocate Grace Darling Toilet Block Groyne at Eddies Point – Partway out to Eddies Island	PMR2
Yes	NR1
No option	DN1

OTHER COMMENTS – MAPS ON WALLS	MAP LOCATION
Yes – maintain existing structures	NR2
Collateral damage. Has potential	AV
No to groyne, seawall, artificial reef, break with levy	
Band aid with consequences	PR1
Buying time	AC/PR
Not an option	Ac1
Tetrapod on the outer reef	
Edwards Island Point loss of sand & south bay to Back Beach	
Solution – walk ways elevated above vegetation in place of informal tracks	
Vegetation replant & massive sand dune replenishment – especially Grace Darling Park south to the point at Edwards Island	
Dune preservation by restrictive vehicle access	
4WD control access – designated beach entry points	LA1, LA4
4WD free beaches for pedestrians	
Make 4WD access points known and attractive to use	
I am concerned that decisions being made on these 1 in 100 year events are used to make Govt and Shire decisions	
Use of boat harbour only?	
Stormwater management – with rising seawater	
Beach use in future which areas should we manage well	
Surprised by how the point at Eddy Island changes so significantly from week to week	
LEDGE POINT	
Number of visitors increasing exponentially with no increase to infrastructure	
Litter left in the dunes	
Tourists burn out of season – fines?	
Most efficient and cost effective strategy is to buy back front row private property – everything on seaside of De Burgh	
Formalise one track & provide air-up facility	
Close illegal track and revegetate	
Put signage to new track	

OTHER COMMENTS – MAPS ON WALLS	MAP LOCATION
4WD illegal tracks	
SEABIRD	
4WD traffic in front of Seabird Caravan Park is accelerating erosion issues	
GUILDERTON	
River erosion of dunes south of estuary when bar broken to south is problem rather than erosion from ocean storms. This will worse with heavier rainfall which increases flow of river particularly in late winter –	
Break bar manually centrally!!	
Erosion hazard lines assume erosion in previous decade or 20 year period has happened –	
With careful vegetation of dunes this should be slowed	
Defined tracks to beach managed better from Gordon Rd	
Protect the foreshore from people / vehicle / building abuse / damage	
Foreshore vegetation preserved & protected & added to	
Pathways / tracks to beach front	
If the ocean level rises 1cm then this implies ocean will move / inundation inland - What does this mean for the Moore River estuary? - 'Beaches' will be narrower -> therefore possible encroachment of vegetated dunes	

OTHER NOTES
Model options / combo of options
Benchmark options implemented in other regions?
Project review after 'X' time of implementation – did it work? WWW? EBif?

OPTIONS
Do nothing not an option "While Rome burns" – we are doing nothing
Undeveloped land – yes should be subject to locating assets to non-vulnerable areas
Foreshore amenities e.g. toilets should be removed if damaged in a coastal hazard
Enables existing development and use rights to continue until such time as impacts arise – could be considered
Design assets – particularly public to withstand the impacts

OPTIONS
Dune system as an asset – protect with revegetation and in-fills. Monitor after storm events to identify areas impacted.
Allow natural processes to occur to encourage dunes to develop.
Beach nourishment is used a lot in Lancelin. Not always popular as fills bay and covers seaweed beds. Also provides just a great place for kids to play on, but has saved infrastructure e.g. Grace Darling Park (to a point – slow death) and sea rescue building
Groynes – not an option in our small bay – "for every action there is a reaction" would lead to multiple groynes
Sea walls – expensive to build & maintain. Would change the nature of Lancelin with the risks involved. Loss of beach etc
Artificial reefs – sounds interesting but not know of impacts
Monitoring – needs to be complicated (nb: complimented) with action in affected areas picked up with monitoring
Audit – OK for public, who drives private
Notification on titles – not popular, but will happen anyway
Evac Plans – yes there should be a plan

APPENDIX C

APPENDIX C: WORKSHOP PRESENTATION SLIDES DAY 2

APPENDIX D

APPENDIX D: DAY 2 POST-IT NOTES

OBSERVATIONS - FEEDBACK AFTER DAY 1
We have to avoid further infrastructure on the dunes & within 300 metres of shore line. Dunes should be reconstructed where they have been removed by development
Current Lancelin ground water levels. Has this been mapped & any historic mapping to identify movement over a long period of time? Then add 0.9m sea rise to this & how does it compare to the inundation plans being used?
Much better informed somewhat more worried! Want to know more about issues & what I can do!..
I felt that I needed a lot more information to be able to make any suggestion on decision. The errors on the hazard lines shown on the Lancelin map is confusing. I'm not sure that we can make a general decision for all areas.
Eye opening experience - simple awareness has already changed my families behaviour eg... dunes.
A cultural shift (ie change of perception) is required to jolt people out of apathy + toward protecting the coast *Not just rules and from young age
[Lancelin] • Since last week we started the process of placing new dune protection signs in front of our foredune. • We have had some positive comments "Looking good", "keep it up", "Thank you", etc. • We have promoted via facebook. • People have shown concern to preserve foredunes.
There is conflict in between the interests of the front-line residents and the broader community who access and use the beach.
Greatest concern is lack of funding for this area due to low population. However within the 100 year point Lancelin will be suburbia.

APPENDIX E

APPENDIX E: COMMUNITY PANEL MEMBER WRITTEN COMMENTS RESPONDED TO THE OPTIONS DISCUSSION

OPTIONS	PANEL COMMENTS
Locating assets in areas that will not be vulnerable to coastal hazards (AV)	Local government land considered for development or residential should be re-assess
	[Guilderton] Move Caravan Park
	The supply of suiTable land will need to be considered as servicing is a constraint
Leaving assets unprotected (PMR1)	[Guilderton] e.g. Caravan Park at Guilderton
	Consider the amenity or unsightliness as well.
Demolition / removal / relocation of asset from inside hazard area (PMR2)	Opportunistic relocation before it is "required" may also make sense
Voluntary acquisition (PMR4)	Quantification is required. Regardless of the economic model, land should be brought online to allow for voluntary relocation. Co-ordinating timing will be challenging.
	[Seabird] Maybe only option for ocean front homes/ buildup in Seabird
Design assets to withstand impacts (AC1)	Very specific & limited criteria for mitigation strategies is required.
Revegetation (AC/PR)	This might buy time if it is needed.
	[Guilderton] Important for coastal dunes at Guilderton
Beach nourishment or replenishment (PR1)	How sustainable is this solution?
	Rising sea levels I presume would mean this would be a waste of money in most cases
Groynes (PR2)	[Guilderton] Maybe a groyne properly constructed at Guilderton would be worth investigating and worth the expense
Protection Structure Audit (NR2)	[Guilderton] Wall alongside river estuary – 'wall' below walkway to beach
Notification on title (NR3)	BUT how certain is the risk that is noted AND for how long into the future?? Changes to protection barriers?

APPENDIX F

APPENDIX F: OPTIONS ANALYSIS PAGES

APPENDIX G

APPENDIX G: PHOTOGRAPHS OF 4WD AND BEACH ACCESS WORKS AT LANCELIN



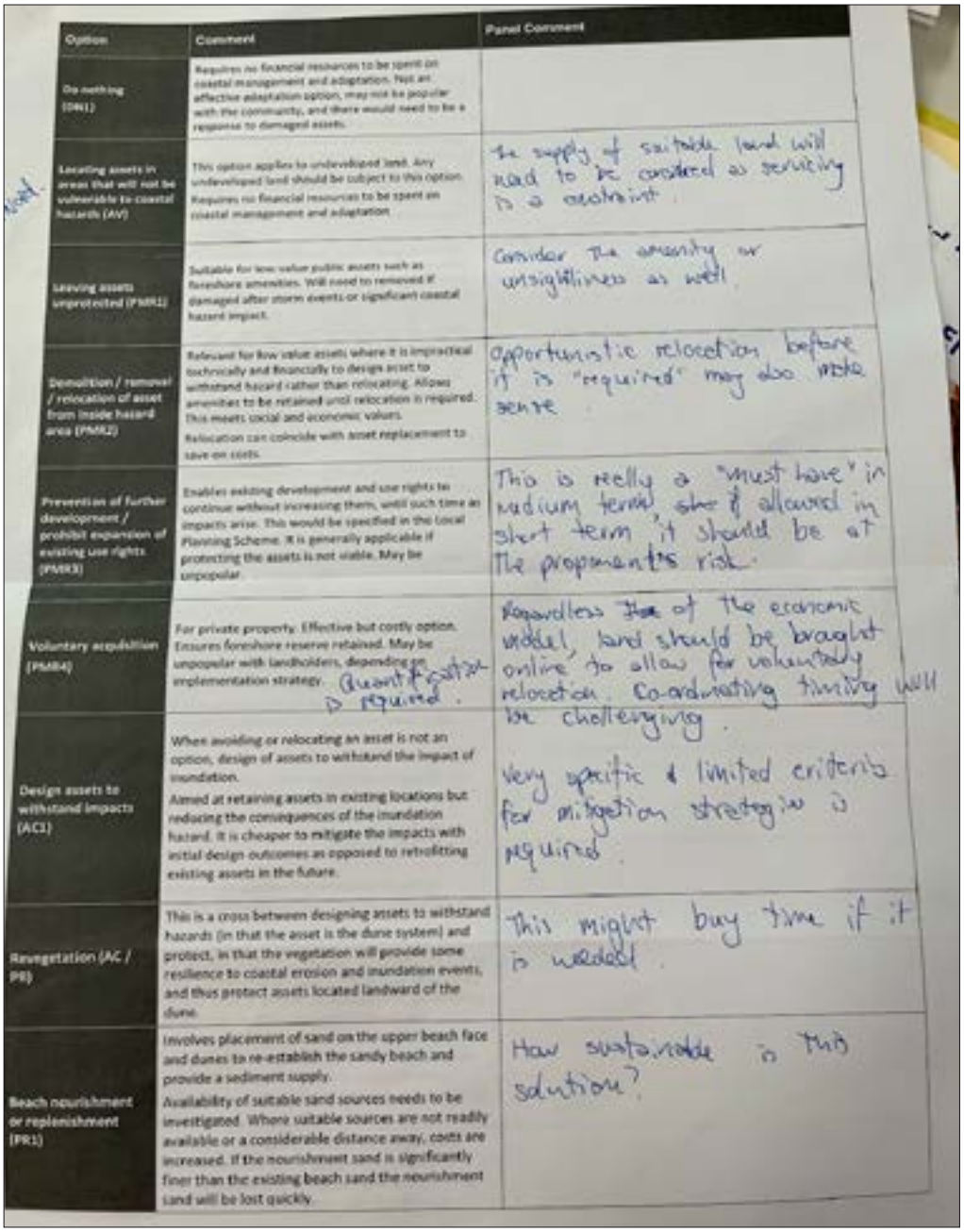






APPENDIX H

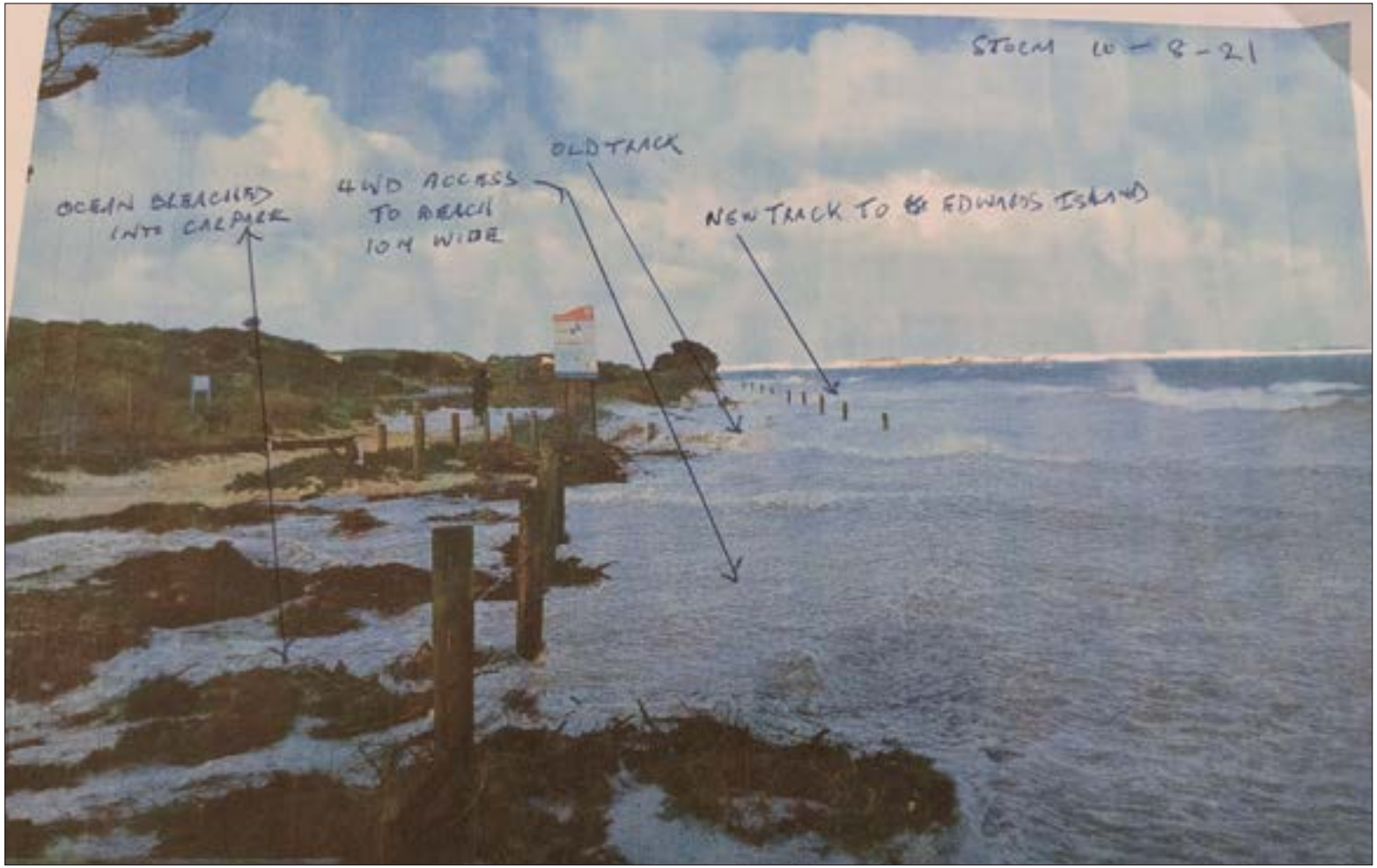
APPENDIX H: FEEDBACK ON GENERAL ADAPTATION OPTIONS



Option	Comment	Panel Comment
Do nothing (DN1)	Requires no financial resources to be spent on coastal management and adaptation. Not an effective adaptation option, may not be popular with the community, and there would need to be a response to damaged assets.	
Locating assets in areas that will not be vulnerable to coastal hazards (AV)	This option applies to undeveloped land. Any undeveloped land should be subject to this option. Requires no financial resources to be spent on coastal management and adaptation.	The supply of suitable land will need to be considered as servicing is a constraint.
Leaving assets unprotected (PM#1)	Suitable for low value public assets such as foreshore amenities. Will need to removed if damaged after storm events or significant coastal hazard impact.	Consider the amenity or unsightliness as well.
Demolition / removal / relocation of asset from inside hazard area (PM#2)	Relevant for low value assets where it is impractical technically and financially to design asset to withstand hazard rather than relocating. Allows amenities to be retained until relocation is required. This meets social and economic values. Relocation can coincide with asset replacement to save on costs.	Opportunistic relocation before it is "required" may also make sense.
Prevention of further development / prohibit expansion of existing use rights (PM#3)	Enables existing development and use rights to continue without increasing them, until such time as impacts arise. This would be specified in the Local Planning Scheme. It is generally applicable if protecting the assets is not viable. May be unpopular.	This is really a "must have" in medium term, else if allowed in short term, it should be at the proponents risk.
Voluntary acquisition (PM#4)	For private property. Effective but costly option. Ensures foreshore reserve retained. May be unpopular with landholders, depending on implementation strategy. Quantification required.	Regardless of the economic model, land should be brought online to allow for voluntary relocation. Co-ordinating timing will be challenging.
Design assets to withstand impacts (AC1)	When avoiding or relocating an asset is not an option, design of assets to withstand the impact of inundation. Aimed at retaining assets in existing locations but reducing the consequences of the inundation hazard. It is cheaper to mitigate the impacts with initial design outcomes as opposed to retrofitting existing assets in the future.	Very specific & limited criteria for mitigation strategies is required.
Revegetation (AC / PR)	This is a cross between designing assets to withstand hazards (in that the asset is the dune system) and protect, in that the vegetation will provide some resilience to coastal erosion and inundation events, and thus protect assets located landward of the dune.	This might buy time if it is needed.
Beach nourishment or replenishment (PR1)	Involves placement of sand on the upper beach face and dunes to re-establish the sandy beach and provide a sediment supply. Availability of suitable sand sources needs to be investigated. Where suitable sources are not readily available or a considerable distance away, costs are increased. If the nourishment sand is significantly finer than the existing beach sand the nourishment sand will be lost quickly.	How sustainable is this solution?

APPENDIX I

APPENDIX I: PHOTOGRAPHS OF STORM BREACH INTO CAR PARK AND 10M 4WD ACCESS TRACK AT EDWARDS POINT ISLAND LOCATION













APPENDIX F

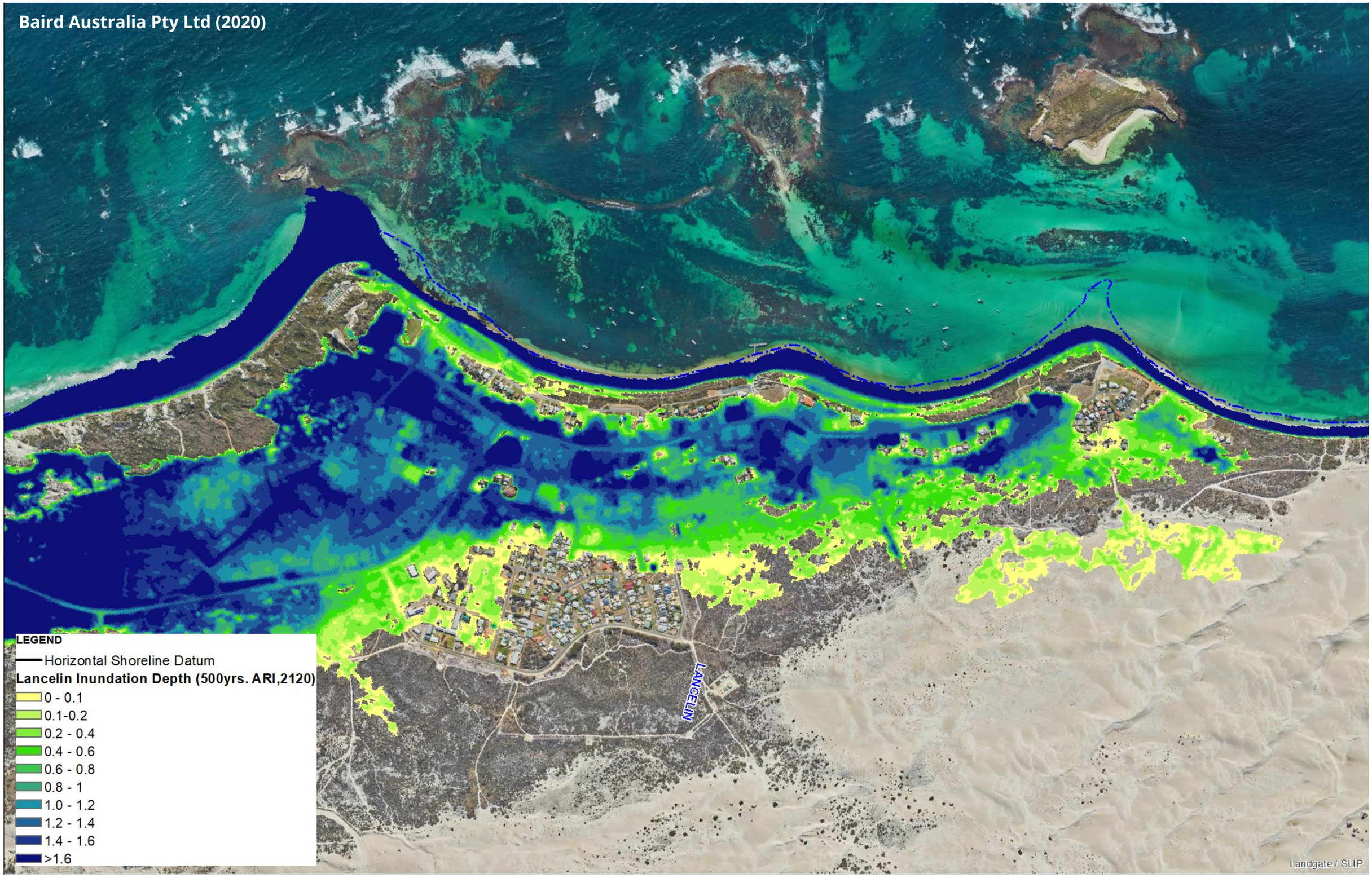
Appendix F - Hazard Maps

Lancelin Erosion Mapping



Shire of Gingin Coastal Hazard Risk Management Adaptation Plan and Coastal Management Strategy mapping - Last Updated 23 December 2022

Lancelin Inundation Mapping



Shire of Gingin Coastal Hazard Risk Management Adaptation Plan and Coastal Management Strategy mapping - Last Updated 23 December 2022

Ledge Point Erosion Mapping



Shire of Gingin Coastal Hazard Risk Management Adaptation Plan and Coastal Management Strategy mapping - Last Updated 23 December 2022

Ledge Point Inundation Mapping



Seabird Erosion Mapping



Shire of Gingin Coastal Hazard Risk Management Adaptation Plan and Coastal Management Strategy mapping - Last Updated 23 December 2022

Seabird Inundation Mapping



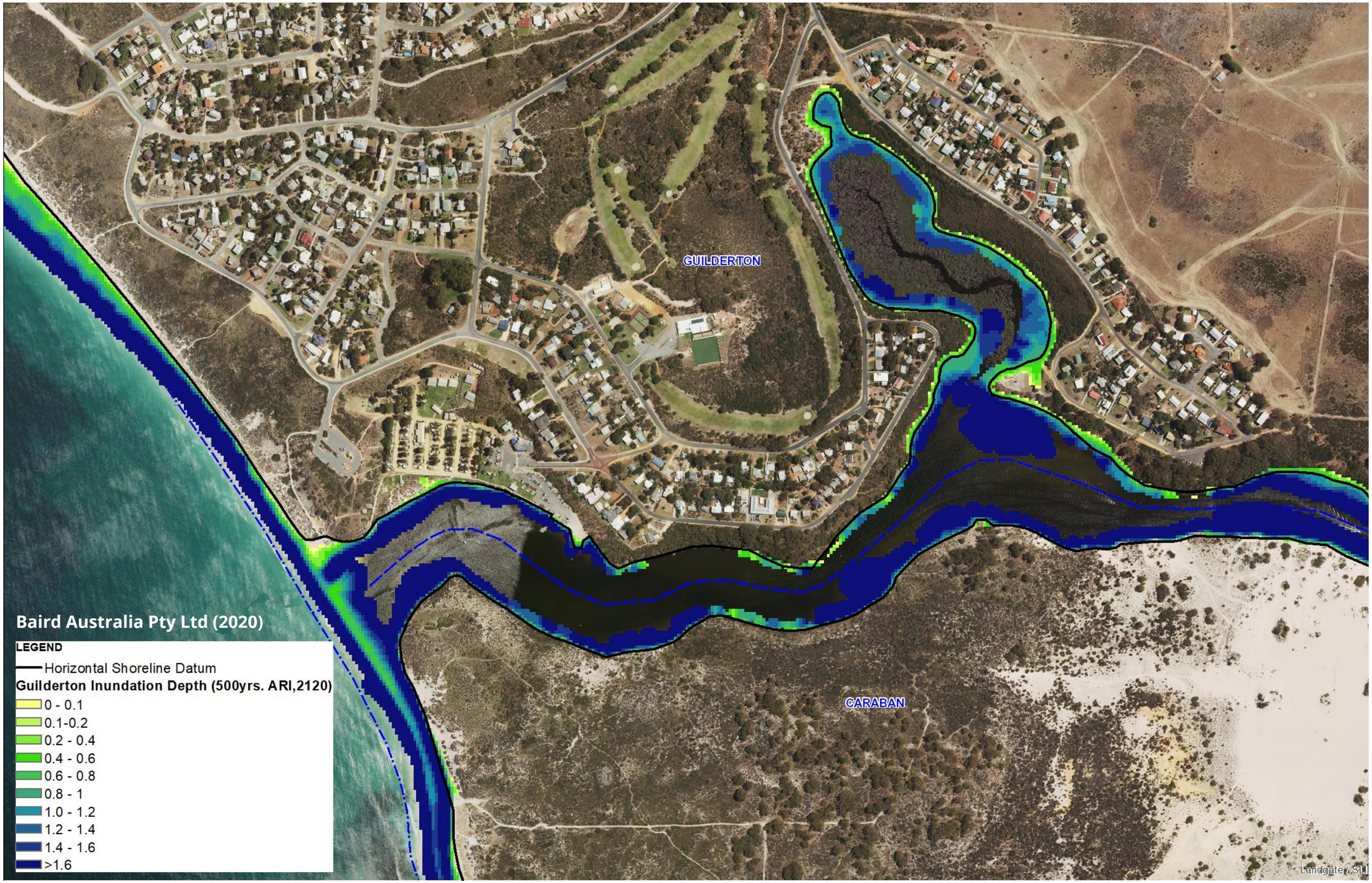
Shire of Gingin Coastal Hazard Risk Management Adaptation Plan and Coastal Management Strategy mapping - Last Updated 23 December 2022

Guilderton Erosion Mapping



Shire of Gingin Coastal Hazard Risk Management Adaptation Plan and Coastal Management Strategy mapping - Last Updated 23 December 2022

Guilderton Inundation Mapping



Shire of Gingin Coastal Hazard Risk Management Adaptation Plan and Coastal Management Strategy mapping - Last Updated 23 December 2022

APPENDIX G

Appendix G - Benefit Distribution Analysis Report

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COASTAL MANAGEMENT STRATEGY - BENEFIT DISTRIBUTION ANALYSIS

SHIRE OF GINGIN

MARCH 2023

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1 Reliance and Disclaimer

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2 EXECUTIVE SUMMARY

This report provides a Benefit Distribution Analysis (BDA) for the Shire of Gingin's comprehensive Coastal Hazard Risk Management Adaptation Plan 2023.

The coastal hazards of erosion and inundation, combined with rising sea levels, are impacting the safety and existence of coastal communities around the globe. The Shire of Gingin (Shire) has an extensive coastline and numerous coastal communities that will potentially be impacted by these coastal hazards. The Shire's four primary coastal settlements are considered in this report – Lancelin, Ledge Point, Seabird and Guilderton.

Where coastal hazards are deemed a risk to a community, a range of interventions may occur to mitigate this risk. These includes consideration of options to avoid impacts, retreat, accommodate or to protect.

When investment is made in interventions, different individuals, enterprises or groups may experience different levels of benefit. This report develops a BDA to systematically estimate benefits to different parties as the result of these interventions in the Shire.

The BDA in this report is therefore developed to:

- Develop a shared understanding of who will benefit from coastal hazard interventions.
- Ensure a broad understanding is developed by capturing a range of benefits from different perspectives.
- Inform any future decision-making relating to funding contributions for interventions (noting that a cost distribution analysis is out of scope for this report).

The BDA quantifies the estimated proportional benefit accruing to relevant groups of asset holders against a do-nothing base case, thereby informing future structures for robust and fair cost allocations in the future. The BDA takes a broad view of the benefits resulting from coastal management interventions, including consideration of benefits to landowners, tenants, agencies, interest groups, and the community as a whole.

For this work, benefit is defined as "the continued existence and operation of an asset, at its existing full functionality, landholding, service, or economic/commercial outcome as at the time of the BDA". A key assumption is that coastal management interventions will result in beneficiaries continuing to enjoy these benefits in perpetuity.

A summary of beneficiary findings by community is at Table 1.

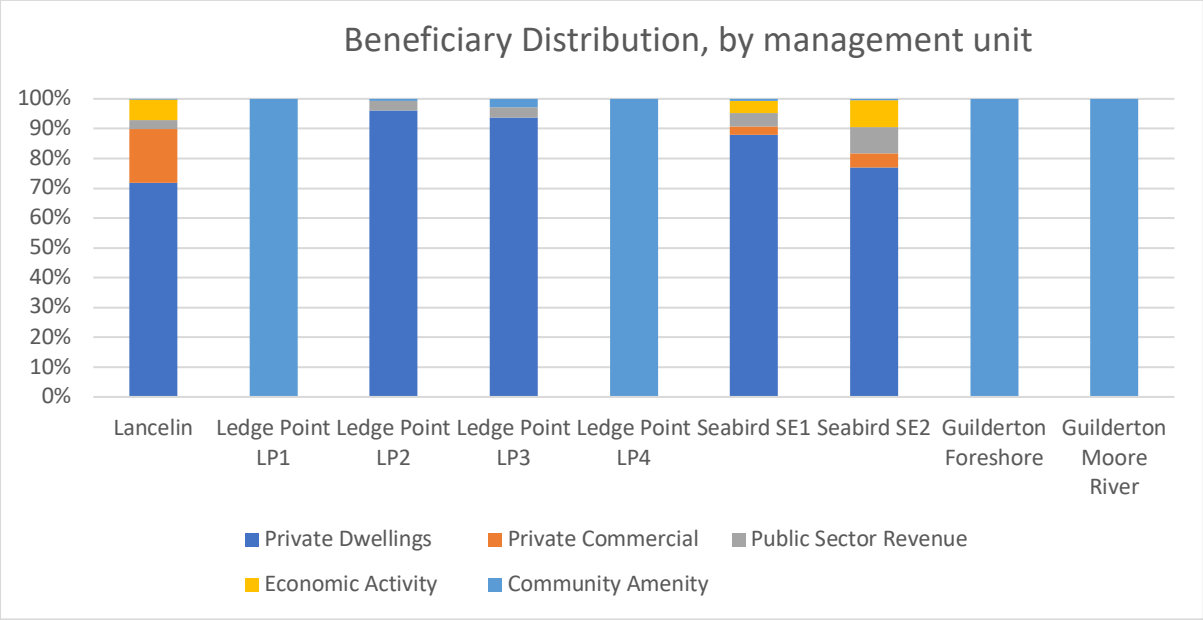
Table 1 - Summary of beneficiary findings by community

Coastal Settlement	Total Value of Benefit (Net Present Value)	Primary beneficiary
Guilderton	$621,688	Community amenity
Seabird	$48,452,782	Private dwellings
Ledge Point	$20,188,101	Private dwellings
Lancelin	$775,033,802	Private dwellings; Commercial properties; Local workforce

Source: FAR Lane, 2023.

Beneficiary distribution by management unit is at Figure 1.

Figure 1 - Beneficiary Distribution, by management unit



Source: FAR Lane, 2023.

The analysis indicates that:

- Types of beneficiary distribution vary greatly across management units.
- Private dwellings and community amenity are the highest primary beneficiaries.

A summary of infrastructure replacement costs at current value by community area is at Table 2.

Table 2 - Infrastructure replacement costs at current value

Community	Infrastructure value
Lancelin	$42,957,424
Ledge Point	$794,609
Seabird	$927,764
Guilderton	$583,787

Source: FAR Lane, 2023.

The analysis indicates that:

- Guilderton has the lowest value of benefit and infrastructure replacement as only limited community amenity is affected.
- Lancelin has the highest value of benefit and infrastructure replacement as the entire town will potentially be impacted by inundation and therefore be relocated.

3 INTRODUCTION

This report is intended as an attachment to Shire of Gingin's comprehensive Coastal Hazard Risk Management Adaptation Plan 2023. However, some key background is included here for completeness.

3.1 BACKGROUND AND PROJECT SCOPE

The coastal hazards of erosion and inundation, combined with rising sea levels, are impacting the safety and existence of coastal communities around the globe. Coastal flooding and long-term shoreline recession risk making parts of many coastal communities untenable in the longer term unless action is taken.

The Shire of Gingin (Shire) has an extensive coastline and numerous coastal communities that are already impacted by coastal hazards and will be increasingly impacted by rising sea levels. The Shire is therefore taking proactive steps that consider how best to mitigate these effects. This will help the Shire make informed decisions regarding land use and development in its coastal areas, and ensure the long-term resilience of its communities.

Where coastal hazards are deemed a risk to a community, a range of interventions may be considered to mitigate this risk. These includes consideration of options to 'avoid' impact, 'retreat', 'accommodate' or to 'protect'. Gingin already has experience in this space, with the community of Seabird having a seawall installed to mitigate the immediate effects of erosion (protect). When investment is made in interventions, different people or groups may experience different levels of benefit. This report develops a Benefit Distribution Analysis (BDA) to systematically estimate benefits to different parties as the result of interventions.

3.2 STUDY AREA – SHIRE OF GINGIN

The Shire of Gingin (the Shire) is located in the Wheatbelt region north of Perth and includes approximately 80km of coastline. There are four coastal communities in the Shire - Guilderton, Lancelin, Ledge Point and Seabird. This report examines each community individually.

Figure 2 - Map of Shire of Gingin coast communities



Source: Google Maps, 2023.

3.3 POLICY BACKGROUND

The Western Australian Planning Commission's (WAPC) has carriage of Western Australia's governing policy for coastal management via State Planning Policy No. 2.6 - State Coastal Planning Policy (SPP 2.6; 2013a). To guide land use and development decision making in coastal zones, SPP 2.6 recommends management authorities develop a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) in accordance with WAPC's Coastal Hazard Risk Management and Adaptation Planning Guidelines (2019).

SPP 2.6 includes aims to establish coastal foreshore reserves that provide allowance for the protection, conservation and enhancement of coastal values across the state. This process includes identifying existential or intolerable risks to communities and other stakeholders, and developing suitable mitigation approaches that align with SPP 2.6.

3.4 PREVIOUS STUDIES

This report draws heavily on CHRMAPs developed under previous studies that indicate the potential effects of sea level erosion or inundation on the Shire's coastal communities. These include:

- In 2019 Cardno prepared a CHRMAP for the Shire. The report did not consider Guilderton, or the risks of inundation on the considered communities (Cardno 2019).
- In 2020 Baird produced a Coastal Inundation Study (CIS Study) of the four coastal communities. It also did not consider the risks of inundation on the considered communities (Baird 2020).
- The 2023 CHRMAP Technical Report (Shape Urban 2023a) comprehensively addressed the gaps in coastal planning for the four coastal townsites. It, combined with Cardno 2019 and the Baird 2020, were integrated into a single combined Shire of Gingin CHRMAP – Shape Urban 2023b.

4 METHODOLOGY OVERVIEW

The benefit distribution analysis (BDA) in this report is developed to:

- Develop a shared understanding of who will benefit from coastal hazard interventions (existing and future).
- Ensure a broad understanding is developed by capturing a range of benefits from different perspectives.
- Inform future decision-making relating to funding contributions for interventions.

The report breaks down the communities into "management units" which allows for the required level of detail for assessment under the BDA. The BDA captures and, where possible, quantifies relevant proportional benefits associated with existing and proposed protection works identified in the CHRMAP at the management unit level. This includes objective and/or subjective capture of benefits related to, but not limited to:

- Avoided loss of assets and/or asset value
- Retention of opportunities for business activities and earning of wages
- Retention for options for alternative asset utilisation in the future
- Retention of critical infrastructure
- Avoided travel costs
- Avoided clean-up costs
- Retention of amenity.

The BDA quantifies the estimated proportional benefit accruing to relevant groups of asset holders against a do-nothing base case, informing future structures for robust and fair cost allocations in the future. Cost distribution modelling is out of scope for this report and is therefore not considered.

The BDA takes a broad view of the benefits resulting from CMS interventions, including consideration of benefits to landowners, tenants, agencies, interest groups, and the community as a whole.

For this work, benefit is defined as "the continued existence and operation of an asset, at its existing full functionality, landholding, service, or economic/commercial outcome as at the time of the BDA". A key assumption is that beneficiaries will continue to enjoy these benefits in perpetuity.

Methodology for apportioning benefit is:

1. Profile logical groupings of "value units" (at the sub-management unit level) based on groupings of adjoining residential/commercial sites with comparable unimproved land values.
2. Profile relevant benefits against the CHRMAPs for:
    - Owner benefits
    - Community benefits.

3. Calculate total benefit retention/realisation for all owners and users, including public and private landowners; service/utility providers; commercial operators; community groups; and local, state and federal governments.
4. Allocate overall benefit at the unit management level.

Methodology for calculating the value of benefit for each type of beneficiary is at Table 3. Please note that a glossary of definitions can be found at section 10.

Table 3 - Methodology summary table for calculating value of benefit

Benefit type	Value of benefit – calculation methodology
Private dwellings	Net Present Value of Gross Rental Value
Private commercial assets	Net Present Value of Gross Rental Value
Community amenity	Net Present Value of foregone amenity
Public sector revenue - rates	Net Present Value of foregone Shire rates
Economic activity	Net Present Value of indirect and induced economic impact of foregone wages
Infrastructure value	Cost of replacement based on current values

Source: FAR Lane, 2023.

A discount rate of four percent was used for Net Present Value calculations for private dwellings, private commercial assets, and community amenity. This social discount rate was selected to reflect the multigenerational nature of interventions and impacts being considered.

A discount rate of seven percent was used for Net Present Value calculations for public sector revenues and economic activity. This rate was selected to reflect that wages and public sector revenues are not accruing in a multi-generational way but instead are accruing to given individuals/households at a given point in time.

The direct economic impact from wages is assumed to accrue to individuals/households, while indirect and induced accrues to the local economy. For this reason, only the impact from indirect and induced wages are considered in the BDA.

Infrastructure considered in this report is roads, water pipes, sewerage pipes, overhead power cables and power poles, and underground power cables and their protective structures. Infrastructure is not considered with Net Present Value calculations because:

- Infrastructure can, in many cases, generate revenues which are utilised in future infrastructure upgrades (e.g. power, water).
- Much infrastructure is specifically provided to support other assets such as residential and commercial assets.

A full methodology can be found in section 8.

5 OVERVIEW OF POTENTIAL COASTAL HAZARD IMPACT ON AFFECTED COMMUNITIES

This section contains a high-level summary of each community's potential vulnerability from erosion and inundation, including predicted sea level rise of 0.9m in 2120 based on current conditions.[1] Detailed assessments can be found in Shape Urban 2023a and Cardno 2019.

5.1 IMPACTS OF COASTAL HAZARDS ON COASTLINES – EROSION AND INUNDATION

The considered impacts are:

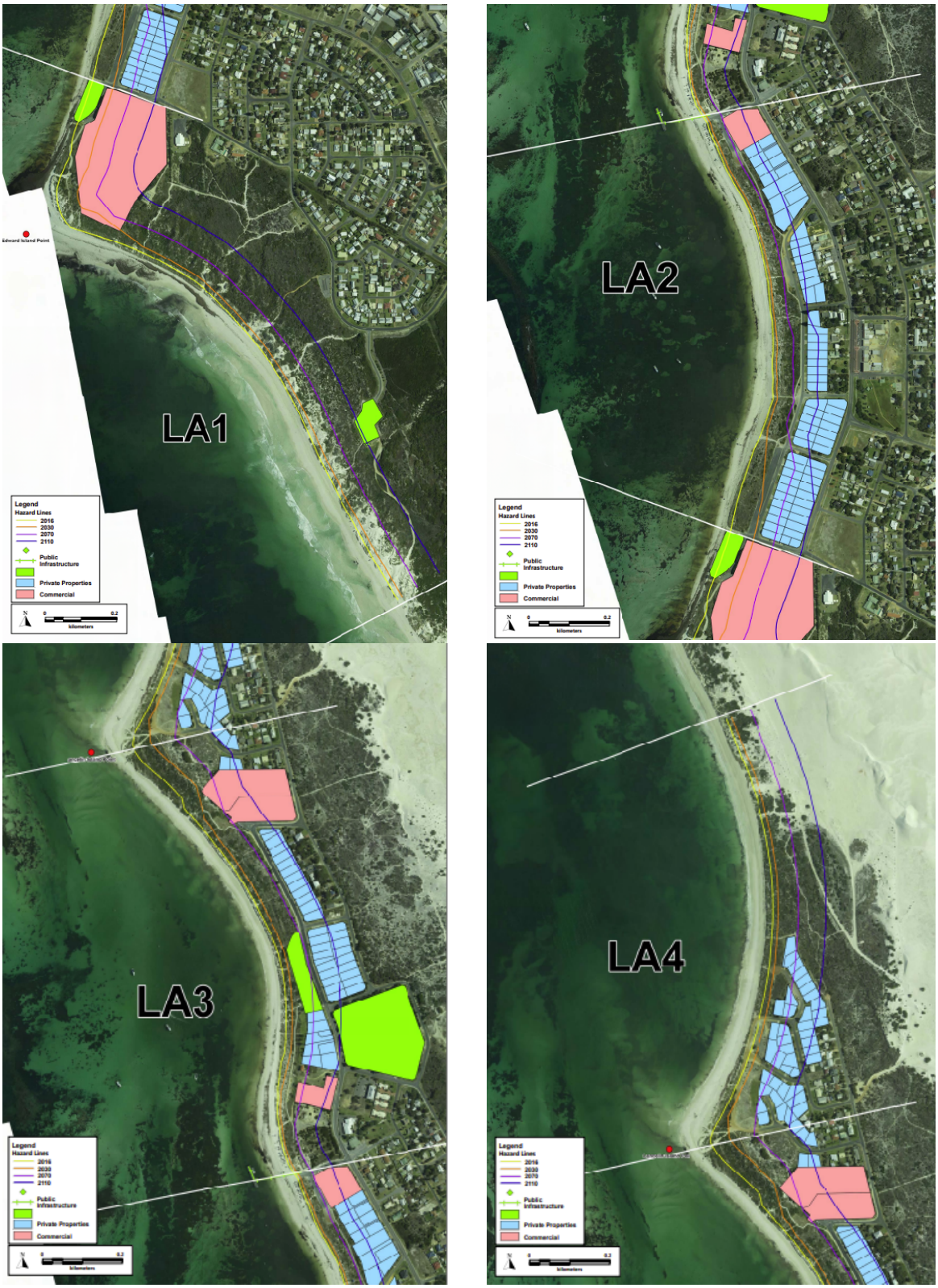
- Erosion – Coastlines composed primarily of loose sediment (such as beaches) recede until a new equilibrium shoreline is found further inland. This report considers predicted erosion levels at 2070.
- Inundation - Storm surges and increased mean sea levels will create flooding in areas adjacent to shorelines. The risk zone is measured based on 500-year average return interval (ARI) storms, combined with 100 years of sea level rise.[2]

5.2 LANCELIN

Lancelin's predicted erosion and inundation hazard lines are at Figure 3 and Figure 4.

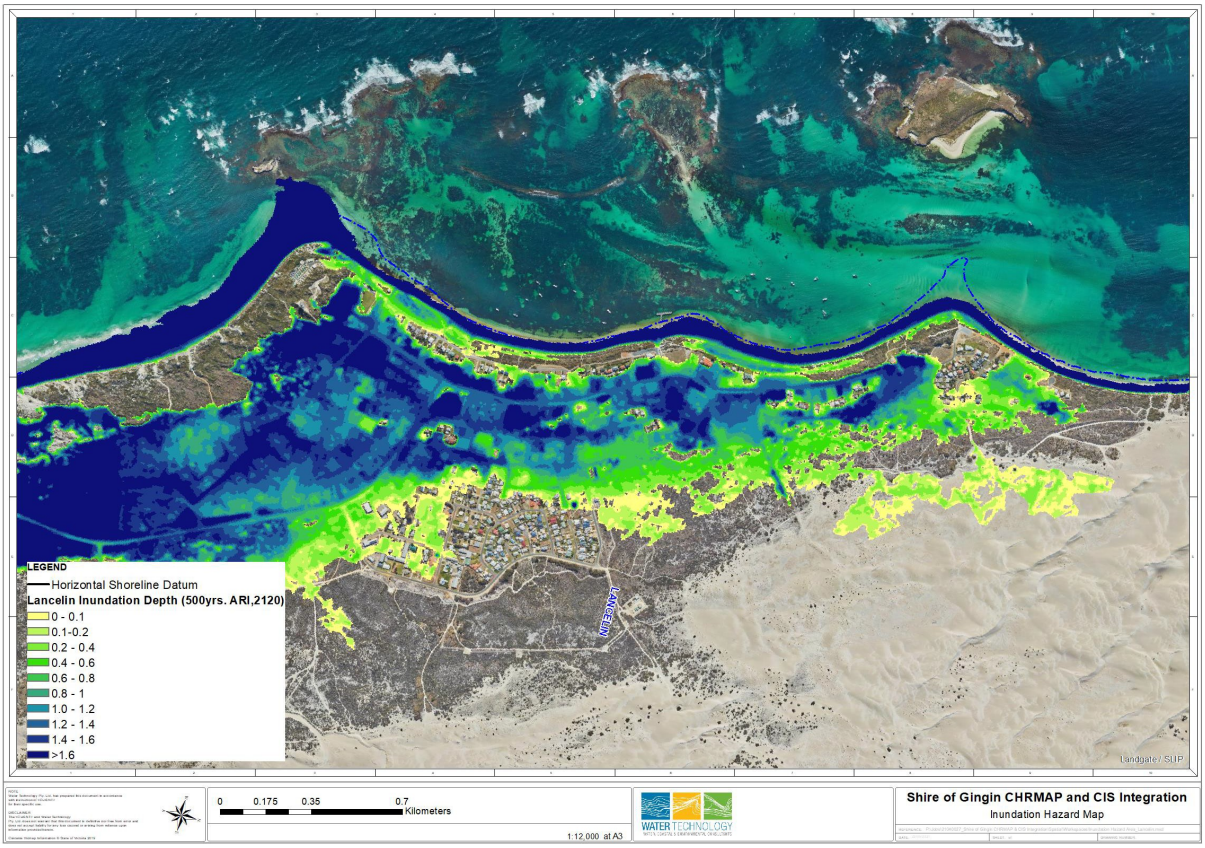
[1] Cardno 2019 & Shape Urban, 2023a.
[2] Baird, 2020.

Figure 3 - Predicted erosion for Lancelin by management unit



Source: Cardno, 2019.

Figure 4 - Predicted inundation for Lancelin: 500-year ARI



Source: Baird, 2020.

The analysis indicates Lancelin will potentially incur:

- High erosion risk at 2070 for some residential properties and considerable beachfront.
- Extremely high risk of inundation 500-year ARI over the next 100 years, including for almost all residential, commercial and community uses.

5.3 LEDGE POINT

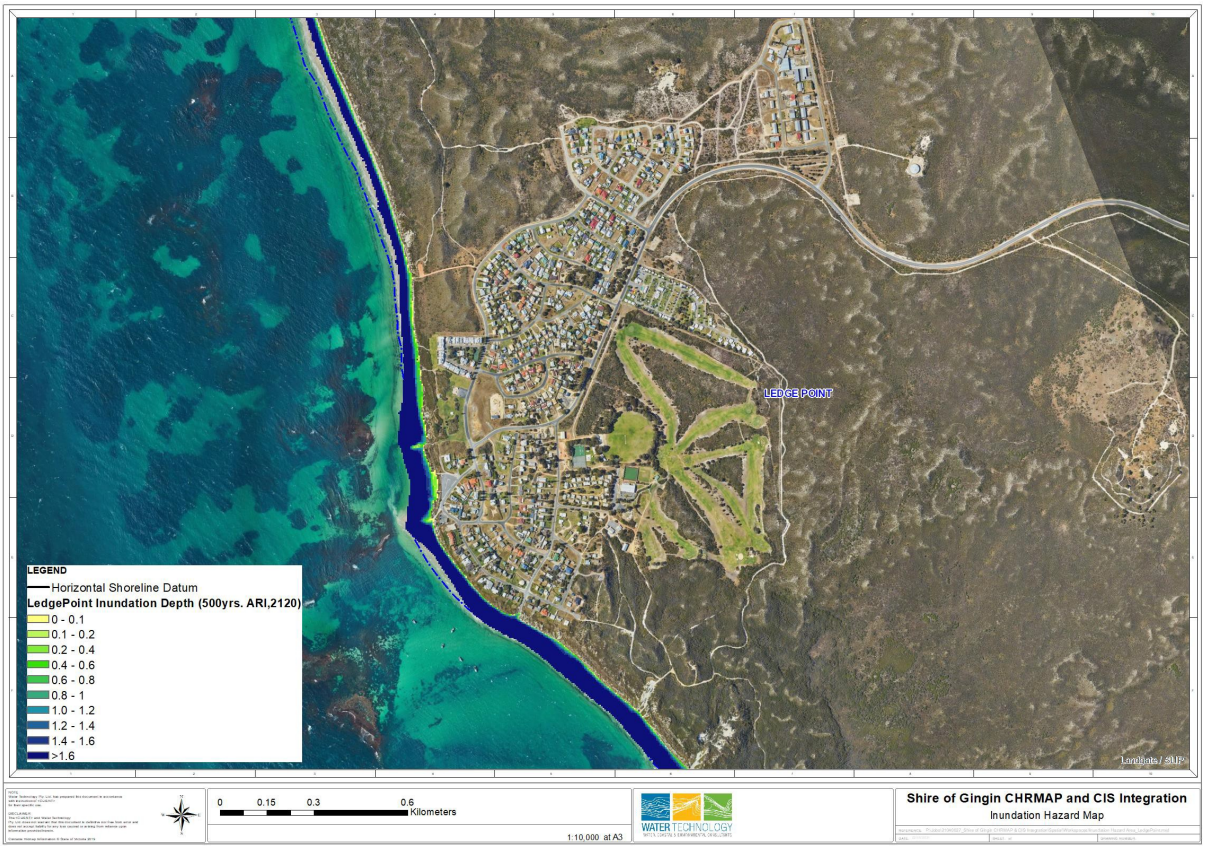
Ledge Point's predicted erosion and inundation hazard lines are at Figure 5 and Figure 6.

Figure 5 - Predicted erosion for Ledge Point by management unit



Source: Cardno, 2019.

Figure 6 - Predicted inundation for Ledge Point: 500-year ARI, 2120



Source: Baird, 2020.

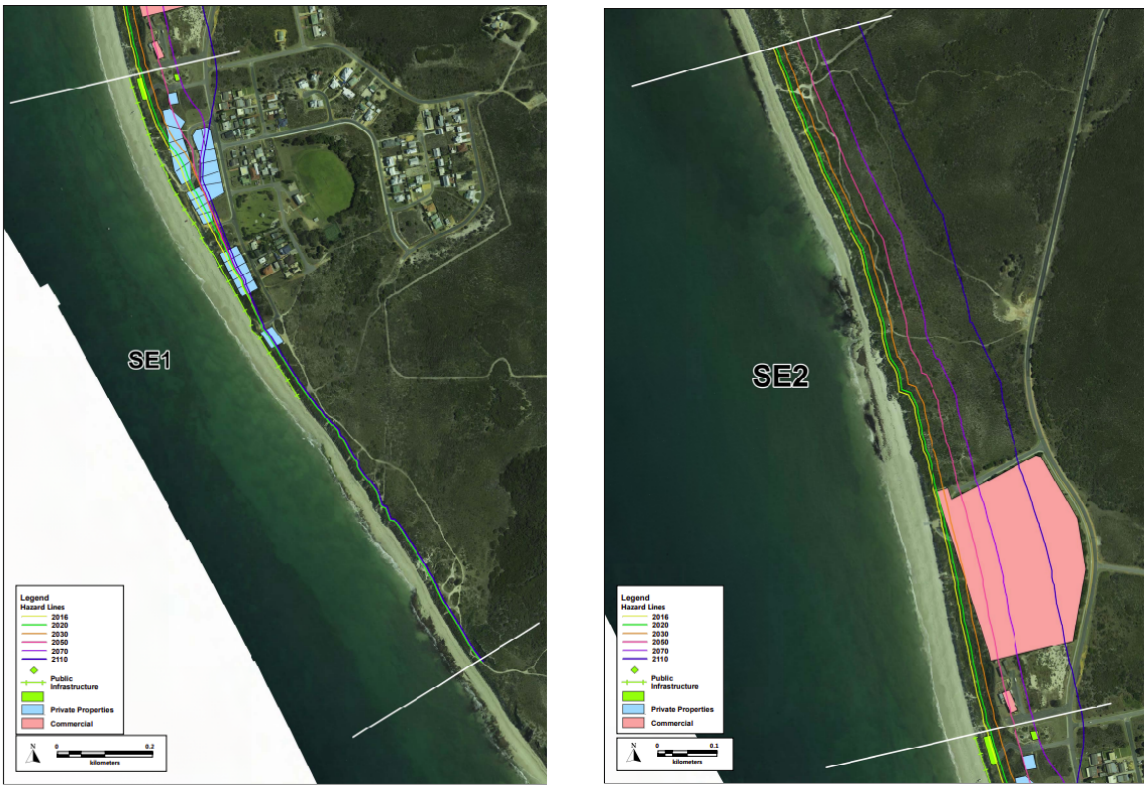
The analysis indicates Ledge Point will potentially incur:

- High erosion vulnerability at 2070 for some residential, commercial, dunes and vegetation areas.
- Low to medium risk of inundation for 500-year ARI some dunes and vegetation areas.

5.4 SEABIRD

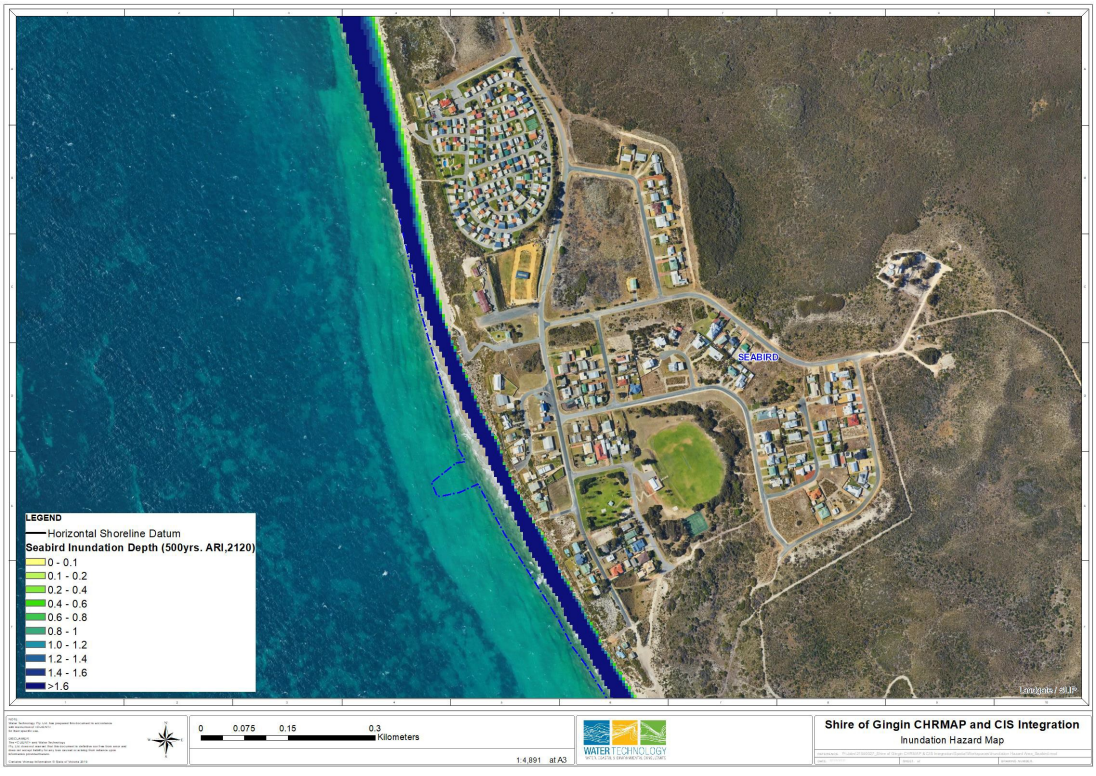
Seabird's predicted erosion and inundation hazard lines are at Figure 7 and Figure 8.

Figure 7 - Predicted erosion for Seabird by management unit



Source: Cardno, 2019.

Figure 8 - Predicted inundation for Seabird: 500-year ARI



Source: Baird, 2020.

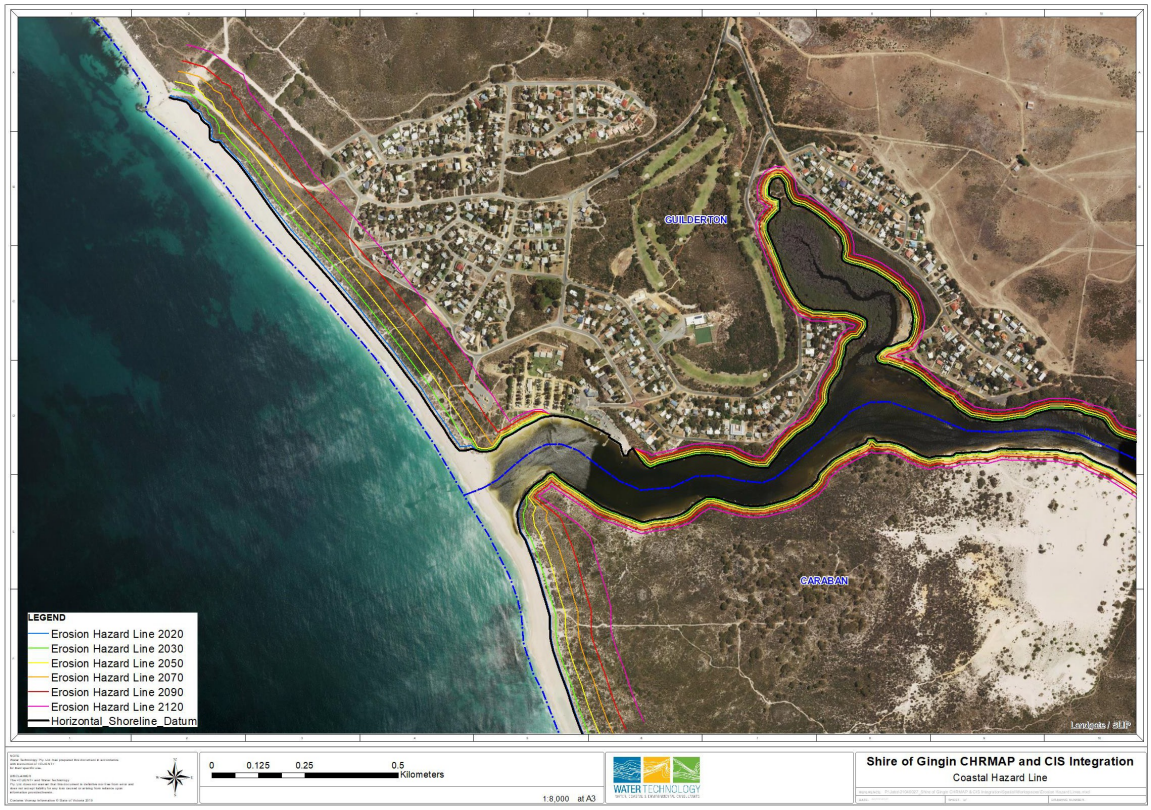
The analysis indicates Sea Bird will potentially incur:

- High erosion vulnerability at 2070 for some recreational, commercial and residential areas.
- Low to medium risk of inundation 500-year ARI for some parks and residential areas.

5.5 GUILDERTON

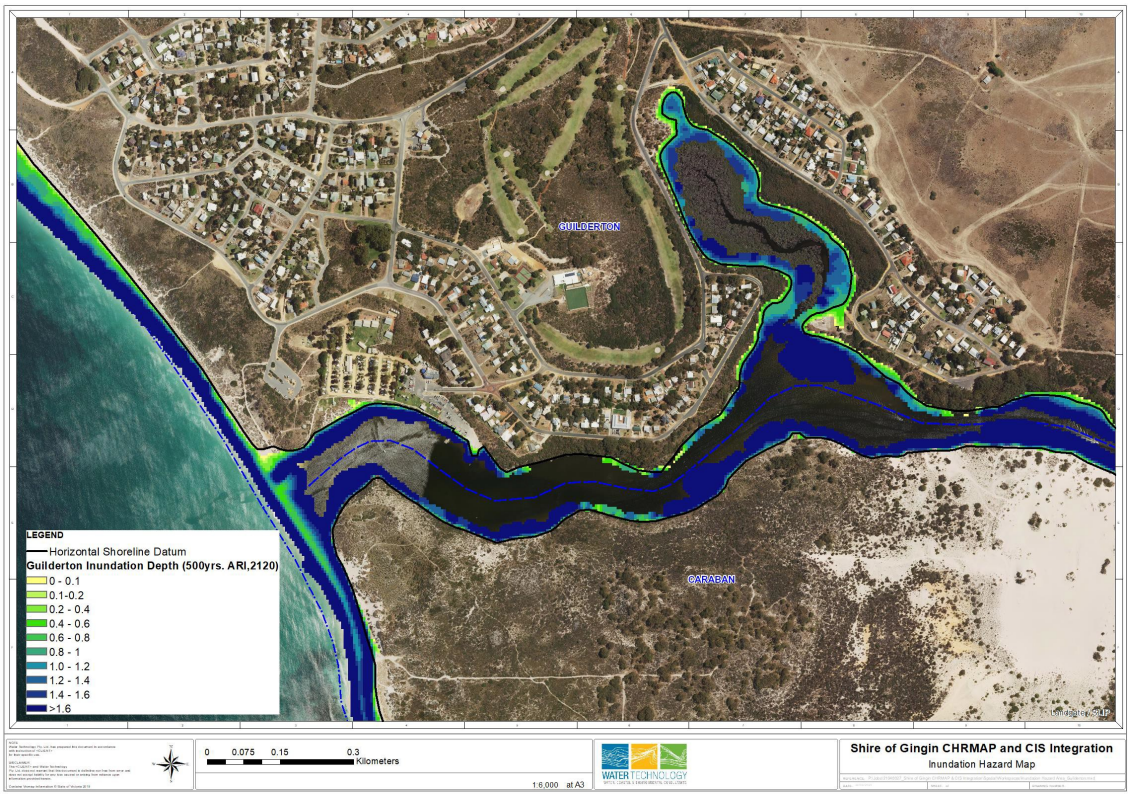
Guilderton's predicted erosion and inundation hazard lines are at Figure 9 and Figure 10.

Figure 9 - Predicted erosion hazard lines for Guilderton



Source: Shape Urban, 2023a.

Figure 10 - Predicted inundation for Guilderton: 500-year ARI, 2120



Source: Baird, 2020.

The analysis indicates Guilderton will potentially incur:

- High erosion vulnerability at 2070 for some recreational, parks and residential areas.
- Low to medium risk of inundation for 500-year ARI for some parks and future development areas.

An image of Guilderton's management units is included for completeness at Figure 11.

Figure 11 - Guilderton's management units



Source: Shape Urban, 2023a. Note the two management units are Moore River (green) and Foreshore (red).

6 KEY FINDINGS – BENEFIT DISTRIBUTION ANALYSIS BASED ON PROPOSED INTERVENTIONS

All calculations are based on the assumption that interventions to mitigate the impact of erosion and inundation successfully protect the assets. Proposed interventions for each management unit can be found in the Shire of Gingin's comprehensive Coastal Hazard Risk Management Adaptation Plan Shape Urban 2023b.

Please note that detailed calculations and breakdowns of value units are at section 9.

6.1 LANCELIN

As noted in section 5.2, Lancelin will potentially incur:

- High erosion risk at 2070 for some residential properties and considerable loss of beachfront.
- Extremely high risk of inundation 500 year ARI over the next 100 years, including for residential, commercial and community uses.

Lancelin represents a unique case of the four considered communities, as its risk of inundation is so great that potential interventions other than relocation will be cost prohibitive and will likely be ineffective against the combination of erosion and inundation. Given this, this report makes the assumption that the entire town will eventually be relocated.

Summary of all owner and community benefit that will be impacted by coastal inundation in Lancelin is at Table 4. As the entire town would potentially be relocated, the economic value for Lancelin has been considered holistically i.e. management units and value units have not been utilised for these calculations.

Table 4 - Summary of economic value in Lancelin that will be impacted by inundation

Beneficiary / community benefit	Value of benefit	Percentage of total benefit
Private dwellings	$ 557,037,308	71.9%
Private commercial assets	$ 139,768,059	18.0%
Community amenity	$ 1,939,837	0.3%
Public sector revenue - rates	$ 22,596,429	2.9%
Economic activity - wages	$ 53,692,169	6.9%
Total	$ 775,033,802	100%

Source: FAR Lane, 2023.

The analysis indicates that approximately $775 million of economic value will potentially be destroyed by inundation in Lancelin over the next 100 years, with the estimated cost of replacement for current infrastructure in Lancelin at $43 million.

Short term interventions are possible to extend the enjoyment of the coastal lifestyle but are likely to be sacrificial in the long term, and any planning should be cognisant of this. Notwithstanding, should any protection be proposed to mitigate the risk of flooding, 90% of the benefit of providing coastal hazard adaptation would be apportioned to private interests, who should be obliged to contribute to protection measures.

Given the extreme likelihood of inundation, the entire town of Lancelin will likely need to be relocated in the medium term. In the case of retreat, no intervention is being proposed that assures "the continued existence and operation of an asset, at its existing full functionality, landholding, service, or economic/commercial outcome as at the time of the BDA". Therefore a BDA is not suitable for considering the preserved benefits of Lancelin.

6.2 Ledge Point

As noted in section 5.3, Ledge Point will potentially incur:

- High erosion vulnerability at 2070 for some residential, commercial, dunes and vegetation areas.
- Low to medium risk of inundation 500 year ARI for some dunes and vegetation areas.

LP1 management unit

Summary of all owner and community benefits for LP1 is at Table 5.

Table 5 - Summary of all benefits for Ledge Point LP1

Beneficiary / community benefit	Value of benefit	Percentage of total benefit
Private dwellings	$ 0	0%
Private commercial assets	$ 0	0%
Community amenity	$159,132	100%
Public sector revenue - rates	$ 0	0%
Economic activity	$ 0	0%
Total	**$159,132**	**100%**

Source: FAR Lane, 2023.

The analysis indicates all benefits in LP1 will go to community amenity, as only natural areas will be affected by erosion or inundation. The benefit of providing coastal hazard adaptation would therefore be considered primarily a shared community benefit, with the entire community obliged to contribute to the response.

The estimated cost of replacement for current infrastructure in the Ledge Point LP1 is zero, as no infrastructure is anticipated to be affected by inundation or erosion.

LP2 management unit

Summary of all owner and community benefits for LP2 is at Table 6.

Table 6 - Summary of all benefits for Ledge Point LP2

Beneficiary / community benefit	Value of benefit	Percentage of total benefit
Private dwellings	$15,299,306	96.2%
Private commercial assets	$0	0.0%
Community amenity	$106,534	0.7%
Public sector revenue - rates	$499,500	3.1%
Economic activity	$0	0.0%
Total	$15,905,340	**100%**

Source: FAR Lane, 2023.

The analysis indicates the majority of benefits in LP2 will go to private dwellings. 96% of the benefit of providing coastal hazard adaptation would therefore be apportioned to private interests, who should be obliged to contribute to protection measures.

The estimated cost of replacement for current infrastructure in the Ledge Point LP2 is approximately $446,000.

LP3 management unit

Summary of all owner and community benefits for LP3 is at Table 7.

Table 7 - Summary of all benefits for Ledge Point LP3

Beneficiary / community benefit	Value of benefit	Percentage of total benefit
Private dwellings	$3,787,932	93.7%
Private commercial assets	$0	0.0%
Community amenity	$113,046	2.8%
Public sector revenue - rates	$142,714	3.5%
Economic activity	$0	0.0%
Total	**$4,043,692**	**100%**

Source: FAR Lane, 2023.

The analysis indicates the majority of benefits in LP3 will go to private dwellings. 94% of the benefit of providing coastal hazard adaptation would therefore be apportioned to private interests, who should be obliged to contribute to protection measures.

The estimated cost of replacement for current infrastructure in the Ledge Point LP3 is approximately $349,000.

LP4 management unit

Summary of all owner and community benefits for LP4 is at Table 8.

Table 8 - Summary of all benefits for Ledge Point LP4

Beneficiary / community benefit	Value of benefit	Percentage of total benefit
Private dwellings	$ 0	0%
Private commercial assets	$ 0	0%
Community amenity	$79,937	100%
Public sector revenue - rates	$ 0	0%
Economic activity	$ 0	0%
Total	**$79,937**	**100%**

Source: FAR Lane, 2023.

The analysis indicates all benefits in LP4 will go to community amenity, as only natural areas will be affected by erosion or inundation. The benefit of providing coastal hazard adaptation would therefore be considered primarily a shared community benefit, with the entire community obliged to contribute to the response.

The estimated cost of replacement for current infrastructure in the Ledge Point LP4 is zero, as no infrastructure is anticipated to be affected by inundation or erosion.

6.3 SEABIRD

As noted in section 5.4, Sea Bird will potentially incur:

- High erosion vulnerability at 2070 for some recreational, parks and residential areas.
- Low to medium risk of inundation 500 year ARI for some parks and residential areas.

SE1 management unit

Summary of all owner and community benefits for SE 1 is at Table 9.

Table 9 - Summary of all benefits for Seabird SE1

Beneficiary / community benefit	Value of benefit	Percentage of total benefit
Private dwellings	$12,526,343	88.0%
Private commercial assets (cafe)	$377,899	2.7%
Community amenity	$81,294	0.6%
Public sector revenue - rates	$642,214	4.5%
Economic activity – wages for 2 FTE	$610,094	4.3%
Total	$14,237,844	100%

Source: FAR Lane, 2023.

The analysis indicates the majority of benefits in SE1 will go to private dwelling owners. 91% of the benefit of providing coastal hazard adaptation would therefore be apportioned to private interests, who should be obliged to contribute to protection measures.

The estimated cost of replacement for current infrastructure in the Seabird SE1 is approximately $833,000.

SE2 management unit

Please note that SE2 contains a strata block caravan park with 180 individual sites which this report treats as a single lot.

Table 10 - Summary of all benefits for Seabird SE2

Beneficiary / community benefit	Value of benefit	Percentage of total benefit
Private dwellings	$26,319,863	76.9%
Private commercial assets (tavern)	$1,645,844	4.8%
Community amenity	$167,162	0.5%
Public sector revenue - rates	$3,031,600	8.9%
Economic activity – wages for 10 FTE	$3,050,469	8.9%
Total	**$34,214,938**	**100%**

Source: FAR Lane, 2023.

The analysis indicates the majority of preserved benefits in SE2 will go private dwelling owners (particularly in the caravan park strata).

82% of the benefit of providing coastal hazard adaptation would therefore be apportioned to private interests, who should be obliged to contribute to protection measures.

The estimated cost of replacement for current infrastructure in the Seabird SE2 is approximately $94,000.

6.4 GUILDERTON

As noted in section 5.2, Guilderton will potentially incur:

- High erosion vulnerability at 2070 for some recreational, parks and residential areas.
- Low to medium risk of inundation for 500-year ARI for some parks and future development areas.

Guilderton Foreshore management unit

Summary of all owner and community benefits for Guilderton Foreshore is at Table 11.

Table 11 - Summary of all benefits for Guilderton Foreshore

Beneficiary / community benefit	Net Present Value of benefit	Percentage of total benefit
Private dwellings	$ 0	0%
Private commercial assets	$ 0	0%
Community amenity	$264,413	100%
Public sector revenue - rates	$ 0	0%
Economic activity	$ 0	0%
Total	**$264,413**	**100%**

Source: FAR Lane, 2023.

The analysis indicates all benefits in Guilderton Foreshore will go to community amenity, as no residential or commercial properties will be affected by erosion or inundation. The benefit of providing coastal hazard adaptation would therefore be considered primarily a shared community benefit, with the entire community obliged to contribute to the response.

The estimated cost of replacement for current service infrastructure in the Guilderton Foreshore is approximately $358,000.

It should be noted that some private residential development will be impacted by erosion beyond 2070, and that this development would eventually benefit from coastal hazard protection measures.

Moore River management unit

Summary of all owner and community benefits for Guilderton Moore River is at Table 12.

Table 12 - Summary of all benefits for Guilderton Moore River

Beneficiary / community benefit	Net Present Value of benefit	Percentage of total benefit
Private dwellings	$ 0	0%
Private commercial assets	$ 0	0%
Community amenity	$357,275	100%
Public sector revenue - rates	$ 0	0%
Economic activity	$ 0	0%
Total	**$357,275**	**100%**

Source: FAR Lane, 2023.

The analysis indicates all benefits in Moore River will go to community amenity, as no residential or commercial properties will be affected by erosion or inundation. The benefit of providing coastal hazard adaptation would therefore be considered primarily a shared community benefit, with the entire community obliged to contribute to the response.

The estimated cost of replacement for current service infrastructure in the Moore River is approximately $225,000.

7 CONCLUSION

This report provides a Benefit Distribution Analysis (BDA) for the Shire of Gingin's comprehensive Coastal Hazard Risk Management Adaptation Plan 2023.

The BDA quantifies the estimated proportional benefit accruing to relevant groups of asset holders against a do-nothing base case, thereby informing future structures for robust and fair cost allocations in the future. The BDA takes a broad view of the benefits resulting from coastal management interventions, including consideration of benefits to landowners, tenants, agencies, interest groups, and the community as a whole.

The analysis in the BDA indicated that:

- Guilderton has the lowest value of benefit and infrastructure replacement as community amenity is the only aspect affected.
- Lancelin has the highest value of benefit and infrastructure replacement as the entire town will potentially be impacted by inundation and therefore be relocated.

8 DETAILED METHODOLOGY

8.1 METHODOLOGY OVERVIEW

The benefit distribution analysis (BDA) in this report is developed to:

- Develop a shared understanding of who will benefit from coastal hazard interventions (existing and future).
- Ensure a broad understanding is developed by capturing a range of benefits from different perspectives.
- Inform future decision-making relating to funding contributions for interventions.

The BDA quantifies the estimated proportional benefit accruing to relevant groups of asset holders against a do-nothing base case, informing future structures for robust and fair cost allocations in the future. Cost distribution modelling is out of scope for this report and is therefore not considered.

The BDA takes a broad view of the benefits resulting from CMS interventions, including consideration of benefits to landowners, tenants, agencies, interest groups, and the community as a whole.

For this work, benefit is defined as "the continued existence and operation of an asset, at its existing full functionality, landholding, service, or economic/commercial outcome as at the time of the BDA". A key assumption is that, for the purposes of the analysis, beneficiaries will continue to enjoy these benefits in perpetuity.

Methodology for apportioning benefit is:

1. Profile logical groupings of "value units" (at the sub-management unit level) based on groupings of adjoining residential/commercial sites with comparable gross rental values (where applicable).
2. Profile relevant benefits against the CHRMAPs for:
    - Owner benefits
    - Community benefits.
3. Calculate total benefit retention/realisation for all owner users, including public and private landowners; service/utility providers; commercial operators; local, state and federal governments; and the community.
4. Allocate overall benefit at the unit management level.

Methodology for calculating the value of benefit for each type of beneficiary is at Table 13, and is detailed below. Please note that a glossary of definitions can be found at section 10.

Table 13 - Methodology summary table for calculating value of benefit

Benefit type	Value of benefit – calculation methodology
Private dwellings	Net Present Value of Gross Rental Value
Private commercial assets	Net Present Value of Gross Rental Value

Community amenity	Net Present Value of foregone amenity
Public sector revenue - rates	Net Present Value of foregone Shire rates
Economic activity	Net Present Value of indirect and induced economic impact of foregone wages
Infrastructure value	Cost of replacement based on current values

Source: FAR Lane, 2023.

Net Present Value considers the lifetime of streams of costs and benefits expressed in constant real dollars. The below equation displays how to calculate the net present value of a cash flow existing in perpetuity:[3]

$$Net\ Present\ Value = \frac{Annual\ Cash\ Flow}{Discount\ Rate}$$

A discount rate of four percent was used for Net Present Value calculations for private dwellings, private commercial assets, and community amenity [4]. This social discount rate was selected to reflect the multigenerational nature of interventions and impacts being considered.

A discount rate of seven percent was used for Net Present Value calculations for public sector revenues and economic activity. This rate was selected to reflect that wages and public sector revenues are not accruing in a multi-generational way but instead are accruing to given individuals/households at a given point in time.

The direct economic impact from wages is assumed to accrue to individuals/households, while indirect and induced accrues to the local economy. For this reason only the impact from indirect and induced wages are considered in the BDA.

8.2 GEOGRAPHICAL DEFINITIONS – MANAGEMENT UNITS AND VALUE UNITS

Management units

The report breaks down Gin Gin's coastal communities into "management units" which allows for the required level of detail for assessment under the BDA (see section 5). The BDA captures, and where possible, quantifies proportional benefits associated with existing and proposed protection works identified in the CHRMAP at the management unit level. This includes objective and/or subjective capture of benefits related to, but not limited to:

- Avoided loss of assets and/or asset value.
- Retention of opportunities for business activities and earning of wages.
- Retention for options for alternative asset utilisation in the future.
- Retention of critical infrastructure.
- Avoided travel costs.
- Avoided clean-up costs.

[3] Assumption: annual cash flows, and the discount rate, are both constant.
[4] CSIRO, Estimating Coastal Values using multi-criteria and valuation methods, 2018, p.59.

- Retention of amenity.

Please note that management units for Guilderton are sourced from Shape Urban 2023a, with all other management units sourced from Cardno 2019.

Value units

Value calculations are based on profile logical groupings of "value units" determined by FAR Lane (at the sub-management unit level) based on groupings of adjoining residential / commercial sites with comparable gross rental values. Where the values of impacted assets are comparable across an entire community or management unit, value units have not been deemed necessary.

A table of management units and value units for each community is at Table 14.

Table 14 - Management units and value units by community

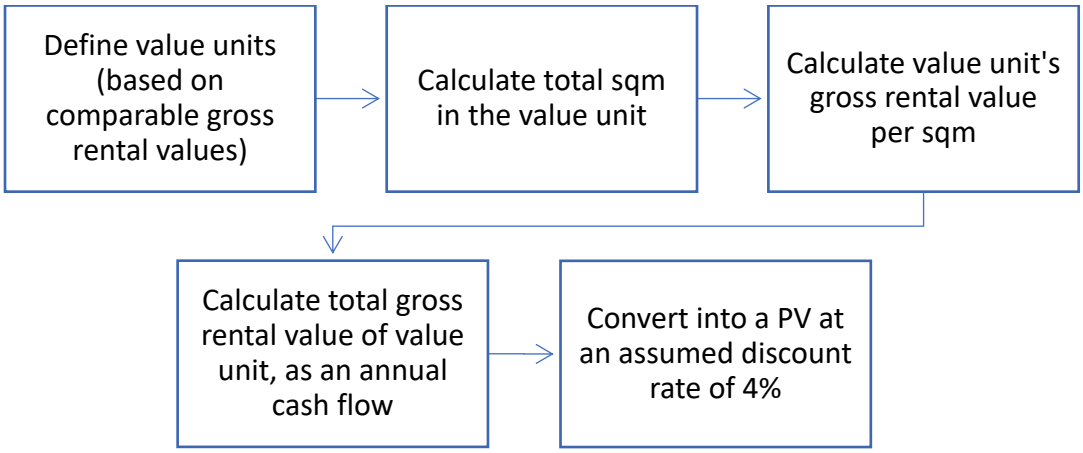
Community	Management units used	Value units
Lancelin	LA1, LA2, LA3, LA4 (noting these units were not utilised for this report)	North Mid North Central South Beachfront South
Ledge Point	LP1, LP2, LP3, LP4	n/a
Seabird	SE1	McCormick South; McCormick Central; Turner Beachfront
	SE 2	Tavern; Strata
Guilderton	G1, G2	n/a

Source: FAR Lane, 2023.

8.3 CALCULATING BENEFITS FOR PRIVATE DWELLINGS AND PRIVATE COMMERCIAL ASSETS

Methodology for calculating the benefit value of preserving residential and commercial property in perpetuity is at Figure 12.

Figure 12 - Methodology for calculating benefit for residential and commercial property



Source: FAR Lane, 2022.

Assumptions:

- Continuation of usability (utility) of property and assets for the same uses.
- Cash flow exists in perpetuity.

8.4 CALCULATING COMMUNITY BENEFIT

Methodology for calculating the benefit value of preserving community benefit in perpetuity is at Table 15.

Table 15 - Methodology for calculating community benefit

Community benefit type	Analysis	Methodology
Community amenity	Loss of access/use of strategic community land (including beach)	Benchmarked amenity calculation per sqm[5] at a discount rate of 4%
Public sector revenues	Foregone LGA rates revenue	Average Gingin rate payment applied to each residential property[6] at a discount rate of 7%
Economic activity	Loss of potential jobs	Indirect and induced economic impact for each job per sqm for that business type[7] at a discount rate of 7%

Source: FAR Lane, 2022.

Assumptions:

- Continuation of community activities, access to services and amenity, rate revenues, jobs.

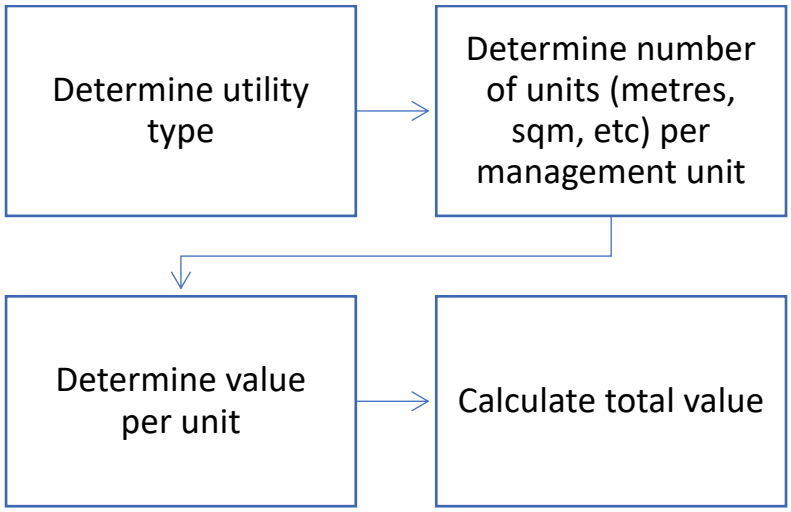
8.5 CALCULATING BENEFITS TO INFRASTRUCTURE OWNERS

Infrastructure considered in this report is roads, water pipes, sewerage pipes, overhead power cables and power poles, and underground power cables and their protective structures. Underground data cables, including the National Broadband Network, has not been included due to a lack of publicly available data on where the cabling is located.

Methodology for calculating the benefit value of preserving infrastructure property is at Figure 13.

[5] CSIRO, Estimating Coastal Values using multi-criteria and valuation methods, 2018, p.59.
[6] Shire of Gingin Adopted Budget 2022-23.
[7] City of Wanneroo 2015/17 Land Use and Employment Survey – Two Rocks. For Lancelin ABS Census 2021. Resident Labour Force was used to estimate total jobs. ABS Census 2021 Industry Median Income applied to calculate total wages in all towns.

Figure 13 - Methodology for calculating infrastructure benefit



Source: FAR Lane, 2022.

Value per unit of infrastructure types is at Table 16.

Table 16 – Value per unit of infrastructure

Infrastructure type	Value/unit[8]
Water pipes (m)	$620.70/m
Overhead cables (m)	$276.00/m
Underground cable (m)	$230.00/m
Underground cable support structures (m)	$600.00/m
Power poles (#)	$7,800/pole
Road (sqm)	$23.64 /sqm

Source: FAR Lane, 2022.

Infrastructure is not considered with Net Present Value calculations because:

- Infrastructure can, in many cases, generate revenues which are utilised in future infrastructure upgrades (e.g. power, water).
- Much infrastructure is specifically provided to support other assets such as residential and commercial assets.

Assumptions:

- Continued operations/ performance of infrastructure.

8.6 LIMITATIONS OF APPROACH

Limitations of the above approach are at Table 17.

[8] Per unit values for water pipes, cables, underground structures and roads obtained from Rawlinsons Construction Cost Guide, 2022. Cost of a power pole sourced from energymatters.com.au, 2013, last accessed February 2023. All values are indexed to reflect a regional area.

Table 17 - Limitations of approach

Assumption/limitation	Comment
Assumes status quo in perpetuity is desirable/beneficial	Consideration of appropriate nature of the status quo is out of scope of this report
Assumes protection in perpetuity	Assumes interventions will be replaced when required to ensure assets remain protected
Assumes equivalent benefit across all assets within a defined management unit	Value units have been specifically selected based on similarity of gross rental value and/or community usage type
Does not account for comparative sunk cost incurred by different stakeholders	Due to the long timeframes involved calculating the BDA (50+ years), there is no mechanism available to determine the nature of any development costs that may improve the land value for each block over such a period
Does not account for comparative opportunities for due diligence by different stakeholders i.e. recent purchases of landholdings should be more aware of risks than those purchasing 30-years ago	Due to the long timeframes involved calculating the BDA (50+ years), and the current interventions in place at Seabird, it is a reasonable assumption that any new purchasers will be aware of the effects of rising sea level on the Shire
Does not dictate cost distributions – further processes need to be developed	Out of scope of this report

Source: FAR Lane, 2022.

9 DETAILED BENEFICIARY ANALYSIS BY MANAGEMENT UNIT

9.1 DETAILED BENEFICIARY ANALYSIS – LANCELIN

As noted in section 5.2, Lancelin will potentially incur:

- High erosion risk at 2070 for some residential properties and considerable loss of beachfront.
- Extremely high risk of inundation 500 year ARI over the next 100 years, including for residential, commercial and community uses.

As noted in 2023 CHRMAP Technical Report (Shape Urban 2023a), Lancelin represents a unique case of the four considered communities, as its risk of inundation is so great that potential interventions other than relocation will be cost prohibitive and will likely be ineffective against the combination of erosion and inundation.

Given the extreme likelihood of inundation, the entire town of Lancelin will likely need to be relocated in the medium term. In the case of retreat, no intervention is being proposed that assures "the continued existence and operation of an asset, at its existing full functionality, landholding, service, or economic/commercial outcome as at the time of the BDA". Therefore a BDA is not considered suitable for considering the preserved benefits of Lancelin. Notwithstanding this, FAR Lane has estimated the value that would impacted below.

Economic value for Lancelin has been considered with sample GRVs obtained from suitable lots across five value units in the town, with all lots in each subsection assumed to have the same GRV per sqm as given by a selected sample lot.[9]

Private dwelling benefit for Lancelin are at Table 18.

Table 18 - Private dwelling benefit for Lancelin

	Area (sqm)	Area Impacted (sqm)	NPV	Value/sqm	Percent	Percent - Total Assets
North	90,887	90,887	$41,059,428	$452	7%	6%
Mid North	152,395	152,395	$62,644,585	$411	11%	8%
Central	367,527	367,527	$202,980,598	$552	36%	27%
South	360,300	360,300	$154,503,646	$429	28%	21%
Beachfront South	143,490	143,490	$95,849,051	$668	17%	13%
Lancelin - total	1,114,599	1,114,599	$557,037,308	$499.76	100.0%	75%

Source: FAR Lane, 2023.

Lancelin includes multiple businesses. These and the commercial benefits for Lancelin are at Table 19.

[9] Assumption: lots within the same subsection share similar physical characteristics, and hence are valued the same per sqm.

Table 19 – List of types of commercial operations and benefits in Lancelin by value unit

Value unit	Type of commercial operation	Area (sqm)	NPV	NPV/sqm	Percent	Percent - Total Assets
North	Pub and Hotel	3,760	$1,698,631	$452	1%	0%
	Caravan Park	11,500	$5,195,280	$452	4%	1%
Mid North	School	27,400	$11,263,241	$411	8%	2%
	Pub	8,790	$3,613,281	$411	3%	0%
	Accommodation	6,775	$2,784,980	$411	2%	0%
	Retail	3,300	$1,356,522	$411	1%	0%
Central	Retail	7,000	$3,866,013	$552	3%	1%
	Light industrial area	68,200	$37,666,013	$552	27%	5%
	Light industrial area	37,220	$20,556,144	$552	15%	3%
	Medical	4,190	$2,314,085	$552	2%	0%
South	Retail	5,290	$2,268,455	$429	2%	0%
	Light industrial area	41,480	$17,787,431	$429	13%	2%
Beachfront South	Caravan Park	9,270	$6,192,213	$668	4%	1%
	Caravan Park	28,600	$19,104,348	$668	14%	3%
	Warehouse	6,140	$4,101,423	$668	3%	1%
Total	All	268,915	$139,768,059	$520	100%	19%

Source: FAR Lane, 2023.

Community benefits for Lancelin are at Table 20. FTE numbers and wages have been calculated by applying the median wages by industry type to total resident jobs, for industries prevalent in the townsite.[10]

Table 20 – Community benefit in Lancelin

	Units	Households	Per unit value	NPV (7% discount)
Wages	153 jobs	n/a	$350,929	$53,692,169
Beach Amenity	44 ha	950	$45	$1,868,275
Park Amenity	2 ha	950	$27	$71,561
Public Sector Revenue	n/a	950	$1,665	$22,596,429

Source: FAR Lane, 2023.

[10] Based on ABS Census 2021, resident industry of employment.

Infrastructure

Cost of replacement for current infrastructure in Lancelin is at Table 21.

Table 21 – Infrastructure value in Lancelin that will be impacted by inundation

Utility Type	Area Impacted (sqm)	Value/Unit	Value	Percent Total Utilities
Road (m2)	214,905	$23.64	$5,080,354	11.8%
Water Pipes (m)	20,904	$891.56	$18,637,200	43.4%
Sewerage Pipes (m)	3,750	$720.00	$2,700,000	6.3%
Overhead cables (m)	21,310	$325.23	$6,930,600	16.1%
Underground cables (m)	9,608	$276.00	$2,651,670	6.2%
Underground Structures (m)	1,330	$720.00	$957,600	2.2%
Power Poles (count)	800	$7,500.00	$6,000,000	14.0%
Total			$42,957,424	100.0%

Source: FAR Lane, 2023.

The analysis indicates the estimated cost of replacement for current infrastructure in Lancelin at $43 million.

Summary of all owner and community benefit that will be impacted by coastal inundation in Lancelin is at Table 4.

Table 22 - Summary of economic value in Lancelin that will be impacted by inundation

Beneficiary / community benefit	Value of benefit	Percentage of total benefit
Private dwellings	$ 557,037,308	71.9%
Private commercial assets	$ 139,768,059	18.0%
Community amenity – beach, park	$ 1,939,837	0.3%
Public sector revenue - rates	$ 22,596,429	2.9%
Economic activity - wages	$ 53,692,169	6.9%
Total	**$ 775,033,802**	**100%**

Source: FAR Lane, 2023.

The analysis indicates that approximately $775 million of economic value will potentially be lost to inundation in Lancelin over the next 100 years, with the estimated cost of replacement for current infrastructure in Lancelin at $43 million.

Short-term interventions are possible to extend the enjoyment of the coastal lifestyle but are likely to be sacrificial in the long term, and any planning should be cognisant of this.

Notwithstanding, should any protection be proposed to mitigate the risk of flooding, 90% of the benefit of providing coastal hazard adaptation would be apportioned to private interests.

9.2 Detailed beneficiary analysis – Ledge Point

As noted in section 5.3, Ledge Point will potentially incur:

- High erosion vulnerability at 2070 for some residential, commercial, dunes and vegetation areas.
- Low to medium risk of inundation 500 year ARI for some dunes and vegetation areas.

LP1 management unit

LP1 is anticipated to experience no affect to benefits for private dwellings, private commercial assets, public sector revenues (rates), economic activity (wages), or infrastructure. Community benefits for LP1 are at Table 23.

Table 23 – Community benefit in Ledge Point LP1

	Units	Households	Per unit value	NPV (4% discount)
Beach Amenity	7.5 ha	473	$45	$159,132

Source: FAR Lane, 2023.

Summary of all owner and community benefits for LP1 is at Table 24.

Table 24 - Summary of all benefits for Ledge Point LP1

Beneficiary / community benefit	Value of benefit	Percentage of total benefit
Private dwellings	$ 0	0%
Private commercial assets	$ 0	0%
Community amenity	$159,132	100%
Public sector revenue - rates	$ 0	0%
Economic activity	$ 0	0%
Total	$159,132	100%

Source: FAR Lane, 2023.

The analysis indicates all benefits in LP1 will go to community amenity, as only natural areas will be affected by erosion or inundation. The benefit of providing coastal hazard adaptation would therefore be considered primarily a shared community benefit, with the entire community obliged to contribute to the response.

The estimated cost of replacement for current infrastructure in the Ledge Point LP1 is zero, as none of the infrastructure categories considered is anticipated to be affected by inundation or erosion.

LP2 management unit

LP2 is anticipated to experience no affect to benefits for private commercial assets or economic activity (wages). Private dwelling benefits for LP2 are at Table 25.

Table 25 - Private dwelling benefits for Ledge Point LP2

	Dwellings	Area (sqm)	Area Impacted (sqm)	NPV	Value/sqm	Average Annual GRV	Percent	Percent - Total Assets
LP2	21	22,336	15,101	$15,299,306	$685	$728,538	100%	97%

Source: FAR Lane, 2023.

Community benefits for LP2 are at Table 26.

Table 26 – Community benefit in Ledge Point LP2

	Units	Households	Per unit value	NPV
Beach Amenity	5 ha	473	45	$106,534
Public Sector Revenue	n/a	21	1,665	$499,500

Source: FAR Lane, 2023.

Cost of replacement for current infrastructure in LP2 is at Table 27.

Table 27 – Cost of replacement for current infrastructure in Ledge Point LP2

Utility Type	Area Impacted (sqm)	Value/Unit	Value	Percent Total Utilities	Percent of Total Assets
Road (m2)	576	$24	$13,615	3%	0%
Water Pipes (m)	38	$891	$689	0%	0%
Sewerage Pipes (m)	0	$720	0	0%	0%
Overhead cables (m)	0	$325	0	0%	0%
Underground cables (m)	0	$276	0	0%	0%
Underground Structures (m)	0	$720	0	0%	0%
Power Poles (count)	0	$7,500	0	0%	0%
Public amenities (toilets)[11]	1139	$379	$431,610	97%	3%
Total	1753	0	$445,914	100%	3%

Source: FAR Lane, 2023.

The analysis indicates the estimated cost of replacement for current infrastructure in Ledge Point LP2 at $446,000.

[11] Inclusive of a car park valued at $23.64 per sqm and public toilets at $3,600 per sqm (regional indexed costs) – Rawlinsons Construction Cost Guide, 2022.

Summary of all owner and community benefits for LP2 is at Table 28.

Table 28 - Summary of all benefits for Ledge Point LP2

Beneficiary / community benefit	Value of benefit	Percentage of total benefit
Private dwellings	$15,299,306	96.2%
Private commercial assets	$0	0.0%
Community amenity - beach	$106,534	0.7%
Public sector revenue - rates	$499,500	3.1%
Economic activity	$0	0.0%
Total	**$15,905,340**	**100%**

Source: FAR Lane, 2023.

The analysis indicates the majority of benefits in LP2 will go to private dwellings. 96% of the benefit of providing coastal hazard adaptation would therefore be apportioned to private interests.

The estimated cost of replacement for current infrastructure in Ledge Point LP2 is approximately $446,000.

LP3 management unit

LP3 is anticipated to experience no affect to benefits for private commercial assets or economic activity (wages).

Private dwelling benefits for LP3 are at Table 29.

Table 29 - Private dwelling benefits for Ledge Point LP3

	Dwellings	Area (sqm)	Area Impacted (sqm)	NPV	Value/sqm	Average Annual GRV	Percent	Percent - Total Assets
LP3	6	5530	411	$3,787,932	685	631322	1	1

Source: FAR Lane, 2023.

Community benefits for LP3 are at Table 30.

Table 30 – Community benefit in Ledge Point LP3

	Units	Households	Per unit value	NPV
Beach Amenity	5 ha	473	$45	$95,377
Park Amenity	1 ha	473	$27	$17,669
Public Sector Revenue	n/a	6	$1,665	$142,714

Source: FAR Lane, 2023.

Cost of replacement for current infrastructure in LP3 is at Table 31.

Table 31 – Cost of replacement for current infrastructure in Ledge Point LP3

Utility Type	Area Impacted (sqm)	Value/Unit	Value	Percent Total Utilities
Road (m2)	4831	$24	$114,207	33%

Water Pipes (m)	171	$720	$123,170	35%
Sewerage Pipes (m)	0	0	0	0%
Overhead cables (m)	206	$276	$56,718	16%
Underground cables (m)	0	0	0	0%
Underground Structures (m)	0	0	0	0%
Power Poles (count)	**7**	**$7,800**	**$54,600**	**16%**
Total			**$348,695**	**100%**

Source: FAR Lane, 2023.

The analysis indicates the estimated cost of replacement for current infrastructure in Ledge Point LP3 at approximately $349,000.

Summary of all owner and community benefits for LP3 is at Table 32.

Table 32 - Summary of all benefits for Ledge Point LP3

Beneficiary / community benefit	Value of benefit	Percentage of total benefit
Private dwellings	$3,787,932	93.7%
Private commercial assets	$0	0.0%
Community amenity (beach, park)	$113,046	2.8%
Public sector revenue - rates	$142,714	3.5%
Economic activity	$0	0.0%
Total	**$4,043,692**	**100%**

Source: FAR Lane, 2023.

The analysis indicates the majority of benefits in LP3 will go to private dwellings. 94% of the benefit of providing coastal hazard adaptation would therefore be apportioned to private interests, who should be obliged to contribute to protection measures.

The estimated cost of replacement for current infrastructure in the Ledge Point LP3 is approximately $114,000.

LP4 management unit

LP4 is anticipated to experience no affect to benefits for private dwellings, private commercial assets, public sector revenues (rates), economic activity (wages), or infrastructure. Community benefits for LP4 are at Table 33.

Table 33 – Community benefit in Ledge Point LP4

	Units	Households	Per unit value	NPV (4% discount)
Beach Amenity	4 ha	473	$45	$79,937

Source: FAR Lane, 2023.

Summary of all owner and community benefits for LP4 is at Table 34.

Table 34 - Summary of all benefits for Ledge Point LP4

Beneficiary / community benefit	Value of benefit	Percentage of total benefit
Private dwellings	$ 0	0%
Private commercial assets	$ 0	0%
Community amenity - beach	$79,937	100%
Public sector revenue - rates	$ 0	0%
Economic activity	$ 0	0%
Total	**$79,937**	**100%**

Source: FAR Lane, 2023.

The analysis indicates all benefits in LP4 will go to community amenity, as only natural areas will be affected by erosion or inundation. The benefit of providing coastal hazard adaptation would therefore be considered primarily a shared community benefit, with the entire community obliged to contribute to the response.

The estimated cost of replacement for current infrastructure in the Ledge Point LP4 is zero, as no infrastructure is anticipated to be affected by inundation or erosion.

9.3 Detailed beneficiary analysis – Seabird

As noted in section 5.4, Sea Bird will potentially incur:

- High erosion vulnerability at 2070 for some recreational, parks and residential areas.
- Low to medium risk of inundation 500 year ARI for some parks and residential areas.

SE1 management unit

Private dwelling benefits for SE1 are at Table 35.

Table 35 - Private dwelling benefit for Seabird SE1

Value unit	Dwellings	Area (sqm)	Area Impacted (sqm)	NPV	Value/sqm	Average Annual GRV	Percent	Percent - Total Assets
Turner Beachfront	11	11825	10083	$3,122,679	$264	$283,880	25%	23%
McCormick South	8	9804	3821	$5,579,167	$569	$697,396	44%	42%
McCormick Central	9	6982	2897	$3,839,613	$550	$426,624	31%	29%

Total	28	28612	16802	$12,541,459	$438	$469,300	100%	94%

Source: FAR Lane, 2023.

SE1 includes a café with a GRV of $15,116.[12] Commercial benefits for SE1 are at Table 36.

Table 36 – Commercial benefit for Seabird SE1

Beneficiary	NPV of Benefit	% of Total Owner Benefit
Private Commercial - cafe	$377,899	3%

Source: FAR Lane, 2023.

Community benefits for SE1 are at Table 37. FTE numbers have been calculated by applying jobs to area ratio[13] with wages applied from hospitality industry award.[14]

Table 37 – Community benefit in Seabird SE1

	Units	Households	Per unit value	NPV
Wages	2 jobs	n/a	$21,353	$610,094
Beach Amenity	6 ha	295	$45	$81,294
Public Sector Revenue	n/a	27	$1,665	$1,123,875

Source: FAR Lane, 2023.

Cost of replacement for current infrastructure in SE1 is at Table 38.

Table 38 – Cost of replacement for current infrastructure in Seabird SE1

Utility Type	Area Impacted (sqm)	Value/Unit	Value	Percent Total Utilities
Road (m2)	10,636	$24	$251,438	30%
Water Pipes (m)	465	$623	$289,800	35%
Sewerage Pipes (m)	0	0	0	0%
Overhead cables (m)	207	$276	$57,218	7%
Underground cables (m)	189	$276	$52,095	6%
Underground Structures (m)	156	$720	$112,032	13%
Power Poles (count)	9	$7,800	$70,200	8%
Total			**$832,783**	**100%**

Source: FAR Lane, 2023.

[12] Café lies within the McCormick Central value unit and hence is valued at the same GRV per sqm as per Landgate GRV estimates, July 2022.
[13] Land Use and Employment Survey (LUES) 2015/17 – City of Wanneroo - Two Rocks.
[14] Fair Work Ombudsman, Hospitality Industry (General) Award 2020.

The analysis indicates the estimated cost of replacement for current infrastructure in Seabird SE1 at approximately $833,000.

Summary of all owner and community benefits for SE 1 is at Table 39.

Table 39 - Summary of all benefits for Seabird SE1

Beneficiary / community benefit	Value of benefit	Percentage of total benefit
Private dwellings	$12,526,343	88.0%
Private commercial assets (cafe)	$377,899	2.7%
Community amenity	$81,294	0.6%
Public sector revenue - rates	$642,214	4.5%
Economic activity – wages for 2 FTE	$610,094	4.3%
Total	**$14,237,844**	**100%**

Source: FAR Lane, 2023.

The analysis indicates the majority of benefits in SE1 will go to private dwelling owners. 88% of the benefit of providing coastal hazard adaptation would therefore be apportioned to private interests, who should be obliged to contribute to protection measures.

The estimated cost of replacement for current infrastructure in the Seabird SE1 is approximately $833,000.

SE2 management unit

Please note that SE2 contains a strata block caravan park with 180 individual sites which this report treats as a single lot.

Private dwelling benefits for SE2 are at Table 40.

Table 40 - Private dwelling benefits for Seabird SE2

Value Unit	Dwellings	Area (sqm)	Area Impacted (sqm)	NPV	Value/sqm	Average Annual GRV	Percent	Percent - Total Assets
Strata	180	55,928	16,455	$25,783,302	$461	$469,300	92%	92%
Williams Way	1	890	890	$536,562	$603	$536,562	2%	2%

Source: FAR Lane, 2023.

SE2 includes a tavern with a GRV of $65,834.[15] Commercial benefits for SE2 are at Table 41.

Table 41 – Commercial benefit for Seabird SE2

Beneficiary	NPV of Benefit	% of Total Owner Benefit
Private commercial - tavern	$1,645,844	6%

Source: FAR Lane, 2023.

[15] Tavern valued as per GRV figure for 22 McCormick Street, as estimated by Landgate, July 2022.

Community benefits for SE2 are at Table 42. FTE numbers and wages have been calculated with the same method as the café in SE1.

Table 42 – Community benefit in Seabird SE2

Benefit	Units	Households	Per unit value	NPV
Wages (tavern)	10 jobs	n/a	$21,353	$3,050,469
Beach Amenity	13 ha	295	$45	$171,309
Public Sector Revenue	n/a	182	$1,166	$3,031,600

Source: FAR Lane, 2023.

Cost of replacement for current infrastructure in SE2 is at Table 43.

Table 43 – Cost of replacement for current infrastructure in Seabird SE2

Utility Type	Area Impacted (sqm)	Value/Unit	Value	Percent Total Utilities
Road (m2)	2,307	$24	$54,541	57%
Water Pipes (m)	0	$-	$-	0%
Sewerage Pipes (m)	0	0	0	0%
Overhead cables (m)	90	$276	$24,840	26%
Underground cables (m)	0	0	0	0%
Underground Structures (m)	0	0	0	0%
Power Poles (count)	2	$7,800	$15,600	16%
Total			$94,981	100%

Source: FAR Lane, 2023.

The analysis indicates the estimated cost of replacement for current infrastructure in Seabird SE2 at approximately $95,000.

Summary of all owner and community benefits for SE2 is at Table 44.

Table 44 - Summary of all benefits for Seabird SE2

Beneficiary / community benefit	Value of benefit	Percentage of total benefit
Private dwellings	$26,319,863	76.9%
Private commercial assets (tavern)	$1,645,844	4.8%
Community amenity	$167,162	0.5%
Public sector revenue - rates	$3,031,600	8.9%
Economic activity – wages for 10 FTE	$3,050,469	8.9%

Total	$34,214,938	100%

Source: FAR Lane, 2023.

The analysis indicates the majority of preserved benefits in SE2 will go private dwelling owners (particularly in the caravan park strata).

82% of the benefit of providing coastal hazard adaptation would therefore be apportioned to private interests, who should be obliged to contribute to protection measures.

The estimated cost of replacement for current infrastructure in the Seabird SE2 is approximately $95,000.

9.4 Detailed beneficiary analysis – Guilderton

As noted in section 5.2, Guilderton will potentially incur:

- High erosion vulnerability at 2070 for some recreational, parks and residential areas.
- Low to medium risk of inundation for 500-year ARI for some parks and future development areas.

Guilderton Foreshore management unit

Guilderton Foreshore is anticipated to experience no affect to benefits for private dwellings, private commercial assets, public sector revenues (rates), or economic activity (wages). Community benefits for Guilderton Foreshore are at Table 45.

Table 45 – Community benefit in Guilderton Foreshore

	Units	Households	Per unit value	NPV (4% discount)
Beach Amenity	13 ha	473	$45	$264,414

Source: FAR Lane, 2023.

Cost of replacement for current infrastructure in Guilderton Foreshore is at Table 46.

Table 46 – Cost of replacement for current infrastructure in Guilderton Foreshore

Utility Type	Area Impacted (sqm)	Value/Unit	Value	Percent Total Utilities
Road (m2)	14,851	$24	$351,078	98%
Water Pipes (m)	0	0	0	0%
Sewerage Pipes (m)	0	0	0	0%
Overhead cables (m)	0	0	0	0%
Underground cables (m)	0	0	0	0%
Underground Structures (m)	0	0	0	0%

Power Poles (count)	1	$7,800	$7,800	2%
Total			**$358,878**	**100%**

Source: FAR Lane, 2023.

The analysis indicates the estimated cost of replacement for current infrastructure in Guilderton Foreshore at approximately $359,000.

Summary of all owner and community benefits for Guilderton Foreshore is at Table 47.

Table 47 - Summary of all benefits for Guilderton Foreshore

Beneficiary / community benefit	Net Present Value of benefit	Percentage of total benefit
Private dwellings	$ 0	0%
Private commercial assets	$ 0	0%
Community amenity - beach	$264,413	100%
Public sector revenue - rates	$ 0	0%
Economic activity	$ 0	0%
Total	**$264,413**	**100%**

Source: FAR Lane, 2023.

The analysis indicates all benefits in Guilderton Foreshore will go to community amenity, as no residential or commercial properties will be affected by erosion or inundation. The benefit of providing coastal hazard adaptation would therefore be considered primarily a shared community benefit, with the entire community obliged to contribute to the response.

The estimated cost of replacement for current service infrastructure in the Guilderton Foreshore is approximately $359,000.

It should be noted that some private residential development will be impacted by erosion beyond 2070, and that this development would eventually benefit from coastal hazard protection measures.

Moore River management unit

Guilderton Foreshore is anticipated to experience no affect to benefits for private dwellings, private commercial assets, public sector revenues (rates), or economic activity (wages). Community benefits for Moore River are at Table 48.

Table 48 – Community benefit in Moore River

	Units	Households	Per unit value	NPV (4% discount)
River Amenity	31 ha	473	$25	$357,275

Source: FAR Lane, 2023.

Cost of replacement for current infrastructure in Moore River is at Table 49.

Table 49 – Cost of replacement for current infrastructure in Moore River

Utility Type	Area Impacted (sqm)	Value/Unit	Value	Percent Total Utilities
Road (m2)	8,854	$24	$209,309	93%
Water Pipes (m)	0	0	0	0%
Sewerage Pipes (m)	0	0	0	0%
Overhead cables (m)	0	0	0	0%
Underground cables (m)	0	0	0	0%
Underground Structures (m)	0	0	0	0%
Power Poles (count)	2	$7,800	$15,600	7%
Total			$224,909	100%

Source: FAR Lane, 2023.

The analysis indicates the estimated cost of replacement for current infrastructure in Guilderton Foreshore at approximately $225,000.

A summary of all owner and community benefits for Moore River is at Table 50.

Table 50 - Summary of all benefits for Moore River

Beneficiary / community benefit	Net Present Value of benefit	Percentage of total benefit
Private dwellings	$ 0	0%
Private commercial assets	$ 0	0%
Community amenity - beach	$357,275	100%
Public sector revenue - rates	$ 0	0%
Economic activity	$ 0	0%
Total	**$357,275**	**100%**

Source: FAR Lane, 2023.

The analysis indicates all benefits in Moore River will go to community amenity, as no residential or commercial properties will be affected by erosion or inundation. The benefit of providing coastal hazard adaptation would therefore be considered primarily a shared community benefit.

The estimated cost of replacement for current service infrastructure in the Moore River is approximately $225,000.

10 GLOSSARY OF KEY TERMS AND ACRONYMS

Amenity - an asset, facility or place that is a desirable or useful feature of a given area, which individuals find value in having access to. Includes natural environments such as beaches, waterways or parklands.

Benefit Distribution Analysis – a method of systematically estimating benefits to different parties from an action.

Benefit - the continued existence and operation of an asset, at its existing full functionality, landholding, service, or economic/commercial outcome as at the time of the BDA.

CHRMAP - Coastal Hazard Risk Management and Adaptation Plan.

Commercial benefit – benefit that sustains a commercial return from an intervention that preserves a business location.

Community amenity – see amenity.

Economic activity – wages generated by Full Time Equivalent jobs.

Erosion - Coastlines composed primarily of loose sediment (such as beaches) recede until a new equilibrium shoreline is found further inland. This report considers predicted erosion levels at 2070.

GRV – Gross Rental Value. The value expected to be gained from renting a property to a tenant/lessee.

Infrastructure – as defined in section 8.5.

Intervention – a deliberate action to avoid coastal hazards to townships that are deemed a risk to a community. Includes consideration of options to 'avoid' impact, 'retreat', 'accommodate' or to 'protect'. Gingin already has experience in this space, with the community of Seabird having a seawall installed to mitigate the immediate effects of erosion (protect).

Inundation - Storm surges and increased mean sea levels will create flooding in areas adjacent to shorelines. The risk zone is measured based on 500-year average return interval (ARI) storms, combined with 100 years of sea level rise.

Management unit – a sub-unit of a community which allows for the required level of detail for assessment under the BDA (see section 8.2).

Net Present Value in perpetuity – difference in present value of cash inflows and present value of cash outflows, that will exist in perpetuity.

Private dwelling benefit – benefit value from an intervention that protects a private dwelling.

Value unit - logical groupings at the sub-management unit level based on groupings of adjoining residential / commercial sites with comparable gross rental values.


Photo Point