Shire of Northampton

Horrocks Beach CHRMAP

October 2020

Executive summary

Horrocks was established in the late 1800s as a coastal holiday town through the grant of the land by the then owner of the adjoining pastoral property. Subsequently, Horrocks also became a popular safe harbour with the cray fishing fleet during the season as a consequence of the protected water offered within the bay at Horrocks and the adjacent Little Bay to the north. The coastal town and environment of Horrocks support a diversity of important infrastructure and land use assets, including transport, services and community infrastructure, urban land, and the coastal foreshore reserve. These are assets strongly valued by the community:

- for recreation opportunities
- as a social space to meet and interact
- for its cultural value
- for its character, sense of place and scenic landscape
- as an ecosystem and place of biodiversity
- as a commercial economic resource
- as a personal economic resource

Horrocks Beach is vulnerable to coastal processes, including erosion and inundation. Over time, the area will become increasingly vulnerable to the impacts of sea level rise and storm surges which will impact on the ability of the beach to recover from storm events. This Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) identifies and considers coastal hazards and risks for Horrocks culminating in a series of recommendations to assist in adapting to immediate, medium and long term coastal inundation and erosion risks.

Based on the hazard assessment (refer to Appendix C), coastal erosion presents an immediate level of intolerable risk to individual assets that requires ongoing risk management, particularly:

- Boat launch facilities
- A portion of Glance Cove
- Jetty Beach
- Universal beach access

Current erosion risk in Horrocks is currently being actively mitigated by a geotextile seawall, revegetation projects, and management of the boat launch facilities.

In the medium term (to 2050), erosion hazards are likely to put increasing risk on assets and private property within Horrocks. By 2120, erosion risk is modelled to present intolerable risk to the majority of the Horrocks settlement.

It is not possible to ascertain the viability of interim protection for the long term, as this judgement is made based on the social, environment and cost viability which cannot be determined based on current values. However, the financial cost of interim protection to protect only a portion of the town is likely to be greater than the financial value of land and assets that would be protected. The scale of infrastructure required to protect the entirety of the Horrocks settlement, taking into account sea level rise to 2120, would likely be of a scale that would not be consistent with social values, and would be expected to significantly alter the coastal environment. This may make the ongoing presence of a town in this location unviable in the long term. Relocating the town should therefore be discussed as a potential long term scenario even though implementation is not required on a town-site scale currently.

In the short to medium term, an evaluation of adaptation options suggests that ongoing interim protection in Horrocks may be viable based on social and environmental criteria, therefore potentially delaying the need to commence relocation of the town to beyond 2050. However, the cost implications are considerable, with the cost of interim protection potentially exceeding the financial value of land and assets that would be afforded the interim protection. A feasibility study is recommended, therefore, to confirm if the financial cost of interim protection is a feasible endeavour considering the temporary design life of interim protection and the social and environmental values of the assets to be protected. This investigation is required to confirm whether cost implications of interim protection are viable for a community the size of Horrocks, and the willingness and ability of the Shire and community to meet those costs.

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Appendices

1. Introduction

Horrocks Beach Townsite is located on the Mid-West coast, approximately 20 kilometres west by road of Northampton and approximately 70 kilometres north of Geraldton, within the Shire of Northampton.

Horrocks was established in the late 1800s as a coastal holiday town through the grant of the land by the then owner of the adjoining pastoral property. The land was granted to the Shire to facilitate the establishment and management of a coastal holiday destination for farm families and residents of the district.

Subsequently, Horrocks also became a popular safe harbour with the cray fishing fleet during the season as a consequence of the protected water offered within the bay at Horrocks and the adjacent Little Bay to the north.

In 2013 the Western Australian Planning Commission acknowledged the importance of planning our coastal settlements in a manner that addresses current and future risks of coastal erosion and inundation through State Planning Policy 2.6 State Coastal Planning Policy. The policy recommends the development of coastal hazard risk management and adaptation plans (CHRMAP). This CHRMAP has been prepared for Horrocks to specifically consider:

- Immediate (2019), short (to 2030), medium (2050, 2070) and long-term (2090, 2120) planning timeframes
- Almost certain, possible and rare scenarios
- Projected impact of climate change
- Other requirements of SPP2.6, particularly with regard to coastal foreshore reserve requirements and coastal risk management.

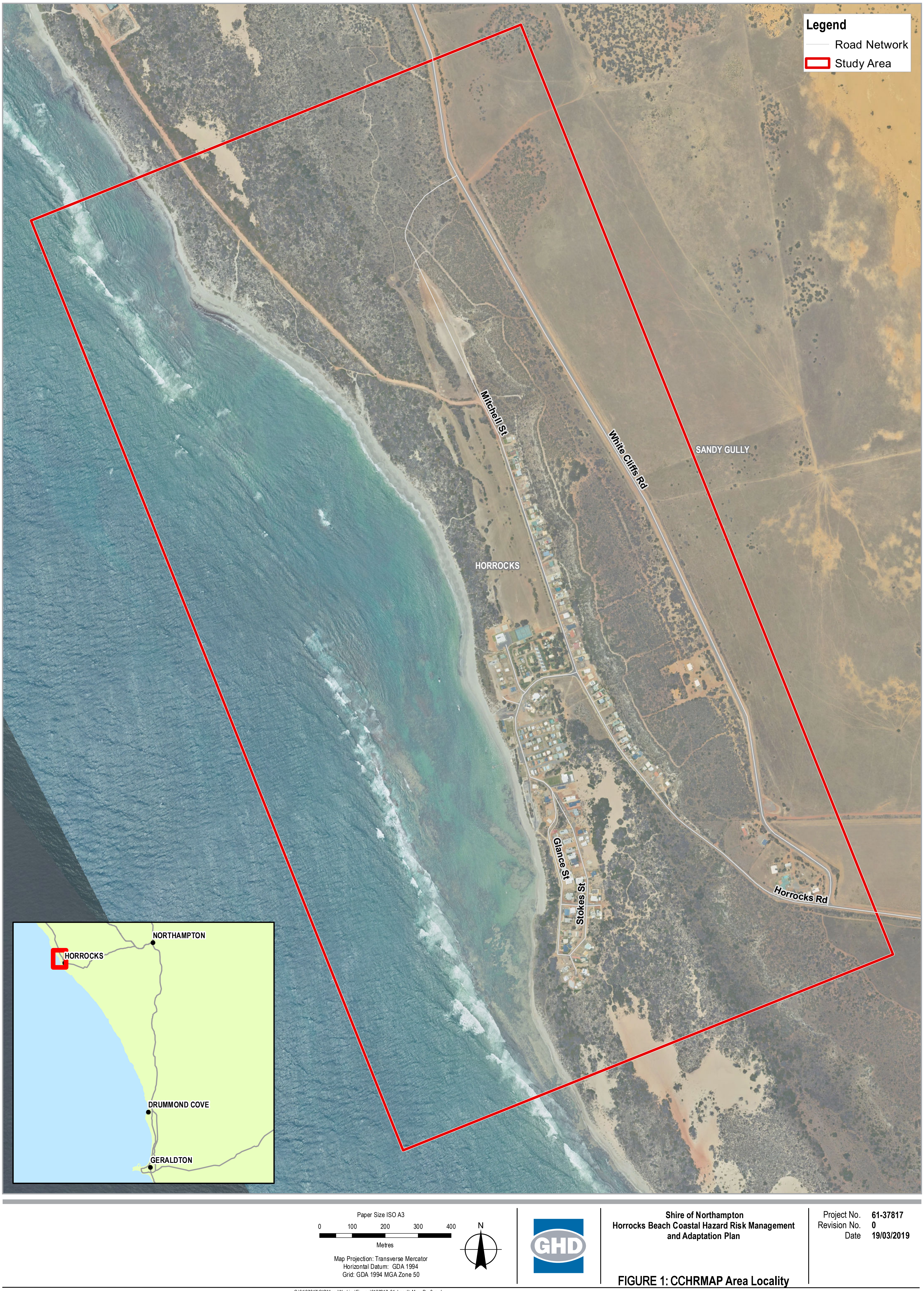
1.1 Purpose of the plan

The purpose of this CHRMAP is to provide a coastal management decision-making framework to adapt to coastal inundation and erosion risks for immediate, short, medium and long-term timeframes for coastal areas in Horrocks Beach.

As the Shire of Northampton and the Department of Planning, Lands and Heritage and the community learn more and understand more about how the coast and waterfront area will change in the future, this CHRMAP and recommended adaptation responses will need to be reviewed and updated to reflect and respond to the values, aspirations, and learnings of the community and stakeholders.

The CHRMAP area is defined as the foreshore and infrastructure along the Horrocks Beach shoreline (Figure 1).

This plan has been prepared for implementation through local planning frameworks and capital works programs, including the Shire of Northampton's Local Planning Scheme and Corporate Business Plan.



Shire of Northampton
Horrocks Beach Coastal Hazard Risk Management and Adaptation Plan

Project No.	**61-37817**
Revision No.	**0**
Date	**19/03/2019**

FIGURE 1: CCHRMAP Area Locality

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The plan can be used by the key stakeholders for their asset management activities now and in the future.

In the immediate and short-term (to 2030), this plan provides recommended management actions to conserve the functional and natural coastal values, and for sustainable land use and development. Where possible, the development of immediate and short-term management actions should not limit future management options unless there is justification based on these values.

In the medium to long-term (2030-2120), this plan provides a long-term implementation framework to incorporate adaptation planning into the Shire of Northampton's land use planning framework and long-term financial plan.

1.2 Objectives

The objectives of the CHRMAP are to:

- Improve understanding of coastal features, processes and hazards in the Horrocks Beach area
- Gain an understanding of the vulnerability of the Horrocks Beach foreshore area to coastal processes
- Identify vulnerability trigger points and respective timeframes for each foreshore area to identify the need for immediate or medium-term risk management and adaptation
- Identify assets (natural and man-made) and their services and functions situated in the coastal zone
- Identify the value of at-risk-assets that are vulnerable to adverse impacts from coastal hazards
- Determine the likelihood and consequence of the adverse impacts from coastal hazards on assets, and assign a level of risk
- Identify possible (effective) management and adaptation measures (or 'actions') and how these can be incorporated into short and long-term decision-making.

1.3 Planning context

This CHRMAP sits within the local planning framework and provides guidance to the Shire to develop a strategic planning framework that adequately responds to coastal vulnerability over time.

1.3.1 State Planning Policy 2.6 State Coastal Planning Policy

State Planning Policies (SPPs) are prepared by the Western Australian Planning Commission and guide all local planning strategies, schemes and decisions. SPP2.6 provides a range of policy measures that require planning authorities to consider the long-term nature of coastal processes in decision-making and sets the framework for coastal adaptation and risk management to inform decision-making.

This CHRMAP, prepared in accordance with SPP2.6 and associated policy guidelines, provides a blueprint for local planning frameworks to deliver the requirements of the policy. SPP2.6 recognises that in certain circumstances development may need to occur within an area identified to be potentially impacted by physical coastal processes within the planning timeframe. Such a development should always be considered within a coastal hazard risk management and adaptation planning process, should only proceed once adequate management and adaptation planning measures have been agreed to including stipulation of the Avoid – Planned or Managed Retreat - Accommodate – Protect hierarchy in the SPP2.6 Policy Measures.

For example, SPP2.6 allows for development within the foreshore reserve when there is an expected useful lifespan of less than 30 years for public recreation purposes on the proviso that the development be removed or modified should it be threatened by erosion or creates an erosion threat to other land. Such development may include, for example, minor car parks for coastal recreational users, recreational amenities (e.g. public ablutions, barbeque/picnic/shade areas, playground and other recreational equipment), infrastructure for public safety, and pedestrian access structures (e.g. ramps, stairs and paths).

1.3.2 Horrocks Beach Local Planning Strategy

The purpose of local planning strategies is to set out the local government's objectives for future planning and development, which include a broad framework by which to pursue those objectives. The planning strategy is therefore the appropriate document to clearly enunciate the longer-term nature of the challenges arising from coastal hazards such as sea level rise and their associated effects on the coastline, and the Shire's response to those challenges.

The Shire's Horrocks Beach Local Planning Strategy was approved in October 2015 with the purpose of guiding future growth and development. The strategy seeks to establish an overall pattern of development that respects the key physical, environmental and social issues together with the reasonable expectations of the community and facilitates economic provision of services and infrastructure of Horrocks Townsite and the broader expansion area. The strategy supports the application of SPP2.6 and therefore the development of this CHRMAP.

The strategy proposes that the lower portions of the coastal region in Horrocks (Lot 20 (Cell 3)) be identified as a Coastal Investigation Area, however this is outside of the area covered by this CHRMAP.

This CHRMAP reviews the coastal hazards associated with Horrocks Beach. The effects of coastal hazards and risks identified in the CHRMAP area will be taken into account when assessing development and land use proposals. It is not appropriate to use this CHRMAP outside of this area.

1.3.3 Shire of Northampton Local Planning Scheme No. 10

The local planning scheme provides the statutory framework for land use in the Shire of Northampton. Informed by the local planning strategy, the local planning scheme will be a key tool to deliver land use and development that responds to the recommendations of the coastal hazards and risks.

The Local Scheme Reserves and Zones in Horrocks include (refer to Figure 2):

Local Scheme Zones

Residential

Town centre (subject to scheme amendment, to rezone to Commercial)

Special use

Caravan, camping and cabin

Local Scheme Reserves

Public Purposes – Dune preservation

Public Purposes –Ambulance, fire station and council depot

Public Purposes – Water supply, sewerage and drainage

Parks and Recreation

Other Categories

Special Control Area 6 – Horrocks development area (SCA6)

Special controls have been included in the local planning scheme to be applied in SCA6 with the intent to protect and enhance the environmental, cultural, recreational and/or scenic values of the area and ensure coordinated expansion through structure planning. A special control area for coastal planning and management (SCA1) is a mechanism included in the local planning scheme, however, has not been applied within Horrocks Beach at this time.

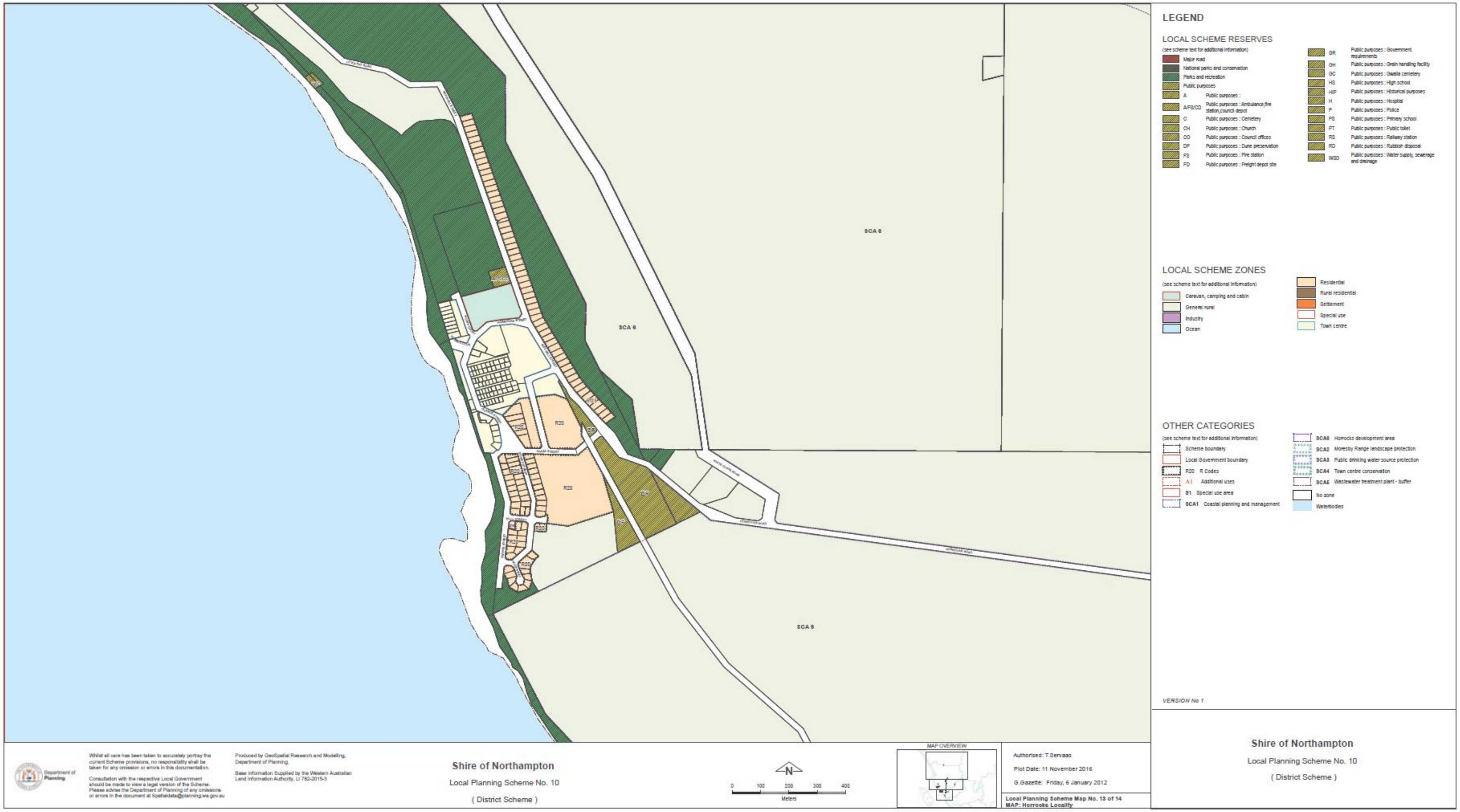

Figure 2 Local Planning Scheme Horrocks Locality (Department of Planning, Lands and Heritage)

1.4 Planning timeframes

The four planning periods used to assess coastal hazards, risks and develop adaptation plans align with the timeframes assessed in the Coastal Hazard Assessment – 2019, 2030, 2050, 2070, 2090 and 2120 (refer to Appendix C).

Planning periods	Outcome
Immediate term (2019):	Actions recommended to address current intolerable risks
Short term (2019 to 2030):	Actions recommended to address short term intolerable risks to 2030
Medium term (2030 to 2070):	Planning decisions, additional investigations and decision making required to address risks that will become intolerable between 2030 and 2070
Long term (2070 to 2120):	Planning approaches to assist the Shire prepare for long-term risks to 2120

The long-term planning period is comparable with the 100-year planning timeframe recommended in SPP2.6.

1.5 Limitations

This report: has been prepared by GHD for Shire of Northampton and may only be used and relied on by Shire of Northampton for the purpose agreed between GHD and the Shire of Northampton as set out in section 1.1 of this report.

GHD otherwise disclaims responsibility to any person other than Shire of Northampton arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Shire of Northampton and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The purpose of estimating the coastal hazards of erosion and inundation in this study is to assess the risks to coastal assets and values to assist in the analysis of coastal adaptation solutions and is not to be used for the purpose of determining coastal setback distances for new development.

Climate change is a significant current and future issue and effects, such as sea level rise, are at this time difficult to quantify to a high degree of certainty. The following assumptions have been made during the preparation of this report:

- The sole purpose of the reports are for evaluating coastal hazard risks and developing adaptation plans associated with coastal hazards and sea level rise for the Shire of Northampton.
- The data and processes herein are to be used for coastal hazard risk assessment and adaptation planning purposes, approved by the Shire of Northampton, and based on Australian and state government guidelines:
  - Western Australian Planning Commission and Department of Planning (2014). Coastal hazard risk management and adaptation planning guidelines, Perth, Australia.
  - Western Australian Planning Commission (2013). State Planning Policy No. 2.6 State Coastal Planning Policy.
  - Western Australian Planning Commission (2013), State Coastal Planning Policy Guidelines.

These guidelines have been considered as per the requirements of the brief. This information has not been independently verified. Assumptions and recommendations that need further testing are noted in the text of the report.

- The establishment of the sea level rise aspects of the project uses data and scenarios based on publicly available information by the Intergovernmental Panel on Climate Change and guidance by the Western Australian Department of Transport:
  - Bicknell (2010). Sea Level Change in Western Australia: Application to Coastal Planning, prepared by the Department of Transport, Fremantle, WA.
- Climate change and coastal hazard assessment by its nature is a dynamic and ongoing process. As the sea level rise projections used are uncertain by nature, it is possible that the effects that actually occur may not be as assumed and stated in this exercise. Therefore, it is recommended that the Shire of Northampton routinely incorporate the latest climate change science and sea level rise knowledge into all future planning.

2. Coastal Risk Management and Adaptation

2.1 An evolving coast

Horrocks Beach is vulnerable to coastal processes, including erosion and inundation. Over time, the area will become increasingly vulnerable to the impacts of sea level rise, storm surges and changes in sediment transport and natural sediment stores.

The two main processes considered in this area are erosion and inundation:

Erosion is the loss of sand. An eroding coastline refers to shoreline movement where the shoreline shifts landwards, potentially reducing the width of the coastal foreshore reserve or reducing the distance to fixed features on the land. Erosion is the result of either sediment moving offshore or sediment moving along the shore by waves and currents. Erosion can be a slow, seasonal process, such as sand moving from one end of a beach to the other and back over a year as a result of change in seasonal wind and wave directions. Alternatively, it can be sudden, resulting in sudden changes in the shape of the beach or vertical drops in the sand level, such as during storm events. Erosion is a natural process, balanced by the opposite process of accretion, the accumulation of sand, which causes beaches to replenish and rebuild over time in some instances, dependent on the nature and severity of the erosive event.

Inundation is the flow of water onto previously dry land. It may be either a permanent (for example permanent elevation of sea levels due to sea level rise) or temporary (flooding during a storm) occurrence. Excluding the regular short-term variations in water levels caused by tides, factors which may temporarily increase water levels include:

- Falling barometric pressure which causes the water surface to rise (inverse barometric effect)
- The action of wind and waves that can cause water to pile up against the coastline (setup)
- Waves breaking and pushing water up the beach face (wave run-up).

  (Department of Transport, 2010).

Our coastline is reacting and responding to changes in sea levels. In the immediate to medium planning period, it is expected that sea level rise will continue to be slow and linear, but by the latter half of this century, sea level rise rates are expected to accelerate. Increases in mean sea level will result in increased risk of inundation of low lying areas during storm events and migration of permanently inundated areas of the beach. These changes will be most noticeable on beaches with flat gradients. Increases in sea level will also contribute to higher water levels during extreme events, greatly increasing areas inundated by significant storm events, and increasing the potential frequency of inundation in areas that are already affected.

As mean and extreme water levels increase as a result of sea level rise, the areas of beaches that wave and tidal energy act upon will change and may result in increased rates of shoreline erosion in response. Areas most susceptible to erosion will be those most exposed to coastal processes (e.g. Horrocks Beach adjacent to the community kitchen) and those with limited dune areas for beach reshaping.

2.2 What is adaptation planning?

Horrocks Beach has always been a dynamic, changing environment. Coastal processes combined with the impacts of climate change (including more extreme storm events and sea level rise) will present increasing risks and impacts to the area – including social, environmental, and economic assets and values. Adaptation planning is preparing the most appropriate decisions and options to implement over time to manage the risks of erosion and inundation.

A risk management approach is increasingly used nationally and internationally to deal with potential adverse impacts of coastal hazards. A risk management and adaptation planning approach is a systematic way to identify and understand coastal hazard risks, and to implement controls and measures for the management of those risks in consultation with the community and stakeholders.

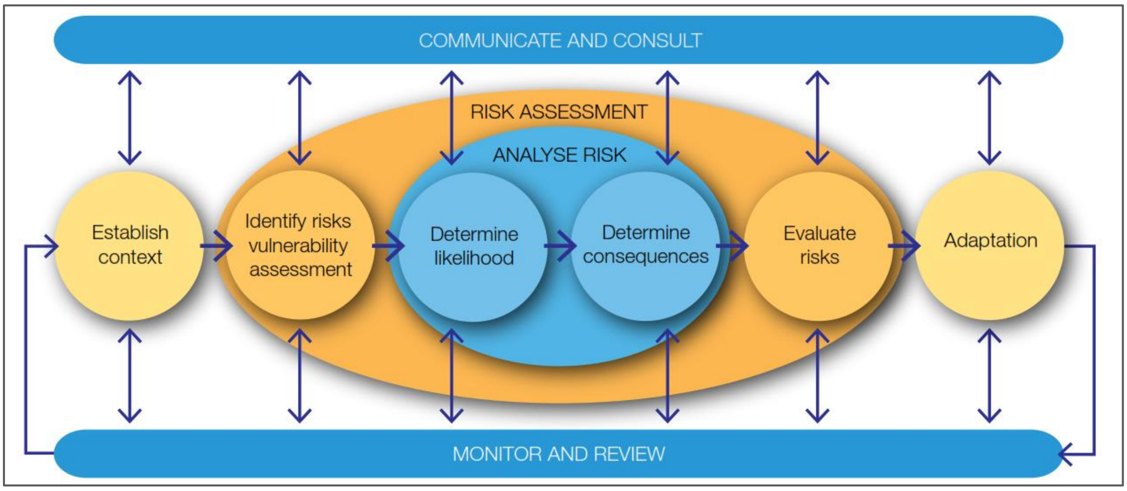

Figure 3 Risk management and adaptation process from the coastal hazard risk management and adaptation guidelines (WAPC, 2014)

SPP2.6 includes a requirement for 'responsible management authorities' to prepare CHRMAPs, where an existing or proposed development(s) is located in an area at risk from coastal hazards over a 100-year planning timeframe. Local government is the land manager for many coastal areas and so has been leading the development of CHRMAPs. For this CHRMAP, the land manager is either local government or private residential landholders. Where possible, and where known, the responsible parties are incorporated into the recommendations.

Irrespective of the lead for preparing adaptation plans, successful adaptation planning requires cooperation from all stakeholders and decision-makers involved. Key stakeholders and responsibilities for adaptation planning are shown in Table 1.

Table 1 Adaptation planning - roles and responsibilities

Role	Responsibility	Key Stakeholders
Planners and decision makers	Strategic planning responsibilities: • Prepare adaptation plan for coastal land within their management. • Inform asset owners and users about risk and decision-making. Decision-making responsibilities. • Make adaptation decisions on land and assets within their management/jurisdiction.	Western Australian Planning Commission Department of Planning, Lands and Heritage Shire of Northampton
Asset owners	Manage assets in the context of coastal risk. Undertake accommodation measures, where consistent with government decisions. Decommission and relocate assets where required by government decisions to retreat.	Private land owners Business owners and operators Shire of Northampton Infrastructure agencies
Other coastal users	Engage with decision makers regarding the values of the coast to inform decision-making.	Local community Day-trippers Tourists

2.3 Adaptation measures

There are four key options available when making decisions about managing erosion and inundation. These are:

- **Avoid** the construction of new public and private assets within areas identified to be impacted by coastal hazards by ensuring future development is located in areas that do not experience intolerable risk at some stage during the planning timeframe.
- **Retreat** (withdraw, relocate, abandon) assets and development away from the risk to allow land at risk to naturally experience erosion and/or inundation. Planned or managed retreat involves relocating or sacrificing public assets and private property, when erosion and recession impacts reach action trigger points (Figure 5). Large-scale strategic retreat will therefore require coordination and partnership between local government and private land owners whose landholdings will likely be affected by retreat decisions.
- **Accommodate** the risks (e.g. occasional flooding) through asset-specific design or retrofitting that enable an asset to continue to operate whilst being affected by coastal risks or impacts. In relation to inundation, this includes measures to enable an asset to manage occasional flooding, such as raising of habitable floor levels and emergency management plans.
- **Protect** assets through coastal engineering works to reduce the risks associated with the coastal hazards of erosion and inundation to land and assets. Protect risk treatment options should be primarily proposed in the public interest, and preserve beach and foreshore reserve amenity.

The most appropriate adaptation option may differ based on the values to be protected in a certain location, and the social, environmental and economic costs of the options. The Coastal Hazard Risk Management and Adaptation Planning Guidelines (WAPC, 2014) explain that the adaptation options should be considered as a hierarchy – the further down the hierarchy, the less flexibility there is to consider alternative adaptation measures. Effectively, these options become decisions for government and the community to make when planning for the future of coastal assets and land.

Figure 4 **Hierarchy of risk management and adaptation options (WAPC, 2014)**

The above four options are the key options for risk management in coastal areas, however, the Coastal Hazard Risk Management and Adaptation Planning Guidelines (WAPC, 2019) also include a **no regrets** option which covers the period while a range of assessments and works are required to determine the preferred treatment option. This is particularly important where there are costly or difficult risk treatment options.

Do nothing is also included as an option that assumes that all levels of risk are acceptable and no action will be taken. In reality this is unlikely to be the case, but it is useful to consider as a basis of for comparison.

2.4 Adaptation principles and strategic pathway

Adaptation planning is a very long-term process, and it is important to agree to a decision-making pathway to provide context and benchmarks for shorter-term decision-making.

The following principles, developed by GHD in 2015 for the purposes of coastal adaptation planning, underpin the adaptation planning process and guide the decision-making process set out in this adaptation plan. These principles are described in more detail in Appendix A.

Principle 1 **Adaptation planning in the current planning timeframe does not impede the ability of future generations to respond to increasing risk beyond current planning timeframes.**

Principle 2 **Adaptation requires a decision-making framework that enables the right decision to be made at the right time, in line with the values and circumstances of the time.**

Principle 3 **Adaptation planning reflects the public's interest in the social, environmental, and economic value of the coast.**

Principle 4 **Alternative adaptation measures should consider the full range of land uses and values.**

Principle 5 **The full life-cycle benefits, costs and impacts of coastal interim protection works should be evaluated when considering adaptation options.**

Informed by these adaptation principles, the most appropriate adaptation pathway to adapt to erosion and inundation on the Horrocks Beach foreshore is one that enables decision-making on adaptation measures to be made at the right time, in line with the values of that time. The pathway is shown in Figure 5.

The 'right times' for decision-making are called triggers. The trigger for a decision about erosion and inundation (avoid, retreat, accommodate, interim protection) is the time when the risk to assets and values increases from tolerable to intolerable. These triggers are shown and defined in the strategic pathway in Figure 5.

Successful long-term adaptation is achieved when decisions made now, in 20 years or in 50 years do not prevent the selection of other measures later, thereby retaining ongoing flexibility in decision-making consistent with the hierarchy of options. For example, at the end of the design life of interim protection structures, the full suite of adaptation options are reassessed, and the most appropriate measure for the values at the time is implemented. There may be a point in future when interim protection or accommodation are no longer viable due to social, environmental or economic costs. Therefore, even if we choose to accommodate or protect in the shorter-term, we need to undertake longer term strategic planning to prepare for possible retreat in the long-term.

As illustrated in Figure 5, the adaptation pathway provides a framework to deliver retreat measures on the most vulnerable coastal land in the long-term. The pathway also facilitates responsible interim adaptation measures that continue land uses where those measures are justified on social, economic and environmental grounds.

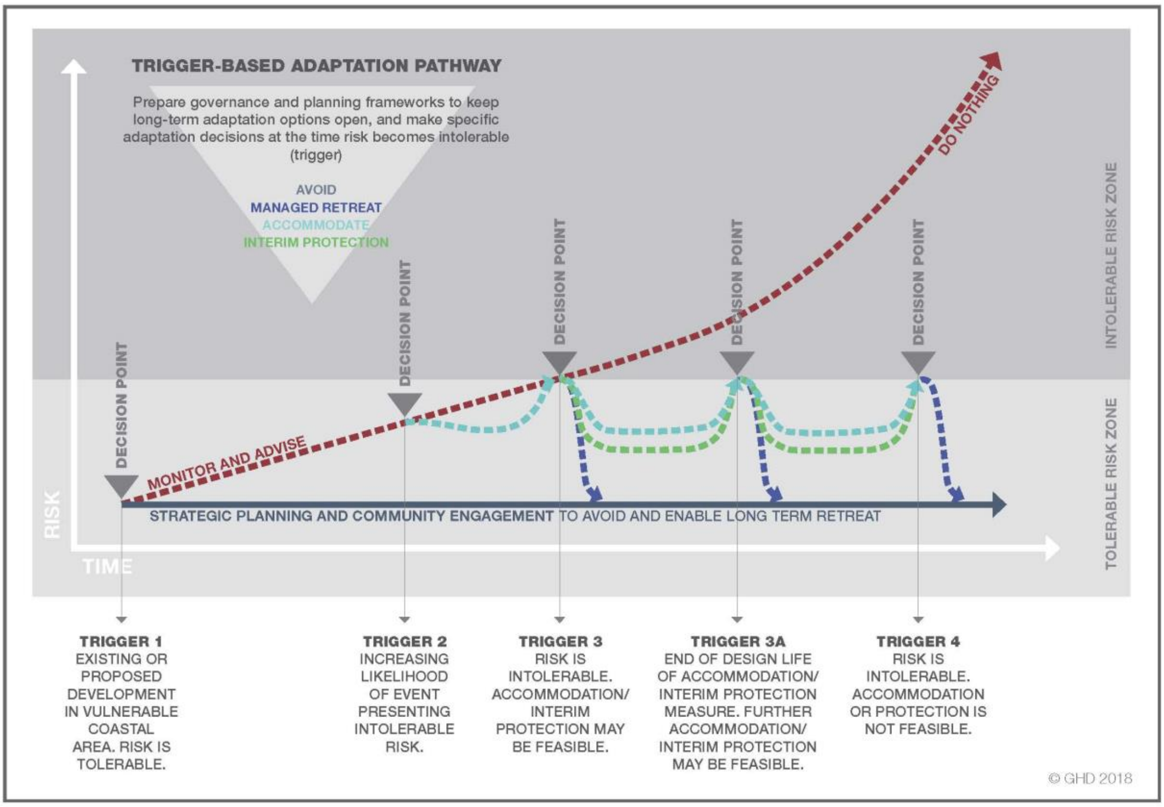

Figure 5 Coastal adaptation pathway

In line with the strategic adaptation pathway, this CHRMAP focuses on the two strategic areas of adaptation actions:

- Implement appropriate adaptation actions in response to immediate term triggers
- Develop strategic planning frameworks for flexibility in the medium and long-term.

This CHRMAP presents strategic planning measures to incorporate a flexible pathway into the short-term (2019-2030), medium-term (to 2070) and long-term (to 2120) planning timeframes. The plan identifies triggers for adaptation in the immediate and short term and recommends adaptation measures for further investigation and implementation.

2.5 Adaptation planning within Horrocks Beach

Historically, adaptation decisions have been made in Horrocks with the removal of the historical holiday shacks and tents in the late 1970s. This represents a retreat decision (as shown in Figure 5) due to the unsustainable location of the shacks. More recent decisions have focused on interim protection of the same site to protect current community values associated with the site (e.g. to protect the socialisation space that includes the community kitchen). Existing interim protection measures include:

- Geotextile sandbag seawall to the beach side of the community kitchen and to the south of the northern boat launch
- Revegetation of the sand dunes
- Wind fencing to build up sand.

Investment in this infrastructure effectively means that the decision point for trigger 3 (refer to Figure 5) has been reached and the decision made to provide interim protection to the assets/values within these areas. The next decision point will be at the end of the design life of this coastal protection infrastructure (trigger 3A in Figure 5).

Figure 6 Geotextile sandbag sea wall protection at Horrocks Beach (GHD, 2019)

3. Values associated with Horrocks Beach

The coastal setting and history associated with Horrocks is key to its character and community.

Determining the risk of coastal hazards, identifying triggers for adaptation and selecting the most appropriate adaptation responses is informed by the assets at risk, and the values of Horrocks Beach and coastline.

3.1 Assets at risk

Understanding the value of assets at risk alongside broader coastal values is important in coastal hazard risk management and adaptation planning. Managing risk to particular assets has to consider how risk management relates to broader coastal values. The most appropriate approach may need to balance the value of specific assets against broader coastal values. The following assets support a diversity of coastal values (which are described in section 3.2).

Individual assets are mapped in Figure 8.

3.1.1 Transport infrastructure

Transport infrastructure facilitates the movement of people and freight, which is vital for economic, cultural, and social exchange activities. Key transport infrastructure within the area includes:

- Local roads providing access to and from Horrocks
- Access roads to the water treatment plant and northern beaches
- Horrocks Beach jetty.

Transport infrastructure within Horrocks is strongly valued by the community; roads are the only way to access Horrocks for most visitors and users. Value is implied due to the importance of access to the beach and as the roads allow transport of goods such as crayfish out of Horrocks to be sold to Geraldton Fisherman's Co-Op Export.

Transport infrastructure provides the community access into and out of the place they live, work, play and do business and provides important pathways for evacuating from coastal hazards during extreme events.

3.1.2 Services infrastructure

Service infrastructure provides essential services to land use and development. Key service infrastructure within the area includes drinking water, reticulated sewerage, electrical, and telecommunications supply and distribution infrastructure.

Services infrastructure is generally located within road reserves. Key utilities are not specifically mapped within the CHRMAP area, however the associated road reserves are shown on the asset map in Figure 8. Services infrastructure assets within Horrocks are highly important for commercial (tourism) and residential uses and if road reserves are impacted by coastal hazards this may impact on how the area as a whole is used.

3.1.3 Community infrastructure

Community infrastructure is essential for community wellbeing and provides opportunities for community interaction.

Horrocks Beach supports key pieces of community infrastructure such as the Horrocks Beach Community Centre and community kitchen. The coastal foreshore provides important community infrastructure that facilitates community use and enjoyment of the area including:

- Footpaths
- Street/beach furniture
- Shaded pergolas (on the beach)
- Signage
- Playground and other recreation equipment e.g. fish cleaning station
- Change rooms and toilets
- Car parks.

Located adjacent to the coastal foreshore reserve is community infrastructure that is privately run:

- General store/café
- Caravan Park
- Holiday cottages/short-term tourist accommodation
- Community centre (leased from the Shire).

Specific coastal values (including environmental values) that are supported by the coastal foreshore reserve are described in the next section.

3.1.4 Urban land

Urban land facilitates all forms of infrastructure, services, and land use to support a community. Because it supports all aspects of community (including housing, employment, community infrastructure, other infrastructure) urban land is a key input to this CHRMAP in terms of considering impact of coastal hazards on assets.

Within the CHRMAP area, urban land includes the existing residential, townsite, community facilities and future residential growth areas. Urban areas are highly valued – providing local residents a place to live and visitors a place to stay near the coast. It is the co-location of urban land and the coastal amenity of Horrocks that provides specific value in this area.

The Shire of Northampton Local Planning Strategy identifies Horrocks as a Major Growth Townsite accommodating future population growth within the Shire. To date, the majority of residential expansion has been confined to the existing townsite, particularly the southern portions. However, the bulk of future expansion opportunities lie within the former farming lands to the immediate east of the townsite, which have been identified as a Special Control Area under Council's Town Planning Scheme 10 (Horrocks Beach Local Planning Strategy, Shire of Northampton, 2015).

To support the development of urban land within the CHRMAP area it is important to properly consider identified coastal hazards and risks, prevent undesirable impacts to the developments and outline if/when retreat from areas of intolerable coastal risk is required. The land identified for urban development is necessary to support a growing community and tourism.

3.2 Values at risk

Values considered in the risk assessment and adaptation plan are the elements of the environment, both physical and intangible, that bring benefit to the community.

Community engagement was undertaken in January and February 2019 to understand the values associated with Horrocks Beach. Appendix B provides information about this consultation, and detailed results from the coastal values survey about use and values of particular foreshore/beach areas.

The coastal areas within the CHRMAP area are used and valued for a diversity of purposes and reasons. The overall value of Horrocks and its coast are summarised in the following value statements:

The community values Horrocks Beach…

…for coastal amenity and recreation

…as a social space to meet and interact

…for its character, sense of place and scenic landscape

…for its environmental attributes

…as a commercial economic resource

3.2.1 Coastal amenity and recreation

Recreation on the coast is one of the strongest social values in the Horrocks Beach project area. The water around Horrocks and the recreational opportunity it presents is central to the lifestyle of people in Horrocks, the surrounding area and visiting tourists. Participation in water activities was the most popular survey response for the beach areas surrounding the jetty and Whiting Pool.

Recreation on the sandy beach was a popular response in all beach locations within the study area. Other forms of recreation that are enjoyed by the community (based on survey participants) include walking, dog walking, photography and playgrounds.

A range of recreational opportunities are afforded by the specific characteristics of different coastal areas. For example, whilst survey responses indicate that the coastal setting and views are enjoyed throughout the Horrocks Beach foreshore area, they are most popular at the community centre location. This is likely to be due to differences in landscape providing a higher viewpoint and the community infrastructure design to easily allow appreciation of the views. The sheltered nature of the beach jetty area and Whiting Pool also explain the increased popularity of water activities in those locations.

3.2.2 Social space to meet and interact

The Horrocks Beach study area includes a number of key areas for social interactions. Social interactions and community participation are vital to a healthy community, and contribute to mental health and lifestyle.

Socialising with friends is particularly important to people using the areas adjacent to the jetty, Whiting Pool and the area adjacent to the community centre (socialise with friends is in the top three responses in these locations). This is reflective of the facilities and infrastructure provided in those locations that facilitate social gatherings and meetings. For example, barbeques are close to Whiting Pool/the jetty area, the community kitchen also provides a location for people to meet and interact.

The community centre provides a hub to foster community spirit. The centre hosts events/clubs and fundraisers, has a playground and ancillary facilities.

3.2.3 Cultural value

Survey participants did not indicate specific cultural values associated with Horrocks Beach.

This is indicative of the absence of registered Aboriginal Heritage Sites in the CHRMAP area. It is important to note, however, that places of significance may not be registered, and there are additional areas valued and used by the Aboriginal community beyond formally protected sites.

The townsite of Horrocks is listed on the Shire of Northampton's Municipal Inventory due to its very high historic and social significance as the holiday destination and summer location for Northampton. This significance is reflected in the importance of the coastal character of the location which was identified by 91 percent of survey respondents as important.

3.2.4 Character, sense of place and scenic landscape

As mentioned in section 3.2.3, the town of Horrocks is a unique place. The character of the area is influenced by its coastal setting and history as a holiday destination. The beauty of the coastal environment, the scenic value and the sense of place are key attractors for people visiting or living in Horrocks and are strongly valued. The views and coastal amenity were key values indicated and the loss of these would be significant.

3.2.5 Ecosystem and place of biodiversity

Protection of the environment was indicated by survey respondents as of key importance. Particularly, when asked to list the three most important things to protect in the area, protection of the environment was the most popular response and included by half the total survey participants.

Key environmental features to protect include:

- Coastal vegetation and the fauna it supports (such as nesting Osprey)
- Freshwater wetland (Frog Pond) and associated biodiversity
- Maintaining clean ocean water
- Marine ecosystems.

3.2.6 Commercial economic resource

The character of Horrocks is significantly impacted by its nature as a tourist destination. It is not only a locally significant destination but also attracts visitors from Geraldton, Perth and interstate/international. The tourism industry is the key economic driver for the town, allowing for businesses such as the caravan park, holiday chalets and general store to exist and supporting local employment. For example, the fourth highest industry of employment for Horrocks residents is accommodation (Australian Bureau of Statistics, Census Data, 2016).

Further to this, Horrocks supports a low-scale crayfishing industry, with 8 residents indicating Rock Lobster and Cray Potting as their industry of employment in the 2016 census. This is the second largest employment industry in Horrocks (Australian Bureau of Statistics, Census Data, 2016).

3.2.7 Personal economic resource

Personal economic resource was considered to be somewhat important to community survey respondents. Protection of private residential properties was included as one of three most important values by 22 percent of survey respondents and commercial businesses by 13 percent of respondents. It is the co-location of private properties with the beach and coastal amenity of Horrocks that supports the personal economic value.

Further, more detailed prioritisation of values and adaptation feasibility factors (e.g. cost) for specific areas is part of evaluating the available adaptation options for the Horrocks Beach area.

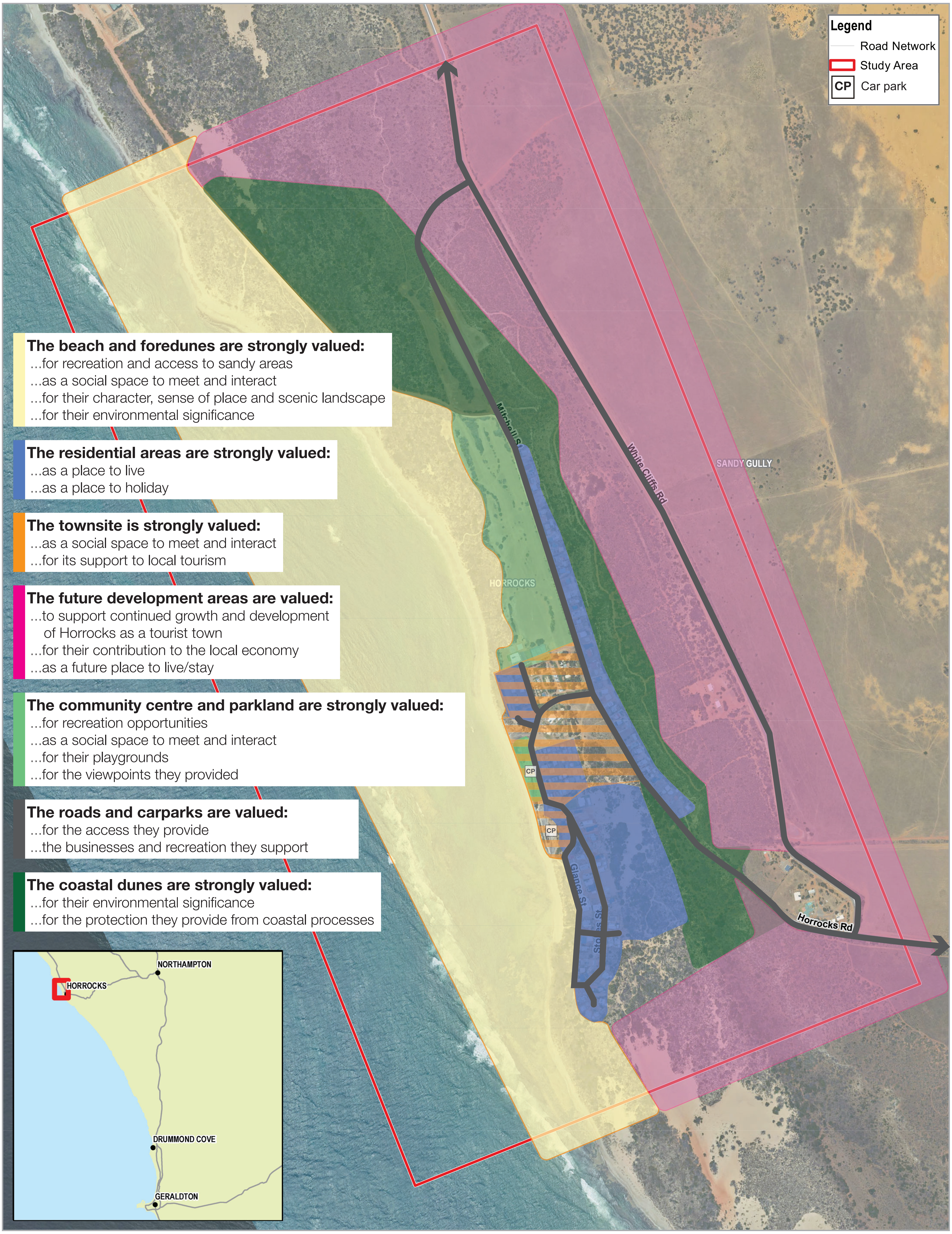

Figure 7 Asset values map G 1

4. Adaptation Pathways

Adaptation pathways for Horrocks have been developed through modelling of coastal hazards (Appendix C), an assessment of risks to coastal values and assets (Appendix D) and an evaluation of available adaptation options (Appendix E).

The coastal hazard assessment was used to assess risk tolerance to assets and values and to identify the required urgency of actions. The coastal hazard assessment was a high-level assessment to identify large scale patterns, and did not take into account secondary risks, which may occur after an erosion or inundation event has occurred and have further impact on assets or values.

The risk assessment evaluated the risk to individual assets, based on the values that each asset supports as reported in the preceding section. The coastal hazard risk levels and tolerability ratings from the risk assessment, provided in Appendix F, have been used to establish the tolerance profile and trigger point for each asset within both coastal planning areas in the immediate, current and long-term.

The evaluation of adaptation options undertakes a multi-criteria analysis of potential adaptation options for each asset/grouping of asset at risk in the immediate and current planning timeframes. This analysis is a decision-making tool to consider, in particular, the social and environmental viability of adaptation options against weighted cost considerations. As discussed later in this section, additional feasibility assessments should be undertaken to confirm the financial viability of preferred adaptation responses.

These investigations have identified the triggers for adaptation planning in Horrocks, and the most appropriate options for Council to consider in consultation with the community.

4.1 Coastal planning units

The nature of coastal values, particularly in relation to land use, change across the Horrocks Beach study area, although some key values occur across the entire area. To reflect this, the study area has been divided into two distinct planning areas.

Planning area 1:	Largely undeveloped vegetated bushland to the north of Horrocks. Assets include the northern portion of Mitchell Street, Little Bay Rd, beach access tracks, private residences (along Mitchell Street), golf course
Planning area 2:	Horrocks townsite including private residences, roads, community centre, parkland, playground, bbqs, car parking, coastal path, boat ramps, seawall, jetty

The planning areas allow for some triggers and adaptation pathways and recommendations to be considered at the precinct scale, however, assets have also been assessed individually. Planning areas and assets contained within them are shown in Figure 8. Assets have been grouped where triggers and/or resulting management measures are consistent.

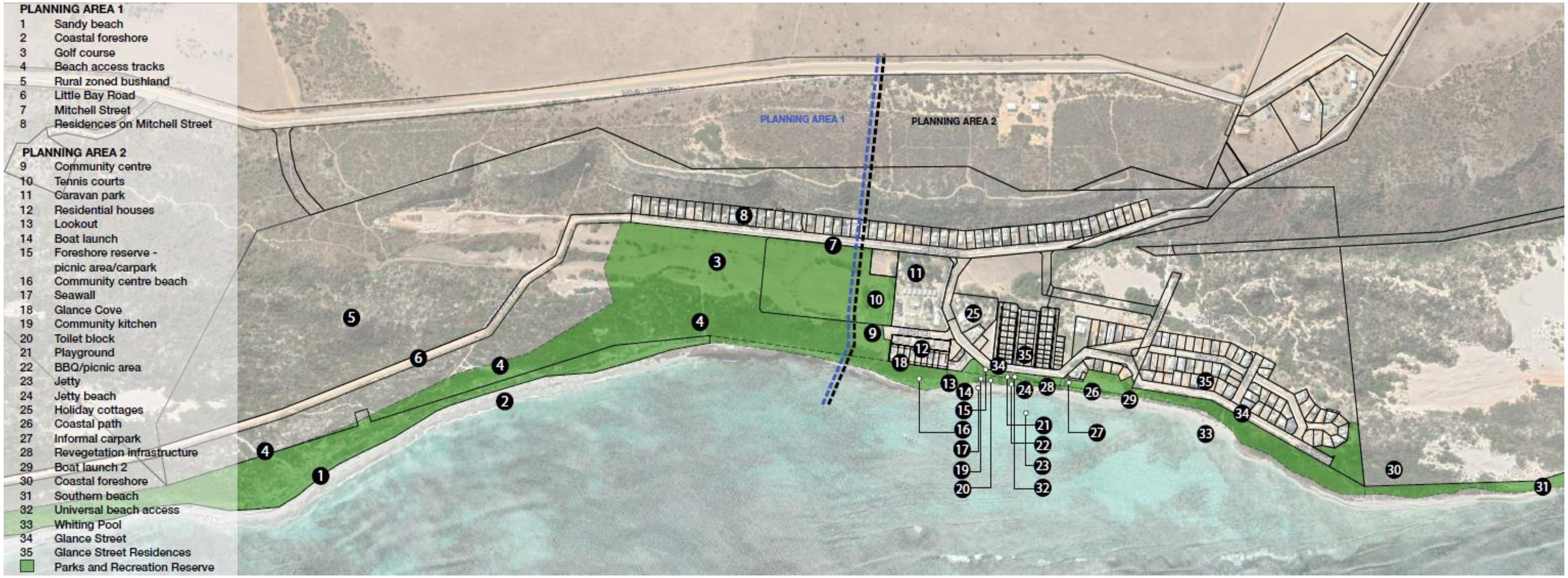

Figure 8 Planning areas and asset mapping (GHD, 2019)

4.2 Risk tolerance and adaptation triggers

Adaptation principles and strategic pathways are described in Section 2.4, with decision trigger points (Figure 5) based on risk.

Trigger 1: **E**xisting or proposed development in vulnerable coastal area. Risk is tolerable.

Trigger 2: Increasing likelihood of event presenting intolerable risk.

Trigger 3: Risk is **intolerable**. Accommodation/ interim protection may be feasible.

Trigger 3A: End of design life of accommodation/interim protection. Further accommodation/interim protection may be feasible.

Trigger 4: Risk is intolerable. Accommodation or protection is not feasible.

Detailed adaption planning for Horrocks is presented below for each of the planning areas described in Section 4.1 and in Section 5.

4.2.1 Planning area 1

No intolerable risks as a result of inundation have been identified over the planning timeframes.

Erosion risk to individual assets (Figure 8) have been assessed across planning area 1. Erosion risks are identified to the sandy beach, coastal foreshore and beach access tracks (Table 2). These risks are considered to be either tolerable or acceptable in the immediate (2019) and medium (2050) planning timeframes. This is due to the presence of the coastal foreshore buffering impacts, allowing for example, other beach tracks to be created. The risk to the beach is assessed as tolerable because although events may impact on the beach, the vegetated dunes and coastal foreshore allow the beach to naturally recover. There are also other nearby beach areas that can be accessed as alternatives.

There is no requirement for decision-making in the short-term for planning area 1 in relation to erosion risks. It is however, important to monitor the area to ensure that change is as anticipated and any future planning proposals consider these identified risks.

Table 2 Erosion Risk Tolerability in Planning Area 1

Asset No.	Asset Name	Immediate (2019) risk	Medium (to 2050) risk	Long term (to 2120) risk
1	Sandy beach	Tolerable Trigger 1 (consider risk for any proposed development)	Tolerable Trigger 1 (consider risk for any proposed development)	Intolerable (Trigger 3 or 4) (risks to road, tracks, rural land, foreshore become intolerable – assessment of accommodation or interim protection required at this time based on values of the time, development proposals, available protection measures)
2	Coastal foreshore	Acceptable	Acceptable	
3	Golf course	No impact	No impact	
4	Beach access tracks	Acceptable	Acceptable	
5	Rural zoned bushland	No impact	No impact	
6	Little Bay Road	No impact	No impact	
7	Mitchell Street	No impact	No impact	No impact
8	Residences on Mitchell Street	No impact	No impact	No impact

4.2.2 Planning area 2

No intolerable risks as a result of inundation have been identified over the planning timeframes. Glance Street and some associated housing is known to flood in rare events currently, however, impacts of flooding are managed once flood waters retreat. It is expected that over time, the number of houses impacted by flooding will increase, however temporary inundation as a result of a rare event was not identified as being an intolerable risk.

The risks from erosion to individual assets (Figure 8) have been assessed across planning area 2 (Table 3). In the short-term, intolerable erosion risks are identified to the two boat launches, Glance Cove (road), the beach adjacent to the Jetty and the universal beach access. Tolerable erosion risks are identified for the toilet block, barbeques/picnic area, revegetation infrastructure, and the southern beach area. There are acceptable risks within the coastal foreshore.

By 2050, there are intolerable risks to most assets within planning area 2, increasing to the majority of the existing settlement area in the long term.

In the immediate term, intolerable risk affects individual assets, enabling an asset-based approach to risk mitigation. In the medium term, this risk increases therefore requiring, at least, consideration at the level of asset groupings. In the long term, the entire settlement is at risk, therefore adaptation planning should consider management of coastal risk at a strategic townsite level.

Table 3 Erosion Risk Tolerability in Planning Area 2

Asset No.	Asset	Immediate (2019) risk	Medium (to 2050) risk	Long term (to 2120) risk
9	Community centre	No impact	Intolerable (Trigger 3A – erosion modelled to impact upon community centre, assessment on the feasibility of protection required)	Intolerable (Trigger 3 or 4 – risks to most of townsite become intolerable – assessment of the feasibility of interim protection required at this time based on values of the time, cost, environmental and social impacts and available measures)
10	Tennis courts	No impact	No impact	
11	Caravan park	No impact	No impact	
12	Residential houses	No impact	Intolerable (Trigger 3A – erosion modelled to impact upon residential housing, assessment on the feasibility of protection required)	
13	Lookout	Tolerable (Trigger 1)	Intolerable (Trigger 4 – protection unlikely to be feasible given cost of infrastructure, consider relocation)	
14	Boat launch	Intolerable (Trigger 3 – interim protection is being implemented by the Shire – gravel replenishment)	Intolerable (Trigger 3A – ongoing assessment of feasibility interim protection)	
15	Foreshore reserve - picnic area	No impact	Intolerable (Trigger 3A – consider with seawall)	
16	Community centre beach	Tolerable (Trigger 1)	Intolerable (Trigger 3A)	
17	Seawall	Tolerable* (Trigger 1)	Intolerable (Trigger 3A – at end of design life consider feasibility of replacement, consider as part of Glance St grouping)	
18	Glance Cove	Intolerable (Trigger 3A – detailed feasibility of interim protection required, sand replenishment may prolong the time to make interim protection decision)	Intolerable (Trigger 3A – feasibility of interim protection required)	
19	Community kitchen	No impact	Intolerable (Trigger 3A – at end of design life consider feasibility of replacement, consider as part of Glance St grouping)	
20	Toilet block	Tolerable (Trigger 1)	Intolerable (Trigger 3A – at end of design life consider feasibility of replacement, consider as part of Glance St grouping)	
21	Playground	No impact	Intolerable (Trigger 3A – at end of design life consider feasibility of replacement, consider as part of Glance St grouping)	
22	BBQ/picnic area	Tolerable (Trigger 1)	Intolerable (Trigger 3A – at end of design life consider feasibility of replacement, consider as	

Asset No.	Asset	Immediate (2019) risk	Medium (to 2050) risk	Long term (to 2120) risk
			part of Glance St grouping)	
23	Jetty	No impact	No impact	
24	Jetty beach	Intolerable (Trigger 3 – Known risk managed with sand nourishment as required)	Intolerable (Trigger 3A – at end of GSC Seawall design life consider feasibility of replacement, consider as part of Glance St grouping, management of area would require continued sand replenishment)	
25	Holiday cottages	No impact	No impact	
26	Coastal path	No impact	Intolerable (Trigger 3A – consider feasibility of relocation as part of Glance St grouping)	
27	Informal carpark	No impact	Intolerable (Trigger 3A – consider feasibility of relocation as part of Glance St grouping)	
28	Revegetation infrastructure	Tolerable	Intolerable (Trigger 3A – consider revegetation as part of Glance St grouping)	
29	Boat launch 2	(Trigger 3 – interim protection is being implemented by the Shire)	Intolerable (Trigger 3A – ongoing assessment of feasibility interim protection)	
30	Coastal foreshore	Acceptable	Tolerable	
21	Southern beach	Tolerable	Tolerable	
32	Universal beach access	Intolerable (Trigger 3 – continue management until end of design life then consider redesign/alternatives/relocation)	Intolerable (End of design life triggers consideration of continued provision, relocation etc.)	
33	Whiting Pool	No impact	Intolerable (Trigger 3A – monitor and consider sand nourishment if required)	
34	Glance Street	No impact	Intolerable (Trigger 3A – consider interim protection options as part of Glance St grouping)	
35	Glance Street residences	No impact	Intolerable (Trigger 3A – consider interim protection options as part of Glance St grouping)	

** Risk tolerability adjusted manually to reflect Shire's current acceptance of risk to structure (as discussed in Appendix F)*

It is not possible to ascertain the viability of interim protection for the long term, as this judgement is made based on the social, environment and cost viability which cannot be determined based on current values. However, as indicated by the evaluation of adaptation options for the immediate and medium planning timeframes in Appendix E, the financial cost of interim protection to protect only a portion of the town is likely to be greater than the financial value of land and assets that would be protected. The scale of infrastructure required to protect the entirety of the Horrocks settlement taking into account sea level rise to 2120 would likely be of a scale that would not be consistent with social values, and would be expected to significantly alter the coastal environment. This may make the ongoing presence of a town in this location unviable in the long term. Relocating the town should therefore be discussed as a potential long term scenario even though implementation is not required on a town-site scale currently.

In the medium term, when considered at the townsite (rather than asset grouping) level, Appendix F suggests that the available suite of interim protection options may be viable based on social and environmental criteria (however in some locations retreat may be preferred for some asset groupings), therefore potentially delaying the need to commence relocation of the town to beyond 2050. However, the cost implications are considerable, with the cost of interim protection exceeding the financial value of land and assets that would be afforded the interim protection. A feasibility study is recommended, therefore, to confirm if the financial cost of interim protection is a feasible endeavour considering the temporary design life of interim protection and the social and environmental values of the assets to be protected. This investigation is required to confirm whether cost implications of interim protection are viable for a community the size of Horrocks, and the willingness and ability of the Shire and community to meet those costs. If not considered feasible, then trigger 4 will be reached in the current planning horizon, and strategic planning for retreat should be commenced (see section 5.3). If interim protection is financially feasible, then the localised adaptation options set out in section 5.1 and 5.2 may be appropriate for implementation.

5. Implementation Plan

The following implementation plan provides immediate, short and medium-term risks and actions, as well as immediate, short, medium and long-term planning considerations for coastal adaptation.

Actions to address intolerable risks that are currently affecting parts of Horrocks Beach are recommended for implementation in the immediate term. Short and medium term actions are recommended to plan for and address intolerable risks to 2050.

Implementation to 2050 is due to the end of the design life of existing protection infrastructure (Geotextile Sandbag Seawall) and risks that become apparent to key community infrastructure at this time (e.g. access roads, Horrocks Community Centre).

Consideration of the long term risks is required to strategically plan for those risks and prepare the community. Planning considerations has resulted in immediate actions to prepare for future risk scenarios.

5.1 Localised adaptation recommendations – asset groupings

5.1.1 Glance Cove and Community Centre – Road/Easement, Residential Housing and Community Infrastructure (Asset Numbers 9, 12 and 18)

The hazard assessment suggests that in the present term, possible and rare erosion events, would impact upon Glance Cove (Figure 9). This is a current risk that is not being managed and is considered intolerable due to the risks to the road/easement which provides access.

By 2050, the possible and rare erosion event is modelled to impact upon a significant area of road and up to eleven properties located on Glance Cove and the community centre. This is an intolerable risk.

Risk treatment options have been considered for the road, housing and community centre as one asset grouping because the road provides access to houses located on Glance Cove. The community centre is also included in this grouping because implementation of interim protection measures only to the road and housing, may increase the impacts of erosion at the community centre and because all assets could be protected with the same measures.

Figure 9 Erosion likelihoods Glance Cove, 2019 (left) and 2050 (right)

Immediate adaptation options

On the basis that immediate risk affects a single asset (road), it is recommended that the Shire of Northampton investigates short term sand replenishment, dune stabilisation and revegetation to manage short term risk to Glance Cove, pending confirmation of the adaptation approach for the asset grouping in the medium term.

Given the risks, it is important to avoid further development in this area. The Local Planning Scheme and Horrocks Beach Local Planning Strategy should be reviewed and updated to identify a special control area and establish development controls. This is further discussed in Section 5.3.

It is also important that prospective property buyers are aware of future risks. Section 70A of the *Transfer of Land Act 1893* allows notifications to be placed on certificates of title advising prospective purchasers that the land is identified as being vulnerable to coastal erosion and/or inundation over the next 100 years. The Shire should start placing these notifications on titles where possible as part of development or subdivision approval.

Grouping specific short term adaptation:

Sand replenishment, dune stabilisation, revegetation

Townsite adaptation:

Update Local Planning Strategy and Scheme – include this asset grouping in special control area, establish development controls to allow for Section 70A notifications, temporary development, removal of development as/if risks are realised

Figure 10 Short term adaptation options (Glance Cove asset grouping)

Medium term adaptation options

Interim protection options suitable to this section of the foreshore include dune stabilisation and revegetation, geotextile sandbag seawall and rock seawall. Offshore breakwaters and groynes are not considered appropriate due to the social impacts of limiting access to the deep water impacting navigation safety, and visual impacts. The adaptation option of a seawall has been included as it is a measure that is acceptable in the current term (in a different area), however, it should be noted that a rock seawall will have social impacts (loss of sandy beach and associated amenity).

Managed retreat would likely require:

- Immediately ceasing the approval of development in this area
- Investigation of land swaps/opportunities to utilise publically owned/managed areas as an interim measure (allows continued enjoyment of Horrocks in the 100 year planning timeframe)
- Including this area within a Special Control Area under the Local Planning Scheme
- Staged relocation of community assets as the assets reach their useful design life

The evaluation of adaptation options (Appendix F) identified that passive forms of interim protection via dune stabilisation and revegetation is a preferred option for this area. However, hard active interim protection (seawall options) is less preferred than managed retreat.

It is noted that community-informed weighting of decision criteria did not differentiate between managed retreat and passive interim protection, whereas elected member-informed weighting clearly preferred the passive interim protection option. The differences in results highlight the greater weighting the Councillors placed on protection of private property and implementation costs. The community values the loss of social spaces more highly.

The indicative cost of passive interim protection (via dune stabilisation and revegetation) for this grouping of assets involves a capital cost of $1.51 million, with an annual maintenance cost of $65,000 (recurring over 50 years). The indicative value of private properties maintained by this investment is $3.3 million in today's dollars (based on 11 houses valued at $300,000).

Table 4 High level cost comparison Glance Cove and Community Centre adaptation options[1]

<table>
<tr><th>Adaptation Option</th><th>Estimated expenditure (current timeframe)</th><th>Estimated maintenance expenditure</th><th>Purpose of feasibility study</th></tr>
<tr><td>Passive interim protection</td><td>$1.51M</td><td>$65,000/annum
($3.25M over 50 years)</td><td rowspan="2">Confirm costs
Undertake MCA, inc.
• Financial viability
• Social impacts
• Environmental impacts</td></tr>
<tr><td>Land acquisition</td><td>$3.3M</td><td>N/A</td></tr>
</table>

[1] These are high level costings based on internet property searches and Shire expenditure. A more detailed cost comparison should be included in the recommended feasibility study

The results indicate that further community consultation is required to inform the decision between managed retreat and interim protection in the current planning timeframe on the basis that a decision to undertake interim protection would only delay the need to retreat and the cost of protection over 50 years is an important consideration, especially given there is a potential pathway to retreat (section 5.3).

A feasibility study is recommended to confirm if the capital and recurring costs associated with interim protection are warranted, considering the value of private property retained for the 50 year life of the interim protection.

Even in the event that a decision to incorporate interim protection is made, a long term retreat plan is recommended, for example, the end of the design life of the community centre could be the trigger to retreat, instead of locating a replacement building in the current location, a new location would be determined, protection of the housing would also cease at that time. Depending on the timing of relocation of community assets, the feasibility of interim protection may reduce over time as its benefit becomes predominantly related to protection of private property rather than community infrastructure.

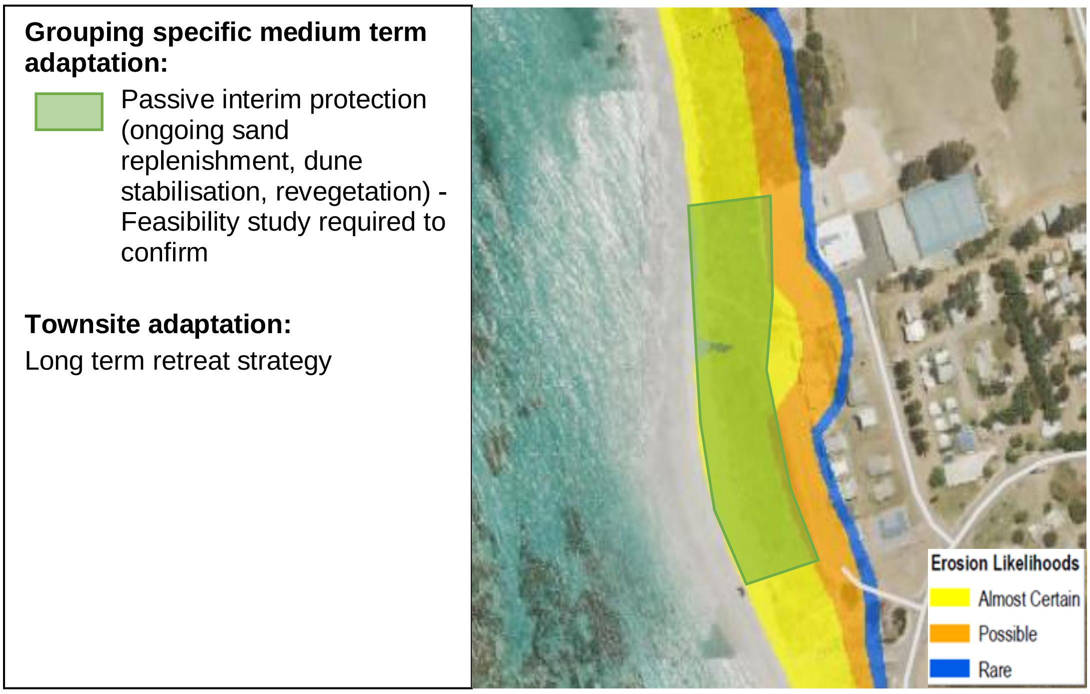

Figure 11 Medium term adaptation options (Glance Cove asset grouping)

Table 5 Glance Cove and community centre action plan

	Action	Timing	Responsibility
1	Undertake further community consultation – managed retreat vs. protection	Immediate	Shire
2	Place Section 70A of the *Transfer of Land Act 1893* notifications on certificates of title advising prospective purchasers that the land is identified as being vulnerable to coastal erosion and/or inundation over the next 100 years (Glance Cove properties)	Immediate	Shire
3	Investigate and implement short term sand replenishment	Immediate	Shire
4	Update Local Planning Scheme – • Application of Special Control Area 1 • Potential zone changes • Update provisions to allow for temporary dwellings	Immediate	Shire DPLH
5	Update Horrocks Local Planning Strategy – consideration of identified coastal hazards/ expansion areas	Immediate	Shire
6	Implement either interim protection or managed retreat	Short	Shire
7	Develop a long term retreat plan	Short	Shire

5.1.2 Glance Street and community coastal infrastructure (asset numbers 17, 19, 20, 21, 22, 24, 26, 27 and 28)

This grouping of assets includes the community kitchen, toilet block, playground, barbeques, picnic areas, Glance Street, Glance Street residences, coastal path and car parks.

These assets have been grouped as erosion in this area is currently managed through dune stabilisation (revegetation) and an existing Geotextile Sandbag Seawall.

The existing Geotextile Sandbag Seawall is an interim protection measure allowing the foreshore and associated assets in this area to be enjoyed in the immediate and short term. It is expected that the seawall will provide protection from erosion until 2035 (assets and seawall are shown on Figure 12). The coastal path and carpark between the dunes and the Glance Street is at almost certain risk from erosion in the short term (to 2030). There is a small section of Glance Street and associated residences that is at risk of erosion by 2050 in possible and rare events (Figure 12).

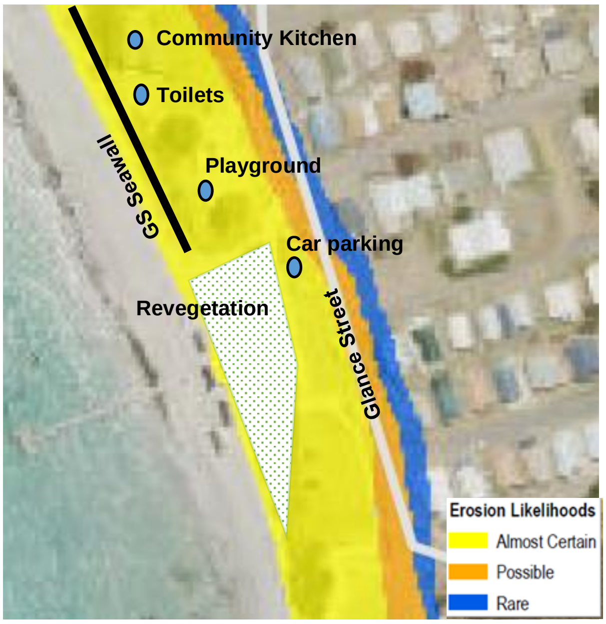

Figure 12 Glance Street erosion likelihood, 2050 (GHD 2019)

Immediate term adaptation options

Given the seawall was designed for a one in 50 year event, it is important to monitor this infrastructure, especially following large events to ensure safety of people using the beach and parkland and associated assets in this area.

The Shire has incorporated wind fencing to build up sand and undertaken significant revegetation in conjunction with the community in this area. The success of this should be monitored and supplemented as necessary.

Given the risks, it is important to avoid further development in this area. The Local Planning Scheme and Horrocks Beach Local Planning Strategy should be reviewed updated to identify a special control area and establish development controls. This is further discussed in Section 5.3.

It is also important that prospective property buyers are aware of future risks. Section 70A of the *Transfer of Land Act 1893* allows notifications to be placed on certificates of title advising prospective purchasers that the land is identified as being vulnerable to coastal erosion and/or inundation over the next 100 years. The Shire should start placing these notifications on titles where possible as part of development or subdivision approval.

Grouping specific short term adaptation:

- Monitor GSS seawall
- Monitor wind fencing, revegetation, supplement as necessary

Townsite adaptation:

Update Local Planning Strategy and Scheme – include this asset grouping in special control area, establish development controls to allow for Section 70A notifications, temporary development, removal of development as/if risks are realised

Figure 13 Short-term adaptation options (Glance Street asset grouping)

Short (2030) to medium (2050) term adaptation options

Interim protection options suitable to this section of the foreshore include dune stabilisation and revegetation or extension of the existing geotextile sandbag seawall to provide interim protection to Glance Street and residences behind. The resulting seawall would be approximately 180 metres in length rather than the current 90 metres. Offshore breakwaters and groynes are not considered appropriate due to social impacts and reduced access to the deep water impacting navigation safety.

Managed retreat would likely require:

- Immediately ceasing the approval of development in this area
- Investigation of land swaps/opportunities to utilise publically owned/managed areas as an interim measure (allows continued enjoyment of Horrocks in the 100 year planning timeframe)
- Including this area within a Special Control Area under the Local Planning Scheme
- Staged relocation of community assets as the assets reach their useful design life

The evaluation of adaptation options (Appendix F) identified that passive forms of interim protection via dune stabilisation and revegetation is a preferred option for this area. However, hard: active interim protection (seawall option) still ranked above managed retreat.

The indicative cost of passive interim protection for this grouping of assets involves a capital cost of $960,000. Extension and upgrading of a seawall has an indicative capital cost of $1.8 million. The indicative value of private properties maintained by this investment is $1.2 million.

Table 6 High level cost comparison Glance Street and Community Coastal infrastructure adaptation options[2]

Adaptation Option	Estimated expenditure (current timeframe)	Purpose of feasibility study
Passive interim protection	$960,000	Confirm costs Undertake MCA, inc. • Financial viability • Social impacts • Environmental impacts
Land acquisition	$1.2M	

A feasibility study is recommended to confirm if the capital and recurring costs associated with interim protection are warranted, considering the value of private property retained for the 50 year life of the interim protection.

The community assets and parkland in this area should be assessed at the end of their design life as it may be appropriate to relocate them to mitigate against future erosion risks (especially if it is expected that when/if the seawall is replaced it will be located further landward to accommodate conditions at that time). Depending on the timing of relocation of community assets, the feasibility of interim protection may reduce over time as its benefit becomes predominantly related to protection of private property rather than community infrastructure.

Grouping specific medium term adaptation:
Feasibility study – passive interim protection, extension of the GSS Seawall

Townsite adaptation:
Update Local Planning Strategy and Scheme – include this asset grouping in special control area, establish development controls to allow for Section 70A notifications, temporary development, removal of development as/if risks are realised

Figure 14 Medium term adaptation options (Glance Street asset grouping)

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[2] These are high level costings based on internet property searches and Shire expenditure. A more detailed cost comparison should be included in the recommended feasibility study

Table 7 Glance Street and surrounds action plan

	Action	Timing	Responsibility
1	Monitor seawall for function and safety	Ongoing	Shire
2	Continue dune stabilisation and revegetation	Ongoing	Shire
3	Detailed assessment seawall replacement/extension requirements/feasibility	Prior to 2035 (preparation for end of design life)	Shire
4	Decision trigger for interim protection or managed retreat	End of design life of current seawall unless otherwise indicated by action 1 or 3	Shire
5	Place Section 70A of the *Transfer of Land Act 1893* notifications on certificates of title advising prospective purchasers that the land is identified as being vulnerable to coastal erosion and/or inundation over the next 100 years (Glance Street properties)	Short	Shire
5	Update Local Planning Scheme – • Application of Special Control Area 1 • Potential zone changes • Update provisions to allow for temporary dwellings	Immediate – preparation for future risks	Shire DPLH
6	Update Horrocks Local Planning Strategy – consideration of identified coastal hazards/ expansion areas	Immediate	Shire
7	Community consultation – further investigate support for interim protection/managed retreat	Immediate	Shire
8	Monitor assets, relocation decisions based on risks at end of design life	Ongoing	Shire

5.2 Localised adaptation recommendations – individual assets

5.2.1 Boat launches (Asset 14 and 29)

Both boat launches located in Planning Area 2 are identified as being at intolerable risk to erosion. Interim protection is currently considered feasible and the Shire actively manages this infrastructure, depositing gravel at the base of each launch as required to mitigate against erosion and allow continuing use. As the gravel is removed by erosion forces, trigger 3A is reached, however while the decision to replenish the gravel continues, the trigger point returns to 2. At some point in the future, it may no longer be feasible to replenish the gravel, however, it is likely that the boat launch can retreat into the car park area before trigger 4 is reached and accommodation is no longer feasible.

Action: Continue current monitoring and gravel nourishment

5.2.2 Jetty Beach (Asset 24)

The area of beach is identified in the hazard assessment as at almost certain risk of erosion. This is a known risk and has resulted in the installation of the Geotextile Sandbag Seawall, which protects the assets behind the beach. Installation of the seawall included sand nourishment. The requirement for further nourishment is monitored by the Shire and will be undertaken as necessary as part of ongoing maintenance.

Action: Monitor, nourish beach as required

5.2.3 Universal beach access (Asset 32)

The universal beach access track is at almost certain risk of erosion. This is most apparent at the end of the track which is not always at the beach level and would restrict usage (Figure 15). This is considered to be an intolerable risk as there is no alternative universal access, however, in reality condition is likely to change with sand movement and it would be difficult to manage.

Figure 155 Beach edge of universal access pathway

This is low cost infrastructure that that is relatively easy to relocate.. At the end of the design life of the infrastructure an assessment should be conducted to consider alternative designs or solutions, such as provision of a beach wheelchair that can be booked though the Shire. Relocation into a different area could also be considered as part of this process. Accommodation through redesign or upgrade scored most highly in the MCA.

Action: Monitor infrastructure, manage as required

Action: Investigate alternative designs, alternative solutions and alternative locations to improve functionality and reduce erosion impacts. Implement preferred option at the end of the design life.

5.2.4 Informal parking (Asset 27)

There is a more informal area for parking at the southern end of the study area, adjacent to the southern boat launch. It is a defined area but has no marked bays. This area is at possible risk in the short term and reaches almost certain risk by 2050. This is low cost infrastructure that could be sacrificed rather than spending funds that could be expended elsewhere, especially given the number of nearby roads on which roadside parking could potentially be accommodated.

Figure 16 Informal parking area

The MCA conducted for this area supports this approach (application of either the Council or the community weightings). However, because sacrifice of the carpark puts one house at risk of erosion by 2050, it is important to consider further.

Further work is required to determine the acceptability of retreat in this location compared to interim protection so the adaptation pathway is determined in advance of risk impacts being realised. This is especially relevant if protection to private properties has been implemented elsewhere.

Table 8 Informal parking area action plan

	Action	Timing	Responsibility
1	Monitor condition	Ongoing	Shire
2	Community consultation – further investigate support for interim protection/managed retreat	As part of consultation for other areas	Shire
3	Determine implementation option: • Relocation of parking • Seawall • Managed retreat via acquisition/land swap/lease	Medium	Shire

5.2.5 Whiting Pool (Asset 33)

Whiting Pool appears to be accreting in the immediate term, however, modelling suggests that erosion is the trend that will continue. This area has sufficient coastal foreshore to accommodate the predicted erosion in the short term and although the beach will retreat landward, it can still be utilised and enjoyed by the community.

Action: Monitor and beach nourishment if required.

5.3 Implementing planned/managed retreat

The WAPC Coastal Hazard Risk Management and Adaptation Planning Guidelines (2019) (the guidelines) describe planned or managed retreat as a risk treatment option to preserve beach and coastal foreshore assets, public access, recreation, conservation and coastal foreshore management. This risk treatment option allows coastal physical processes to occur with as little impediment from development as possible in the future, allowing natural dynamic movement and retreat in response to coastal physical processes, particularly sea level rise.

Planned or managed retreat for existing development involves relocating or sacrificing infrastructure, both public assets and private property, when erosion and recession impacts reach action trigger points.

In Horrocks, managed retreat would involve:

- No construction of new coastal structures (when interim protection is no longer considered feasible)
- Avoidance or minimisation of new development within high risk areas.
- Where possible and practical, restore or enhance dunes to maintain or create a buffer against storm erosion (protecting remaining assets)
- Removal of existing assets as they reach the end of their functional life (or if they are substantially damaged by a storm event), or if a trigger for removal is reached including any associated coastal protection structures (e.g. temporary protection works that extended the life of the asset).

Whilst the evaluation of adaptation options identified that there are interim protection options viable on social and environmental grounds, confirmation of the financial feasibility of the preferred options is required to inform decision making as to when strategic retreat within Horrocks should be implemented. This reflects that interim protection does not provide permanent protection, therefore serves to delay the cost of managed retreat. A detailed financial analysis would enable determination of whether it is viable to delay retreat in the medium term.

Regardless of short and medium term decision making, in accordance with the adaptation pathway presented in Section 2, strategic planning should prepare for the eventual realisation of long term risks in preparation for Trigger 4 when retreat is required. Planning for the future layout for the townsite should include the establishment of an appropriate foreshore reserve that extends beyond the long term physical processes allowance. By 2120, this is likely to require much of the remaining land that is not modelled to be affected by erosion before the scarp is reached.

Implementation options for planned/managed retreat detailed in the guidelines includes voluntary acquisition. Acquisition of property at risk (over a 100 year timeframe) requires a level of funding that is unlikely to be available through local or State government in the long term. For example, assuming an average price house price of $300,000[3] and a total of 16 residences at risk by 2050, this presents an approximate acquisition cost of $4.8 million for priority properties today which is comparable to the cost of coastal protection infrastructure. The area of private land affected by intolerable risk in the long term, being the majority of existing residences in town, presents an approximate acquisition cost of $36 million in today’s dollars.

[3] estimated using current house listings on realestate.com.au and reiwa.com.au

Conversely, unmanaged retreat (which involves no government intervention, with loss of the foreshore reserve occurring before houses at risk are abandoned due to safety) does not require public funding however, shifts the cost onto coastal property owners and will result in the loss of social and environmental values associated with the coastal foreshore reserve. In the long term, an unmanaged retreat policy in Horrocks would, in effect, represent abandonment of the settlement.

As an alternative to acquisition or unmanaged retreat, the Shire has the potential to utilise freehold land in Shire ownership, outside of the coastal vulnerable area, in a land swap scenario. Long term planning should investigate areas that might be used as leasehold residential and holiday accommodation so that over time the townsite can be relocated over time into these areas.

A long term plan is recommended to facilitate long term retreat/relocation of the town. This may include:

1. Land use zoning and policy changes – to minimise development in high risk areas and support temporary/low cost dwellings e.g. transportable dwellings (that allow the area to continue to be enjoyed until triggers for retreat are reached)
2. Update the Local Planning Scheme to apply Special Control Area 1 to Horrocks Beach
3. Public infrastructure asset management plan
4. Land acquisition policy and management plan/guidelines – to determine priorities for acquisition, potential staging, lease arrangements, land swaps
5. Private residence relocation
6. Future land use plan and update to local planning strategy and scheme (update expansion areas using hazard risk mapping)

These are discussed further below.

5.3.1.1 Special Control Area

A key planning mechanism to deliver coastal adaption is a special control area applied to an identified retreat zone, which provides additional planning controls to support long-term retreat, ahead of formal reservation and acquisition of land/land swaps at the time of intolerable risk.

In developing a special control area for the retreat zone, the following elements should be considered in the local planning strategy review:

- Determination of an appropriate special control area for the long-term “retreat zone”. The extent of the Special Control Area should include the areas identified as vulnerable to erosion by 2120. As so much of the town is affected, and the Shire has the opportunity to explore lease arrangements for its own land, the incorporation of the entire town, or west of Mitchell Street could also be considered.
- Development controls for the special control area, and the timing or trigger points for inclusion of those controls in the scheme. It is recommended that controls include:
    - Notifications on title for properties within the special control area, placed on as a condition of development approval or subdivision, which are reviewed and updated over time
    - Mandate that all development requires approval, thereby providing the power to regulate development that may otherwise be exempt from development control

- Policy provisions requiring all new permanent land use and development to be located outside of the retreat zone, which would facilitate incremental and opportunistic relocation (retreat) of private development over time.
- Policy provisions that facilitate granting of temporary approval (e.g. for 10 years) for development and land use deemed appropriate for short term, which facilitates continued land use whilst taking into account future risk and a policy of eventual retreat (this is especially important given the reduction in land available outside of the 100 year retreat zone) and allows for triggers to remove development if the erosion encroaches too far into the retreat zone.

5.3.1.2 Horrocks Beach Local Planning Strategy

The current local planning strategy for Horrocks Beach identifies a number of expansion areas. It is important that the local planning strategy consider expansion of the townsite in the context of coastal hazards and therefore requires review.

The review would include:

- Delineation of the retreat zone (and application area for the special control area discussed in Section 5.3.1.1)
- Identify future townsite area
- Identify at what point the scheme should incorporate controls on development
- Include coastal policy statements to enable the policy to apply to all planning proposals, including subdivision and rezoning which are approved at the state level
- Include coastal policy statements to allow assessment of proposals of infill development against SPP2.6 as if it were new development (i.e. avoiding any new development within the retreat zone, with the exception of temporary development)

5.3.1.3 Land acquisition policy and management plan/ retreat strategy

This plan would detail how land is to be acquired in a retreat scenario. Priorities for acquisition, compensation, land swaps and lease arrangements would be outlined to guide the practical application of retreat. This affords the opportunity for the Shire to clearly specify an approach to retreat, how it will work and obtain community input.

It is recommended that the Shire investigate the potential to provide affected landowners with a lease opportunity within its own freehold landholdings rather than through land acquisition and financial compensation. Lease opportunities are preferable to allow for long-term coastal hazard risks beyond the timeframes considered in this CHRMAP.

5.4 Other adaptation recommendations

5.4.1 No regrets risk treatment

Some time is required to understand the practicalities of implementing managed retreat from the current townsite and to understand the pros and cons of interim protection compared to managed retreat, particularly in relation to community support and financial burden.

No regret risk treatment options such as development of a land acquisition process is likely to help ensure risks are treated in a no-regrets manner and are beneficial even if protection measures are implemented in the short to medium term.

5.4.2 Engage the community in decision-making

Further discussion with the community is required to ensure better understanding of the current and medium term erosion risks and what this means in the long term. Risks can be discussed in terms of economic, social and environmental risks and how they change over time.

It is important that the community contribute to the conversation to guide the approach in the medium and long term to coastal erosion. For example, the community ranked the importance of protecting private residences low in comparison to other factors. If this is a true reflection of priority, this indicates that public funding should not be spent on the protection of private residences. However, if public buildings and private residences can be protected by the same solution, is that more acceptable to the community?

Community engagement is also essential to long term planning. This is discussed further in Section 5.3.

5.4.3 Foreshore Monitoring

The Shire currently undertakes monitoring of the coastal conditions at Horrocks through site inspections and photographic records. A list of monitoring and data acquisition/analysis that would be also be beneficial for coastal management of Horrocks is summarised below:

- . Existing LiDAR datasets and vegetation line mapping are available and added to periodically by the Department of Transport. Review of shoreline movement data and aerial photography by the Shire approximately every 5 years is recommended. This will support the identification of trends in shoreline erosion and interpret coastal management pressures that may be affecting the coastline. This can then be used to identify social impacts and impacts to coastal infrastructure (and if required financial costs to replace, or social impacts of doing nothing).
- The nearest long-term historical wave and water level data to Horrocks is available at Geraldton. For improved understanding of the transfer of offshore waves and water levels to the inshore beaches at Horrocks, capture of near shore wave and water levels inside and outside of the nearshore reef chain during a stormy period is recommended. Installation of nearshore hydrodynamic instrumentation to collect wave and water level conditions at locations where interim protection is planned to be implemented will also enable better calibration and validation of any numerical coastal processes modelling required and assist to inform interim protection structures design.
- Photo monitoring should be continued but it is recommended that key monitoring points are established and recorded, for ease of comparison. Photo monitoring of all of planning area 2 and key erosion hotspots in planning area 1, is recommended on a biannual (winter/summer) frequency and prior/post significant storm events, in accordance with the methodology recommended by Department of Transport (DaSilva 2012). Visual comparison of site photos provides context for interpretation of the measured profile, vegetation line and bathymetric changes. Opportunities for citizen participation in science may be used to assist in photo monitoring in combination with Shire staff.
- Beach surveys, in conjunction with aerial photography should be undertaken regularly to give a record of shoreline changes. This will help improve understanding of the vulnerability of the coast to storms, the extent of usable beach for habitat and recreation, and the risks to public and private land.

5.4.4 Update modelling

A conservative approach to tide and storm surge inputs to the inundation modelling was taken due to limitations in the information currently available. This value should be reviewed and refined in future revisions of the CHRMAP covering Horrocks as additional data is measured, existing studies are refined, additional studies are undertaken, and tropical cyclone modelling methodologies and capabilities further improve.

Table 9 Summary of other adaptation options

	Action	Timing	Responsibility
1	Special Control Area	Immediate	Shire DPLH
2	Review of Horrocks Local Planning Strategy	Immediate	Shire DPLH
3	Land Acquisition Policy and Management Plan	Short	Shire
4	Community engagement	Ongoing	Shire
5	Foreshore Monitoring	Ongoing	Shire
6	Update modelling	As possible	Shire (Department of Transport can provide technical assistance)

5.4.5 Adaptation timeframes

Strategic planning is required to be undertaken between now (2019) and 2050 and the implementation of adaptation solutions recommended as a result of the outcomes of the current planning are anticipated to occur between 2030 and 2050.

The overlap between the immediate risk actions and the current planning is because planning is an ongoing process that will inform future adaptation actions, whereas immediate actions are generally actions focussing on informing or undertaking the implementation of specific coastal engineering adaptation protection options.

In some cases, for example Glance Cove, immediate actions have been recommended based on the need to further investigate the feasibility of recommendations for the current planning timeframe, however an adaptation pathway should be agreed as soon as possible to avoid the realisation of risk impacts and increasing the likelihood of reactive decision making and potential regrets.

5.5 Funding

5.5.1 Managed retreat

In Planning Area 2, the adaptation pathway (Section 4.2.2) identifies that an interim protection decision is unlikely to prevent a subsequent need for managed retreat. Acquisition of private land is unlikely to be financially viable for the Shire or the State or Commonwealth Governments.

It may however be possible to utilise the Coastal Management Plan Assistance Program (CMPAP) grants, administered by the Department of Planning, Lands and Heritage on behalf of the Western Australian Planning Commission. The CMPAP grants support coastal land managers to develop strategies and management plans for coastal areas that are, or are predicted to become, under pressure from a range of challenges. CMPAP may therefore be a source of funding for the proposed land acquisition policy and management plan (5.3.1.3), which will be used to guide retreat. State Government funding is subject to change over time and there are no guarantees as to how long this funding will be available.

The purpose of the proposed land acquisition and management plan is to allow strategic retreat from the current townsite, whilst allowing continuing enjoyment for as long as possible.

5.5.2 Interim protection

The Coastal Adaptation and Protection (CAP) Grants are available through the State Government (Department of Transport). CAP Grants provide financial assistance for local projects that identify and manage coastal hazards. The program seeks to preserve and enhance coastal assets for the general public, building partnerships with local coastal managers and helping them to understand and adapt to coastal hazards (www.transport.wa.gov.au, accessed February 2020).

CAP Grants do not exclude the possibility of traditional coastal protection structures. However, under the State Planning Policy 2.6, protection is at the bottom of the response hierarchy. It is expected that the managed retreat and accommodate options in the hierarchy will be used more frequently in the future. This new approach will limit the implementation of adaptation options where the context of the situation is not well understood (Department of Transport, 2019). For this reason, Managers are steered away from options that would limit future flexibility in management and where long term protection is not likely to be financially or environmentally sustainable for the local community. However, in the short to medium term, CAP Grants can support some interim protection of existing public assets in immediate hazard zones to give councils time to develop adaptive coastal land use strategies.

There is a project application minimum of $10,000 ex GST and project application maximum of $300,000 ex GST. Up to 50 per cent of the total project cost is available for all project types; the remainder of the project cost is to be funded by the applicant.

CAP Grants may therefore be accessible for interim protection measures allowing time to properly develop a retreat strategy. For Horrocks, however, interim protection measures such as sand nourishment and revegetation are likely be considered for funding as a preference over hard structures such as seawalls. This is because these measures will allow time to properly consider the feasibility of hard interim protection versus managed retreat and a long-term retreat strategy.

CAP Grants are available for monitoring.

There are examples of local governments in Western Australia considering the use of specified area rates to fund interim protection. In Horrocks, the CHRMAP survey results indicate that the financial burden of coastal protection should not be borne solely by Horrocks residents as it is a known destination for all Shire residents and tourists from outside the municipality. The rate base is also not large and funds collected may take some time to accumulate. Other measures, such as paid parking, were unpopular with survey respondents. However, over time such measures may have to be considered more seriously as impacts from erosion are realised but this will require further consultation.

5.6 Summary

The table below summarises the Implementation Plan.

Table 10 Adaptation Summary

Asset	Immediate Actions (2020)	Medium Actions (to 2050)	Long-term Actions (to 2120)	Responsibility	Performance measure
Planning Area 1					
All	Monitor Community consultation (managed retreat vs. interim protection) Initiate long term retreat strategy	Monitor Community consultation (managed retreat vs. interim protection)	Managed retreat or significant interim protection	Shire	Area included in long term retreat strategy/ land acquisition plan
Planning Area 2					
Boat launch facilities	Monitor Interim Protection via sand/gravel replenishment **Trigger:** Launches become unusable **Budget:** Within existing budgets	Continue Interim Protection via sand replenishment **Trigger:** Launches become unusable OR Managed retreat **Budget:** Within existing budgets	Townsite-wide Managed retreat or significant interim protection Decision to be confirmed following feasibility study and long term retreat plan	Shire	Boat launches are maintained and used safely by the community

Universal beach access	Monitor Interim Protection via sand replenishment **Trigger:** Access track becomes unusable	Managed retreat via redesign/relocation **Budget:** Within foreshore management budget		Shire	Universal access is maintained and used safely by the community
Existing Geotextile Seawall	Monitor	Monitor Interim protection OR Managed retreat (based on feasibility assessment) **Trigger:** End of design life **Budget:** Shire budget/CAP Grant		Shire	GSS Seawall is maintained and continues to protect public infrastructure
Jetty Beach	Monitor Interim Protection via sand replenishment **Trigger:** Reduced beach width **Budget:** Incorporate into Shire budget as required	Interim Protection via sand replenishment Managed retreat (included in GSC seawall replacement feasibility) **Trigger:** End of design life of GSC seawall		Shire	Jetty beach is maintained and actively used by the community
Informal parking area	No risk Community consultation (managed retreat vs. interim protection) **Budget:** Feasibility study/land acquisition	Managed retreat – parking relocation OR Interim protection **Trigger:** Loss of land		Shire	Area included in long term retreat strategy/ land acquisition plan

	policy/long term retreat plan to include consultation – include in CMPAP grant application for joint State/Shire funding	**Budget:** Incorporate into Shire budget as required			
All other assets	Monitor	Monitor		Shire	
Glance Cove asset grouping	Interim protection - dune stabilisation and revegetation to allow time for feasibility study Review local planning strategy Determine special control area/ development controls Place Section 70A of the *Transfer of Land Act 1893* notifications on certificates of title Update Local Planning Scheme Community consultation **Trigger:** CHRMAP outcome **Budget:** Shire officer time, consultancy budgets, CAP Grant funding	Interim protection via dune stabilisation and revegetation OR Managed retreat Decision to be confirmed following feasibility study			

Glance Street and Jetty Beach asset grouping	Monitor GSC Seawall Interim protection - dune stabilisation and revegetation to allow time for feasibility study Review local planning strategy Determine special control area/ development controls Place Section 70A of the *Transfer of Land Act 1893* notifications on certificates of title Update Local Planning Scheme Community consultation **Trigger:** CHRMAP outcome **Budget:** Shire officer time, consultancy budgets, CMPAP/CAP Grant funding	Interim protection via dune stabilisation and revegetation OR Managed retreat Decision to be confirmed following feasibility study		Shire	

6. Review framework

6.1 Adaptation plan review

This plan should be reviewed regularly, alongside the review of the Shire's strategic plans and/or five-yearly reviews of local planning strategies.

Review processes should include targeted community consultation to update values and views about coastal development and assets that will be at risk both within a 15-year planning horizon and beyond. Revised values and new learnings should be used to test recommendations of this adaptation plan, and determine whether adaptation strategies for the 15-year planning horizon require modification as a result of changing values.

The regular testing of values and adaptation measures will involve the following actions incorporated into the review of future strategic plans, for land and assets identified as being at risk within 15-years of the strategic plan review:

- Identification of any new or alternative adaptation options based on greater information and new technology;
- Review of criteria used in the multi-criteria assessment;
- Community, stakeholder and industry consultation on the weighting of criteria;
- Review of the weighted scoring of adaptation options;
- Confirmation of adaptation options for a 15-year planning horizon.

6.2 Future hazard assessment

It will be necessary to update the hazard mapping from time to time to reflect actual sea level rise, updated projections of future sea level rise and the response of the coast to changing conditions.

These updates should occur either as new information becomes available; an event occurs that prompts a change in the level of risk identified in the current timeframe; or every 10 years, whichever occurs first.

7. References

Department of Transport (2019), Coastal Adaptation and Protection (CAP) Grants Frequently Asked Questions

Western Australian Planning Commission (2019) Coastal Hazard Risk Management and Adaptation Guidelines

Western Australian Planning Commission (2014) Coastal Hazard Risk Management and Adaptation Guidelines

International Panel on Climate Change (2014) Fifth Assessment Report, New York USA.

Australian Bureau of Statistics (2016) Census data,

Western Australian Planning Commission (2013) State Planning Policy 2.6 State Coastal Planning Policy

Western Australian Planning Commission (2013) State Planning Policy Guidelines

Shire of Northampton (2015) Horrocks Beach Local Planning Strategy

Shire of Northampton (2012) Local Planning Scheme No. 10

Appendices

Appendix A - GHD Adaptation Principles

Principle 1 Adaptation planning in the current planning timeframe does not impede the ability of future generations to respond to increasing risk beyond current planning timeframes.

The preparation of erosion and inundation risk mapping to inform this plan considers possible scenarios for sea level rise to 2120. These hazard risks include projections for sea level rise that are dependent on the global action taken to mitigate climate change impacts through greenhouse gas emission reductions. The modelled scenarios considered by the Intergovernmental Panel on Climate Change (IPCC) give rise to a range of predictions of sea level rise, which show increasing variability in sea level estimates with increasing time into the future.

The implementation of adaptation solutions should, where possible, not be tied to specific timeframes, but tied to trigger points in coastal risks due to uncertainty about the timing of when and if risks may be realised. The implementation of short and medium-term coastal adaptation measures should not adversely impact upon coastal adaptation measures implemented in the medium and long-term.

Principle 2 Adaptation requires a decision-making framework that enables the right decision to be made at the right time, in line with the values and circumstances of the time.

The dynamic nature of community needs and values requires a flexible approach when considering adaptation options. The effects of climate change on the coast, and changes to our beaches from erosion and engineered changes have been identified as potential concerns for some in the community. The interest and values of the community will change over time as more information becomes available, and impacts of climate change become more apparent. Our approach to coastal adaptation will likely evolve as new technology and information opens up new approaches to manage risk.

Making decisions based on community values that are likely to change may potentially prevent achieving the best possible outcome when considering short, medium and long-term measures to adapt to changing coastal processes. Adaptation planning should provide opportunity for future action to utilise new technologies and reflect community values at the time of the decision.

Principle 3 Adaptation planning reflects the public's interest in the social, environmental, and economic value of the coast.

Western Australia is renowned for its extensive coastline and beaches. Social and recreational use of these features form an integral part of Western Australian culture. Continued public access to the coast and beaches is an iconic part of Western Australia's lifestyle, contributing to the high quality of public spaces enjoyed by the community. Our economy and quality of life is supported by coastally dependent infrastructure and industries. In addition the coast might support future projects critical to the development of the Western Australian economy. The coast also provides important environmental values, with a unique ecology that includes marine, intertidal, and dune habitats.

Adaptation planning should respect the inherent value of the coast that is ingrained in the state's social, environmental and economic interests.

Principle 4 Alternative adaptation measures should consider the full range of land uses and values.

The objectives of State Planning Policy 2.6 include the retention of coastal areas for a range of public and private uses including economic uses, coastal foreshore access and social and environmental uses and values, including:

- Housing, tourism, recreation, ocean access, maritime industry, commercial and other activities;
- Public coastal foreshore reserves and access to them; and
- Landscape, biodiversity and ecosystem integrity, indigenous and cultural significance.

Principle 5 The full life-cycle benefits, costs and impacts of coastal interim protection works should be evaluated when considering adaptation options.

Coastal engineering works have the potential to provide protection to nearshore coastal assets over their design life, dependent on the rate of future sea level rise. There are two broad categories of protection with potential for use of Horrocks coastal foreshore areas. These are:

- Engineering (hard) measures: seawalls, revetments, levees, groynes/breakwaters
- Regenerative (soft) measures: beach replenishment and dune and mangrove restoration

Seawalls and revetments, if implemented in response to persistent erosion but without ongoing beach replenishment, will eventually lead to a loss of beach and coastal habitat seaward of the structures, particularly as sea levels rise. Nourished beaches require ongoing maintenance to offset sediment losses incurred from storm-related erosion events and sea level rise. Coastal protection measures taken in a specific location may also influence adjacent coastal cells.

Interim protection measures also bring cost impacts. Engineering works can have a high capital cost, and require ongoing investment in maintenance. The cost impact of coastal engineering works should also consider decommissioning costs. Engineering options are designed to mitigate against a particular level of risk and have a discrete design life. However, the presence of protection works can set expectations for asset owners, and can potentially limit future decision-making flexibility. SPP2.6 includes a presumption against coastal protection measures unless "all other options … have been fully explored".

Appendix B – Community Engagement

The following information describes the activities and tasks undertaken by the project team to engage with the local community in the development of the CHRMAP.

Community engagement is an important part of the coastal hazard risk management and adaptation planning process; the level of risk presented to coastal areas is strongly influenced by the value of the area. The appropriate adaptation decision is also dependent on the values of coastal assets and areas. The community's feedback to determine values and consider the relative contribution of those values – including social, environmental and economic – to decision-making is important to ensure the right decisions are made.

The function of the community and stakeholder engagement during the project was to:

- Inform the community and stakeholders about the risk associated with coastal processes at work in the study area
- Inform the community and stakeholders about the risk associated with coastal processes at work in the study area
- Determine the community values associated with existing and future assets to inform the consequence assessment and management adaptation measures
- Consult with the community and stakeholders on the draft CHRMAP through a public consultation process.

To deliver the required function, objectives of the engagement strategy were:

- Consult with stakeholders to determine monitoring, maintenance and management responsibilities of foreshore areas and coastal protection structures.
- Inform the community and stakeholders about the risk associated with coastal processes in the study area.
- Determine community values associated with existing and future assets to inform the consequence assessment and management/adaptation measures.
- Consult with the community and stakeholders on the draft CHRMAP through a public consultation process.

Phases of engagement

The engagement methodology involved a number of key activities to identify stakeholders, inform them about the project process, provide opportunities for comment and document feedback for consideration from the project team.

The consultation process was undertaken in three key phases:

- Phase 1: scoping – to engage with key community and stakeholder representatives
- Phase 2: awareness and values – to inform and educate the community about the CHRMAP project and to obtain feedback related to community and stakeholder values
- Phase 3: coastal risks and adaptation (formal advertising) – to inform the community of the results of the vulnerability and risk assessment, present the draft adaptation plan and to obtain feedback on the adaptation options proposed

Awareness and values

The initial scoping engagement phase facilitated the identification of key stakeholders such as local business owners, local community groups and NRM groups. The awareness and values phase then commenced on the 28 January 2019 when the community values survey was opened and concluded on 28 February 2019 when the community values survey was closed. Community drop-in sessions were also held on the 29 and 30 January 2019 in Horrocks.

This stage of engagement involved:

- Informing the community about the project through the Shire's website, social media posts, media releases and project flyers located at the Horrocks general store and circulated through community groups.
- Obtaining feedback from the community regarding values of the coast through a survey.
- Community and stakeholder drop-in sessions/intercept surveys.

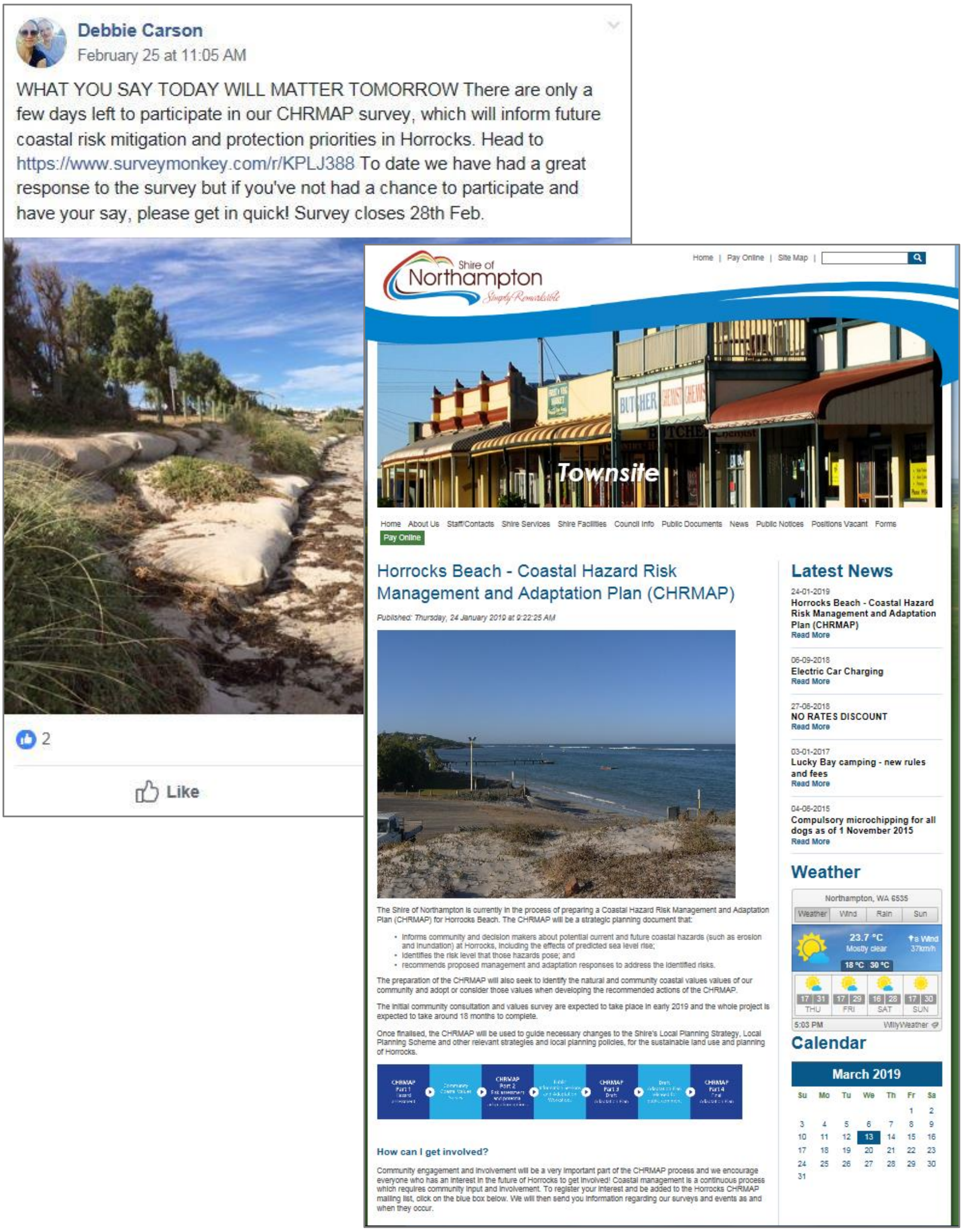

Figure 16 Project Communication Examples

Roving intercept surveys were conducted on the afternoon of the 29 January 2019 and the morning of the 30 January 2019 in Horrocks. Community drop in sessions were also held at these times. The Shire utilised distribution lists and drop in information was sent out via community groups. Drop-in sessions were attended by representatives of the Horrocks Beach Caravan Park, Horrocks Beach holiday cottages, Horrocks community centre, cray fishermen, and members of the broader community. The general store was also briefed about the project and displayed a project flyer.

Engagement levels

The survey opened on the 28 January 2019 and closed on the 28 February 2019. Approximately 15 people attended the community information session and/or were intercepted to complete the survey. The survey received 149 responses, including both in-person and online participants. Figure 17 illustrates the response volume across the period of survey.

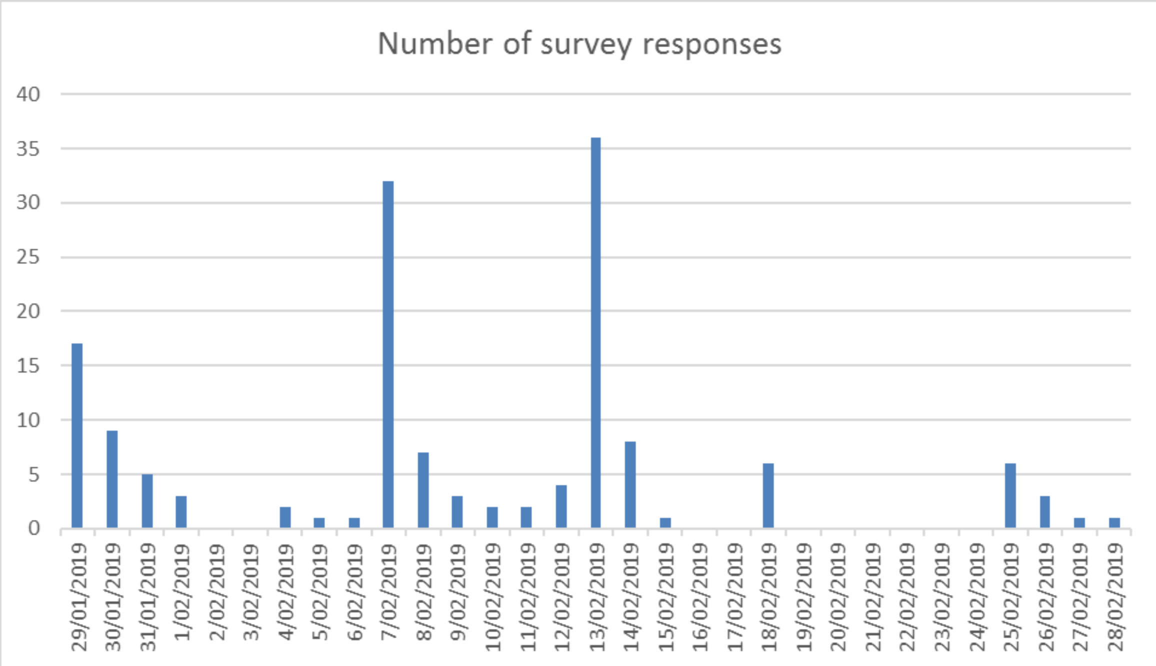

Figure 17 Number of responses to community values survey (by day)

Engagement outcomes

The values survey comprised 16 questions, a summary of responses is outlined below.

Question 1: Which beach and/or foreshore areas do you use?

There are four broad foreshore areas within the study area. Survey respondents indicated visitation to between one and all of these areas, with the majority of people indicating visitation to more than one area (82 percent of respondents visited two or more areas). Survey responses indicate the beach area surrounding the jetty where car parks and toilets are located is the most popular area with 85 percent of respondents indicating that they use this area. Beaches to the south of Horrocks (Whiting Pool) are also well frequented, and received the second highest response rate with 70 percent of respondents.

The beach area adjacent to the community centre was the third most popular location with 56 percent of respondents whilst the northern beach area/Stinky Point received the lowest response rate with 46 percent of respondents indicating visitation to this area.

The survey included the opportunity to specify alternative locations, however, no additional locations of place names were indicated by survey respondents.

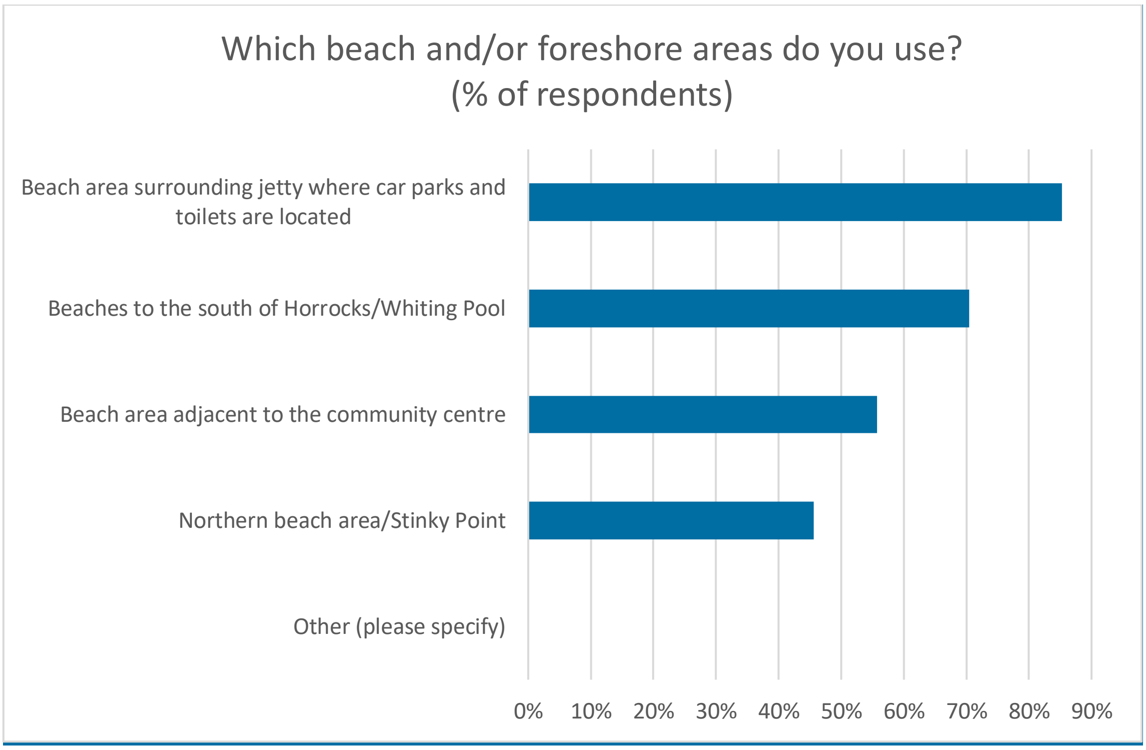

Figure 18 Beach and foreshore area popularity

Question 2: How often do you stay when you visit Horrocks?

Due to unique characteristics associated with Horrocks – and its value not just as a place to live, but also as a local beach to residents of the entire municipality and a holiday destination, respondents were asked to provide detail about how often they stay in Horrocks. It is important to capture responses from a broad range of user groups to ensure values of all groups are assessed and any differences identified.

Visitors with a holiday house in Horrocks staying for extended periods of overnight or longer received the highest response rate, at 43 percent of respondents. Daytrips from visitors who live either in the surrounding area, or in Horrocks, received the second and third highest response rate at 27 and 20 percent respectively.

One percent of respondents indicated that they were not staying at Horrocks, but rather just making a stop as part of their journey whilst two percent indicated that the visit was either an occasional or first time destination attributed to holiday use rental accommodation. Seven percent of respondents indicated that they were staying in holiday use rental accommodation and regularly choose Horrocks as a destination.

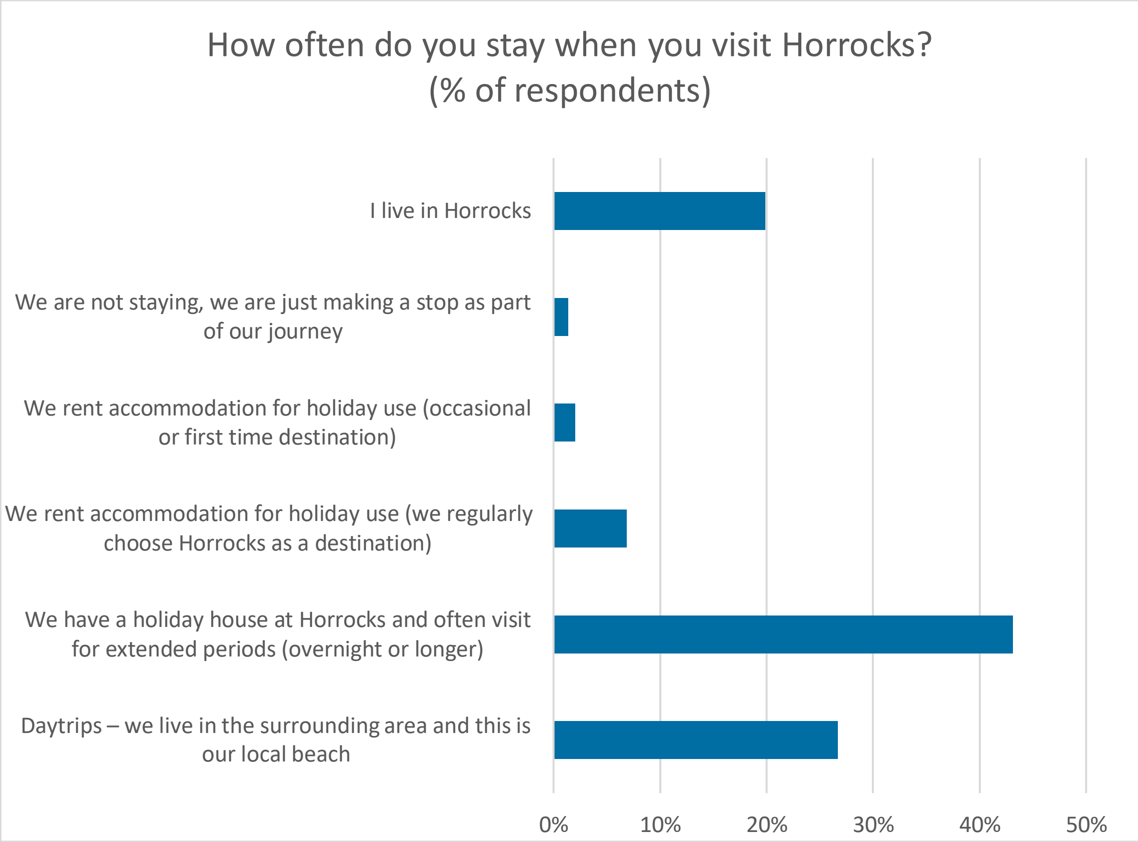

Figure 19 Length of stay in Horrocks

Questions 3 and 4 of the survey directed respondents to questions specifically relating to each of the beach areas visited (as determined by the answer to question 1). This allows the key features of and values associated with each area to be investigated. Each area is individually presented below.

Beach area surrounding the Jetty

The beach area surrounding the jetty where car parks and toilets are located is the most popular beach area with 85 percent survey respondents indicating they visit this part of Horrocks Beach. People visit this part of Horrocks Beach for a variety of reasons, the most popular being to participate in water activities such as swimming (82 percent of survey respondents indicated this as a reason to visit this beach area).

Other popular activities for this area include:

- Socialising with friends (76 percent)
- Activities on the sandy beach (71 percent)
- Other recreation near the beach, e.g. walking, BBQ (70 percent)
- Enjoying the views (70 percent)
- Social interaction, e.g. attend events (65 percent)

These activities are reflective of the provision of shade and picnic tables and a wide section of sandy beach.

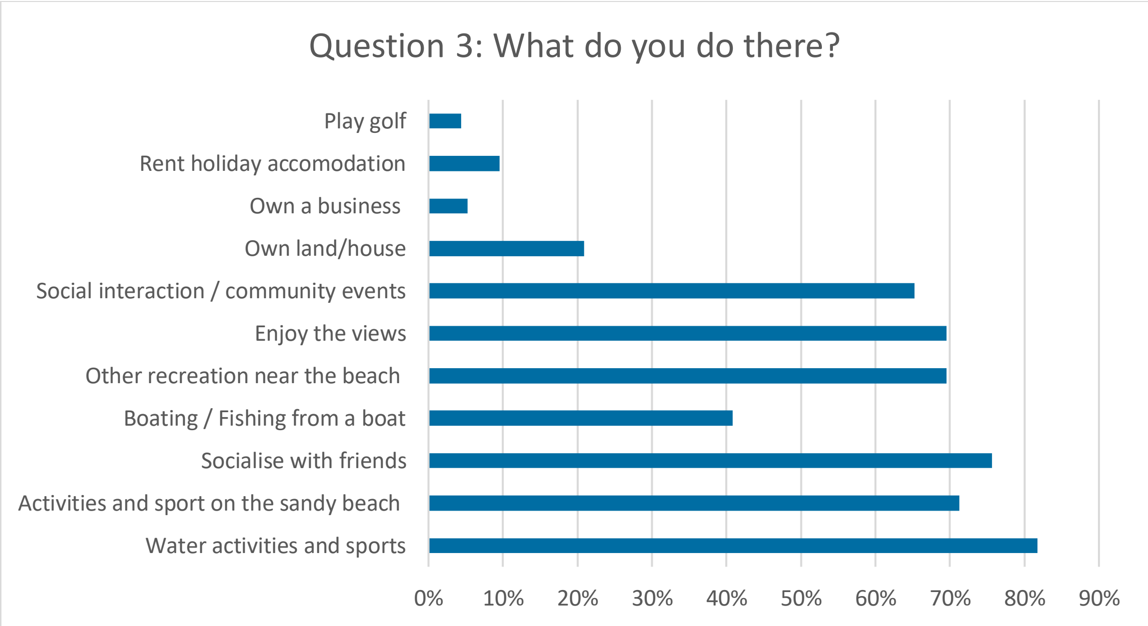

Figure 20 Recreational use of the beach area surrounding the jetty

87 percent of survey participants' value coastal/beach character. Access to a sandy beach also received a significant number of responses with 82 percent of respondents identifying this as an important aspect of this location. Other aspects considered important at this location include:

- Safety of water (63 percent)
- Access to an unspoilt, lesser known beach location (63 percent)
- Community events/ place to meet people (58 percent)
- Access to jetty (57 percent)
- Parkland and public facilities – seating, BBQ, change rooms, toilets (52 percent)

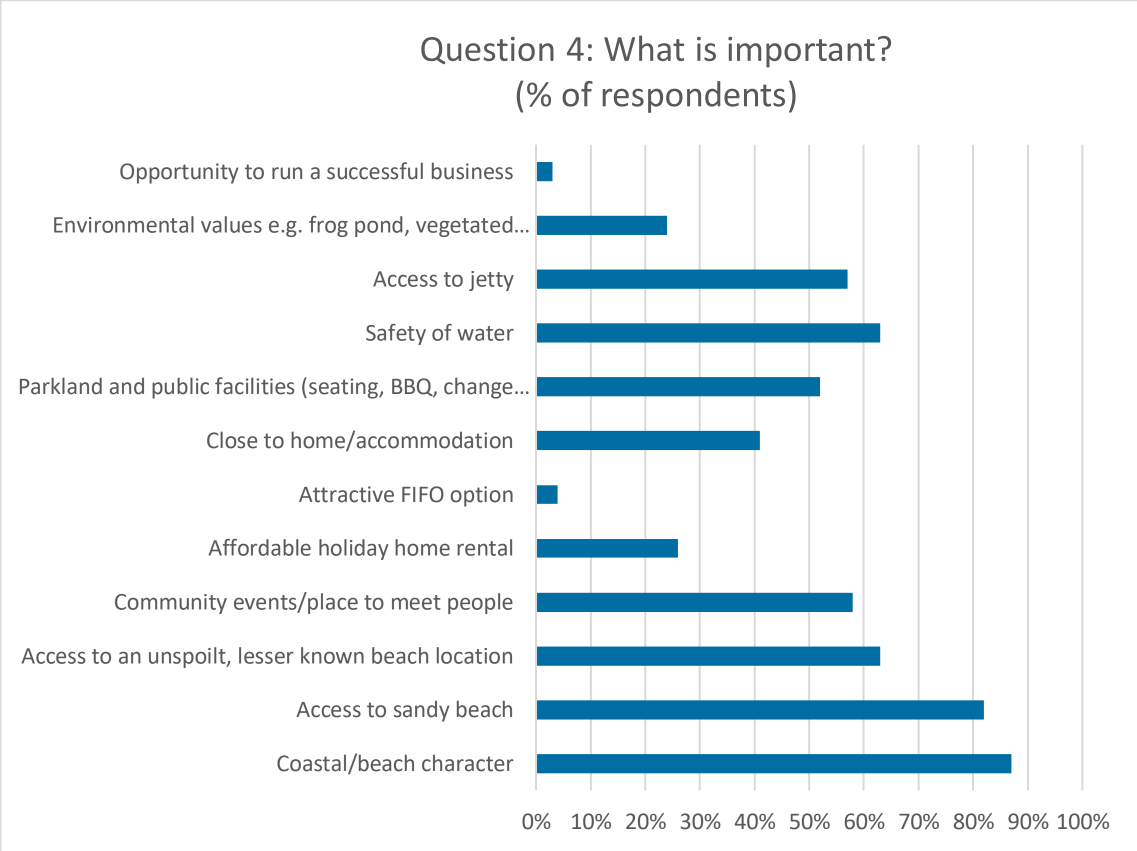

Figure 21 Attractors to the beach area surrounding the jetty

Southern beach area/Whiting Pool

The beach to the south of Horrocks, also known as Whiting Pool, is the second most popular section of the study area (70 percent of survey respondents indicate they use this area). Respondents indicate that the most popular reason to visit this area is to participate in water activities such as swimming (84 percent of respondents). Other popular activities include

- Participation in activities on the sandy beach (79 percent)
- Socialising with friends (77 percent)
- Enjoying the views (71 percent)
- Other recreation near the beach (67 percent)

These responses reflect the relatively calm nature of the ocean and shallow water at this section of the study area (due to the offshore reef), the relatively wide section of beach, the rocky landscape and the provision of shelters and picnic tables.

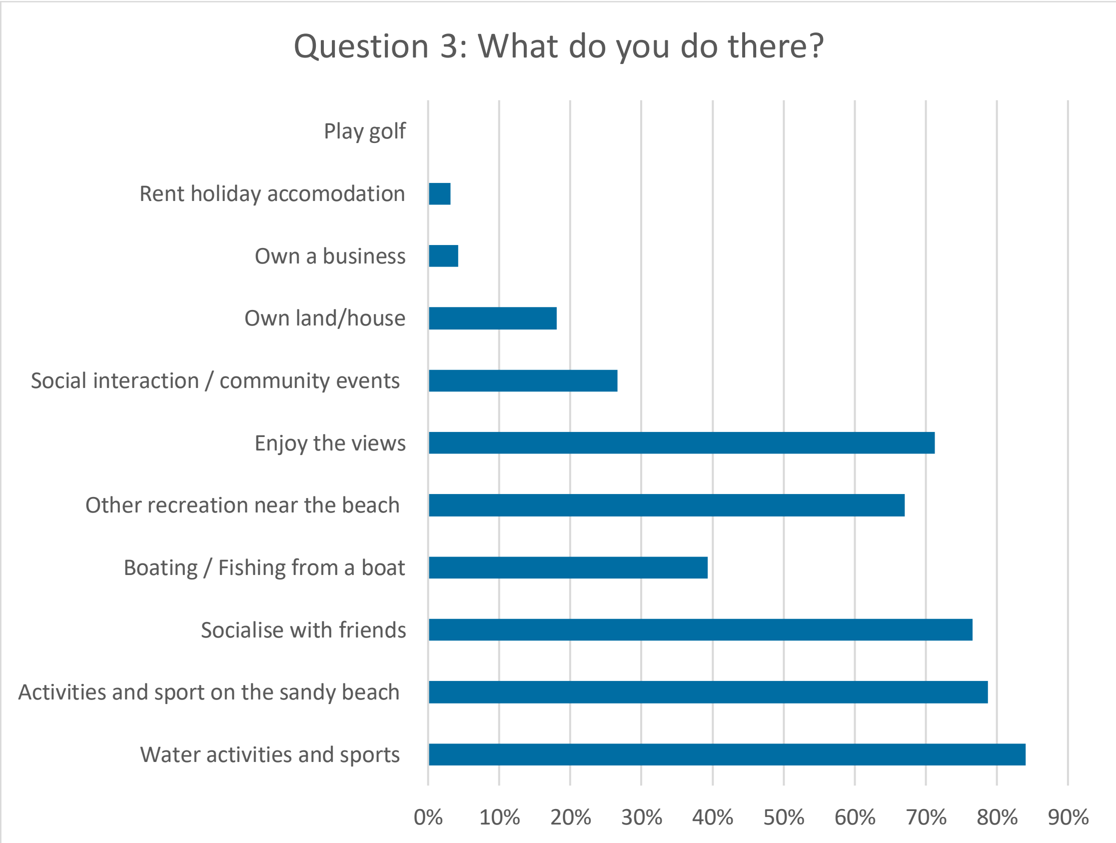

Figure 22 Activities at the southern beach/Whiting Pool

Access to a sandy beach and coastal/beach character were considered to represent important features at this area by the highest number of respondents (94 and 93 percent respectively). To a lesser extent, but identified as being important to two-thirds of survey participants, was access to an unspoilt, lesser known beach location. Other aspects considered important by respondents included:

- Safety of water (52 percent)
- Community events/place to meet people (37 percent)
- Close to home/accommodation (35 percent)
- Environmental values (20 percent)
- Access to jetty (19 percent)

- Parkland and public facilities – seating, BBQ, change rooms, toilets (18 percent)

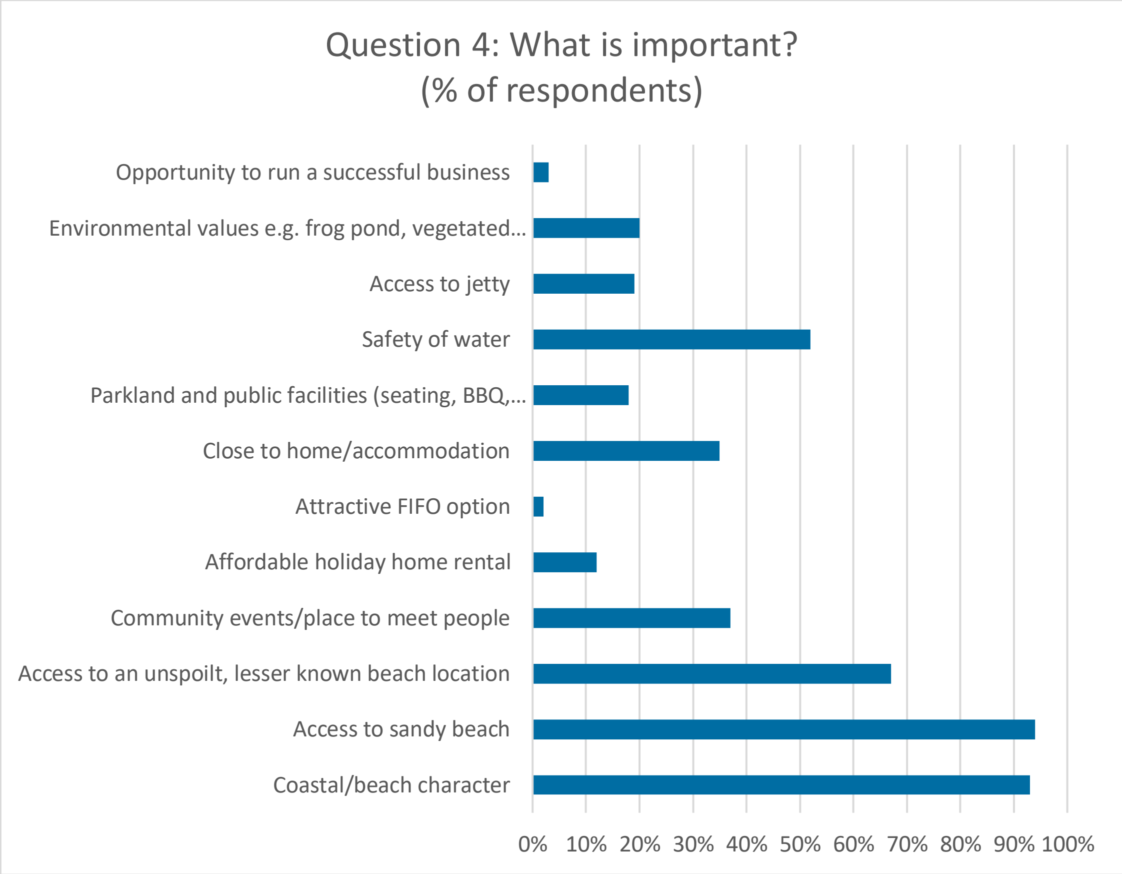

Figure 23 Attractors to the southern beach area/Whiting Pool

Beach adjacent to the community centre

The beach area adjacent to the community centre is the third most popular beach area with 56 percent of respondents indicating that they visit this area. Respondents indicate that they visit this area because of the views (77 percent of respondents), participate in activities on the sandy beach (72 percent), socialise with friends (67 percent) and participate in water activities such as swimming (65 percent).

These activities are likely to respond to the physical nature of this area, for example, the high dunes make appreciation of the views easier. The beach in this area is also wide and lends itself to activities on the sand and the community centre also provides opportunities to socialise and participate in other recreation activities.

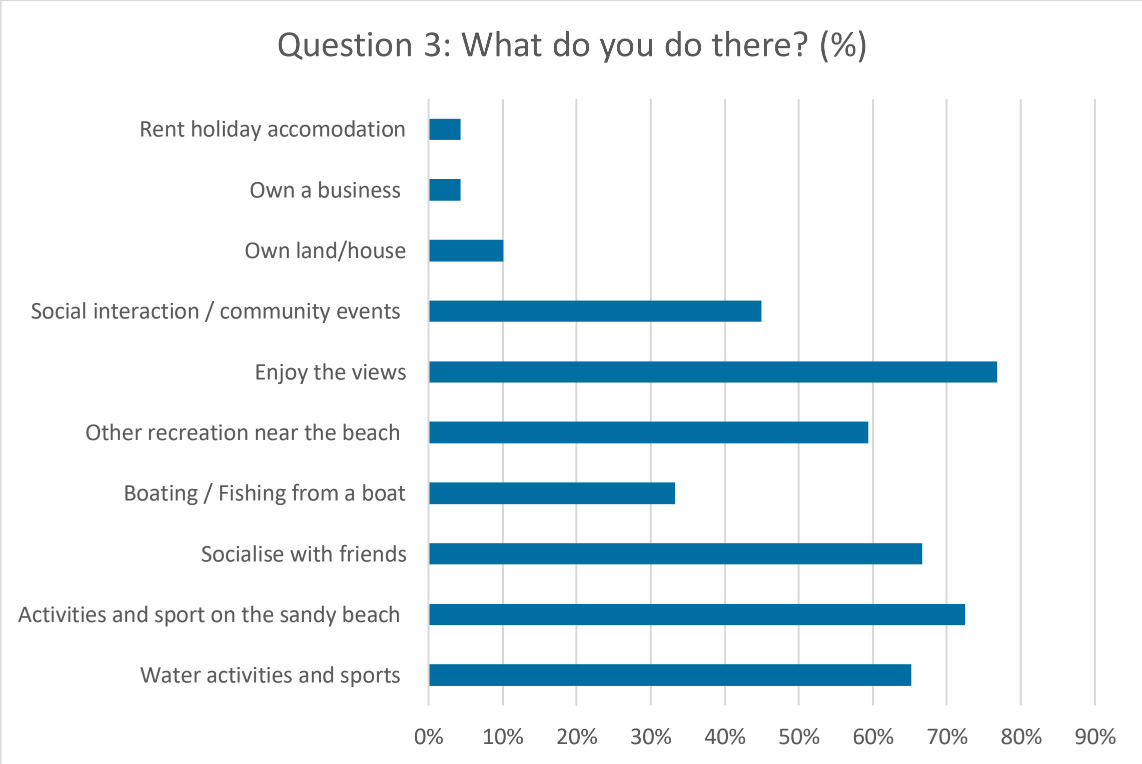

Figure 24 Activities at the beach adjacent to the community centre

Access to a sandy beach and coastal/beach character both received the highest number of responses with 85 percent of respondents identifying these as important features at this location. Access to an unspoilt, lesser known beach location and community events/place to meet people were also identified as important features by 59 and 54 percent of respondents respectively.

Respondents also identified the following as important:

- Safety of water (39 percent)
- Parkland and public facilities – seating, BBQ, change rooms, toilets (35 percent)
- Close to home/accommodation (32 percent)

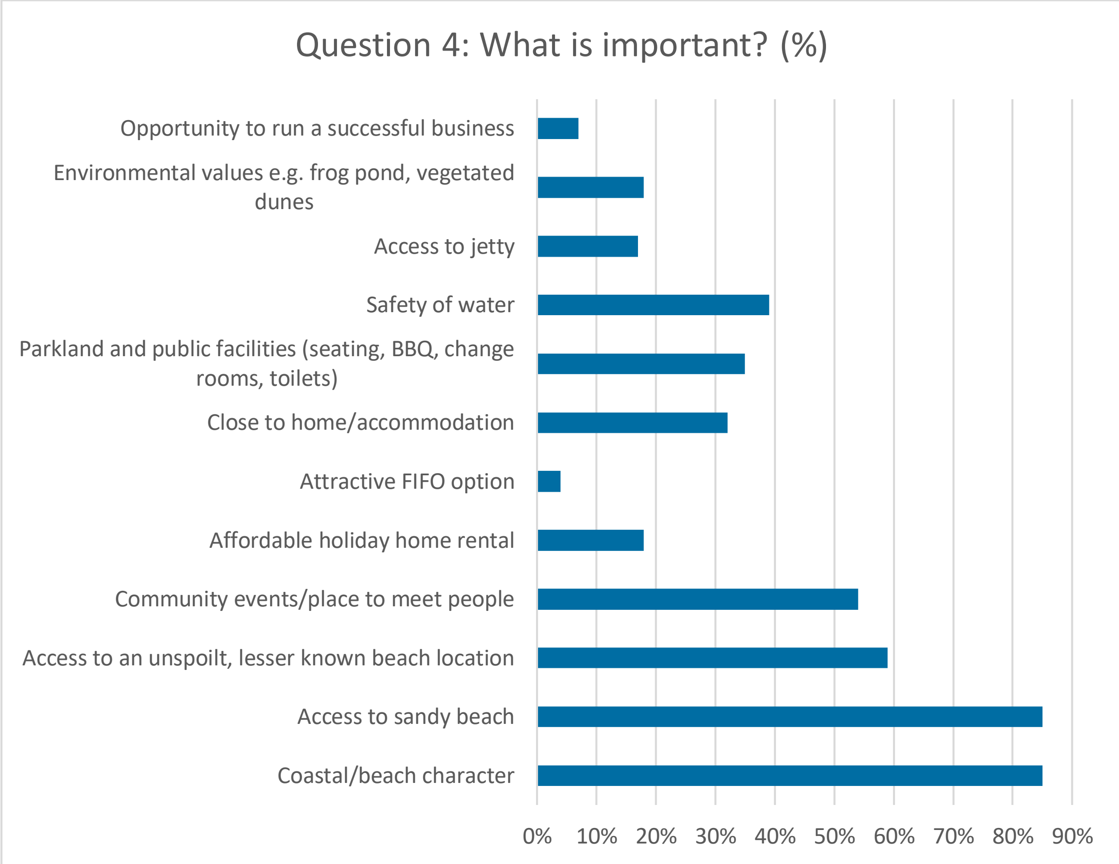

Figure 25 Attractors to the beach area adjacent to the community centre

Northern beaches/Stinky Point

The northern section of the study area and Stinky Point is the least popular beach area, however, 46 percent of survey respondents indicated that they visit this area. The most popular activity to participate in at this section of beach is activities and sport on the sandy beach (77 percent of respondents included this). Other popular activities include participation in water activities (71 percent), other recreation near the beach e.g. walking (63 percent) and enjoying the views (61 percent).

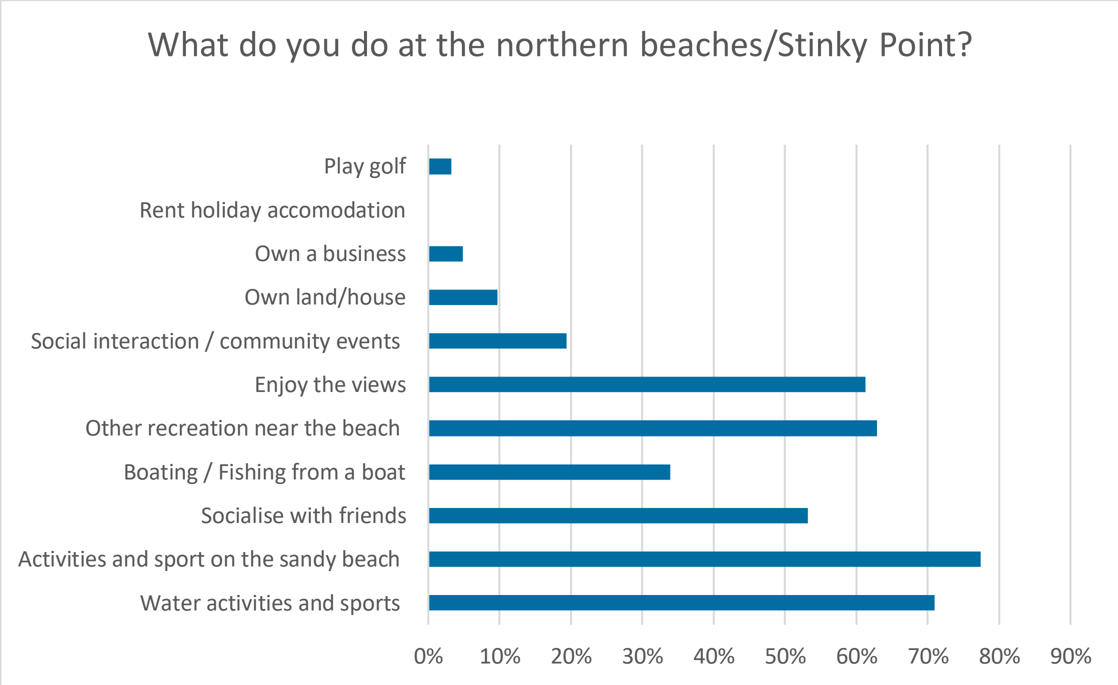

Figure 26 Activities at the northern beaches/Stinky Point

Coastal/beach character received the highest number of responses with 89 percent of respondents identifying this as an important feature in this area. Access to both a sandy beach, and an unspoilt, lesser known beach location also received a significant number of responses, at 77 and 74 percent of respondents respectively.

Other aspects identified as important by some survey participants at this location include the following:

- Safety of water (32 percent)
- Close to home/accommodation (31 percent)
- Community events/place to meet people (26 percent)
- Parkland and public facilities – seating, BBQ, change rooms, toilets (21 percent)
- Environmental values e.g. frog pond, vegetated dunes (21 percent)

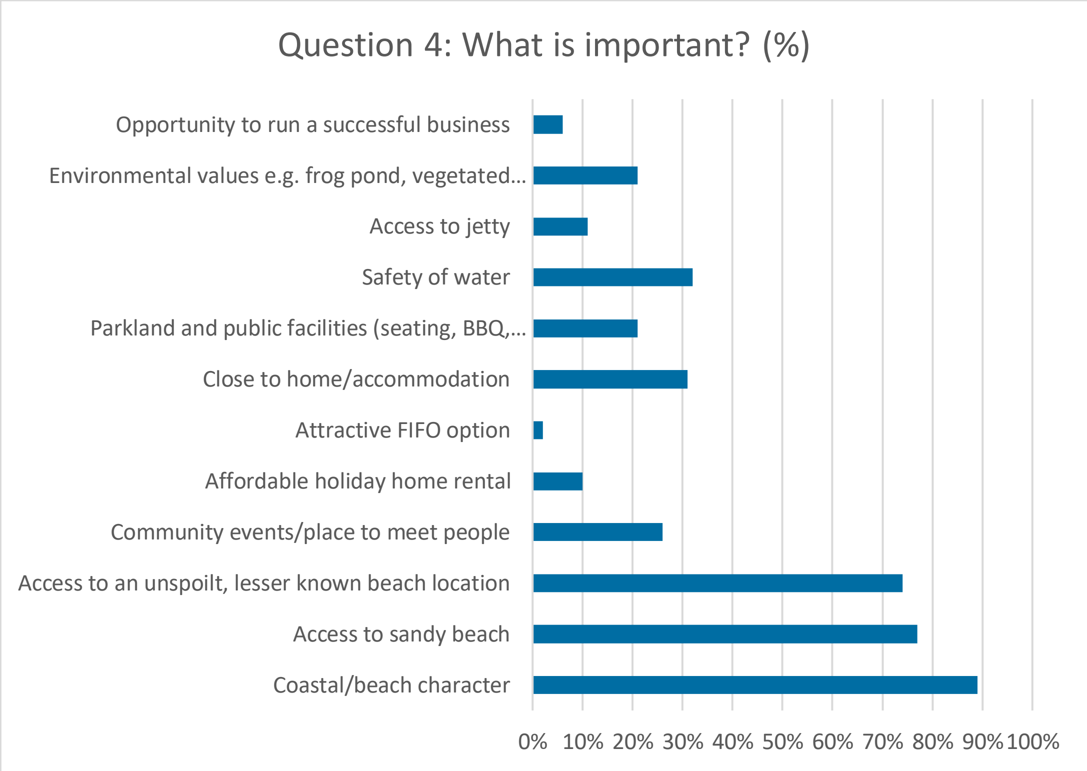

Figure 27 Attractors to the northern beach area/Stinky Point

Question 5: How important is it to access the following in Horrocks?

Beach recreation, and coastal character and scenery were rated as very important for the vast majority of respondents, at 92 and 86 percent respectively, with one percent indicating these aspects were not important to access.

Access to the marine environment, coastal facilities, and a lesser known beach location were all rated as very important by between 61 to 68 percent of respondents and somewhat important by 22 – 23 percent of respondents.

Overall, 53 percent of respondents indicated that entertainment and social activities on the coast were very important to them, whilst 36 percent rated this aspect as somewhat important.

A total of 42 percent of respondents identified access to affordable holiday accommodation in Horrocks as very important, with 20 percent of respondents indicating this was somewhat important. In respect of affordable housing to live in permanently in Horrocks, 32 percent of respondents indicated that was very important, with 16 percent seeing this as somewhat important. Conversely, between 24-31 percent of respondents indicated that access to affordable accommodation in Horrocks, on a temporary or permanent basis, was not important to them.

Access to affordable housing to FIFO is not important to 72 percent of survey participants, with only 6 percent of respondents identifying this as a very important aspect to them. This reflects this value as important to only those people that are employed on a FIFO basis.

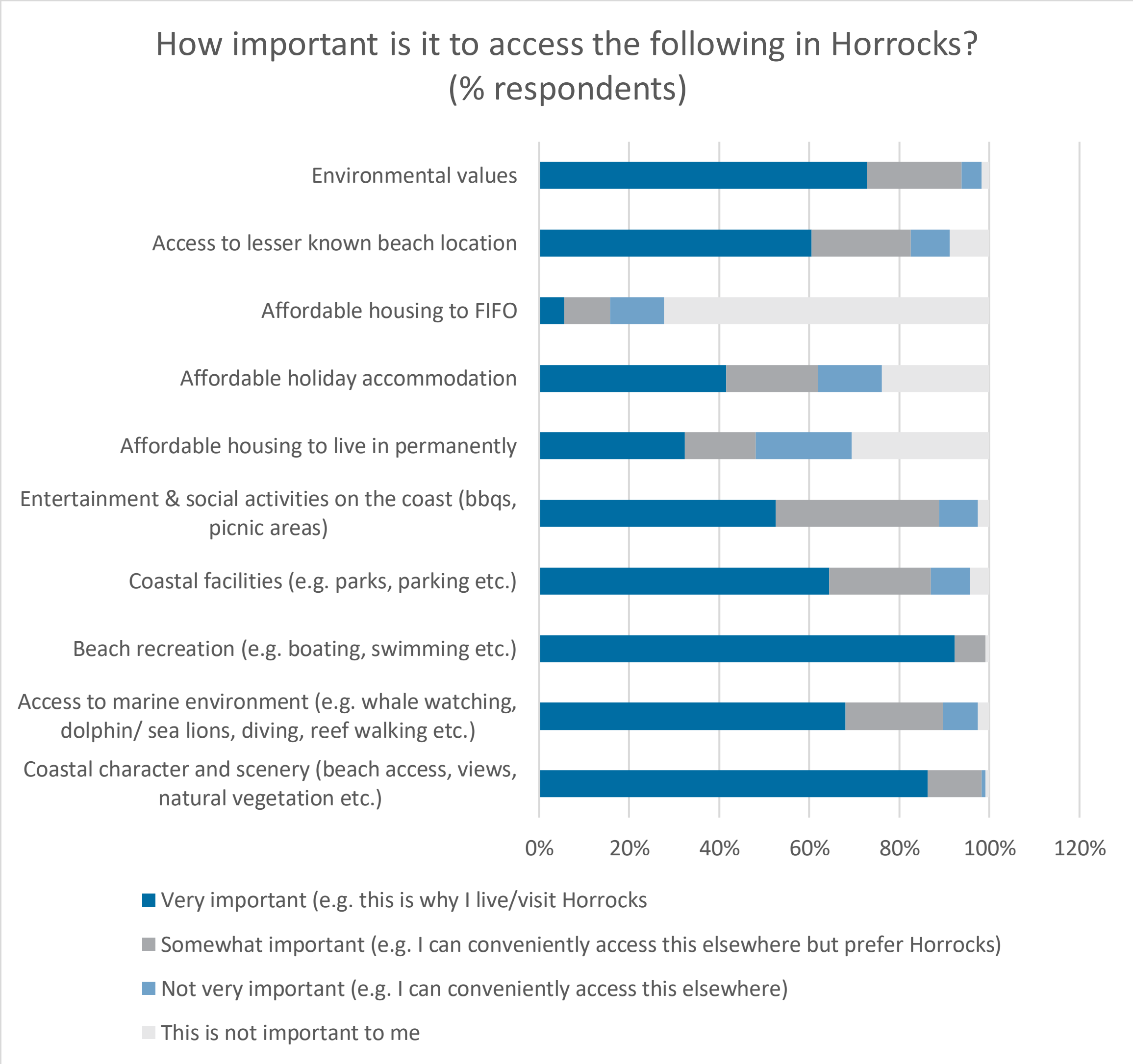

Figure 28 Importance of features of Horrocks Beach

Question 6: How much would the loss of the following impact your way of life?

Overall, the majority of respondents indicated that the loss of beach recreation (92 percent), coastal character and scenery (91 percent), environmental values (82 percent), access to the marine environment (81 percent), access to a lesser known beach location (78 percent), coastal facilities (76 percent) and entertainment & social activities on the coast (74 percent) would impair their lives. Notably, the loss of beach recreation, environmental values, and coastal character and scenery would significantly impair the lives of between 49 and 58 percent of respondents.

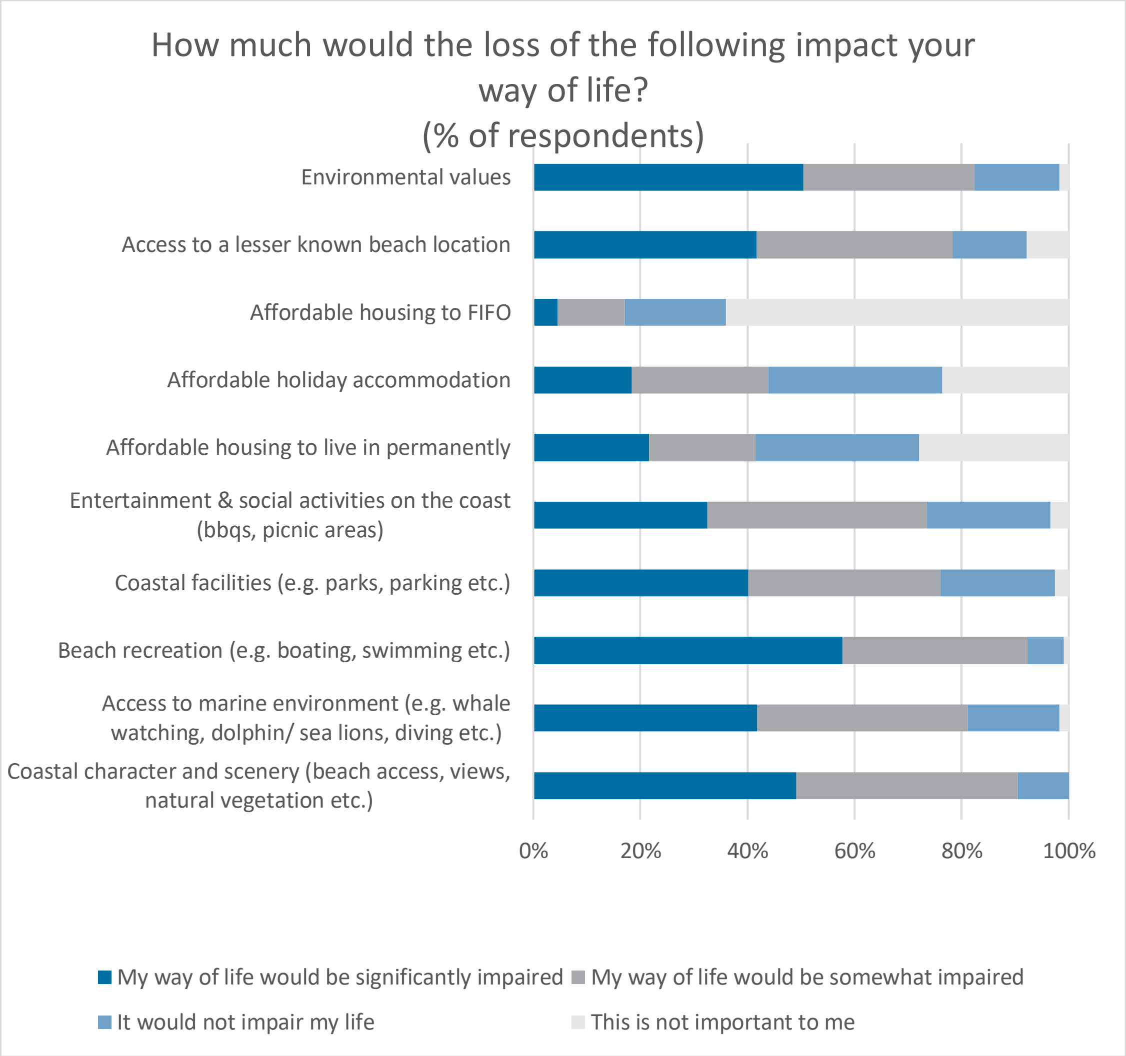

Figure 29 Impact of loss of values of Horrocks Beach

Question 7: What are the three most important things to consider or protect when making decisions about managing erosion or flooding in Horrocks Beach?

Protection of the environment was rated as the most important thing to consider or protect when making decisions about managing erosion or flooding with a total of 74 responses. Maintaining access to the marine environment was rated as the second most important consideration with 52 responses.

The jetty, and maintaining a sandy beach for amenity and use was also identified as important considerations with 44 and 43 responses respectively, and to a lesser extent the protection of private properties and residences, coastal and beach amenity and scenery, and the protection of commercial businesses.

Other responses identified keeping the area clean, protecting community amenities and re-planting and revegetation

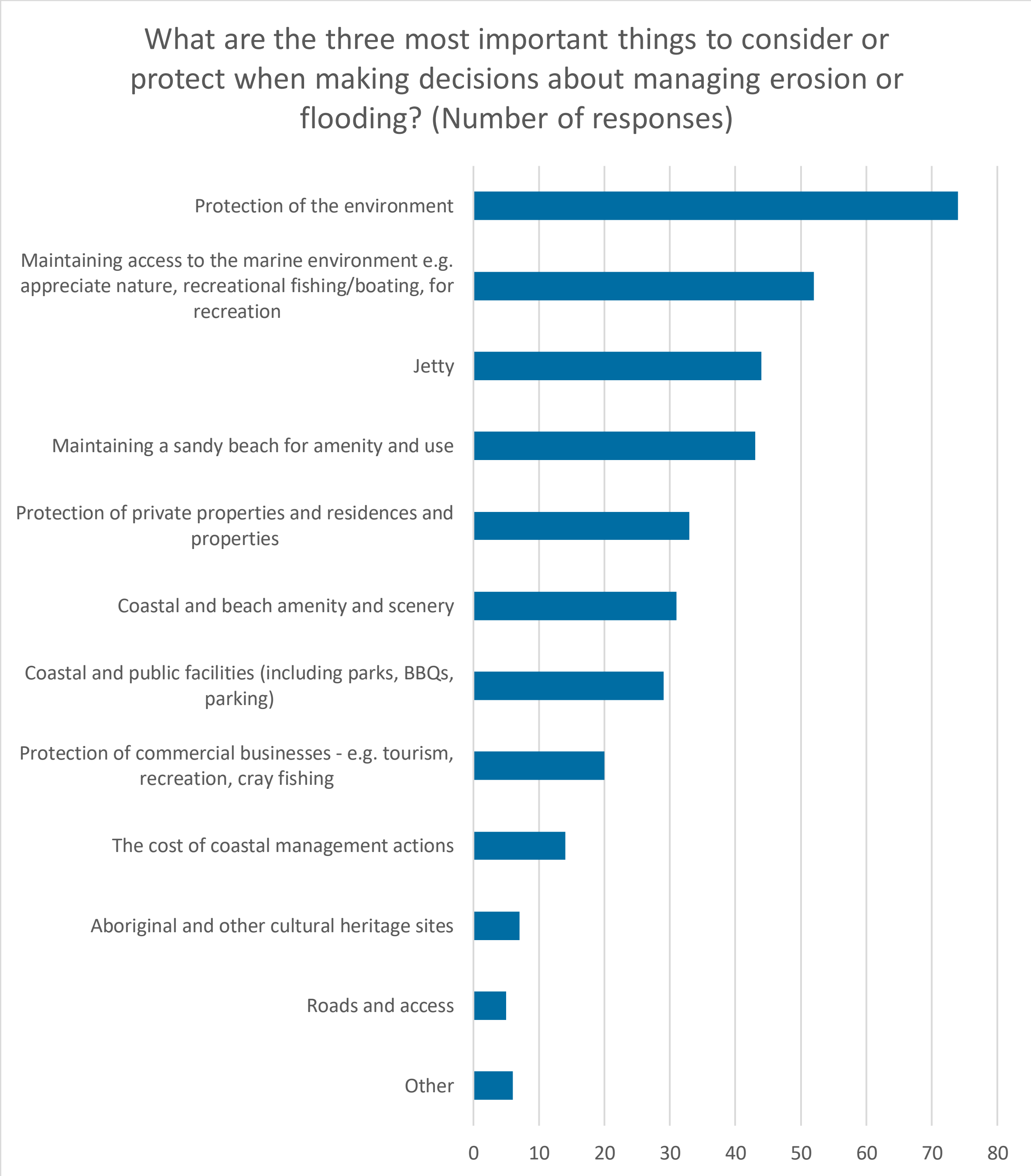

Figure 30 The most important things to consider/protect when making decisions about managing erosion/flooding in the Horrocks area

Question 8: What are the three least important things to consider or protect when making decisions about managing erosion or flooding in the Horrocks area?

At 72 responses, the cost of coastal management actions was identified as the least important consideration by the highest number of respondents. Aboriginal and other cultural heritage sites was identified as the second least important aspect to consider when making decisions about managing erosion or flooding by 55 respondents. Coastal and public facilities, and the protection of private properties and residences were also identified as some of the least important considerations with 39 and 38 responses respectively, and to a lesser extent roads and access, and the protection of commercial businesses.

Other responses identified the difficulty in prioritising due to the importance of all of the considerations presented. It was also highlighted that certain considerations are subjective and would be more important to different people, again emphasising the difficulty in prioritising.

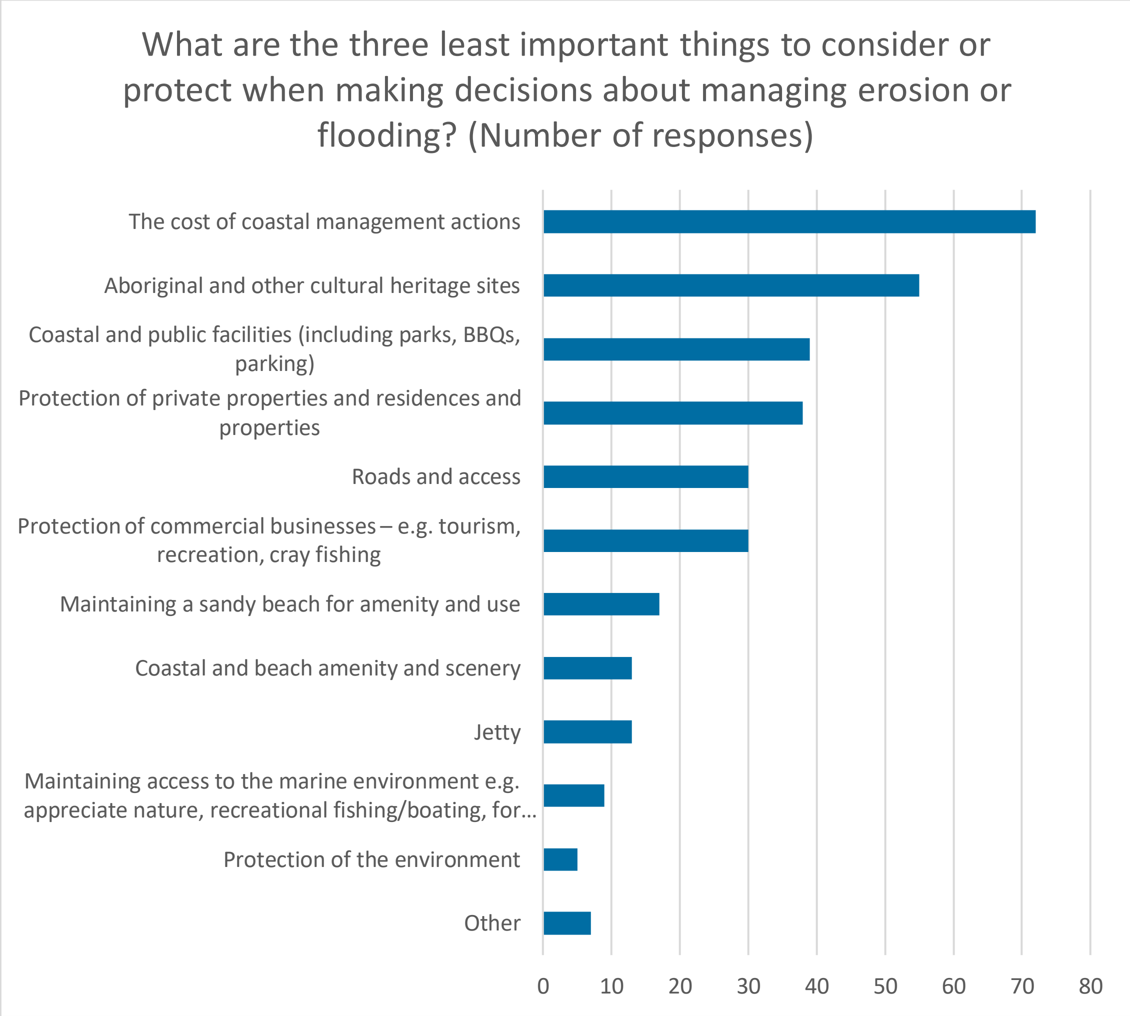

Figure 31 The least important things to consider/protect when making decisions about managing erosion/flooding in the Horrocks area

Question 9: Horrocks Beach is likely to be affected by increasing coastal hazards over time, e.g. due to erosion and sea-level rise. Who do you think should pay to manage the impacts from coastal hazards?

Overall, respondents (42 percent) felt that State Government should pay to manage the impacts from coastal hazards, compared to 3 percent of respondents that indicated affected landowners should be responsible.

A similar number of respondents indicated that local government, federal government and the entire community should be responsible for the costs, at 15, 16 and 17 percent of respondents respectively.

Other responses received highlighted that respondents also felt that the responsibility to pay to manage the impacts should be shared by a combination of government and the entire community.

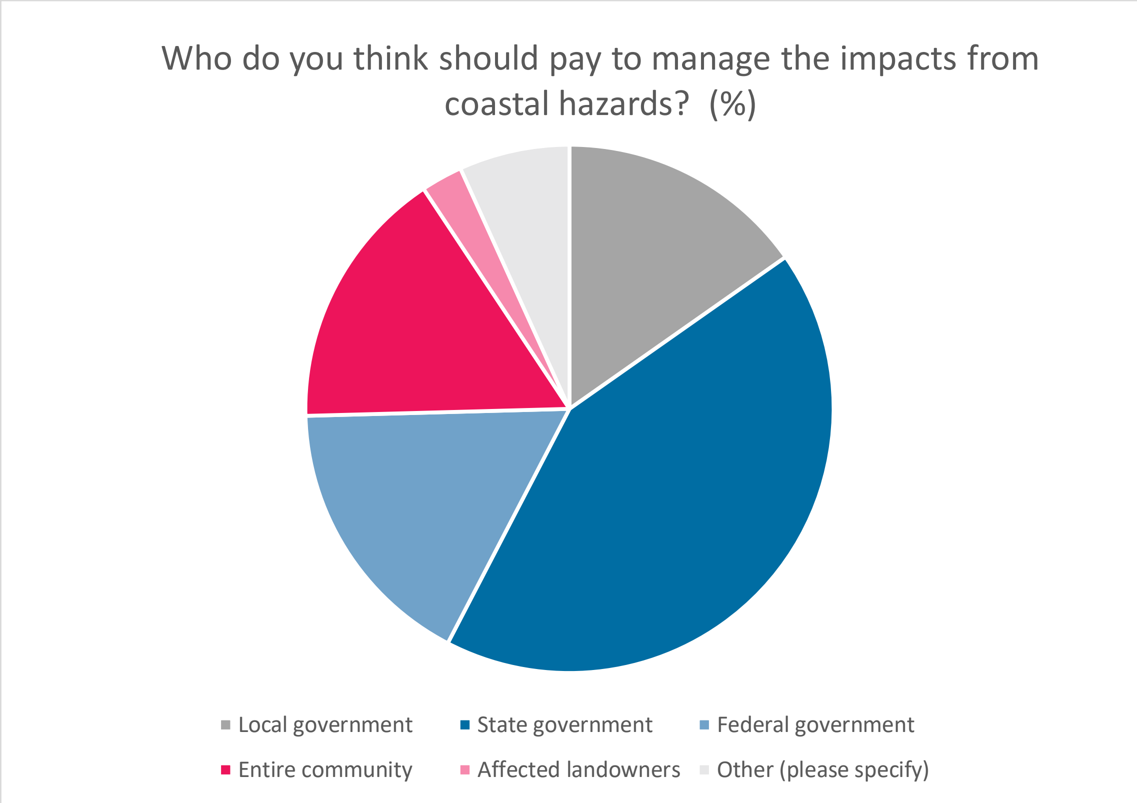

Figure 32 Who should contribute to the cost of coastal adaptation?

Question 10: Do you think residents/accommodation owners should contribute more than visitors or should the costs be shared amongst all those who access and enjoy Horrocks Beach?

Figure 33 illustrates that 83 percent of respondents identified that the costs of managing the impacts from coastal hazards should be shared amongst all those who access and enjoy Horrocks Beach compared to 17 percent who feel that residents/accommodation owners should contribute more.

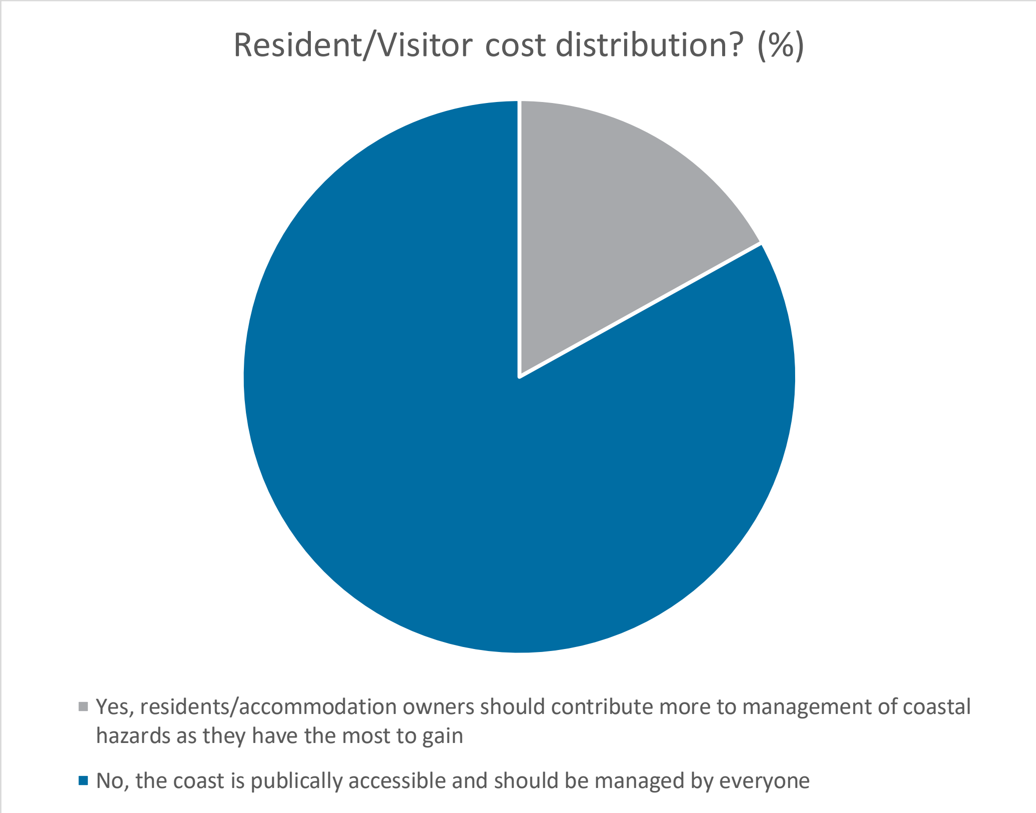

Figure 33 Should home/accommodation owners contribute more to coastal adaption?

Question 11: Hypothetically, would you be willing to pay more in rates or other levies to fund coastal hazard management?

As shown below, 67 percent of respondents that answered this question would not be willing to pay more in rates or other levies to fund coastal hazard management.

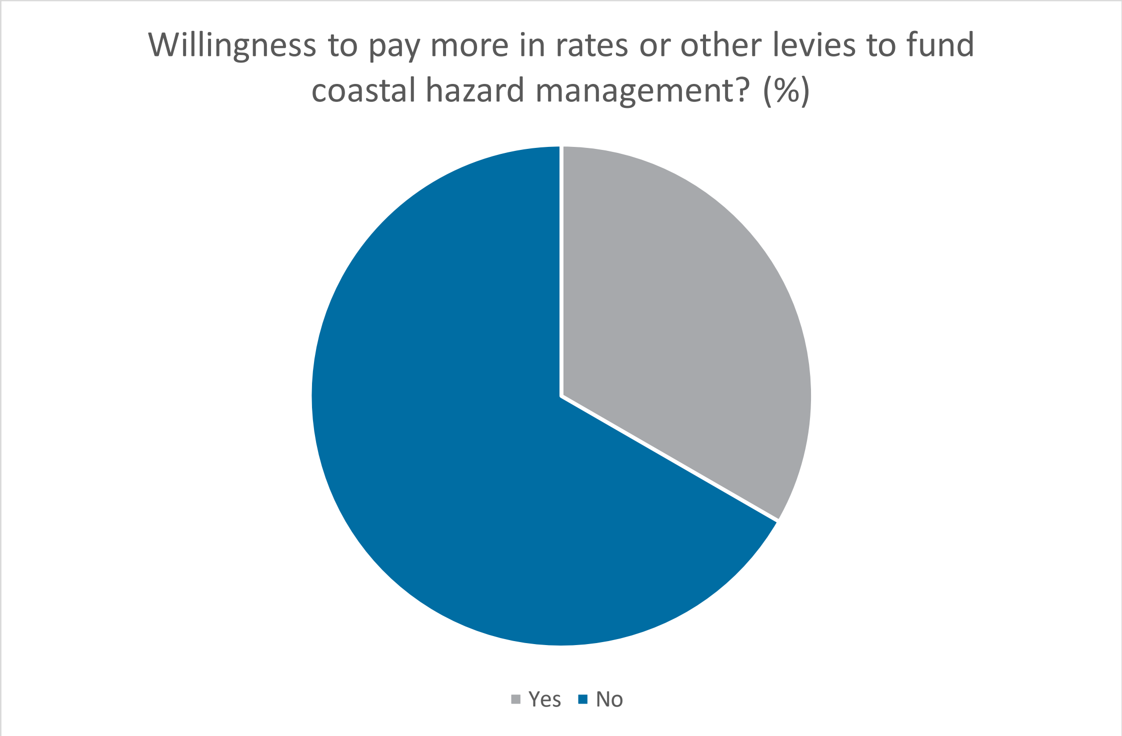

Figure 34 Willingness to pay increased rates/levies for coastal hazard management

Final questions

The survey included questions to determine the demographic profile of respondents. These questions revealed:

- Three Aboriginal or Torres Strait Islanders responded to the survey (3 percent)
- Most respondents were between the ages of 35 and 64 (70 percent)
- The most prevalent age group was the 50 to 64 age bracket, at 38 percent of respondents.
- 50 percent of survey respondents were residents of Horrocks or the Shire of Northampton
- Most survey respondents were female (71 percent)

The age of the respondents is reflective of the median age in Horrocks (57) and the Shire (51). Aboriginal and/or Torres Islander representation is lower than would be expected from the broader population (in the Shire Aboriginal/Torres Strait Islander population is 5.5 percent). Although, there is no recorded Aboriginal and/or Torres Strait Islander population within Horrocks itself (Australian Bureau of Statistics, Census data 2016).

Although the male and female responses from Horrocks residents is even (50 percent female and 50 percent male), significantly more survey responses were received from females (71 percent) - although 3 percent preferred not to say.

Twenty seven percent of survey respondents did not specify where they live, however, 50 percent of respondents indicated that they were either residents of Horrocks (20 percent) or the Shire of Northampton (30 percent). Generally the remaining responses were either from residents of the Perth Metropolitan Area or the Geraldton area. It is important that the survey obtained responses from all user groups – residents, day trippers, weekenders and holiday makers. This information indicates that there was a reasonable number of responses from each group to gain informed insight into user values.

There are 29 responses from Horrocks residents, given the entire population of Horrocks is 138 (Australian Bureau of Statistics), it is important to ensure enough residents complete the survey to provide a representative view of this population. The survey response provides reasonable confidence that a representative view of the population has been captured (with a standard error of 16.86).

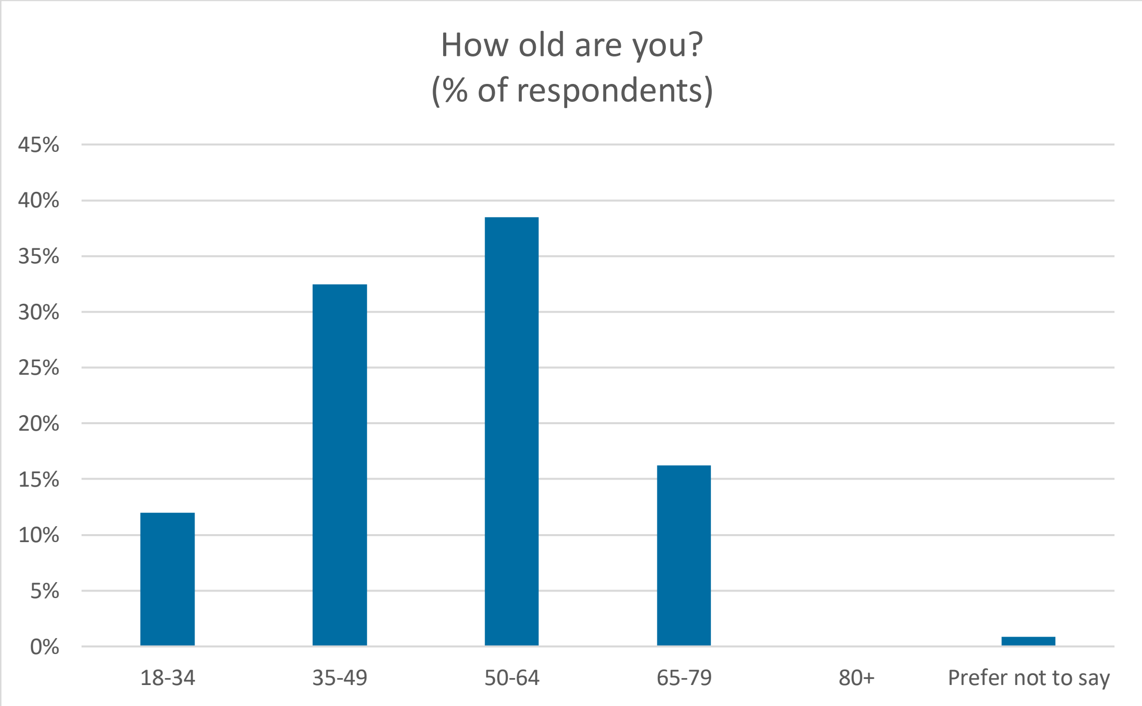

Figure 35 Survey respondent age

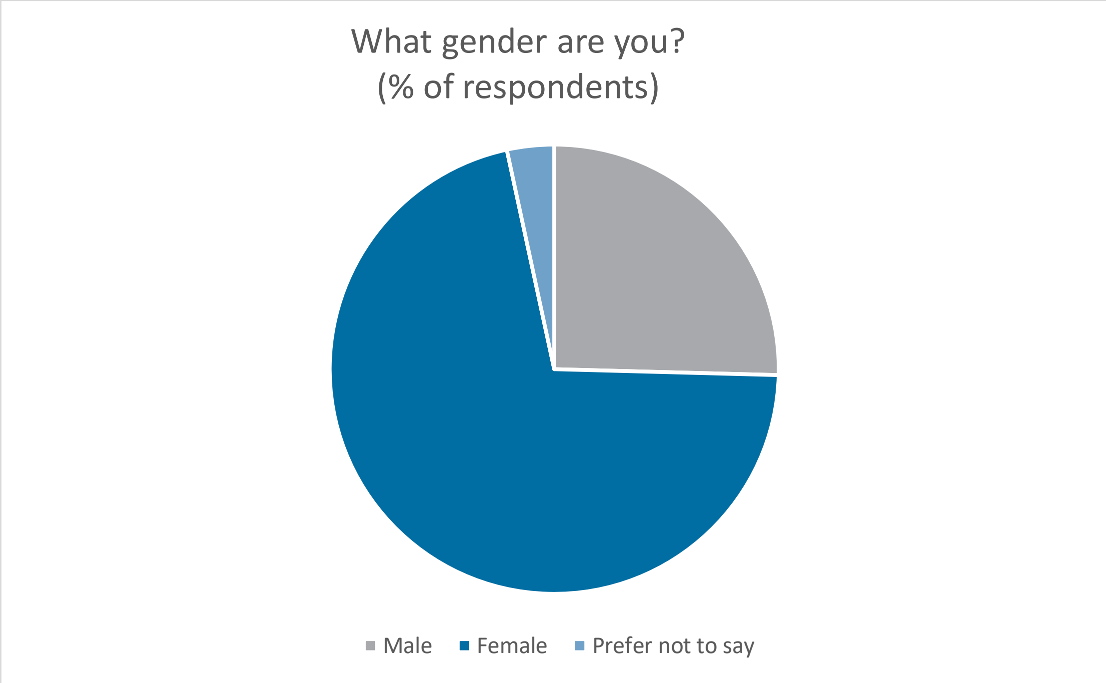

Figure 36 Survey respondent's gender

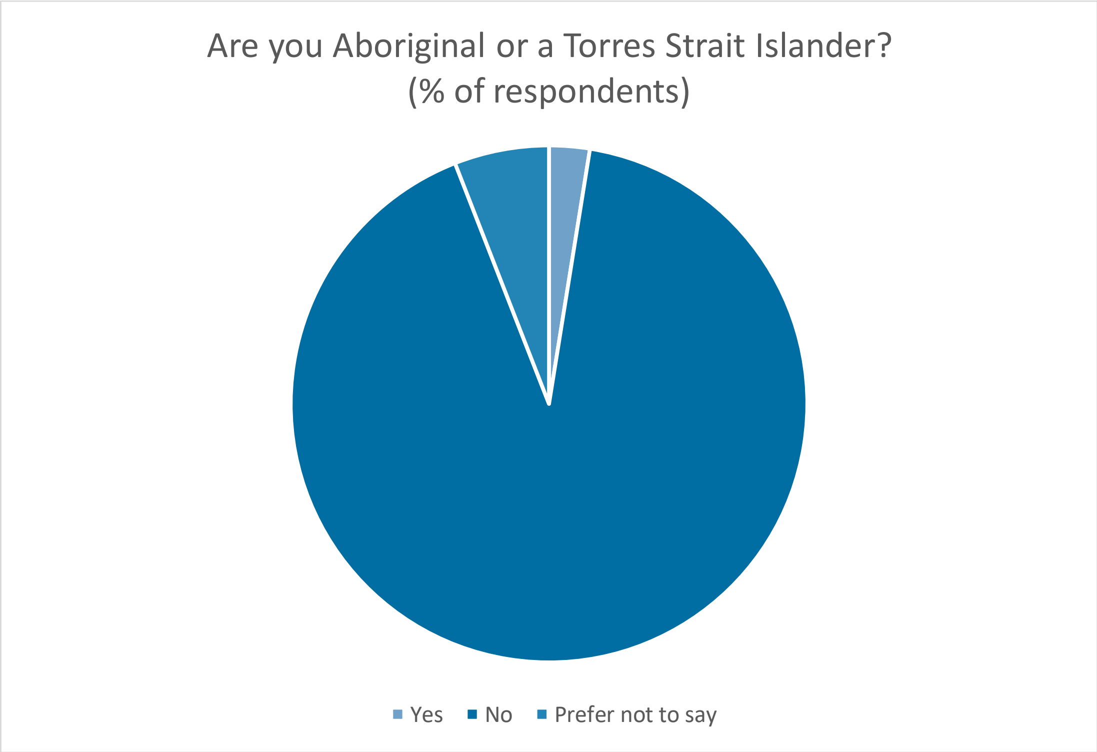

Figure 37 Aboriginal and/or Torres Islander response

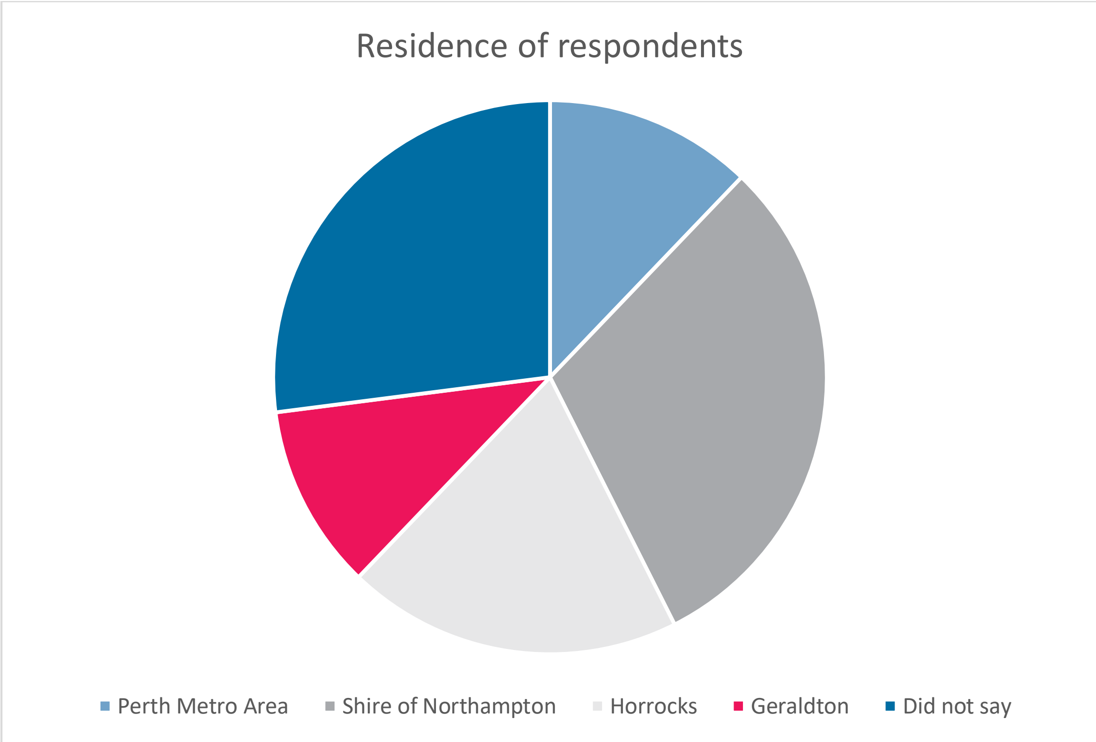

Figure 38 Respondent resident information

Appendix C – Coastal Hazard Assessment

Shire of Northampton

Horrocks Beach CHRMAP

Coastal Hazard Assessment (CHA)

October 2020

This document will form one of the appendices to the final CHRMAP document.

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Appendices

1. Introduction

1.1 Purpose of this Report

This Coastal Hazard Assessment (CHA) is a supporting technical document to the Horrocks Beach Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) that summarises the assumptions, methodology and results of the CHA and should be read in conjunction with the overarching CHRMAP. These CHA results will inform asset and land use risk assessment; identification of risk, vulnerability and tolerance; and the development of adaptation pathways and a coastal processes management plan (i.e. CHA informs preparation of the CHRMAP).

1.2 Objectives

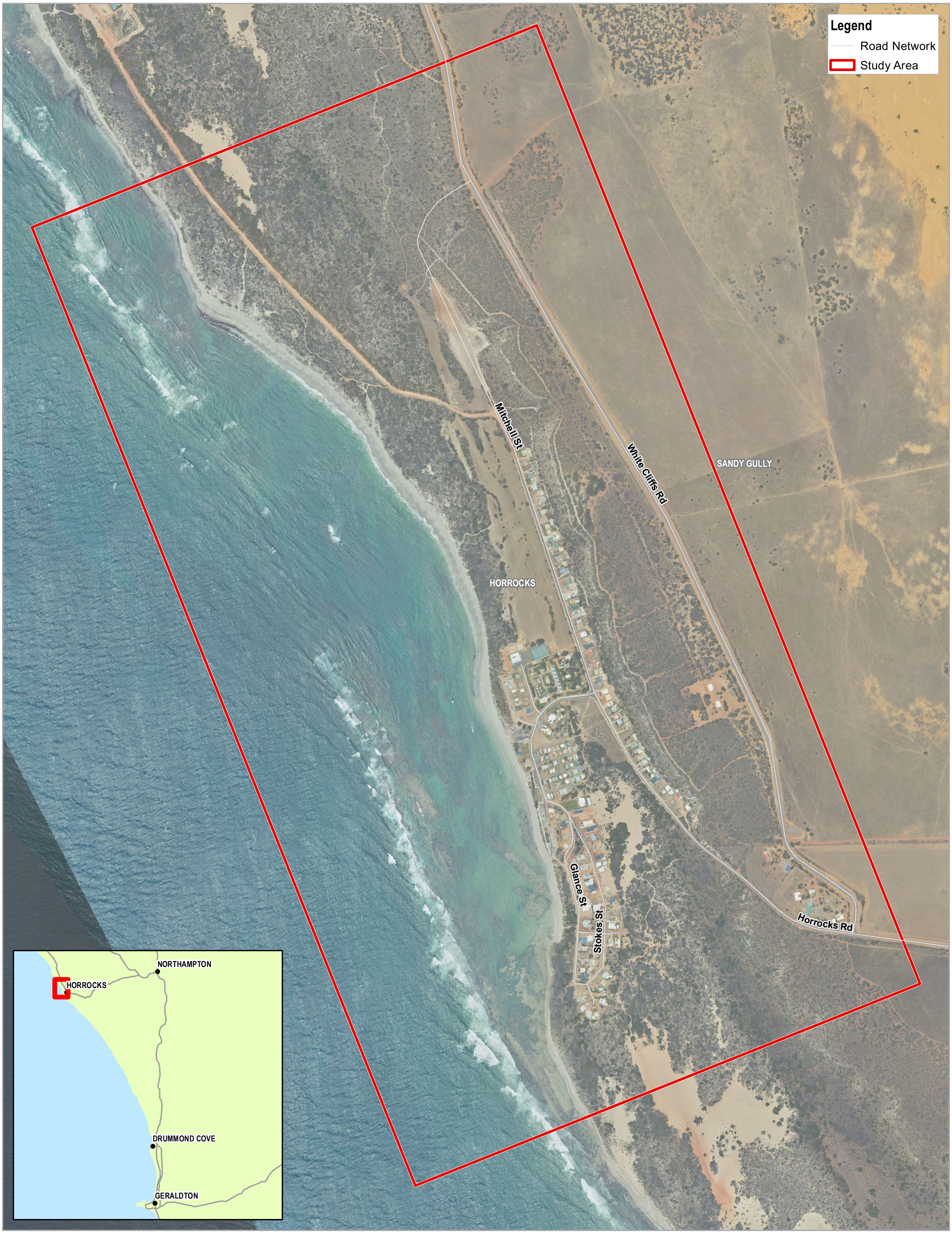
The objectives of this assessment are to:

- Undertake a CHA of risks from coastal erosion and inundation hazard events of varying likelihood (almost certain, possible and rare) to develop a range of erosion and inundation hazard allowances; and
- Prepare coastal hazard maps to allow stakeholders and the community to make informed decisions about assets and foreshore values in the future (including how these assets and values may be protected).

Results of the CHA and associated hazard mapping will be used to further assess coastal risks and vulnerabilities as part of the CHRMAP process.

1.3 Assessment Area

The assessment area which is covered by this CHA and the overarching CHRMAP is shown in Figure 1-1.



Paper Size ISO A3

0 100 200 300 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

Shire of Northampton
Horrocks Beach Coastal Hazard Risk Management and Adaptation Plan

FIGURE 1-1:
CHRMAP Area locality

Project No. **61-37817**
Revision No. **0**
Date **19/03/2019**

G:\61\37817\GIS\Maps\Working\Figures\6137817_01_LocalityMap_Rev0.mxd
Print date: 06 Oct 2020 - 09:45

Data source: GHD: Study Area - 20190319; Landgate: Suburbs - 20180319, Imagery (Accessed) - 20201006; MRWA: Road - 20171211; Geoscience Australia: GeoData Topo 250k Series 3. Created by: mmikkonen

1.4 Scope and Limitations

The scope of this CHA includes:

- Undertaking both literature and desktop reviews of information relevant to the assessment area (e.g. inundation water levels, storm wave conditions, and historic shoreline data);
- Defining coastal erosion scenarios of almost certain, possible and rare likelihood for six different planning timeframes (i.e. present day [2019], 2030, 2050, 2070, 2090 and 2120);
- Estimating coastal erosion allowances for the assessment area based on the methodology in State Planning Policy 2.6: State Coastal Planning Policy (SPP2.6);
- Defining coastal inundation scenarios of almost certain, possible and rare likelihood for the same six planning timeframes (i.e. present day [2019], 2030, 2050, 2070, 2090 and 2120);
- Estimating coastal inundation allowances for the assessment area on the basis of SPP2.6 methodology;
- Preparing hazard maps of both erosion and inundation hazards across the assessment area for the six planning timeframes; and
- Preparing this technical report to document the CHA methodology and results.

This report: has been prepared by GHD for Shire of Northampton and *may only be used and relied on by Shire of Northampton for the purpose agreed between GHD and the Shire of Northampton as set out in section 1.1 of this report.*

GHD otherwise disclaims responsibility to any person other than Shire of Northampton arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer section(s) 1.5. of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Shire of Northampton and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

Climate change is a significant current and future issue and effects, such as sea level rise, are at this stage difficult to quantify to a high degree of certainty. The following assumptions have been made during the preparation of this report:

- *The sole purpose of the reports are for evaluating coastal hazard risks and developing adaptation plans associated with coastal hazards and sea level rise for the Shire of Northampton.*
- *The reports are produced for use by the Shire of Northampton, and are not for use by any third party person or organisation. The information and recommendations are to be read and considered holistically, and content is not to be used selectively for purposes other than coastal hazard risk management (e.g. design) as this may misrepresent the data and processes herein and provide erroneous project or decision outcomes.*

- *The data and processes herein are to be used for coastal hazard risk assessment and adaptation planning purposes, approved by the Shire of Northampton, and based on Australian and state government guidelines:*
  - *Western Australian Planning Commission and Department of Planning (2014). Coastal hazard risk management and adaptation planning guidelines, Perth, Australia.*
  - *Western Australian Planning Commission (2013). State Planning Policy No. 2.6 State Coastal Planning Policy.*

  These guidelines have been considered as per the requirements of the brief. This information has not been independently verified. Assumptions and recommendations that need further testing are noted in the text of the report.

The establishment of the sea level rise aspects of the project uses data and scenarios based on publicly available information by the International Panel on Climate Change, summarised by the Western Australian Department of Transport:

- *Bicknell (2010). Sea Level Change in Western Australia: Application to Coastal Planning, prepared by the Department of Transport, Fremantle, WA.*

Climate change and coastal hazard assessment by its nature is a dynamic and ongoing process. As the sea level rise projections used are uncertain by nature, it is possible that the effects that actually occur may not be as assumed and stated in this exercise. Therefore, it is recommended that the Shire of Northampton routinely incorporate the latest climate change data and update inundation and erosion risk maps.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

1.5 Assumptions

The hazard assessment and hazard mapping was based solely on a LiDAR survey captured by DoT in 2016 and provided by the Department of Transport (DoT) to GHD. GHD has not independently checked or verified this survey data.

This assessment relied on the latest available predictions of sea level rise (IPCC 2013) to estimate erosion and inundation hazards to 2120. Revisions to future sea level rise predictions may materially affect this CHA's outcomes and any future revisions to this CHA are to utilise the latest future sea level rise predictions such as from the Intergovernmental Panel on Climate Change (IPCC).

2. Literature Review

This section presents the results of a review of existing literature, reports and data relevant to this CHA.

2.1 State Coastal Planning Policy (WAPC 2013)

2.1.1 Introduction

Schedule One of SPP2.6 provides guidance on how to calculate the required component of the coastal foreshore reserve to allow for coastal processes. The width calculated from Schedule One does not delineate a coastal foreshore reserve width. Schedule One stipulates that “the site specific coastal foreshore reserve width to allow for coastal processes should be calculated based on the coastal classification, and should consider each of the factors listed for that coastal type”. For sandy coasts, Schedule One stipulates that the allowance for erosion should be measured from the Horizontal Shoreline Datum (HSD) and calculated as the sum of the following factors:

Allowance for erosion on sandy coasts = S1 + S2 + S3 + Allowance for Uncertainty + Allowance for Landform Instability

These various components are described in the following Sections 2.1.2 to 2.1.7.

SPP 2.6 provides details on coastal classifications and assessment of coastal hazards for rock coastline (Hard rock coast, soft sedimentary rock coast and weakly lithified sedimentary rock coast) and mixed sandy and rocky coasts (fringing reefs, rocky platforms and discontinuous rock shoreline). Within the rocky coast classification it is stated that *“Coasts with discontinuous or low elevation rock shall be classified as mixed sandy and rocky coasts”* and erosion allowances calculated the same as for a sandy coast.

2.1.2 S1 - Allowance for the Current Risk of Storm Erosion

The allowance for absorbing the current risk of storm erosion (S1) is calculated by modelling the impact of an extreme storm event sequence on the shoreline. In the absence of modelling this value shall be set to 40 m for cross-shore erosion caused by a 100-year ARI storm event on a typical sandy coast.

SPP2.6 recommends that the storm event used to model cross-shore storm erosion should be an event with a 1% or 1-in-100 probability of being equalled or exceeded in any given year over the planning timeframe. The selection of storm event should be based on the location of the assessment area. SPP2.6 separates WA into four areas and Horrocks is located in Coastal Area 3. For this area, SPP2.6 recommends that the allowance for the current risk of storm erosion should be based on a mid-latitude depression or extra-tropical low storm event.

Horizontal Shoreline Datum (HSD)

The HSD is defined as the seaward shoreline contour representing the Peak Steady Water Level (PSWL) under the defined storm condition. In this assessment it has been determined for each of the ten profiles using the results of the SBEACH modelling. These HSD results are presented in section 6.2.

2.1.3 S2 - Allowance for Historic Shoreline Movement Trends

The allowance for historic shoreline movement should be based on a review of the available shoreline records. The allowance for historic shoreline movement trends should generally be calculated as 100 times the historic annual rate of erosion.

For shorelines with a long term accretion rate of less than 0.2 m per year, the S2 allowance should be set to zero.

For shorelines where the long-term accretion rate is in excess of 0.2 m per year, with compelling evidence that accretion is likely to continue at the same rate for at least the next 50 years, the allowance for historical shoreline movement trends should be calculated as minus 50 times the historical longer term annual rate of accretion.

The main limitation of analysing historical shoreline movement is that historical rates of erosion may not reflect current and future changes in long term erosion forces and processes. Therefore, a degree of caution must be used when applying rates of erosion over long time periods.

2.1.4 S3 - Allowance for Erosion caused by Future Sea Level Rise

SPP2.6 recommends the allowance for erosion caused by future sea level rise on sandy coasts should be calculated as 100 times the adopted sea level rise value over a 100-year timeframe and recommends adopting a 100-year SLR value of 0.9 m, which yields an S3 allowance of 90 m over 100 years. The multiplier of 100 is based on the Bruun rule (Bruun 1962) on a mildly sloping shoreline. This assessment has utilised different sea level rise values (see Section 4.5.3) with the S3 erosion allowances calculated as 100 times the sea level rise value of each scenario.

2.1.5 Allowance for Uncertainty

Schedule one of SPP2.6 requires that the allowance for erosion on sandy coasts include an allowance for uncertainty of 0.2 m per year (total of 20 m over a 100-year planning timeframe).

2.1.6 Allowance for Consideration of Landform Instability and Sediment Cell System Dynamics

In addition to the S1, S2 and S3 allowances for erosion processes and the allowance for uncertainty; consideration of landform instability, net long shore sediment transport, structures potentially affecting longshore transport, and offshore sand bars that may input sand to the system should be considered on a sediment cell scale. Based on current knowledge of the sediment dynamics of the assessment area, it is not anticipated that any significant landform instability occurs in the assessment area in the short-medium term, and so an additional allowance was not incorporated. Any significant changes to landform stability or sediment cell dynamics (e.g. significant changes in longshore sediment transport rates, sediment availability or coastal structures) should be reviewed as part of future revisions of this CHA and the overarching CHRMAP.

2.1.7 S4 - Allowance for Storm Surge Inundation on all Coasts

Coastal inundation is the natural process of flooding of land by the sea. It can be caused by storm surge, floods, tides, tsunamis and changes in sea level. In this assessment, the definition of inundation is based on short term or temporary inundation from storms events.

According to SPP2.6, the allowance for the current risk of storm surge inundation is the maximum extent of storm inundation, defined as the peak steady water level (PSWL) plus wave run-up. The PSWL is defined in SPP2.6 as the highest average elevation of the sea surface caused by the combined effect of storm surge, tide and wave setup. If the cross-sectional area of the dune above the PSWL is less than 100 m^3 then the dune should be assumed to be removed during the storm and inundation extents should be calculated without the dune. The peak steady water level is defined by the 0.2% Average Exceedance Probability (AEP) water level event.

SPP2.6 recommends that the event for storm surge inundation should have a 0.2% or 1-in-500 probability of being equalled or exceeded in any given year over the planning timeframe. The selection of the storm event should be based on the location of the assessment area. SPP2.6 separates WA into four areas and Horrocks is located in Area 3. For this area SPP2.6 recommends that the allowance for the current risk of storm surge inundation should be based on a tropical cyclone storm event. Tropical cyclone events are rare in the Horrocks area and so there are very limited measurements of actual events.

2.2 Design Event Selection for Erosion Hazard Assessments: West & South Coasts of WA (MRA 2018)

The Department of Transport (DoT) commissioned this study (MRA 2018). "*The purpose of this study is to provide regionally appropriate recommendations to aid in the assessment of coastal erosion risk for South West WA. This includes recommendations of plausible regional events to be used to calculate erosion with various likelihoods for several different timeframes. Additionally, this includes a recommendation of the regionally appropriate representative mild, stormy and average years for medium term coastal evolution or coastal management structure impact assessment.*"

The study subdivided the South West WA coastline into seven key coastal regions, with Horrocks being located in the Mid-west region.

The study undertook analysis of historical storms with data captured by DoT wave rider buoys and available meteorological records. Storms were classified based on key factors of wave height, storm power and water level. "The cross-shore profile model SBEACH was used to simulate identified storms; and indicate potential capacity to cause acute erosion." Results from SBEACH were used to determine relationships between erosion potential and the key factors of wave height, storm power and water levels.

Results were validated against available information such as historical aerial imagery and shorelines and available survey data for two selected profiles at seven key coastal regions. A correlation between "Net Cluster Power", the impact of closely spaced storms, and erosion potential was established for each region.

For each region identified, storm clusters were ranked on Net Cluster Power and extreme analysis was used to determine the recurrence interval for both Net Cluster Power and erosion potential simulated in SBEACH for each of the top storm clusters. To identify storm sequences with Net Cluster Powers for specific average recurrence intervals (ARI's) (for use in coastal erosion risk assessments), different combinations and repeats of discrete storms were identified to be combined for each region. Table 2-1 provides the summary details for each of the discrete storms identified for use for the Mid-West Region (Geraldton).

Table 2-1 Details of Discrete Storms used in Synthesis from MRA (2018)

Storm Reference Number	Start Date	End Date	Duration (days)	Net Exceedance Power (MWDays)	Mean Hs (m)	Mean EL (mAHD)
G1	9/08/1997 11:00	11/08/1997 11:00	2	0.46	3.97	-0.04
G2	21/05/2009 2:00	24/05/2009 14:00	3.5	0.82	4.01	0.39
G3	19/09/1989 17:00	22/09/1989 20:00	3.13	0.87	4.09	-0.01

G4	27/06/2009 14:00	1/07/2009 8:00	3.75	1	4.31	0.26
G5	10/07/2002 14:00	13/07/2002 23:00	3.38	1.2	4.63	0.07
G6	23/08/2004 14:00	27/08/2004 2:00	3.5	1.25	4.7	0.06
G7	15/07/1996 20:00	6/06/1997 20:00	3.38	1.31	4.67	0.05
G8	15/07/1996 20:00	20/07/1996 8:00	4.5	1.92	4.97	0.28

Two different design storms for coastal erosion were derived for each region for the 1, 10, 25, 50, and 100 average recurrence intervals.

The particular storms for the Mid-west region are discussed in Section 4.6.1. Two different design storm sequences were identified in this region due to the potential sensitivity of beach profiles to storm parameters and it is recommended that both should be assessed for any given location.

For the assessment of representative years, the study selected the following for the Mid-west region:

- 1994 as a mild year;
- 2005 as an average year; and
- 1988 as a stormy year.

The study also examined extreme wave and water levels that are more appropriate for structural design or similar applications.

2.3 Design Storms for Western Australian Coastal Planning: Tropical Cyclones (Seashore 2018)*

* Note: This document was retracted from DoT's website subsequent to issues identified with tropical cyclone tracks for Coastal Area 3. Literature review is provided, however this information was not relied upon for the final estimation of cyclonic water levels at Horrocks.

Seashore Engineering (2018) undertook an extensive analysis of design storms for tropical cyclones for Western Australian coastal planning for DoT. The study was undertaken to support application of the Design Storms (tropical cyclones) approach to coastal hazard assessment in accordance with SPP2.6. Seashore (2018) developed storm scenarios based on regional variation in storm characteristics, including cyclone intensity, frequency, scale and tracks. Seashore (2018) states that the key objective of the Design Storms (tropical cyclones) approach is to provide a simple and cost-effective approach to assess development setback for green field sites along the WA coast and notes that alternative methods for evaluation of coastal hazard are valid, including comprehensive 'synthetic storm database' modelling. Seashore (2018) presents information which enables a specialist coastal practitioner to apply the Design Storms (tropical cyclones) approach to define erosion and inundation hazard zones associated with tropical cyclones. The study is applicable to the area from Augusta north to the WA-NT border. The report highlights that it is a non-statutory document to support the application of SPP2.6.

Horrocks Beach falls within Coastal Area 3 of SPP2.6 but is in the northern quarter of the area. For Coastal Area 3, SPP2.6 requires that a tropical cyclone be considered for the 500-year ARI Inundation hazard but not the (100-year ARI) erosion hazard; so Seashore (2018) only includes a design tropical cyclone for 500-year inundation hazard for each site in Coastal Area 3. Seashore (2018) includes the following important notes for Coastal Area 3:

"Design tropical cyclones for Coastal Area 3 are intended for the evaluation of extreme inundation situations and therefore only the inundation case (approximately 500-year ARI) is considered. Coastally trapped waves are also likely to provide important contribution to the storm surge, with TC Narelle (Jan 2013) providing the largest recorded continental shelf wave at all locations along the coast.

For this section of coast, 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 evaluation of the Bureau of Meteorology database has been used to provide an estimate of scale suitable for use with a vortex model. However, 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.

It is noted the lowest central pressure achieved during the tropical cyclone's passage typically occurs some time before landfall. Due to the relative interplay of intensity, scale and proximity, it is expected that the highest surge level will generally occur near to the time of land-crossing (or peak winds for those storms which do not cross land).

For all sites in Coastal Area 3, a constant 'background' water level equal to the tidal plane of Mean Higher High Water (MHHW) is specified.

The relatively limited range of tropical cyclones within the possible event-space in Coastal Area 3 limits the confidence with which design storms have been established. For all the nominated sites, the design storms described should be considered preliminary in nature."

Seashore (2018) presents design tropical cyclones for locations both north (Kalbarri) and south (Geraldton) of Horrocks.

2.3.1 Kalbarri

Seashore (2018) includes the following notes for Kalbarri (Figure 2-1):

"Kalbarri does not have a tide gauge to assist with identification of extreme historic surges. Due to the propagating nature of the continental shelf wave, it is expected that TC Narelle (Jan 2013) is likely to have produced a large surge at Kalbarri. The design storm has been developed using a modified storm track from TC Narelle's path, incorporating a recurve to produce onshore winds as the system passes Kalbarri."

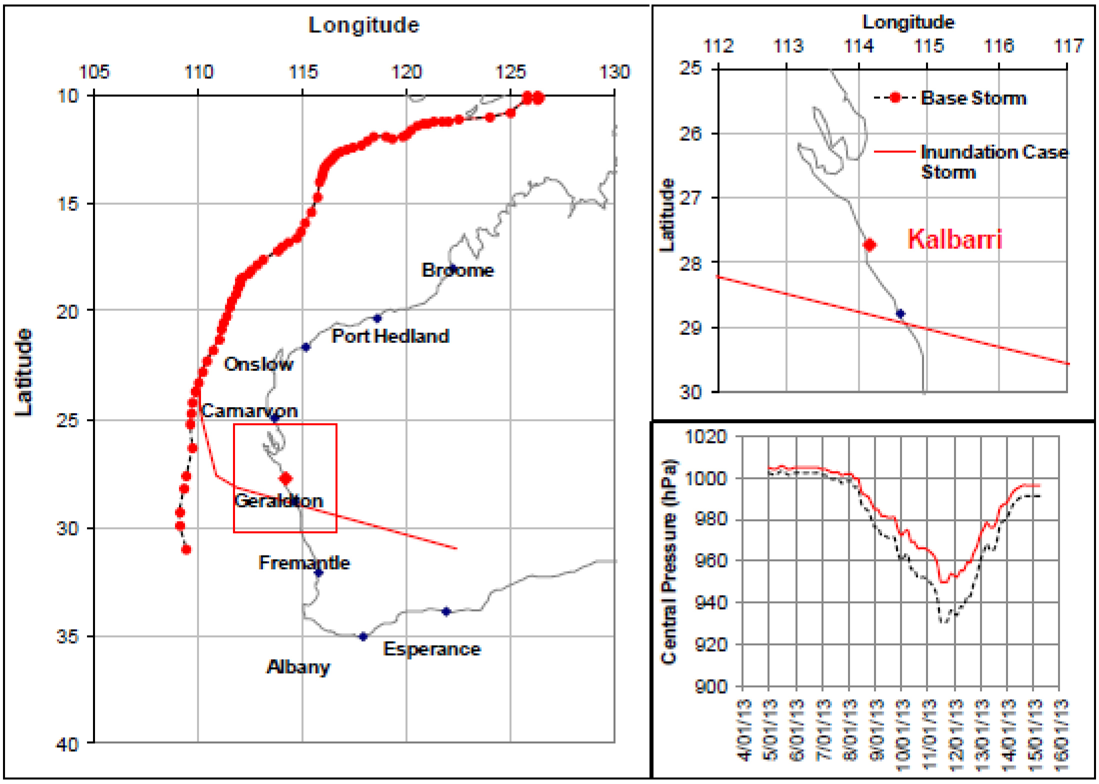


Figure 2-1 Kalbarri Design Storm based on TC Narelle (Jan 2013) (Seashore 2018)

2.3.2 Geraldton

Seashore (2018) includes the following notes for Geraldton (Figure 2-2):

"High water levels at Geraldton have been associated with two different event types: (i) those that track near to the coast, and may generate a large barometric surge; and (ii) those which travel well west of the continent before recurving, allowing a sustained approach from the northwest. The latter type of events typically has experienced extra-tropical transition, such that they grow significantly in scale. The largest measured surge event was caused by TC Narelle, which produced almost the optimum path and speed to amplify shelf wave generation. TC Glynis (1970) also generated a significant shelf wave due to travelling near to the critical speed parallel to the coast. Extreme surge and wave conditions were further reported from a tropical cyclone in 1956, which tracked along the Western Australian coast from the Pilbara to Geraldton, impacting many town sites."

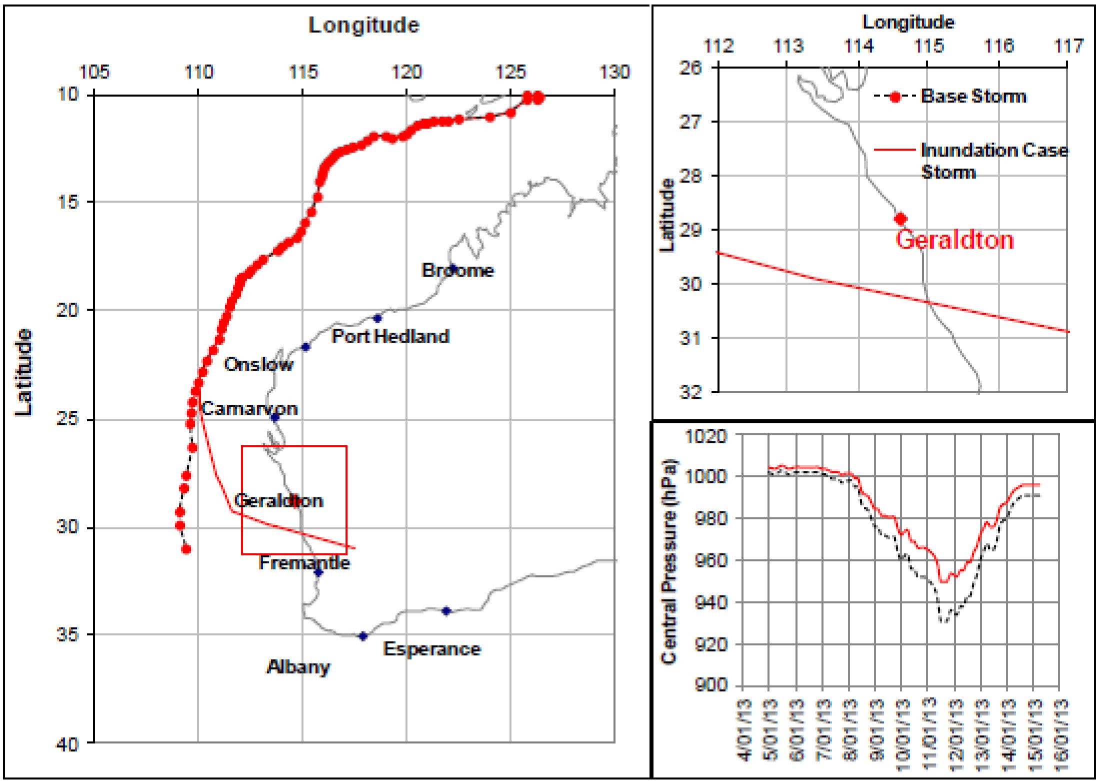


Figure 2-2 Geraldton Design Storm based on TC Narelle (Jan 2013) (Seashore 2018)

A key feature of tropical cyclones and the influence of specific cyclonic events on specific locations is that the wind direction is opposite between one side and the other and that in the southern hemisphere tropical cyclones rotate in a clockwise direction. This is particularly important for inundation hazards as, when a cyclone makes landfall on an approximately north-south oriented coastline like at Horrocks, the winds to the south of the cyclone eye are roughly offshore (reducing the inundation hazard) whereas to the north of the cyclone eye they are roughly onshore which significantly increases the inundation hazard of the cyclone for the area to the north of the landfall location. As can be seen in Figure 2-1 and Figure 2-2, the landfall location of the design event is to the south of the townsite of interest.

Additionally, Seashore (2018) identified preliminary extreme water levels for town sites along the WA coast, including Geraldton, as a secondary product of the study. The report acknowledges the deliberatively conservative nature of these preliminary extreme water levels and states it is generally recommended that the preliminary water levels be applied for initial planning or for sites where a more detailed hazard assessment is unlikely to be economic (Seashore 2018). The preliminary extreme water levels developed in Seashore (2018) for Geraldton are presented and further discussed in section 4.5.2.

2.4 Geraldton Coastal Hazard Risk Management and Adaptation Planning (CHRMAP) Project (Baird 2018)

The City of Greater Geraldton completed a CHRMAP study for Geraldton in 2018 (Baird 2018). This study utilised three coastal processes studies which covered different parts of the Geraldton coastline (MRA 2015, 2016, 2017). These studies are relevant to Horrocks in that they included tropical cyclone modelling and extreme water level analysis for Geraldton, which is the closest tidal gauge location to Horrocks (~50 km south of Horrocks). The extreme water level results from these studies are presented for reference in section 4.5.2.

2.5 Shire of Northampton Coastal Management Strategy (Land Insights 2017)

"*This document presents the Coastal Management Strategy (CMS) for the Shire of Northampton. The purpose of the report is to identify current land uses, values and issues along the Shire's coast and to make recommendations for future management.*

The Shire's coastal areas have been planned over many years. An original Coastal Management Strategy was prepared and adopted by the Shire in 2006. Subsequently Coastal Management Strategies have been prepared in the last 2-3 years for the coastal nodes of Kalbarri and Horrocks. These node-specific documents are still current and guiding coastal management in these locations.

The Study Area for this Coastal Management Strategy covers the remaining areas of the Shire, extending from Wagoe (north) to Oakabella Creek (south). ***It excludes the coastal areas included in the Horrocks Coastal Management Strategy (Little Bay to Bowes River Mouth)*** **(refer Section 2.6 of this document).** *It updates the earlier Coastal Management Strategy prepared by Landvision and the Shire in 2006.*

Planning for coastal areas is about balancing often competing needs and desires in a way that takes into account the values of the coastal zone, which include its scenic, aesthetic and ecological qualities; recreational opportunities; and social, indigenous, cultural and economic importance. In addition, consideration also needs to be given to coastal hazards relating to marine safety and long-term climate change. The overall trend is seeing growing and ongoing pressure on coastal resources as the State's population increases, coastal-based industries expand and technological changes make remote areas more accessible.

The overall effect of these values contributes to the psychological well-being and health of the local and regional community. Successful coastal planning today will ensure that current and future generations can benefit from the opportunities presented by the values and resources of the coast.

In recognition of these values and resources the Shire of Northampton identified the need to update the 2006 Coastal Strategy to guide future coastal uses along the coast. To ensure its continuing relevance to land use planning objectives it was recommended that this report be reviewed within a 10 year timeframe.

Through development of this new strategy, a number of issues have been identified."

2.6 Horrocks Coastal Management Strategy (2015)

This report (Essential Environmental 2015) was prepared to provide guidance for the management of coastal and human use impacts along Horrocks Beach from the Bowes River mouth to Little Bay (larger area than this CHRMAP). This study separated the Horrocks Townsite as one of three areas.

2.6.1 Existing Facilities and Infrastructure

"Existing facilities at Horrocks Beach foreshore include a wooden jetty, shade shelters, a fish cleaning table, picnic tables, toilets and shower, community kitchen, barbecues, lookout and playground (Figure 4). There are tennis courts, a sports ground, community pavilion with barbecue facilities and a golf course extending north of the town centre. Accommodation for visitors and tourist is provided by a caravan park, holiday cottages and backpackers hostel. There is a well presented general store with fuel and a café.

Car parking facilities are provided throughout the townsite (Plate 3). Well-defined bitumen car parks are located at the boat launching area, Glance Street behind the jetty and next to the *tennis courts. There are two gravel car parks in the foreshore area; one next to the general store and one at the south of the foreshore with a gravel access track to the beach.*

Boats are launched from two locations on the beach; via a boat launch access adjacent to the lookout at Glance Street and at the southernmost point of the beach near the Whiting Pool. Vehicles drive onto the beach at both locations. Trailers can be parked near the boat launch access, at the Glance Street car park and in the southern gravel car park but vehicles and trailers are also parked on the beach at the launch points.

The boat launch access facility is managed by the Shire of Northampton. The boat launch can only be operated in certain weather conditions. Inexperienced boat handlers are reported to have difficulty using the facility and navigating the passage through the reef to open water. The launch access operates as an unmanaged facility with no control on parking, entry or exit.

The beach in front of the boat launch access and beach access ramp from the southern car park are subject to action from coastal processes and scouring from stormwater runoff which adds to the difficulty experienced by boat handlers visiting Horrocks who are unfamiliar with the location. The location is considered exposed and hazardous by the Department of Transport and does not meet AS 3962-2001 Guidelines for the Design of Marinas.

There is pedestrian access to the beach at several points in the foreshore. There is a ramp at the jetty that was installed to improve access to the beach, particularly for the elderly and prams. At the time of the visits the cyclical action of accretion/erosion of sand due to coastal processes had resulted in the launch access terminating via a large step onto the beach. There are two beach access points via stairs; one south of the jetty from the gravel car park and another from Glance Street opposite Killy Street. At the southern end of the beach Glance Street is several meters above the height of the beach and access is via gravel tracks, steps and a wooden stairway.

There are several shelters throughout the foreshore reserve with the majority located at the foot of the jetty on the beach. They are heavily utilised and people spread onto the dunes to the rear of the shelters in times of high beach use."

2.6.2 Climate

"The nearest Bureau of Meteorology observation station is located in Geraldton. Data from this location is used as a proxy for climatic conditions at Horrocks. The Horrocks area experiences a mild, Mediterranean-type climate with hot, dry summers and cool, wet winters. Mean annual maximum and minimum temperature is 24.7 and 14.4 degrees C, respectively (Bureau of Meteorology).

The long-term average annual rainfall is 446 millimetres per annum with the majority falling between May and August (Bureau of Meteorology). Dissipating tropical cyclones and winter gales can bring heavy rainfall, large waves and storm surge.

The land-sea breeze system influences the conditions experienced in the area during summer with moderate easterly offshore land breezes in the morning changing to south west onshore winds in the afternoon. In winter the winds vary from north east in the morning to south west in the afternoon."

2.6.3 Landscape and Coastal Geomorphology

"The shape of the south westerly facing coast is controlled by a straight fringing limestone reef that runs parallel to shore through the study area. The reef…separates with distance at Horrocks Beach where, at the townsite, it is 500 m offshore forming a wide lagoon and beach inside this.

The nearshore reef affords protection to the study area. There are gaps in the reef at Bowes River and at Horrocks Beach. The latter location has a breach at the northern end of the beach that permits boat traffic through the reef to the Indian Ocean.

The frontal dunes are well vegetated at the south of the townsite but become lower, less well vegetated and discontinuous southwards to the river where they are all but gone. A narrow foredune ridge with low vegetation cover is separated from the parabolic dunes by a bare deflation surface where wind, aided by damage from human activities, has removed the vegetation cover.

Horrocks Beach is a curving 2.5 km long, reflective beach which has formed in the lee of the reef. The gap in the reef that is used by boats also permits low energy waves to reach the shore at the northern end of the beach. The beach itself is steep and narrow with a beach step found at the low water mark; a feature of reflective beaches (Scott, 2006). The foreshore at Horrocks has evidence of erosion and recent efforts to stabilise sections of the beach with sand filled geotextile defences have been made and proved successful at that location. North of the townsite the dune system is well developed and well vegetated."

"*The beach, dunes and sandsheet in the study area* (note: this study area was larger than the CHRMAP study area) *are dominated by unconsolidated calcareous sands of the Quindalup unit. Further inland lie red and brown tamala sand* (Eliot et al, 2012)."

As shown in Figure 2-3, the vast majority of the landform underneath the Horrocks Townsite was classified as "*Lacustrine flats*" (Eliot et al 2012). There is a small area classified as "*Active parabolic dune lobes and blowouts, Quindalup Dunes*" in the south of the Horrocks Townsite and the scarp behind Horrocks is "*Barrier Complex: Spearwood Dune System sand*" with a small strip of "*Degraded scarps and cliffs, Spearwood Dune System*" in between.

Figure 2-3 Landform at Horrocks Townsite (Modified from Eliot et al (2012) as presented in Essential Environmental (2015))

2.6.4 Coastal Processes

"*The coastal processes operate as a single cell between the Bowes River and Little Bay. The area is characterised by a sediment cell with low susceptibility to environmental change and of high instability. It is described as moderately vulnerable with coastal risk of salient migration, dune mobility and sandsheet migration. These processes present a risk to further development within the townsite" (*Eliot et al, 20121993 in Essential Environmental 2015).

Waves

"*The coastline in the study area is a low wave energy, surge dominated environment. The nearshore reef system impacts on the beach morphology through refracting and attenuating waves that approach from the south west leading to the variety of coastline formations from Bowes to Little Bay"* (Department of Planning and Urban Development, 1993 in Essential Environmental 2015).

Tides

"*The nearest long term tidal observations have been made at Geraldton and can be assumed to be similar at Horrocks. Typical tidal ranges are around 0.6 m during spring tides, and 0.5 m or less during neap tides. The lowest to highest astronomical tidal range at Geraldton is 1.2 m"* (Department of Defence, 2012 in Essential Environmental 2015)."

Storm Surge

"*During storm events barometric and wind effects can cause significant storm surges. The importance of storm surge on beach processes and morphology is most significant when surge levels exceed the tidal range. In extreme storms the surge in Geraldton (72km south of Horrocks) can exceed 1 metre above the astronomical tide level. Extreme storm surges in*

Horrocks are likely to be similar to this level, which is significantly larger than the tidal range (Department of Planning and Urban Development, 1993 in Essential Environmental 2015).

The area is subject to the effect of tropical cyclones and mid latitude depressions which can both create storm surge. Severe storm events have the potential to cause increased erosion to a shoreline, through the combination of higher, steeper waves generated by sustained strong winds, and increased water levels" (Short, 2006 in Essential Environmental 2015).

If the initial width of the surf zone is insufficient to dissipate the increased wave energy, this energy is often spent eroding the beach face and sometimes dunes. The eroded sand is transported offshore with the return water flow " (Short, 2006 in Essential Environmental 2015).

Sediment Transport (waterborne and wind-blown)

"*Longshore transport of sediment in the inshore zone and windblown transport are dominant coastal processes in the study area. Active sand sheets dunes, deflation zones and blowouts located south of the townsite and south of Little Bay are all evidence of sediment transport in action" (*Eliot et al, 20121993 in Essential Environmental 2015)*.*

"Accretion and erosion of the beach are likely to be of an episodic nature and not a result of long term recession but the local community has concerns that the trend is for rapid shore recession during storms when waves are able to enter the lagoon over the reef. Sea level rise could exacerbate this."

Sea Level Change

This report references the work done by the IPCC and DoT's (2010) analysis and guidance of sea level rise applications to coastal planning.

2.6.5 Flora and Fauna

"*Horrocks is located within the Geraldton Sandplains IBRA bioregion. The Geraldton Sandplains bioregion comprises mainly proteaceous scrub-heaths, rich in endemics, on the sandy earths of an extensive, undulating sandplain"* (Department of Conservation and Land Management, 2002 in Essential Environmental 2015).

"The waters of the Horrocks coast are known for their rich diversity in marine life. This also provides a significant recreational and small professional fishing resource. Reef platforms dominate the coastline. They provide a barrier to the high wave energy and are important feeding and breeding grounds for fish species.

A wetland has been identified within the coastal dunes south of Stinky Point, north of the golf course. Named the "Frog Pond" by the community as a result of the large number of frogs that reside in it, the freshwater pond is considered to have significant biodiversity values and is valued by the local community. The Frog Pond historically supplied the drinking water supply to the townsite.

A search of the EPBC Protected Matters Search Tool (at the time) *identified a range of migratory birds and other fauna that may be present in the foreshore area although existing searches did not identify occurrences of protected flora and fauna in the foreshore reserve. There are three Osprey nest platforms in the study area including one at Little Bay and one at the southern end of Horrocks beach. These are currently inhabited by Osprey pairs with young.*

A search of the Department of Parks and Wildlife NatureMap search tool (at the time) *listed three species of Spider Orchid as 'rare or likely to become extinct' and six species of birds including Fork tailed Swift (Apus pacificus) and White-bellied Sea-Eagle (Haliaeetus leucogaster) as 'protected under international agreement'.*"

2.6.6 Heritage Values

European Heritage "*Horrocks has historic significance as the holiday and summer recreation location for residents of Northampton and surrounding areas since early settlement days. A short history of Horrocks Beach is provided in the Horrocks Beach Coastal Plan (Department of Planning and Urban Development, 1993* in Essential Environmental 2015)*).*

In the 1880s Horrocks was known as Three Mile Bay. It was a holiday destination for pastoral families in the area. As early as the 1930s there were a substantial number of tents and semipermanent shacks on the beach. These were continually improved and replaced with more permanent but still humble dwellings along the foreshore in the 1940s and 1950s. The foreshore cottages were demolished in the late 1970s in response to higher standards of living and pressure from government agencies to create a more modern Horrocks townsite with many cottage owners taking up leaseholds elsewhere in the town. Since then, development has continued throughout the townsite on freehold areas.

The only listed structure on the Heritage Council of WA database (at the time) *is the old wooden jetty that has been replaced.*"

Aboriginal Heritage

"*Horrocks Beach is included within the Hutt River Native Title Application. Native title in the area had not been formally recognised at the time of the study but the application is still active. The study area contains a number of important cultural sites, a number of which are registered with the Department of Aboriginal Affairs* (Note: none are in the Horrocks CHRMAP study area)*. There is significant Nanda heritage at the Willi Gulli caves complex on the Bowes River, inland from the river mouth. The caves feature rock art created by the Nanda people to describe and communicate their traditions, ideas and values.*"

2.6.7 Recreational Values

Essential Environmental (2015) details recreational values of the Horrocks area including:

- Fishing;
- Boating;
- Swimming and snorkelling;
- Surfing;
- Walking;
- Sports and leisure;
- Camping; and
- Off-road driving.

2.6.8 Coastal Risk Assessment

Essential Environmental (2015) included a qualitative coastal risk assessment that was used to inform the strategy. This risk assessment considered risks to the objectives of the study related to environmental and cultural values, the character and attraction of Horrocks as a tourist destination, access for both recreational fishing and the local fishing industry, and public safety and protection of infrastructure.

The qualitative risk assessment found a number of very high and high risks, all of which were reduced to moderate via proposed actions/controls. The actions proposed as part of the risk management response were:

1. Controlled access to the beach should be achieved through restricting access to the foreshore via managed access points;
2. Maintain dune system to protect infrastructure from storm surge and set permanent infrastructure at a suitable level to avoid storm surge;
3. Management of extreme rainfall events should be considered through preparation of a stormwater management strategy for the site;
4. Undertake monitoring and environmental works to assist in dune, beach and ecosystem recovery;
5. Allow appropriate public access to maintain connectivity via improvements to remaining beach access paths;
6. Set back any new facilities and amenities to allow erosion and coastal processes to occur up to/over a 100-year timeframe; and
7. Close assets following significant erosive storm event to protect public safety.

All of the above proposed actions are consistent with CHRMAP principles. The report also acknowledged the need for ongoing monitoring and review in the face of changing knowledge, measurements, needs and aspirations.

2.6.9 Coastal Management Strategy

Coastal Processes

The report highlighted coastal erosion and accretion as naturally occurring processes in Horrocks and that the Shire has successfully responded in the past through the construction of a GSC seawall in the centre of town to protect the pavilion, kitchen and toilets. The existing lookout has been moved inland from its previous position due to ongoing erosion. Additional (unspecified) protection works were therefore recommended to be installed at the Horrocks Beach townsite, particularly under the lookout and south of the access path, to enable them to respond to climatic changes in a natural way and provide protection from storm surge, inundation and erosion.

Stormwater Management

The report identified stormwater management as a priority issue for the community. There were (and still are) numerous stormwater outfalls within the townsite foreshore reserve that discharge directly to the beach and dune system. Scouring and erosion of the dunes, access paths and boat launching area was identified as a moderate to severe problem in Horrocks and intervention and remediation was identified as being required at all storm water outfalls and areas where surface runoff was scouring. Numerous soakwells were identified as being full of sand which exacerbated stormwater issues.

Uncontrolled Access

Uncontrolled vehicular access to the beach was identified as a problem in the Horrocks area, however the report noted it is valued highly by the community and is required by many to launch their boats near Whiting Pool. At the time the risk of conflict between swimming and boating at Whiting Pool was not considered by the community to be significant, however it was identified that the risk of conflicts at Whiting Pool could be reduced through the provision of dedicated trailer parking north of this location in the southern car park.

Access to Recreational Facilities

The community had taken considerable effort to formalise beach access for pedestrian and other users, however the access in 2015 did not meet AS1428 *Access for People with Disabilities*.

Access to Frog Pond was limited to an informal track and it was identified that there was an opportunity to enhance access and facilities at this site for pedestrians and the disabled.

Boat launching was identified as being undertaken at two locations in the Horrocks Townsite, opposite the General Store and from the beach at Whiting Pool. In both cases vehicles must drive onto the beach in areas with other beach users and pedestrians. The townsite boat launch area does not meet AS3962 for the design of boat launching facilities. It is currently operated as an informal facility with few controls on use or etiquette such as parking or entry and exit. DoT considers the current location hazardous due to the difficult passage through the reef and a formal upgrade of the launch access was not considered appropriate at the time.

2.6.10 Recommendations

The report made the following key recommendations for the Horrocks Townsite:

- Improve stormwater management within the townsite;
- Provide protection from coastal processes;
- Install a community walk trail;
- Improve the management of access;
- Erect interpretive and other signage; and
- Improve facilities and infrastructure.

The first two key recommendations are most relevant to the Horrocks Beach CHRMAP and are consistent with CHRMAP principles.

2.6.11 Planning and Policy Context

Appendix 1 of the document provides a useful short summary of a number of previous planning and policy context documents.

2.7 Coastal Sediment Cells for the Northampton Coast – Between Glenfield Beach and the Murchison River, Western Australia (2014)

Stul et al (2014) was prepared for the Department of Transport and the aim was to “identify a hierarchy of sediment cells to assist planning, management, engineering, science and governance of the Northampton Coast.”

The Horrocks Townsite is located wholly within sediment cell R08A2b which covers the area from Bowes River to Whale Boat Cove.

2.8 Horrocks Beach Foreshore Restoration Plan (Coastal Focus 2012)

The Horrocks Coastal Management Strategy (Essential Environmental 2015) summarised the 2012 Horrocks Beach Foreshore Restoration Plan (Coastal Focus 2012) as follows:

“*Developed through consultation with the community, surveying the area and drawing upon existing local and regional coastal management plans and strategies, the restoration plan* *provides solutions and advice for the future management of the Horrocks foreshore based on an understanding of coastal processes, ecosystem services and community aspirations.*"

The stated objective and aims of the study were to "*provide the Horrocks community with tangible solutions and practical advice for the future management of the Horrocks foreshore. The recommendations developed within the Plan draw upon existing local and regional coastal plans and strategies.*

The Horrocks Beach Foreshore Restoration Plan aims to:

- *Establish a shared vision and management priorities developed in collaboration with the community;*
- *Describe the natural, recreational and cultural values present within the study area;*
- *Identify key management issues impacting on these values;*
- *Outline tangible solutions to address specific management issues;*
- *Assign responsibility for implementation of management strategies to the most appropriate group, authority or agency; and*
- *Create awareness in the community of key coastal management issues through participatory processes, on-ground activities and interpretive signage.*"

The study references DPI (2003) and Department of Planning (2012) in relation to climate, metocean and coastal processes (see Sections 2.13 and 2.9, respectively) and includes a visual summary of coastal processes at Horrocks (Figure 2-4). The report separated the Horrocks Townsite into six nodes and identified high-level management recommendations for each node. The management actions were generally consistent with CHRMAP principles and include actions to prevent and repair dune erosion, improve vegetation and biodiversity, improve access to facilities, educate the community on coastal issues, improve parking facilities, and improve stormwater management.

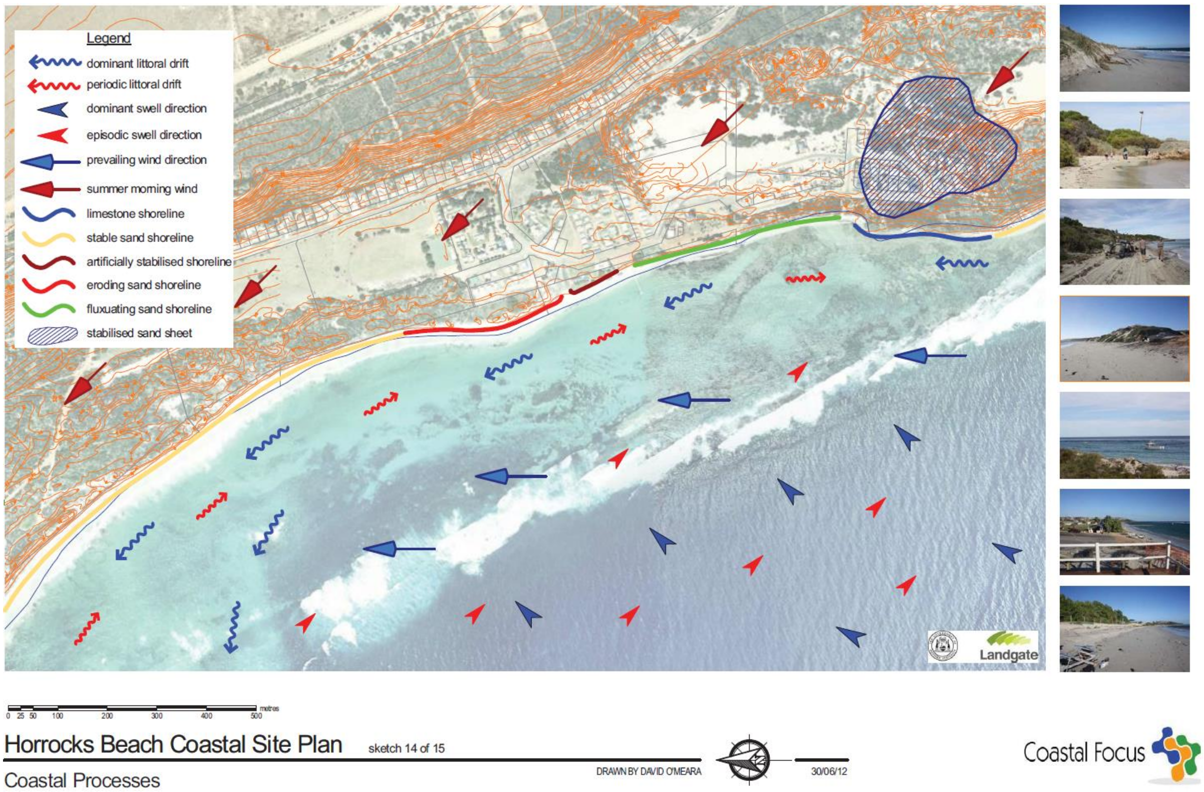


Figure 2-4 Visual summary of coastal processes at Horrocks (from Coastal Focus 2012)

This study found it was apparent that the stormwater management practises at the time were creating issues along the Horrocks Beach foreshore. Stormwater outlet pipes have been placed on beaches and dunes along the foreshore. During intense rainfall events water flows from the hills to lower areas at high speed overflowing stormwater drains and flooding the foreshore which impedes public access and poses health and safety risks. The plan flagged that climate change and increasing urban expansion will further exacerbate the situation.

The plan developed two options for improving the stormwater management at Horrocks and these options were proposed to the community; a clear majority preferred Option 1. This option was that consideration should be given to combining discharges at a common point via a common structure and could be achieved through the following changes:

- Assess water quality
- Divert the Glance Street drain through the foreshore carpark (at the bottom of Glance St), install stormwater infiltration basins (infiltration strategies should consider the risk to the quality of shallow groundwater aquifers) and gross pollutant traps
- Remove three outlet pipes from the beach and dunes (labelled SW2, SW3 and SW4 in the plan)
- Extend the outlet pipe SW5 to less steep area via a flexible pipe
- Re-use stormwater to create a community bio-garden and swales.

The plan recommended that Council develop plans for stormwater management for future developments and that stormwater runoff of new developments should not flow into the existing drains (adding to an already inadequate system).

The plan also recommended that an environmental/coastal engineer be engaged to prepare a stormwater management plan addressing the current stormwater issues in consultation with the community. As of early 2019, some improvements to stormwater management have been implemented by the Shire, mainly in the area of the southern carpark where a shallow sump and DUP have been installed.

2.9 The Coast of the Shires of Coorow to Northampton, Mid-West, Western Australia: Geology, Geomorphology and Vulnerability (2012)

The aim of this report (Department of Planning 2012) was to determine the vulnerability of landforms on the Mid-West coast to changing weather and oceanographic conditions, including projected changes in climate. Information was gathered on coastal landforms and coastal processes to identify vulnerable locations and assist decision-making regarding proposed coastal development and for coastal management purposes. 64 sediment cells were identified along 160 km of coast. Landform vulnerability was estimated as a combination of susceptibility and current condition.

The tertiary sediment cell which covers the Horrocks Townsite is characterised by low susceptibility to environmental change and high instability. It is described as moderately vulnerable with coastal risk of salient migration, dune mobility and sandsheet migration.

2.10 Report for Horrocks Beach Seawall Construction, Progress Report – Shire of Northampton (June 2010) (GHD 2010a)

The Shire of Northampton commissioned GHD in late 2009 to design suitable coastal protection for the foreshore of Horrocks in response to ongoing coastal erosion which had threatened infrastructure in the vicinity of the beach including an ablution block and a children's playground. The Shire and the Horrocks community wished to retain the amenity and functionality of the area. A geotextile bag seawall was designed and the construction contract was awarded in early 2010. GHD was commissioned to provide construction management of the seawall. This seawall was subsequently constructed and is still in place today.

The seawall is composed of layers of Geosynthetic Sand Containers (GSCs). Each GSC is 2.4 by 1.8 by 0.65 deep. The number of layers in the wall ranges from 6 to 8. The main component of the seawall is approximately 90 m long, while the northern and southern return walls are approximately 12m and 22 m in length, respectively. A layer of geotextile was placed and secured prior to the positioning of the GSCs.

In addition to the construction of the seawall, an existing parking area was removed and a beach area reinstated. The new beach area is approximately 90 m in length and involved seeding of a jute blanket over an embankment area.

This report (GHD 2010a) was a progress report to report on project progress, issues discussed on site with the contractor and provide an assessment of the project status based on site inspections up to 2/6/2010.

2.11 Report for Horrocks Beach Seawall Construction, Completion of Works – Shire of Northampton (October 2010) (GHD 2010b)

This report (GHD 2010b) follows on from the above progress report and confirms the works required under contract were completed in accordance with the drawings and specifications. It documents that some very small amounts of asbestos were found during the project and these were removed as per Department of Health guidelines. The total amount of asbestos was very small and the site was assessed as not being contaminated.

2.12 Horrocks Beach Seawall Design – Design Criteria Report (November 2009) (GHD 2009)

This report (GHD 2009) provides the basis and details for the design of the GSC seawall and adjacent beach area. This seawall was subsequently constructed (refer two previous sections).

This report presents the following criteria which are relevant to this CHA:

- The design life of the GSC seawall was nominated as 25 years, but the report noted that the manufacturer only guaranteed 15 years
- A 1 in 50 year design event was applied for the seawall design
- The design levels were based on a topographic survey from October 2009 (expected to be a typical winter profile (i.e. eroded))
- The design water level included a value for sea level rise of 0.425 m at 2060.
- The design water levels were a combination of the Mean Higher High Water tide level and storm surge (refer Table 4-4)
- 1 and 50-year ARI wave heights were derived for a location offshore (based on extreme value analysis of WW3 data) and these were transformed to the project site using a numerical wave model (refer Table 4-8).
- The seawall design includes return walls at both ends of the seawall
- 2.5 m^3 (approximately 4.5 tonne) GSCs were used in the design of the seawall

- Particle Size Distribution (PSD) tests were conducted on sediment samples collected by the Shire of Northampton and the sand which was used to fill the GSCs had a D50 of approximately 0.25 mm.

2.13 Horrocks Foreshore Management: Finalised Investigation for the Shire of Northampton (DPI 2005)

The Shire of Northampton sought advice from the then Department of Planning and Infrastructure (DPI) around 2003 regarding the management of foreshore erosion at Horrocks beach in the vicinity of the townsite. The resulting final report (DPI 2005, preceded by a preliminary version of the report in 2003) found the erosion at Horrocks Beach appears to be mostly attributable to acute, short-term erosion associated with intermittent storm events that was being balanced by subsequent natural beach accretion rather than chronic or prolonged erosion.

DPI reviewed the “managed recession” option then being considered by the Shire and also considered alternative strategies. DPI found that the “managed recession” option under consideration by the Shire had considerable merit, however there are costs associated with this option. DPI also undertook a preliminary review of alternative options of:

- Sand nourishment
- Nourishment with a seawall
- Nourishment with a groyne

DPI (2005) found that each of these options would have both pros and cons at Horrocks. The preliminary (2003) report found further investigation of local erosion and littoral drift rates to assess nourishment volumes and resulting costs was required to properly evaluate these options. DPI (2003) recommended a data collection program for Horrocks to refine understanding of the coastal processes and the foreshore erosion mechanism on both a qualitative and quantitative basis. That investigation was subsequently undertaken and the results and analysis included in the final report (DPI 2005).

This report included the following summary of coastal processes at Horrocks Beach.

2.13.1 Winds

“*Wind patterns are related to the prevailing synoptic weather conditions influencing the region, which include anticyclones (which prevail throughout the year), inter-anticyclonic fronts, mid-latitude cyclones, tropical cyclones and the sea breeze system (DPUD 1993). In summer, winds vary from moderate easterly offshore land breezes in the morning to strong southerly/south-westerly onshore winds in the afternoon, whereas in winter, winds vary from north-easterlies in the morning to south-westerlies in the afternoon (DPUD 1993). Storms accompanied by heavy rainfall, large waves and storm surge occur during late summer due to dissipating tropical cyclones and during winter due to strong westerly/south-westerly gales (DPUD 1993).*”

2.13.2 Waves

“*The continuous natural reef located about 250 metres offshore refracts and greatly attenuates the incoming south-westerly swell waves, incidentally protecting the foreshore from experiencing more severe erosion. Long period seiching related to the offshore swell occurs in the embayment between the shoreline and the offshore reef (M J Paul & Assoc 2001).*

Tremarfon (2000) derived a general wave height distribution for the Horrocks Beach embayment as being:

- *Less than 0.2 metres for 50% of the time;*
- *Less than 0.3 metres for 82% of the time; and*
- *Less than 0.4 metres for 96% of the time.*

Under extreme storm conditions, waves up to 1.2 metres high are known to reach Horrocks Beach (M J Paul & Assoc 2001)."

2.13.3 Longshore Currents

"*There is a strong net northwards longshore current flowing out through an approximately 90 metre wide unmarked channel at the northern end of the embayment known locally as the 'Gap' (M J Paul & Assoc 2001), which is associated with a net northwards littoral drift.*"

2.13.4 Tides

"*The WA coastline is subject to comparatively large seasonal and inter-annual variability of mean sea level (Pariwono et al, 1986). At Horrocks Beach, the wind-driven sea and swell waves plus short period seiching appear to be strongly related to the tide, which increases the vertical range of water over the reef across which wave activity can occur (MJ Paul & Assoc 2001). Tides are diurnal with a very low range; the spring (maximum, bimonthly) tidal range is 0.5 metres from mean lowest low water to mean highest high water (DPUD 1993).*"

2.13.5 Storm Surges

"*Non-tidal residual is the elevation of the sea level above normal astronomic tide. Storm surge is the component of non-tidal residual that is generated by synoptic forcing. Horrocks Beach is a surge-dominated environment, where local storm surge may exceed the tidal range. When surges near Geraldton are in excess of 1 metre, the total water level fluctuation at Horrocks Beach is likely to exceed 2 metres, which is sufficient to expose the reefs during low sea level conditions and erode the foredunes when sea levels are highest (DPUD 1993).).*"

2.13.6 Quantitative Assessment of Erosion Issue

DPI (2005) included a quantitative assessment of the erosion issue using hydrographic surveys and coastline movement plots derived from aerial photography. This found that "*the Horrocks foreshore had been quite stable in the longer term with only a relatively minor amount of chronic recession*. *Meanwhile, acute (episodic) foreshore recession of up to 20 metres has been observed in this vicinity during recent years, in association with intermittent severe storm events (e.g. May 1999, February 2000 and April 2000), these occurrences appear to be balanced out by recovery to most extent by natural beach accretion over subsequent months.*"

2.13.7 Particle Size Distribution (PSD)

DPI (2005) included one PSD analysis from Horrocks Beach with D10 of 0.18 mm, D50 of 0.21 mm and D90 of 0.34 mm.

2.14 Horrocks Beach Improved Maritime Facilities Investigations (MJ Paul & Assoc 2001)

This report (MJ Paul & Associates 2001) was prepared for the Department of Transport in response to representations from the local community for an improvement in the level of maritime facilities available for small craft at Horrocks Beach and an unsuccessful installation of "Fleximat" concrete paving slabs at the existing boat launch site.

This report details a number of coastal engineering investigations undertaken in response to the lack of existing data at Horrocks. These investigations included:

- Hydrographic survey of Horrocks beach anchorage and its approaches
- A detailed beach survey of the Horrocks Beach boat ramp site and the adjacent beaches
- A ground probing survey to determine the level at which limestone rock could be expected to occur in the vicinity of the boat ramp site
- A hydrographic survey of Whaleboat Cove and its approaches
- A detailed beach profile survey at Whaleboat Cove
- Short-term monitoring of wave climate within the Horrocks Bay anchorage and its correlation to available tide levels (at Horrocks beach) and offshore wave records (at Oakajee)
- An assessment of wave breaking conditions on the approaches to the Horrocks Beach Anchorage.

The report prepared concept designs for boat ramp facilities at both Horrocks Beach and Whaleboat Cove with the latter being substantially more expensive due to the requirement for additional installation of an access road, water supply and power supply from Horrocks Beach.

3. Site Inspection

GHD project team traversed the foreshore of Horrocks Beach in January 2019 identifying key coastal features for consideration in the erosion and inundation hazard assessments. From visual assessment beach morphology at Horrocks is principally influenced by the intermittent nearshore reef chain, presence of rock platforms on the beach, beach orientation and dune elevation. The study area has been divided into 10 zones in line with the erosion hazard areas and are described in more detail below.

3.1 Zone 1

The beach in Zone 1 is narrower than adjacent beaches in Zone 2 with high sandy dunes at the rear of the beach, typically in the order of 3 to-5 mAHD. This zone has an intermitted rocky platform on the lower beach face and the offshore reef chain is also close to the shore. The complex nearshore current patterns from reef wave interactions and the perched nature of the beach and dunes above the rock platforms play a strong role in sand deposition and erosion characteristics in this region.

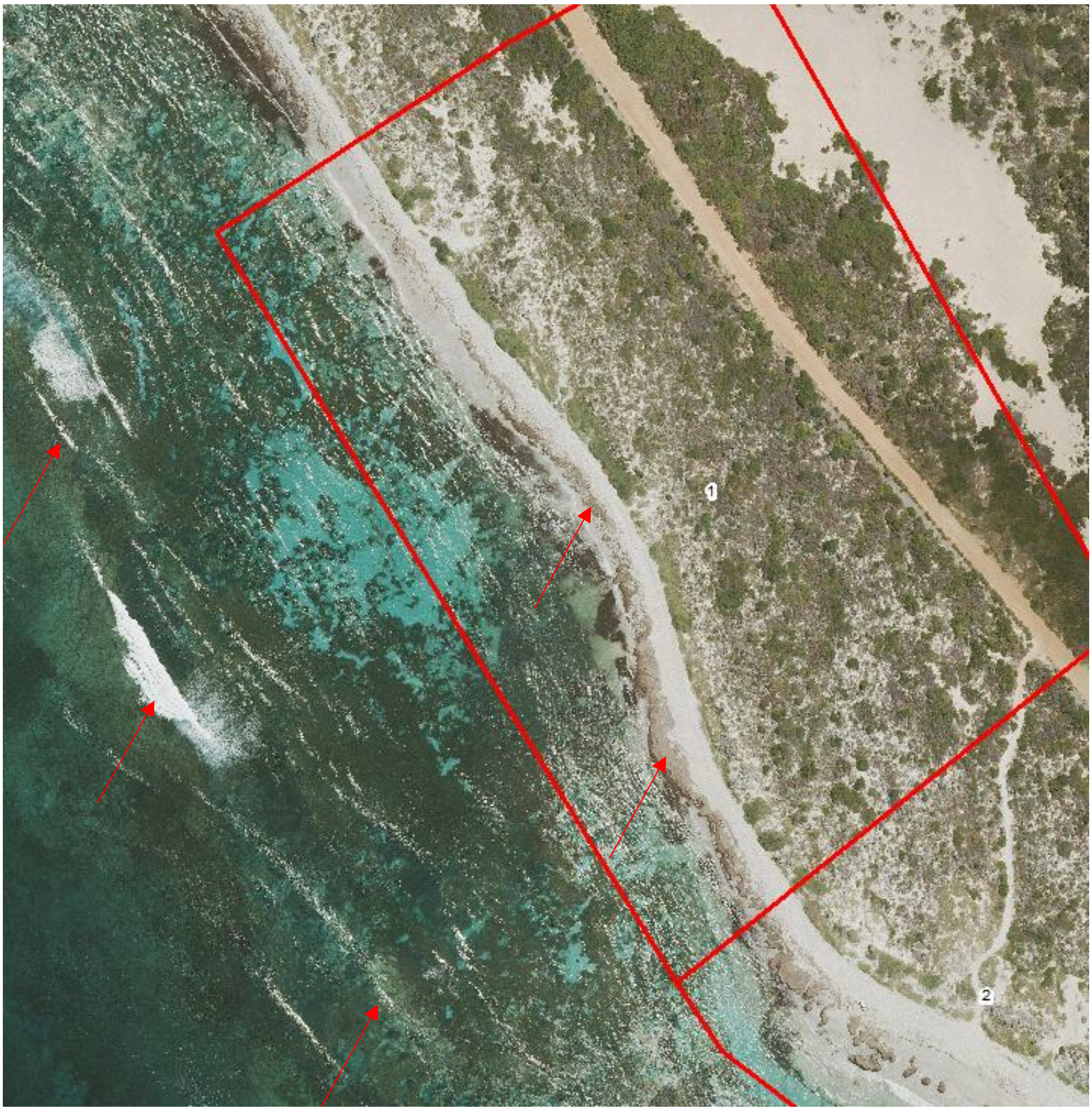


Figure 3-1 Rock platforms and offshore reefs of Zone 1.

3.2 Zone 2

At the northern end of Zone 2 is Stinky Point, aptly names for the smelly wrack that accumulates on the wide sandy beaches (Figure 3-2). The dunes at the back of the beach across Zone 2 are similar in nature to adjacent zones and are high, with moderate vegetation coverage. Access to the foreshore by 4WD vehicles tracks near the base of the dunes may be impacting on the base of the dunes(Figure 3-3).The base of the dunes in some areas show clear evidence of erosion (Figure 3-4) where vegetation has become undercut.

Figure 3-2 Zone 2 - Looking north from near northern boundary of Zone 2.

Figure 3-3 4WD tracks and base of dunes in Zone 2 – northern end.

Figure 3-4 Undercut vegetation at base of dune in Zone 2.

Figure 3-5 Minor cusps on wide sandy beach. Looking south from Zone 2.

3.3 Zone 3

In profile, Zone 3 has wide sandy beaches with minor cusps (Figure 3-6) backed by high eroded foredunes (Figure 3-7 and Figure 3-9), a discontinuous swale behind the foredune (Figure 3-8) and an even higher secondary dune (refer to Profile 3 in Appendix A).

Figure 3-6 Wide flat sandy beach at northern extent of Zone 3 looking south.

Figure 3-7 Beach and steep eroded dune at centre of Zone 3.

Figure 3-8 Swale behind foredune in Zone 3. Photo taken from dune crest in central Zone 3 looking NNE.

Figure 3-9 Erosion damaged foredunes at southern extent of Zone 3.

3.4 Zone 4

Beach width in Zone 4 is narrower than Zone 3 and the beach slope is not quite as flat (Figure 3-11). Dunes in Zone 4 are high and show pronounced evidence of past erosion where sand is exposed and vegetation appears to have slumped down the slopes (Figure 3-10 and Figure 3-12). Some vegetation has regrown, indicating there has been a period or recovery since the erosion event (likely a significant storm experienced in 2009 (Shire CEO, pers comm).

Figure 3-10 Eroded fore dune in northern section of Zone 4. Plants showing some signs of vegetation recovery.

Figure 3-11 Wide sandy beach in central Zone 4., cusps present on beach face.

Figure 3-12 High eroded dune in southern section of Zone 4.

3.5 Zone 5

The foreshore of the northern half of Zone 5 shows evidence of erosion with erosion scarps and collapsed vegetation which get worse (higher) with increasing distance north (Figure 3-13 & Figure 3-15). Dune vegetation coverage is generally good. There is a small intermittent swale behind the primary dune. The height of the seaward edge of vegetation is generally low (Figure 3-14). The sandy beach is fairly flat, with a low berm towards the rear of the beach (Figure 3-14).

South of the most northern pedestrian beach access, the swale behind the foredune becomes more pronounced, but the foredune is still low (Figure 3-16, Figure 3-17). The secondary dune, in front of houses on Glance Cove is probably an artificial dune and water is reported to occasionally accumulate in the swale in front of here. The height of the foredune increase further south along Zone 5 (Figure 3-17 and Figure 3-18). Adjacent the boat ramp at the most southern extent of Zone 5 there is one high elevated dune, with good vegetation coverage (Figure 3-19).

Dumping of gravel reportedly occurs occasionally at the bottom of the boat ramp to improve boat launching and bogging in the sand. There was however no evidence of this material on the beach so it appears to gets redistributed.

Figure 3-13 Erosion of foredunes at northern end of Zone 5.

Figure 3-14 Wide sandy beaches of Zone 5. Photo looking north from centre of Zone 5.

Figure 3-15 Erosion of base of foredune, north of northern access ramp, middle of Zone 5.

Figure 3-16 Low primary dune and potential artificial secondary dune in front of newly constructed house on Glance Cove.

Figure 3-17 Swale between primary and secondary dune in the southern half of Zone 5. Photo looking south.

Figure 3-18 Photo taken from primary dune crest, looking north. Showing swale and newly constructed house at front of secondary dune.

Figure 3-19 High vegetated primary dune at the southern end of Zone 5.

3.6 Zone 6

Zone 6 extends from the boat ramp in the north (Figure 3-20) to the end of the dune rehabilitation area and grassed picnic area in the south (Figure 3-24). The southern end of Zone 6 also aligns with a storm water drain (Figure 3-25). The beaches in this zone are sandy, and the beach faces more southerly than the adjacent beaches in Zone 7.

A 100m long Geotextile Sand Container (GSC) seawall extends south from the boat ramp along the dune front protecting the community kitchen and playground (Figure 3-21 & Figure 3-22). The GSC seawall is in good condition with, with up to three bags remaining buried below the present day sand land levels across the structure. Upper parts of the seawall are partially covered by sand and dune vegetation. The GSC seawall appears to be having no net impact on the longshore sediment transport in the area, with no indication of flanking erosion at either end of the structure.

The southern half of Zone 6 is a dune regeneration (Figure 3-23) area with wind barriers constructed to promote accretion of sand and growth of vegetation. There are no sharp erosion features or any obvious erosion issues.

Figure 3-20 Looking south over Zone 6 from lookout structure at southern end of Zone 5.

Figure 3-21 GSC Seawall, toe bags still buried by sand, and vegetation and sand covering upper layers.

Figure 3-22 Southern extent of GSC Seawall and adjacent beach accesses path.

Figure 3-23 Dune restoration efforts including wind barriers in southern half of Zone 6.

Figure 3-24 Sand beach and jetty. Southern end of Zone 6 looking north.

Figure 3-25 Stormwater drain obscured by vegetation near the boundary of Zone 7 and 6.

3.7 Zone 7

Zone 7 encompasses the beach in front of the most southern car parking areas and informal boat ramp. The level of the dunes and carpark area behind it is quite low, and the dune is very narrow, typically only 2 to 3m in width (Figure 3-26 &Figure 3-27). The carpark area here was historically an informal gravel area and suffered effects of erosion. Carparking, dune access and footpaths have since been formalised and restricted in an effort to protect the narrow dune here.

The dune is still at threat of erosion, with numerous erosion scarps present (Figure 3-28) including undermining of vegetation (Figure 3-29). The erosion is threatening the footpath, predominantly in the northern half of Zone 7.

Figure 3-26 Sandy beach, with low elevated dunes. Looking south towards Zone 8.

Figure 3-27 Narrow, low elevation sand dune in front of footpath and dune fence. Southern end of Zone 7 looking north.

Figure 3-28 Erosion scarp threatening to undermine footpath. Northern Zone 7.

Figure 3-29 Erosion beneath vegetation, northern Zone 7.

3.8 Zone 8

The northern boundary to Zone 8 is the road access which is sometimes used for beach launching of boats (Figure 3-30). This zone includes Whiting Pool, also known as Granny's pool, a protected area of town beach used for swimming (Figure 3-31).

Zone 8 is a sandy foreshore with semi artificial dunes behind it. Historical shacks used to be close to water in this zone and when they were removed, the material they were built upon was flattened and pushed seaward, creating a steep dune. Evidence of the displaced material was observed from the yellow coloured sand of the steep dunes (Figure 3-32, Figure 3-33 & Figure 3-35) along this section of foreshore which contrasts to the white beach sand elsewhere. Note this material was significantly coarser than sand on the beach face and along the foreshore so a sample was collected for analysis (refer to Section 4.7.1.)

The dunes along Zone 8 are quite high and steep, particularly in the south, with height reducing towards the northern end (Figure 3-33 & Figure 3-35) with the occasional erosion scar showing.

There is a storm water drain within Zone 8 that results in erosion of the dune every time there is a significant rainfall event. Construction rubble and rock has been placed around the outfall to minimise scour by water.

The southern boundary of Zone 8 is shown in Figure 3-36 and Figure 3-37 , when the sandy beach turns into 2m high vertical limestone face.

Figure 3-30 Northern end of Zone 8 looking north to informal boat ramp access.

Figure 3-31 Calm water in Zone 8, with waves breaking over reef chain, ~300m from the shore.

Figure 3-32 Exposed dunes in Zone 8.

Figure 3-33 Steep dunes in Zone 8. Looking north across zone.

Figure 3-34 Stormwater drain in central Zone 8 causing water scour of dunes.

Figure 3-35 Steep dune within Zone 8 showing yellow erosion scar between vegetation.

Figure 3-36 Looking south from within Zone 8 towards southern boundary.

3.9 Zone 9

Zone 9 is a small zone, which begins at the north at the abrupt start of a limestone rock outcrop (Figure 3-37). The limestone platform has a vertical face of over 2m high (Figure 3-38) which lessens the further south (Figure 3-39). There is a small sandy beach in front of the vertical rock platform.

Figure 3-37 Start of Zone 9 - where limestone rock begins. Photo looking WSW.

Figure 3-38 Limestone rock platform, ~ 2m high, photo taken from middle of Zone 9 looking north.

Figure 3-39 Southern end of Zone 9 looking north. Variable rocky platform.

3.10 Zone 10

Zone 10 is a mixed sandy and rocky coast, with limestone rock platforms just above the tidal zone across the majority of the zone and with protection offered by the nearshore reef system. The rock platform is variable in width and height (Figure 3-41, Figure 3-42, Figure 3-43), offering more protection from the middle to the south, and in the northern quarter.

Sand dunes are perched above the rock platform and in some areas show slight erosion at the base (Figure 3-43), indicating that in significant events, this zone is still prone to some erosion.

Figure 3-40 Variable rock platform. Looking north.

Figure 3-41 Rock platform protecting base of dunes. Zone 10 looking north, photo taken ~200m south of Zone 9/10 boundary.

Figure 3-42 Low elevation partially sand covered platform. Middle of Zone 10 looking north.

Figure 3-43 Limestone platforms. Photo taken at middle of Zone 10 looking south.

Figure 3-44 Waves breaking over nearshore reef, dissipating wave energy reaching the beach in Zone 10

4. Physical Data

4.1 Introduction

This section provides a summary of available data, measurements and observations of the met-ocean conditions of Horrocks from previous studies in Section 2 as well as new data obtained during this assessment.

4.2 Vertical Datum

Based on the 2019 submergence curve for Geraldton (DoT 2019), the relationship between Australian Height Datum (AHD) and Chart Datum (Lowest Astronomical Tide (LAT) Geraldton 2007) at Geraldton (~50 km south of Horrocks) is AHD is +0.55 m CD i.e. AHD is 0.55 m above Chart Datum.

4.3 Bathymetric and Topographic Data

The Department of Transport captured a LiDAR topographic and bathymetric survey which covered the area between Horrocks and Hillarys between February and April 2016. The spatial extent of this survey data around Horrocks is shown in Figure 4-1.

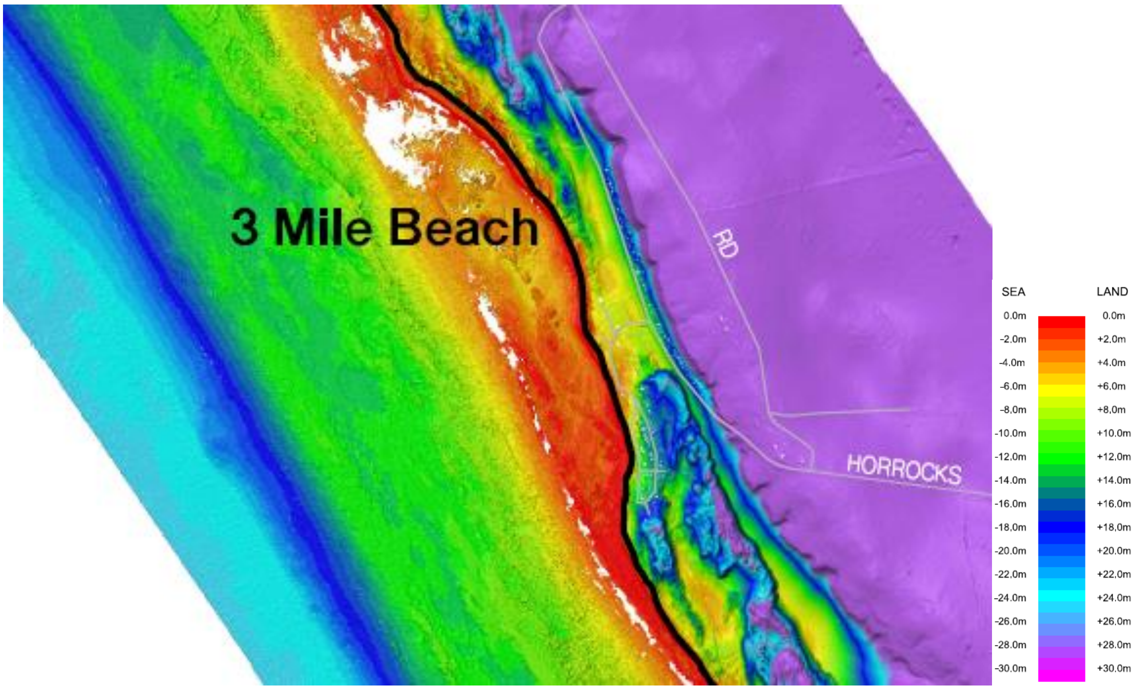


Figure 4-1 DoT 2016 LiDAR survey around Horrocks

There are other previous bathymetric and topographic surveys which cover the area around Horrocks but these cover much smaller areas and are significantly older than the 2016 LiDAR survey so were not used in this assessment.

4.4 Historical Shoreline Data

The Department of Transport provided GHD with 11 historical shorelines (in .shp format) of the Horrocks beach foreshore extracted from stereo aerial imagery analysis. The historical shorelines for the years: 1943, 1956, 1965, 1970, 1980, 1990, 1995, 2002, 2004, 2008 and 2016 were provided and considered in this assessment. Table 4-1 compares significant storm events (MRA 2018) according to the years of historical shorelines provided.

Table 4-1 Cross comparison of aerial image years with significant storm events, ranked by Net Cluster Power identified in MRA 2018.

Aerial image	Event Rank (MRA 2018)	Occurrence
Jan-80	10c	Jun-86
	51c	May-88
	19a	Jul-89
	2a	Jul-90
Nov-90	5a	Jul-91
	3a	Jul-93
	4a	Jun-95
Dec-95	41a	Jun-96
	1a	Jul-96
	8a	Jun-97
	1c	May-99
Mar-02	9a	Jul-02
	5c	Jun-03
Mar-04	7a	Aug-04
	40a	Jul-07
	13a	Aug-07
Oct-08	26a	May-09
	14a	Jun-09
	6a	Sep-09

4.5 Water levels

4.5.1 Tidal Planes

2009 Tidal Planes

GHD (2009) included tidal planes for Horrocks, sourced from the Department of Transport (Table 4-2):

Table 4-2 Horrocks tidal planes from GHD (2009)

Tidal level	Description	AHD level (m)	Chart Datum level (m)
HAT	Highest Astronomical Tide	+0.65	+1.41
MHHW	Mean Higher High Water	+0.27	+1.03
MSL	Mean Sea Level	+0.05	+0.81
MLHW	Mean Lower High Water	+0.02	+0.78
MHLW	Mean Higher Low Water	-0.07	+0.69
MLLW	Mean Lower Low Water	-0.22	+0.54
LAT	Lowest Astronomical Tide	-0.55	+0.21

2019 Tidal Planes

DoT has since produced an updated submergence curve for Geraldton (DoT 2019), which is considered applicable to Horrocks for the purposes of a CHRMAP, and the tidal plane from this is presented in Table 4-3. Geraldton has a mix of diurnal and semi-diurnal tides and has a microtidal range.

Table 4-3 Horrocks tidal planes (DoT 2019)

Tidal level	Description	AHD level (m)	Chart Datum (LAT Geraldton 2007) level (m)
HAT	Highest Astronomical Tide	+0.71	+1.26
MHHW	Mean Higher High Water	+0.46	+1.01
MLHW	Mean Lower High Water	+0.31	+0.86
MSL	Mean Sea Level	+0.09	+0.64
AHD	Australian Height Datum	0	+0.55
MHLW	Mean Higher Low Water	-0.14	+0.41
MLLW	Mean Lower Low Water	-0.28	+0.27
LAT	Lowest Astronomical Tide	-0.48	+0.07

It is worth noting that both the highest and lowest water levels recorded (well above and below HAT and LAT, respectively) in the Geraldton tide gauge record were associated with the Indian Ocean Tsunami in December 2004.

4.5.2 Extreme Water Levels

Horrocks Seawall Design (GHD 2009)

GHD (2009) analysed 23 years of water level records from Geraldton (1986 to 2009) and conducted an extreme value analysis on the storm surge (residuals). These storm surge levels were added to the MHHW tide level to provide design water levels for different return periods (Table 4-4).

Table 4-4 Extreme storm surge and design water level at Horrocks (GHD 2009)

Return Period (yrs)	Storm Surge (m)	Tide (MHHW) + Storm Surge (m AHD)
1	0.6	+0.87
5	0.7	+0.97
10	0.8	+1.07
20	0.8	+1.07
50	0.9	+1.17

Geraldton CHRMAP (Baird 2018)

The Geraldton CHRMAP (Baird 2018) included extreme water levels from three previous coastal processes studies (MRA 2015, 2016, 2017). These values are presented in Table 4-5. These extreme water levels were based on a Monte Carlo simulation resulting in a 2,000-year synthetic cyclone record which was generated and used to determine potential inundation levels associated with cyclone events in Geraldton (MRA 2015, 2016, 2017). The water levels for future timeframes included estimated sea level rise.

Table 4-5 Coastal inundation water levels for Geraldton in future planning periods (from MRA 2015, 2016, 2017)

Planning Timeframe	ARI	Cape Burney to Greys Beach (m AHD)	Point Moore (m AHD)	Geraldton Port to Drummond Cove (m AHD)
2015	20-year	2.0	2.0	2.0
	100-year	2.2	2.6	2.9
	500-year	3.0	3.3	3.6
2030	20-year	2.1	2.1	2.1
	100-year	2.3	2.7	3.0
	500-year	3.1	3.4	3.7
2070	20-year	2.4	2.4	2.4
	100-year	2.6	3.0	3.3
	500-year	3.4	3.7	4.0
2110	20-year	2.9	2.9	2.9
	100-year	3.1	3.5	3.8
	500-year	3.9	4.2	4.5

DoT Design Storms for WA Coastal Planning: Tropical Cyclones (Seashore 2018)

Seashore (2018) derived preliminary extreme water levels for both Geraldton and for Kalbarri (Table 4-6). These values do not include wave setup and are deliberately conservative and intended only as a starting point for assessing coastal inundation risk.

Table 4-6 Preliminary extreme water level (Seashore 2018)

Location	100-year ARI water level (HSD)	500-year ARI water level (S4)
Geraldton	1.7 (2.4)*	3.5 m AHD
Kalbarri	-	3.4 m AHD

* Figures in parentheses are a parametric estimate of the 100-year water level for tropical storm conditions, although they are considered unlikely to be coincident with severe erosion (Seashore 2018).

4.5.3 Sea Level Rise

This CHA is required to consider predicted sea level rise over the 100-year planning timeframe by SPP2.6. DoT's recommended allowance for sea level rise in regards to coastal planning (Bicknell 2010) is based on the 95th percentile of the A1F1 scenario from the IPCC Fourth Assessment Report.

Since 2010, the IPCC's Fifth Assessment Report (AR5) has been released with confidence in the projections of global mean sea level rise increasing (IPCC 2013). The IPCC has developed four representative concentration pathway (RCP) scenarios that demonstrate different population size, economic activity, lifestyle, energy use, land use patterns, technology and climate policy pathways trajectories and their possible resulting emissions. The sea level rise scenarios are referred to as RCP2.6, RCP4.5, RCP6.0 and RCP8.5 with the number being indicative of the W/m^2 reached by the pathway in 2100 (Figure 4-2).

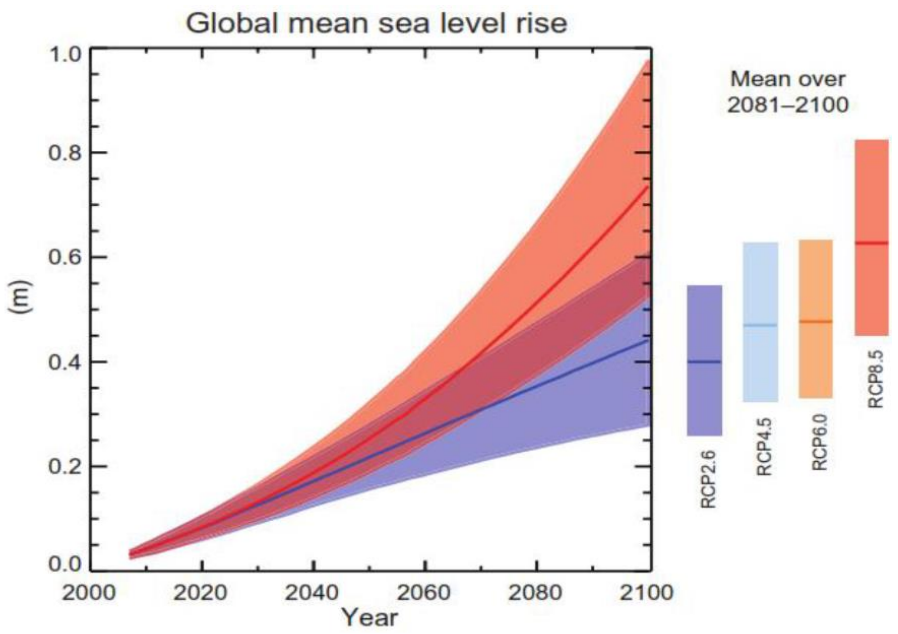


Figure 4-2 Global mean sea level predictions from IPCC AR5* (2013)

* “Projections of global mean sea level rise over the 21st century relative to 1986 – 2005”

For the sea level rise assessment for this CHA, the values from IPCC (2013) AR5 were applied as these are the most recent industry-accepted predictions. The relevant IPCC (2013) values are provided in Table 4-7 with 2010 DoT recommended values for comparison. The various RCP sea level rise values were applied here to assess the likelihood of different erosion and inundation scenarios (see Section 5). Values for 2120 were extrapolated with the rate of SLR between 2090 and 2110.

Table 4-7 Sea level rise scenarios (m) referenced from 2010 water levels

Source	2019	2030	2050	2070	2090	2120
DoT 2010 (4AR A1F1)	0.04	0.09	0.22	0.41	0.64	1.00
RCP 2.6 (AR5)	0.04	0.08	0.20	0.33	0.46	0.67
RCP 6.0 (AR5)	0.04	0.08	0.20	0.35	0.55	0.85
RCP 8.5 (AR5)	0.04	0.08	0.24	0.46	0.74	1.19

4.5.4 Tsunami Water Levels

Geraldton CHRMAP (Baird 2018)

The MRA (2015, 2016, 2017) studies utilised for the Geraldton CHRMAP considered the 2004 Boxing Day tsunami event that impacted water levels at Geraldton and determined that no additional inundation allowance to account for tsunami risk was required for Geraldton.

From a review of available information, MRA concluded that the 2004 Indian Ocean Tsunami had an ARI of between 700 and 3,000 years yet only resulted in a maximum inundation level of around +1.75 mAHD at Geraldton (MRA 2015, 2016, 2017). This level was well below the present day 500-year ARI storm-induced inundation levels from those studies and therefore they concluded an additional allowance for tsunami-induced inundation was not reasonable.

4.6 Wave Climate

Waves approaching the Western Australian coastline come from four dominant sources:

- Offshore swell (from west to southwest) from Southern Indian Ocean with typical wave periods generally over 10 to 12 s.
- Waves generated by (ex-)tropical cyclones or other unusual weather systems which can approach from various directions depending on the weather system type and path.
- Sea and swell generated by storm events associated with mid latitude depressions.
- Wind seas generated by the local sea breeze pattern (typically with periods less than 6 to 8 seconds) from the west to southwest that are most predominant in spring and summer (October to April).

4.6.1 Extreme Wave Conditions

GHD (2009) derived offshore extreme wave conditions from an extreme value analysis of WW3 data offshore of the Abrolhos Islands. These offshore wave conditions were simulated to the nearshore at the project site using a numerical wave model. The design significant wave heights (Hs) from this study are presented in Table 4-8. It should be noted this model was not calibrated and the wave heights were derived to check against the acceptable design wave conditions recommended by the GSC manufacturer.

Table 4-8 Offshore and Nearshore Design Significant Wave Heights for design of Horrocks GSC seawall (GHD 2009)

Return Period (years)	Offshore Hs	Nearshore Hs
1	7.0	0.7
50	8.5	1.2

Severe Storms for the Assessment of Erosion

MRA (2018) (refer Section 2.1) determined two different design storms for multiple ARIs for the Mid-west region, which includes Horrocks. The design storms were derived from combinations of various actual historical storms. The study recommended that both design storms be assessed for any given location to account for variability and different beach profile response etc.

The design storms relevant to this CHA are presented in Table 4-9. It should be noted that these storms are applicable in deep water offshore and need to be simulated to the nearshore using a numerical wave model.

Table 4-9 Design storm sequences for Mid-west region from MRA (2018)

ARI	Design Storm Sequence 1	Design Storm Sequence 2
1-year ARI	G6	G5
10-year ARI	2xG2 + G6	G8 + G3
100-year ARI	2xG8 + G4	3xG3 + G8

Directionality of Waves

Data collected by the Geraldton wave rider buoy is non- directional. Directionality of waves was considered by MRA (2018) and they summarised:

"It is noted that the incidence of severe waves from the north westerly quadrant decreases with distance north along the coast. This decrease is due to the reduced incidence of the aforementioned weather systems (approaching fronts or cut-off low pressure systems) *at these*

northern latitudes. The incidence of storms from the north westerly quadrant in Geraldton is far less than it is at Rottnest, for example."

A Wave rose of hindcast wave data extracted from Wave Watch 3 at Geraldton is shown below in Figure 4-3. WW3 provides directionality for Total Hs and therefore is most representative of swell wave directionality (MRA 2018).

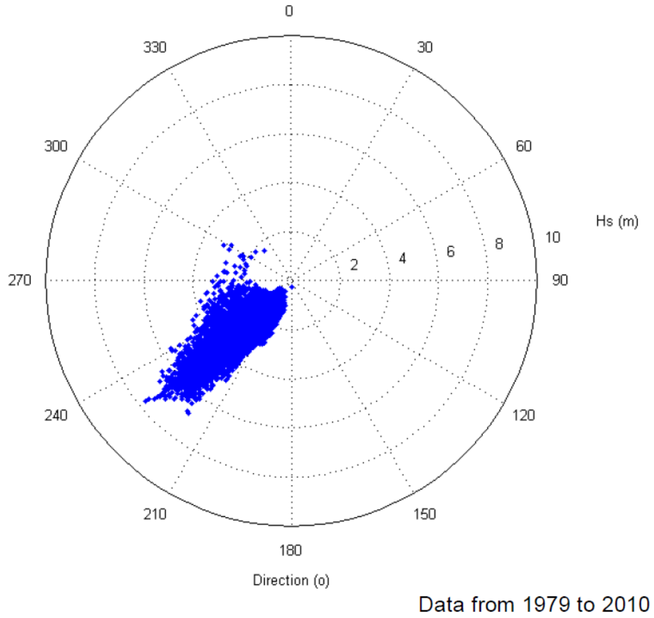


Figure 4-3 Geraldton WW3 Total Hs Direction Wave Rose (MRA 2018).

4.7 Morphology and Sediment Transport

This section presents information on the morphology and sediment transport within the assessment area.

4.7.1 Particle Size Distribution (PSD) Results

GHD (2009)

Four PSD results for the assessment area were collected by the Shire of Northampton as part of the design for the GSC seawall in the centre of Horrocks in 2009. The exact locations of these samples were collected is not available, however it is understood the intent of the samples was to ascertain the grain size of the sand to be used to fill the GSCs.

The D50 values across the four samples varied between approximately 0.2 mm and 0.27 mm.

DPI (2005)

DPI (2005) included one PSD analysis from Horrocks Beach with D10 of 0.18 mm, D50 of 0.21 mm and D90 of 0.34 mm.

Samples collected as part of this study

Based on the lack of existing PSD information across most of the study area, four sediment samples were collected from four different locations along the coastline of the study area during the site visit in January 2019 and analysed. The sample locations and results are presented in Table 4-10:

Table 4-10 PSD sample locations and results

Parameter	Sample 1 – Whiting Pool	Sample 2 – Jetty	Sample 3 – Community Centre	Sample 4 – Stinky Point
Coordinates of sample location	Lat: 28° 23’ 10” S Long: 114° 25’ 51” W	Lat: 28° 23’ 0” S Long: 114° 25’ 48” W	Lat: 28° 22’ 45” S Long: 114° 25’ 44” W	Lat: 28° 22’ 36” S Long: 114° 25’ 40” W
AS Sieve Size (mm)	**Percent Passing**			
1.18	100		100	
0.6	92		96	
0.425	59	100	88	100
0.3	24	94	81	97
0.15	1	6	9	14
0.075	1	1	1	1
D50 (estimated) (mm)	**0.39**	**0.21**	**0.22**	**0.20**

As can be seen from Table 4-10, the sample from Whiting Pool is significantly different from the other three locations (which are very similar). The Whiting Pool sample was collected from part way up the erosion scarp at the back of the beach. The Shire and Horrocks community members advised that there were historical beach shacks in the Whiting Pool area for a number of decades which were eventually demolished and an artificial dune was created during the demolition process. Visual observation by GHD staff during the site visit confirmed the dune is quite high in this area, has a steep erosion scarp and the dune sand appeared visually different to the beach sand in front. The PSD sample results support the hypothesis that the dune sand in the Whiting Pool area is different to the rest of the study area, which is an important observation for the storm erosion assessment in this area.

4.8 Physical Controls

There is only one coastal protection structure within the study area which is the GSC seawall (approximately 100 m in length; constructed in 2010) in the centre of Horrocks in front of the Community Kitchen, park and playground. The GSC seawall has an estimated design life from construction of 25 years, to approximately 2035 when it is anticipated the structure will need to be removed, replaced or upgraded pending assessment of values at risk at that time.

5. Hazard Assessment Methodology

5.1 Coastal Erosion Allowance Methodology

5.1.1 Introduction

The coastal erosion allowances were estimated based on the principles of the methodology described in Schedule 1 of SPP 2.6 (see Section 2.1). Because the method in Schedule 1 was developed for the purpose of assessing of coastal hazards to new development along the coast, and CHRMAP's are undertaken for assessing existing and future potential asset and value risks, the methodology has had to be amended to consider additional timeframes and likelihoods.

Undertaking a coastal hazard assessment for adaptation, requires understanding of how coastal hazards change over time as this allow us to identify when adaptation or risk treatment is required. This assessment has considered six planning timeframes 2019 (present day), 2030, 2050, 2070, 2090 and 2120.

Understanding when risk change occurs is also linked to when there is a change in likelihood. The Schedule 1 methodology is for consideration of coastal hazards to new development and is therefore only required to consider one likelihood event, to make sure that development is beyond the anticipated coastal processes zone. Given that CHRMAP's are used to assess coastal hazards to present day assets and values, it is likely that older assets including coastally dependent assets are already within this hazard zone. Therefore, our approach to hazard assessment also focuses on being assess different event likelihoods to broaden risk levels to values or assets for any given time period.

This assessment has considered three different erosion storm likelihoods (almost certain, possible and rare). Estimates of allowances made here are from the combination of timeframes and likelihoods that are summarised in Table 5-1, which are further described in the following sections.

Table 5-1 Coastal erosion scenarios

Likelihood	2019 (present day)	2030	2050	2070	2090	2120
Almost Certain	Larger of S1 values from two DoT 1-year ARI design storms for Geraldton	Present day S1 allowance + S2 + S3 from RCP 2.6 + allowance for uncertainty				
Possible	Larger of S1 values from two DoT 10-year ARI design storms for Geraldton	Present day S1 allowance + S2 + S3 from RCP 6.0 + allowance for uncertainty				
Rare	Larger of S1 values from two DoT 100-year ARI design storms for Geraldton	Present day S1 allowance + S2 + S3 from RCP 8.5 + allowance for uncertainty				

5.1.2 S1 - Allowance for the Current Risk of Storm Erosion

Definition of project site storm waves

The wave climate along the coast of Horrocks is complex due to the presence of fringing reef. It is influenced by environmental factors including wave setup, nearshore wave breaking, wave-driven current as well as hydrodynamic feedbacks to nearshore waves etc. Offshore wave conditions are not directly applicable in this region, and therefore spectral wave modelling is required to transfer the offshore wave condition to nearshore region.

The storm wave conditions inside the reef were simulated by a coupled MIKE HD and SW modelling approach, where model boundary conditions were extracted from the design storm sequences provided by DoT. The extents of the model and modelling mesh used are shown in Figure 5-1. Grid resolution ranged from ~10km offshore to less than 30 m inside the reef. The refined mesh inside the reef allowed simulation of more accurate hydrodynamics that affected the wave propagation and breaking.

Wave and water level time series were extracted for SBEACH inputs at the offshore end of each of the 10 profiles within the study area as shown in Figure 5-2. These sampling points were determined to represent the reduced wave energy and increased water level caused by waves breaking across the shallow fringing reef.

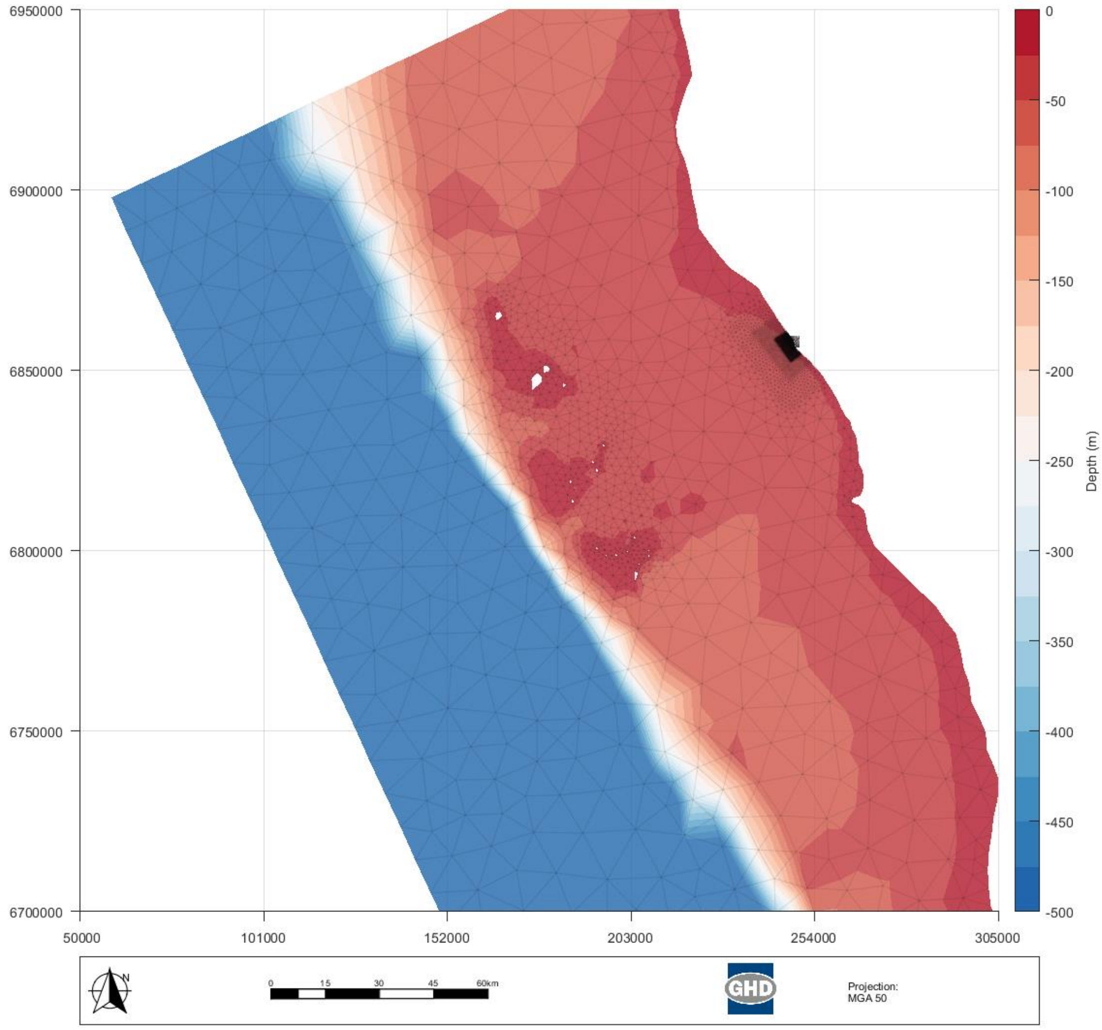


Figure 5-1 Regional Mike 21 Model Extents and Model Mesh.

SBEACH Modelling

The Storm induced BEAch Change (SBEACH) model (Larson and Kraus 2002) was utilised to estimate the potential storm erosion allowance (S1) across the assessment area. SBEACH was developed to calculate cross-shore sand transport rates by comparing the incoming wave energy flux against a stable energy flux to determine wave breaking in the surf zone. It is a widely-applied modelling tool to simulate beach dune erosion under storm wave action, and is commonly adopted to estimate shoreline retreat during storm events (S1 allowance outlined in SPP2.6).

The SBEACH model was applied to simulate storm erosion on ten different cross-shore profiles across the assessment area (see Figure 5-2).

SBEACH modelling was carried out for both design storm sequences for Geraldton for each of the 1-year, 10-year and 100-year ARIs from MRA (2018) (refer section 2.1). Based on the severity of the events, the erosion from the 1-year, 10-year and 100-year ARI design storm sequences were defined as the “almost certain”, “possible” and “rare” erosion likelihoods, respectively.

Wave and water level time series were extracted from these simulations at the boundary of each of the ten SBEACH profiles.

The D50 sediment size values applied in SBEACH were based on the PSD data obtained during this assessment (Section 4.7.1) and are shown in Table 5-2.

Table 5-2 Sediment grain sizes applied in SBEACH modelling

SBEACH Profile(s)	D50 Sediment Size (mm)
1-7	0.2
8	0.4
9 & 10	0.2

Note the significantly higher D50 for profile 8 is a result of the introduced dune sand described in section 3.8. The results of the S1 erosion allowance assessment are presented in Section 6.3.1.

5.1.3 S2 - Allowance for Historic Shoreline Movement Trends

The S2 component of the coastal erosion allowance was estimated as per the SPP2.6 guidance by a review of available historical shoreline changes. The approach generally adopted is to analyse historical aerial imagery and to use the horizontal change in vegetation line as a proxy for historical shoreline changes over the medium to long-term. This approach is applicable on natural coastlines where vegetation is free to naturally recede in response to erosion, but also to prograde in response to accretion. For the whole assessment area, analysis of historical vegetation line changes was undertaken with the DSAS tool in ArcGIS (Thieler et al 2017). Historical vegetation lines provided by DoT from the years 1943 - 2016 were analysed.

Trends in shoreline movement and shoreline movement rates were assessed for each profile between each subsequent timeframe and across the whole time period. Areas of the coast were then grouped according to common trends in shoreline movement rates, which formed the basis of the zones defined across the study area. S2 values for each zone were selected from the transects with the smallest (or most negative) shoreline movement rate across the zone.

The results of the analysis of S2 erosion allowances are presented in section 0.

5.1.4 S3 - Allowance for Erosion caused by Future Sea Level Rise

The S3 component of the coastal erosion allowance is for erosion on sandy coasts caused by future sea level rise. Though the S3 component is strongly dependant on future sea level rise, it is also based on re-shaping of the beach profile under wave action on top of a future higher sea level. Thus a critical element of the S3 component of the coastal erosion allowance is exposure to wave action.

For the assessment areas, the S3 erosion allowance was estimated with a factor of 100 times the expected future sea level rise (Section 4.5.3) in line with SPP2.6 Schedule One. The sea level rise values adopted for the different likelihood scenarios and future time frames are presented in Table 5-3.

Table 5-3 Sea level rise values (m) adopted for different likelihoods and time frames (relative to 2010)

Likelihood	2030	2050	2070	2090	2120
Almost Certain	0.08	0.2	0.33	0.46	0.67
Possible	0.08	0.2	0.35	0.55	0.85
Rare	0.09	0.24	0.46	0.74	1.19

5.1.1 Allowance for Consideration of Landform Instability and Sediment Cell System Dynamics

Sediment transport dynamics along the Horrocks coastline is more complex than a typical straight sandy coastline dominated by wave energy. The influence of intermittent nearshore reefs, intertidal and supratidal (above tidal movements) rock platforms and rocky cliffs all have a strong influence on beach morphology and sediment transport.

Nearshore currents are highly variable along the coast, caused by waves refracting as they interact with the highly variable bathymetry and diffracting as they pass around and through gaps in the nearshore reef chain. The resulting variable radiation stresses inside the lagoon creates currents, returning to the ocean. The distance between the reef chain and the beach also changes along the Horrocks coastline. In the southern and northern ends of the study site, the reef chain is relatively close to the beach, but in central areas, the reef chain is up to 300m from the beach, and there are some larger gaps in the reef chain. This results in variable penetration of wave energy reaching the nearshore environment and beaches.

A number of beaches and dunes in the north and south of the study site are also considered to be perched beaches, where sand is stored above rocky platforms. The perched beaches generally are more protected against erosion, where sand is harder to be removed from the beach unless significant water levels relative to the height of the rock platform are experienced. Conversely, when sand from perched beaches are eroded, they are slower to recover, as sand is not deposited easily above the height of the rock platform and may rely on other process to build back the eroded beach and dune, such as windblown sand.

With respect to net sediment transport movement during ambient conditions within the Horrocks lagoon, a net northwards trend is expected, due to wave and current patterns, however, there is insufficient evidence in the DSAS results to definitively draw this conclusion. There are no significant features along the Horrocks coastline that impede alongshore movement of sand acting like a groynes or headlands impeding the movement of sand along the coast. Whilst a north net sediment transport outside the reef chain may be expected due to the dominance of waves from the south western sector, the influence of nearshore currents, perched beaches and nearshore reefs moderating wave energy reaching the beaches appear to be more important forces influencing beach morphology and changes at Horrocks.

Sources of sediment to the Horrocks lagoon likely include sediment from the degradation of the nearshore reef chain, windblown transport of sand from dunes south of the site into the nearshore and from erosion of the beaches and dunes.

The influence of nearshore reefs, perched beaches and complex hydrodynamics across the Horrocks coastline means that different parts of the shoreline are likely to respond differently to the same event. Further, changes to the shoreline are likely to be in response to events, with a strong dependence on high water levels for significant wave energy to penetrate across the reefs.

5.1.2 Allowance for Uncertainty

An allowance for uncertainty of 0.2 m/year was adopted for all ten SBEACH profiles in accordance with SPP2.6.

5.1.3 Existing Controls

Physical controls influencing the foreshore erosion potential for Horrocks were identified in Section 4.8. In the Request for Quotation document received from the Shire of Northampton, estimation of coastal erosion hazards both with and without existing controls was requested. GHD's approach for considering the impacts of existing controls is in line with the recommendations of SPP2.6. Where there is uncertainty that a structure will exist throughout the 100 year planning period (e.g. a constructed tertiary sediment cell boundary such as the North Mole at Fremantle), it is not recommended that the influence of these structures on erosion hazards be mapped. This is because it assumes an ongoing commitment by the coastal manager to provide and maintain the same level of protection into the future, regardless if this is feasible on an environmental, social or economic basis.

Based on the below discussion, it has been determined that preparing erosion hazard maps for Horrocks with the existing control (GSC Seawall) in place does not make sense, particularly when considering the technical derivation of the erosion hazard components as described below.

- The S1 component is the consideration for the current risk of storm erosion. The S1 is based on the current day profile, which for Horrocks beach was based on a profile of the 2016 Lidar survey after the GSC seawall had been constructed. However due to the limitations of SBEACH modelling, the model has assumed that the profile is erodible, and therefore does not reflect the ability of the structure to limit the erosion. Therefore, the S1 results for Horrocks beach more accurately represents the potential acute erosion, at present if the structure did not exist.
- Even if a section of foreshore is protected, it is possible that over the lifetime of the structure that an event will occur that is greater than what it was designed to withstand and erosion behind the structure may result if it fails. Further, erosion behind structures can occur during significant events from overtopping Therefore if it is assumed that a seawall will prevent all acute event erosion occurring behind it, this is likely to be over estimating the structures actual abilities.
- The S2 component, the historical shoreline movement trend, have been calculated based on changes in the shoreline position from aerial images between 1943- 2016. The seawall was only constructed in 2010 and the influence of the seawall was only captured in the most recent shoreline from 2016. Therefore assumptions can only be drawn for the S2 rate with the structure in place. The S2 values calculated realistically only represent the shoreline movement trend without the structure.

It only makes sense to include existing controls in the hazard assessment if the existing controls are designed to be long lasting structures, able to withstand significant erosion events, made to protect high value assets and include commitments for regular maintenance. For example the presence of breakwater protecting a marina or newly constructed rock revetment with a design life of 50 years and a crest level well above the HSD would be expected to prevent erosion of the foreshore during a minimum 100 ARI event. The Horrocks beach seawall however only has an estimated 15 years remaining and is only designed to withstand a 50 ARI event. Due to the above limitations, effects of existing controls have not been considered in the hazard assessment.

5.2 Inundation (S4) Allowance Methodology

5.2.1 Introduction

The inundation (S4) water levels applied in this CHA were estimated as set out in SPP2.6 (PSWL plus wave run-up). Wave run-up is a slope-dependent process that often has short duration and impacts. It considers the combined effect of wave setup, surf-beat, and wave uprush onto the beach. It is also a stochastic term (values based on AEP; often use 2%) to account for the impacts of dynamic inundation from low frequency waves and wave uprush. Wave run-up is not physically meaningful for simple bathtub inundation modelling, which only reflects the static inundation condition (as time evolution and spatial spreading of flooding are not considered). For these reasons, it is more appropriate to use wave setup instead of wave run-up in this CHA.

Moreover, wave run-up only applies to the foreshore area that is directly exposed to waves, while it does not apply to areas which are inundated via low land flood pathways. Land beyond the foredune is therefore under a low risk of continuous inundation from wave run-up.

The PSWL plus wave setup is appropriate for the S4 inundation allowance for the entire assessment area.

The inundation water levels required for assessment of the coastal inundation hazard are comprised of multiple components: tide, storm surge, wave setup and sea level rise. The derivation of each of the components is presented in the following sub-sections.

5.2.2 Tide and Storm Surge

The extreme tide and storm surge levels at Horrocks for 1 and 10-year ARIs were expected to be caused by non-cyclonic conditions based on previous experience, guidance in SPP2.6 and from DoT (MRA (2018) and Seashore (2018)) and previous studies at Geraldton (e.g. MRA 2015, 2016, 2017). Accordingly, the extreme tide and storm surge levels were derived by conducting an extreme value analysis (EVA) of the tidal gauge record from Geraldton Port from 1986 to 2019 (provided by DoT). The 1 and 10-year ARI values derived from this EVA are presented in Table 5-4.

The 500-year ARI levels at Horrocks are expected to be caused by cyclonic conditions based on previous experience, guidance in SPP2.6 and from DoT (Seashore 2018) and previous studies at Geraldton (e.g. MRA 2015, 2016, 2017).

The 500-year design tropical cyclone for Geraldton from Seashore (2018) was simulated using a coupled wave and hydrodynamic model using the MIKE modelling software package. Cyclone wind fields were generated using a parametric cyclone model, the Holland (1980) single vortex cyclone model. The simulation used the modelling parameters from Seashore (2018) and included a constant water level of MHHW. The only change made to this design cyclone was that the track was shifted ~50 km north to account for the location difference between Horrocks and Geraldton.

The results of this simulation were maximum storm surge water levels at Horrocks of +1.6 mAHD. This was significantly lower than previous 500-year ARI water level values at Geraldton (refer section 4.5.2). Subsequent to the initial modelling, it was determined that there were issues with the track of the synthetic cyclone in Seashore (2018), due to the high crossing speed, low central pressures and large radius to maximum winds as the cyclone approached the coast, resulting in significantly lower strength winds in the wind field, unable to elicit the expected response in wave setup and wind setup at the site.

As this CHA is part of a CHRMAP process investigating coastal hazards and planning, it was recommended that this storm surge value was not appropriate for application as the 500-year ARI inundation level for the Horrocks CHRMAP. Due to the location of Horrocks in SPP2.6 Area 3 and the limited database of tropical cyclones which have affected the area, GHD determined that the most appropriate approach was to adopt the largest value from the three MRA studies at Geraldton (+3.6 mAHD) as a conservative approach.

The deliberate adoption of this largest 500-year ARI water level from existing studies is acknowledged as a limitation of this CHA which may mean the rare likelihood inundation results are conservative. Accordingly, this value should be reviewed and refined in future revisions of the CHRMAP covering Horrocks as additional data is measured, existing studies are refined, additional studies are undertaken, and tropical cyclone modelling methodologies and capabilities further improve.

The combined extreme tide and storm surge levels applied are presented in Table 5-4.

Table 5-4 Extreme tide and storm surge water levels adopted for different likelihood scenarios

Likelihood	Combined Extreme Tide and Storm Surge Water Level	Value (m AHD)
Almost Certain	1-year ARI (63% AEP)	+0.9
Possible	10-year ARI (10% AEP)	+1.1
Rare	500-year ARI (0.2% AEP)	+3.6

5.2.3 Wave Setup

The 1-year and 10-year combined extreme tide and storm surge levels presented in the previous section are based on analysis of Geraldton Port tide gauge data. Due to the water depth and sheltered location of this tide gauge, it is expected that this data does not include the influence of wave setup that occurs on the beach face due to wave breaking. Thus, these S4 inundation levels require the addition of a separate value to account for wave setup. Wave setup values were obtained from the SBEACH modelling undertaken on the ten profiles spread across the assessment area for each of the design storm sequences simulated (Section 5.1.2). Based on analysis of these results, the largest wave setup value across all the design storm sequences and profiles (0.7 m) was adopted for both the 1-year and 10-year ARI extreme water levels.

5.2.4 Sea Level Rise

The same sea level rise values of the S3 erosion allowance were adopted for the S4 inundation allowance (Table 5-3).

5.2.5 Summary

The combined water levels that were applied for the different inundation likelihoods at each of the six planning timeframes for the different assessment areas are presented in section 6.4.

The ‘almost certain’ likelihood scenario reflects the minimum requirement for annually reoccurring inundation that may be important for managing coastal structures that can allow occasional flooding. The rare likelihood scenario is defined to assess the risk of inundation for permanent structures and important assets that should not be at risk from inundation. All conditions are defined to assist coastal asset management and to meet the requirement of the overarching CHRMAP.

6. Results

6.1 Coastal Types

The Horrocks coastline exhibits areas of rocky features such as intermittent rock platforms on the beach face (e.g. zones 1 and 10) and the majority of the shoreline is protected by fringing reefs which generally reduces the wave energy reaching the shoreline. Therefore the coastline of Horrocks is classified as mixed sandy and rocky coast.

The most prominent area of rock identified, in hazard zone 9, is immediately south of Whiting Pool where the shoreline comprises above head height limestone rock cliffs. Whilst a small portion of zones 9 and 10 might meet requirements of weakly lithified sedimentary rock coasts because negligible change is expected to this section of rock over the planning period, the sandy nature of the beach to the north, and the discontinuous nature of the rock to the south, it is possible that this feature in the future may become a more prominent headland as the shorelines retreats to the north and south. Geotechnical assessment has not been undertaken as part of this CHA, and unless such an assessment (requiring an appropriately qualified geotechnical engineer) is undertaken then this section of coast shall also be classified as a mixed sandy and rocky coast.

For the purposes of estimation of erosion hazards, and because mixed sandy and rock coasts can be “sensitive to small variations in climatic conditions and often contain unstable/dynamic landforms”, calculation of erosion allowances for the entire the study assumed the “sandy coast” components detailed in SPP2.6.

6.2 Horizontal Shoreline Datum

The elevation of the Horizontal Shoreline Datum (HSD) was determined from the SBEACH modelling in accordance with SPP2.6. The location of these HSD values on the DEM created for the project was used as the starting point for the erosion allowances in the erosion hazard mapping (Section 6.5). There is only minor variation across the study area with the highest values in the centre and northern parts of the assessment area. This result was expected as these areas are more exposed to wave action either by orientation of the beach and through gaps in the nearshore reef.

Table 6-1 Horizontal Shoreline Datum (HSD) elevations across the assessment area

SBEACH Profile	HSD Elevation (m AHD)
1	+1.3
2	+1.4
3	+1.4
4	+1.3
5	+1.3
6	+1.5
7	+1.4
8	+1.2
9	+1.4
10	+1.4

6.3 Allowance for Erosion

6.3.1 Allowance for Acute Storm Erosion (S1)

The S1 erosion allowances were calculated from the SBEACH modelling results and applied for different erosion likelihoods. The S1 values are provided for both the DoT design storms for each ARI, with the larger of the two results adopted. Summary plots for each storm at each ARI are shown in Appendix A,

For the 1 ARI, Storm 1 and Storm 2 S1 values were very close, if not the same. Differences between Storm 1 and Storm 2 were more pronounced for the 10 and 100 ARI storm sequences. Explanations and other important observations are described below.

Profiles 2's S1 values for storm 1 and 2 for the 10 ARI event are significantly different (29 and 8 m respectively). This is the result of differences in input storm water levels and a result of dune stability. Storm 1 includes two repeats of reference storm G2 and one run of G6, which have a mean water level of 0.39 mAHD and 0.06 mAHD. Storm 2 includes one run each of reference storm G8 and G3, with mean water levels of 0.28 and -0.01 mAHD respectively. The slightly higher water level in storm G2 allows more wave energy to be transferred into the nearshore, allowing Storm 1 to erode away more of the base of the dune than Storm 2. The position of the HSD is moved 3.5m further landward in Storm 1 in comparison to Storm 2, but this results in the dune reshaping for a further 17.5m.

Profile 5 has two dune crests. A small primary dune with a low-lying area (swale) behind it and then a second higher dune behind it. The second dune is potentially an artificial dune or flattened dune to allow for construction of houses on top. The SBEACH results for Profile 5 show erosion of the small primary dune but not of the larger, secondary dune. The HSD was adopted on the seaward side of the foredune across Zone 5, as the swale is not persistent across the whole zone. The erosion allowance in this area should be reviewed carefully in future revisions of the CHRMAP covering Horrocks as it may change significantly if the small primary dune is eroded away.

SBEACH results for Profile 8 show that it is much more resistant to erosion in the modelled scenarios than other profiles, this is likely a twofold effect of the increased protection from the reef and from the larger sand D50 value used, reflecting the stability of the introduced dune material in this area. Given coarse sand is predominantly within the dune area, SBEACH was rerun with a smaller grain size (0.2mm) to determine sensitivity of this profile to grain size. The model results show slightly exacerbated erosion, but this can largely be attributed to avalanche of sand (angle set at 30 degrees). This profile is sensitive to storm surge levels and sea level rise (addressed in S3) and S1 values do not need to be overly conservative.

Profile 9, whilst composed of weakly lithified sedimentary rock cliffs, has been simulated in SBEACH as an erodible profile. Simulated shoreline responses result in small S1 values for this area. Table 6-1 provides a summary of the S1 values adopted.

Table 6-2 S1 erosion allowances

SBEACH Profile	S1 Erosion Values (m)		
	Storm 1	Storm 2	Adopted Value
Almost Certain Likelihood (1-year ARI)			
Profile 1	9	9	**9**
Profile 2	2	2	**2**
Profile 3	17	17	**17**
Profile 4	14	14	**14**
Profile 5	10	10	**10**
Profile 6	8	7	**8**
Profile 7	0	0	**0**
Profile 8	0	0	**0**
Profile 9	0	0	**0**
Profile 10	4	5	**5**
Possible Likelihood (10-year ARI)			
Profile 1	22	19	**22**
Profile 2	29	8	**29**
Profile 3	33	24	**33**
Profile 4	21	17	**21**
Profile 5	35	18	**35**
Profile 6	15	13	**15**
Profile 7	12	8	**12**
Profile 8	0	0	**0**
Profile 9	2	4	**4**
Profile 10	13	11	**13**
Rare Likelihood (100-year ARI)			
Profile 1	22	20	**22**
Profile 2	31	30	**31**
Profile 3	37	34	**37**
Profile 4	24	20	**24**
Profile 5	38	13	**38**
Profile 6	17	14	**17**
Profile 7	12	9	**12**
Profile 8	0	0	**0**
Profile 9	6	4	**6**
Profile 10	13	11	**13**

6.3.2 Allowance for Long-term Shoreline Response to Sediment Supply (S2)

Erosion trends along the study area were assessed at 38 transects spaced at 100m intervals across the foreshore. Results from the DSAS analysis for each transect are provided in **Error! Reference source not found.** and compares the linear regression rate (LRR) from 1943 to 2016, with the linear regression rate from 1995 to 2016 with the incremental shoreline movement rates between each subsequent shoreline.

The shorelines were grouped based on a combination of LRR and underlying geomorphology to form the 10 zones reported on. The LRR from 1943 to 2016 at each transect across the study area is shown in Figure 6-10.

The purpose of undertaking DSAS analysis is to determine long term trends in shoreline movement and not to identify short term shoreline movement rates such as erosion and subsequent recovery of a beach after an event. Incremental erosion rates in **Error! Reference source not found.** are given to provide an understanding of the variability of the shoreline zones to events and should not be used when considering long term erosion rates, as short term responses of the beach in each zone has been assessed individually in the S1 allowance.

A number of factors were considered to determine if there were any causes to the increased erosion trend between 1995 and 2016 that might persist in the long-term including:

- Construction of coastal infrastructure or along shore changes that may impact sediment transport patterns. No changes around this time have been identified. The only coastal protection structure captured within the historical shoreline movement history is the GSC Seawall which is only present in the final year of shorelines.
- Whether any dredging or beach nourishment was undertaken; and
- Review of any outliers in trends of accretion/erosion against the record of storm events in the region (reviewed in section 4.4).

It was concluded that the only contributing factor was significant storms, discussed further below.

Based on the analysis of the DSAS results, the foreshore was divided into zones as described in 5.1.3 and shown in Table 6-3.

Table 6-3 DSAS transect grouping.

Zone	Transects	Beach Description	Southern Boundary
1	1 to 5	Perched beach	End of rock platform, change in beach alignment
2	6 to 10	Sandy beach	Change in beach alignment
3	11 to 15	Sandy beach	Change in beach alignment
4	16 to 19	Sandy beach	Change in beach alignment, change in beach width
5	20 to 22	Sandy beach	Boat Ramp
6	23 to 24	Sandy beach	End of dune revegetation works
7	25 to 26	Sandy beach	Informal boat ramp
8	27 to 29	Sheltered sandy beach	Start of limestone cliff, change in beach shape and width
9	31	Limestone cliffs/ perched beach	Gradual change in height of cliff
10	32 to 38	Variable perched beach	Beyond study area

Figure 6-1 to Figure 6-9, present plots of shoreline position for particular transects within each zone, relative to the shoreline position in 1943 (or 1956). Linear regression trend lines have been included to aid in visual assessment of trends. A general trend observed across Zones 4 to 10 is the significant accretion that occurred between Nov 1990 and Dec 1995. This is likely to be the result of the occurrence of 3 of the top 5 ranked storms (MRA 2018) occurring during the winters of 1991, 1993 and 1995. Following this accretionary period, these shorelines typically respond with either a net erosion trend, or an erosion/ accretion cycle. Due to the significant impact of these storms on shorelines in zones 4 to 10, LRR trends have been calculated between 1995 to 2016 (refer to Table 1 in Appendix B)., These values have been provided for information purposes to demonstrate that erosion rates can be higher, but given these erosion rates are most likely in response to the foreshore re-establishing equilibrium after a significant accretion event, it is not recommended that these values be used to inform S2 as they are only a short term trend. A summary of the shoreline movement trends of the different zones is provided in Table 6-4.

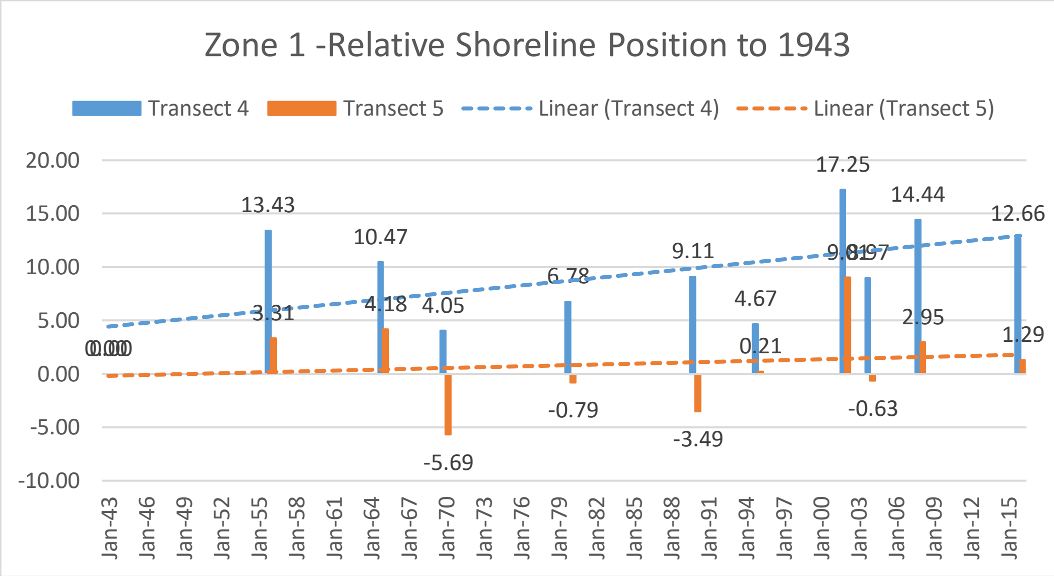


Figure 6-1 Zone 1 relative shoreline position and trend.

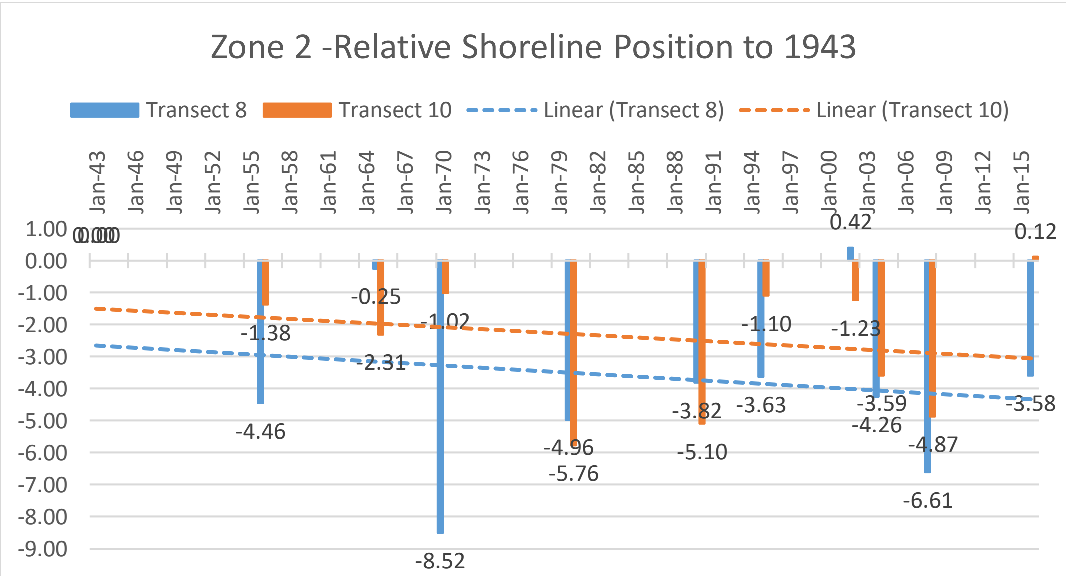


Figure 6-2 Zone 2 relative shoreline position and trend.

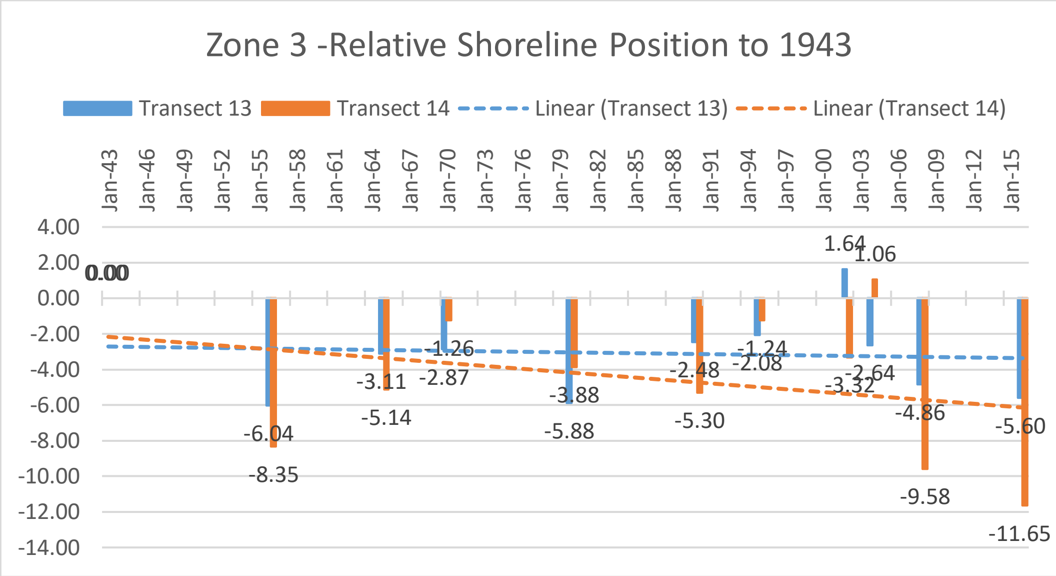


Figure 6-3 Zone 3 relative shoreline position and trend.

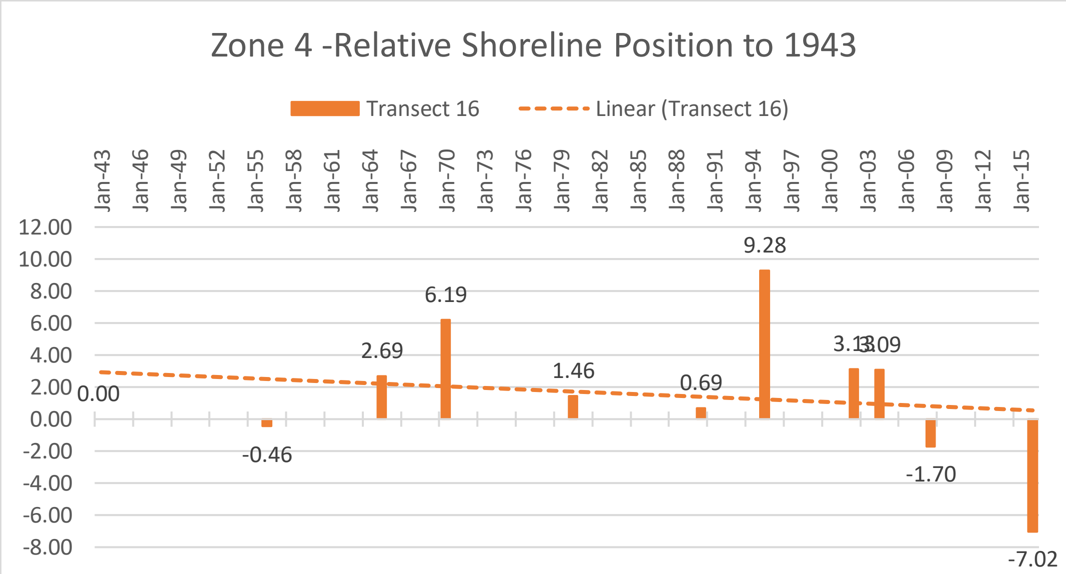


Figure 6-4 Zone 4 relative shoreline position and trend.

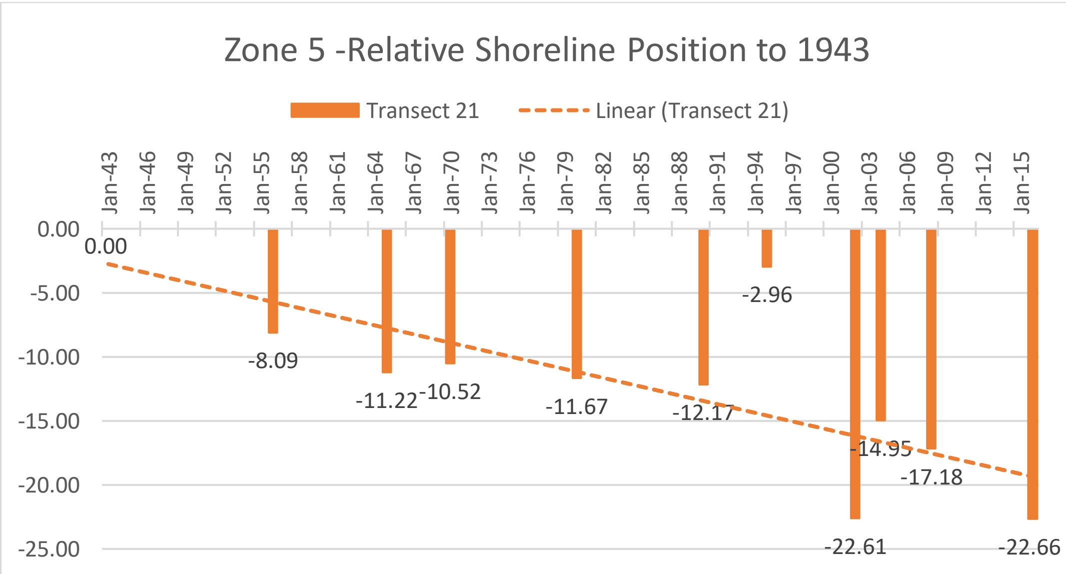


Figure 6-5 Zone 5 relative shoreline position and trend.

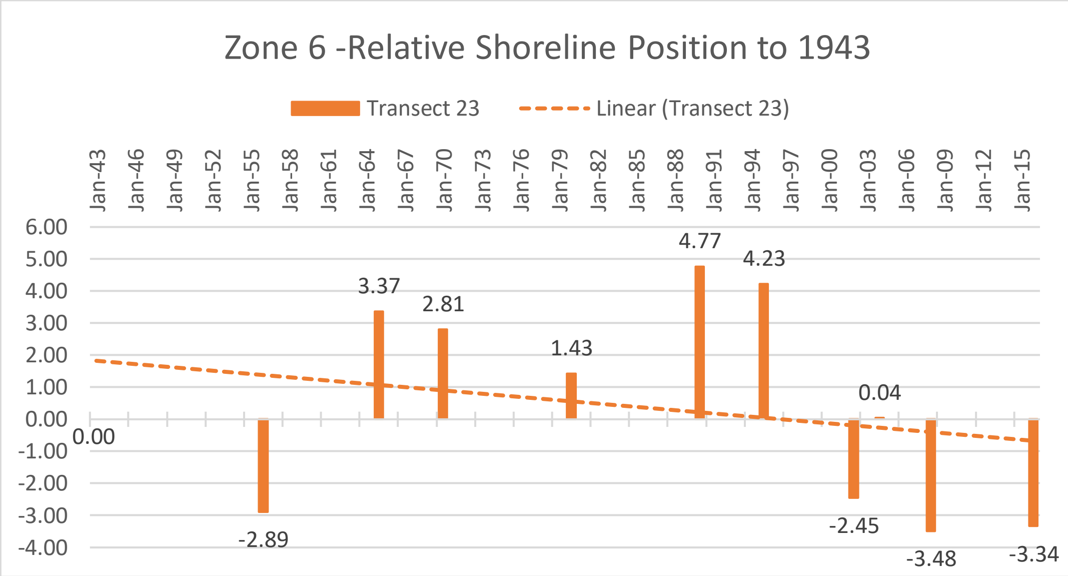


Figure 6-6 Zone 6 relative shoreline position and trend.

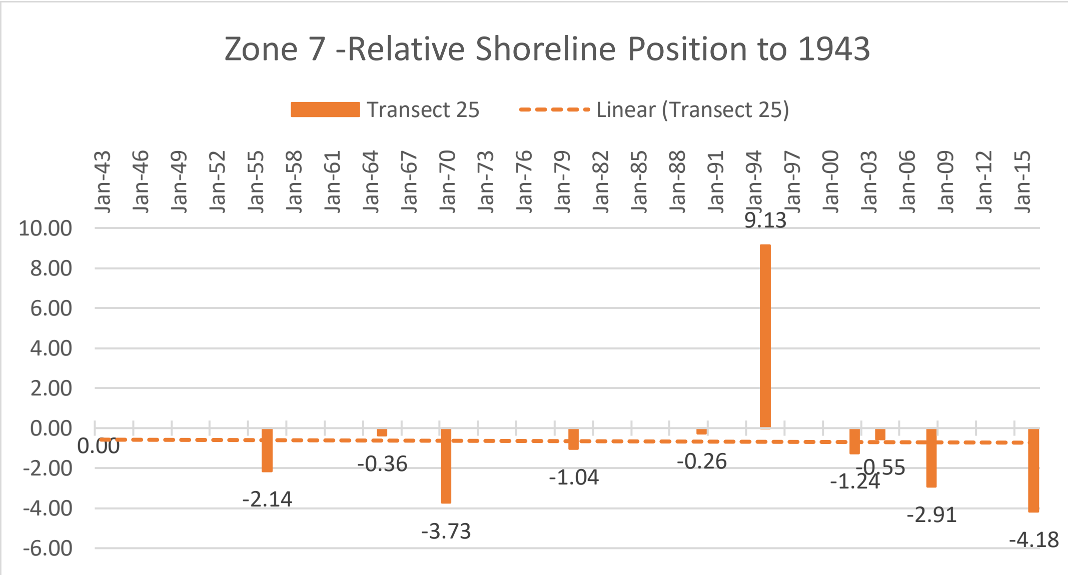


Figure 6-7 Zone 7 relative shoreline position and trend.

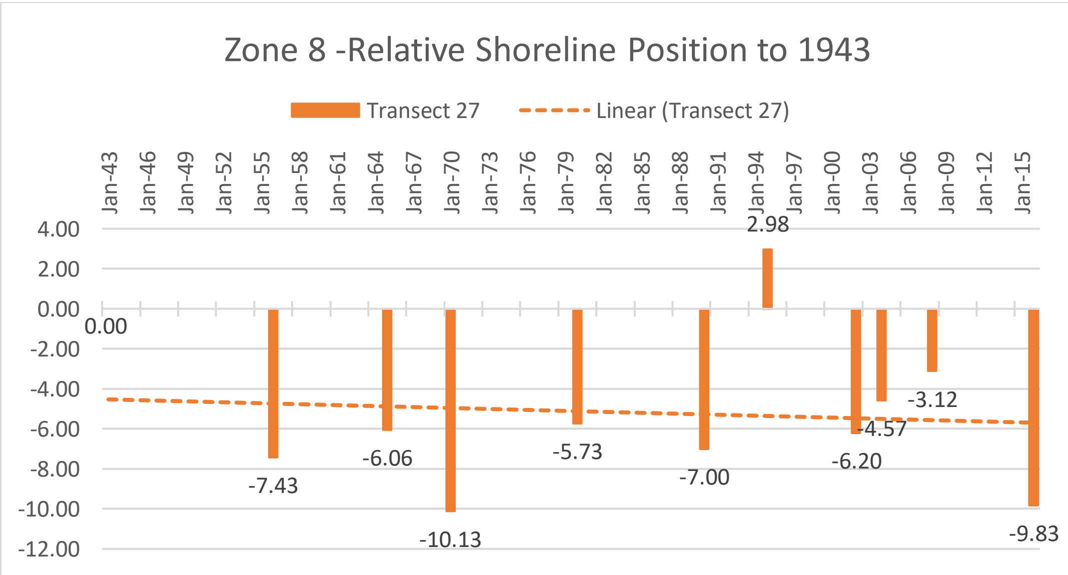


Figure 6-8 Zone 8 relative shoreline position and trend.

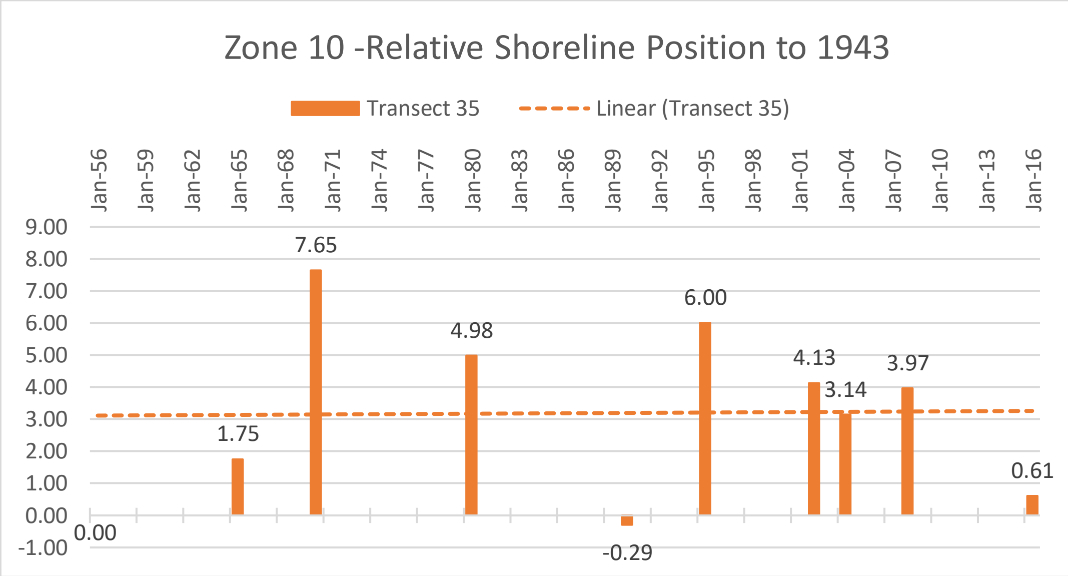
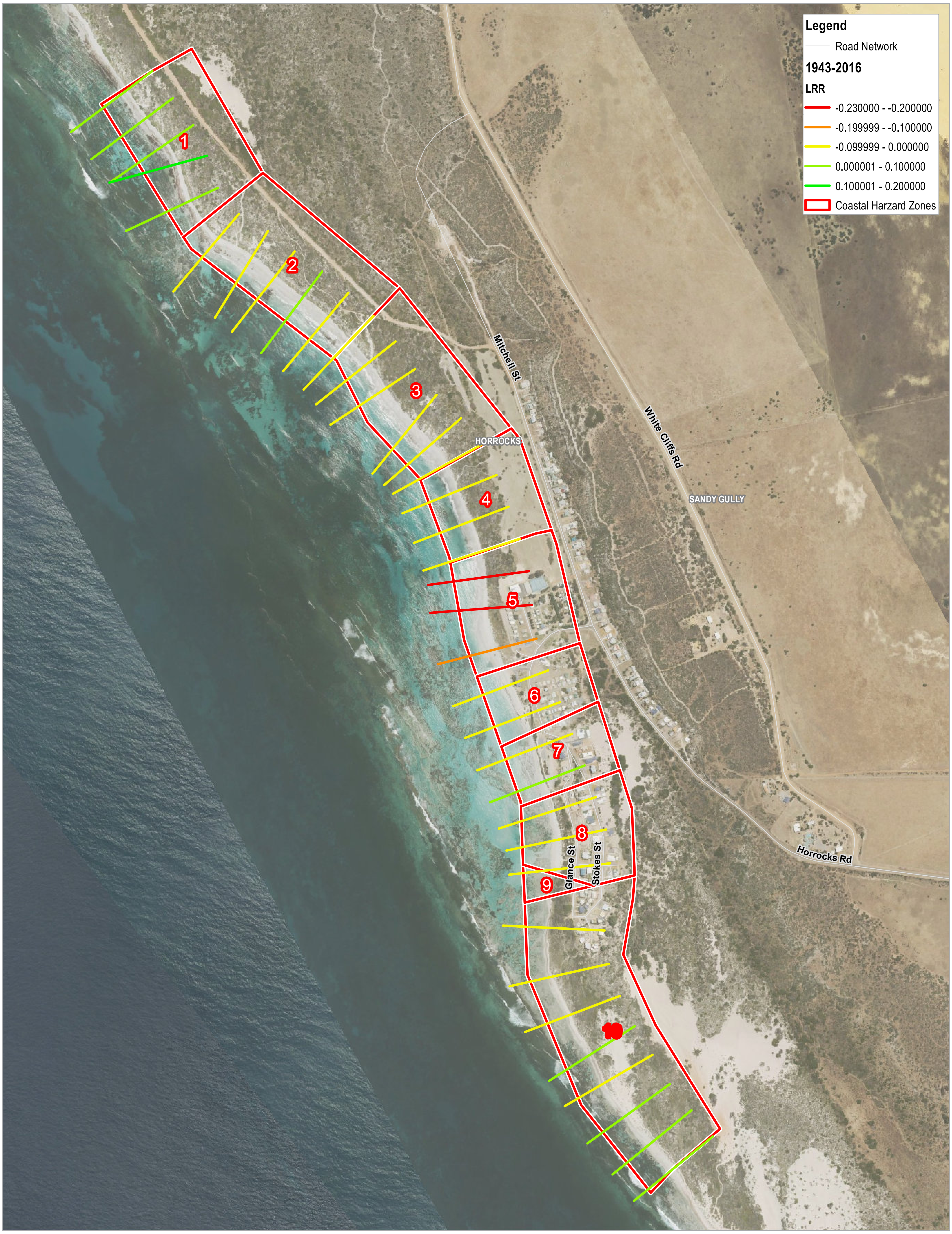


Figure 6-9 Zone 10 relative shoreline position and trend.

Table 6-4 Summary of shoreline movement trends.

Zone	Shoreline Trend	Outliers and observations
1	Accreting	Transects 4 and 5 show cyclical patterns of accretion followed by erosion, with a net accretion trend.
2	Eroding	Transects 8 and 10 show cyclical patterns of erosion and accretion with a net erosional trend.
3	Stable / Erosional	Transects 13 and 14 show cyclical patterns of erosion and accretion with a net erosional trend.
4	Eroding	General erosional trend, however, significant accretion occurred between Nov 1990 and Dec 1995, likely in response to significant storm events in the winters of 1991, 1993 and 1995.
5	Eroding	Consistent erosion trend across all years, except for accretion that occurred between Nov 1990 and Dec 1995.
6	Eroding	Net erosion trend, post 1995.
7	Stable	Relatively stable with a slight erosion trend.
8	Stable / erosional	Highly cyclical shoreline, with a small net erosion trend.
9	N/A - Stable	Insufficient shoreline data. Shorelines trimmed due to presence of rock.
10	Accreting	Cyclical shoreline changes, with a net erosion trend post 1995 accretion.



Paper Size ISO A3

0 100 200 300

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

GHD

Shire of Northampton
Horrocks Beach Coastal Hazard Risk Management and Adaptation Plan

DSAS Transects
Historical Shoreline Rate
Linear Regression 1943 to 2016

Project No.	61-37817
Revision No.	C
Date	22/04/2019

FIGURE 1

Data source: GHD: Study Area - 20190319, Linear Regression 1943 to 2016 - 20190612, Coastal Hazard Zones - 20190429; Landgate: Suburbs - 20180319, Imagery (Accessed) - 20190612; MRWA: Road - 20171211 Created by: slei

The shoreline movement results presented in Table 6-5 are the values used in the S2 calculations. An S2 rate of 0 was adopted for all areas which showed a history of minor accretion.

Table 6-5 S2 erosion allowances

Zone	S2 erosion rate (m/year)	S2 Allowance to 2030 (m)	S2 Allowance to 2050 (m)	S2 Allowance to 2070 (m)	S2 Allowance to 2090 (m)	S2 Allowance to 2120 (m)
1	0	0				
2	0.1	1	3	5	7	10
3						
4						
5	0.25	3	8	13	18	25
6	0.1	1	3	5	7	10
7	0	0				
8	0.1	1	3	5	7	10
9	0	0				
10	0	0				

6.3.3 Allowance for Gradual Change in Shoreline Caused by Sea Level Rise (S3)

The S3 erosion allowances applied in this assessment are presented in Table 6-6.

Table 6-6 S3 erosion allowances for different likelihoods

Likelihood	S3 allowance to 2030 (m)	S3 allowance to 2050 (m)	S3 allowance to 2070 (m)	S3 allowance to 2090 (m)	S3 allowance to 2120 (m)
Almost Certain	8	20	33	46	67
Possible	8	20	35	55	85
Rare	9	24	46	74	119

6.3.4 Allowance for Uncertainty

In line with SPP2.6, a 0.2 m/year allowance for uncertainty was used for each scenario. The total values for each planning timeframe are included in the "AU" column in Table 6-7, Table 6-8 and Table 6-9.

6.3.5 Total Erosion Allowances

The total erosion allowances across the ten profiles and over the six planning timeframes are presented in Table 6-7, Table 6-8 and Table 6-9 for the almost certain, possible and rare likelihoods, respectively.

One additional erosion hazard line has been plotted on the hazard maps, the scenario strictly compliant with SPP2.6. The components and total allowances for each zone are summarised in Table 6-10.

As is often the case for the total erosion allowance on sandy coasts, the S1 allowance generally dominates over the near-term, but the S3 allowance generally dominates over the long-term. This demonstrates the change in the nature of the mechanisms that drive erosion hazard estimates over time. In short, the S1 allowance for storm erosion is an acute event-based hazard, while the S3 allowance for sea level rise erosion is a chronic hazard that is expected to materialise slowly and steadily over the 100-year planning timeframe.

The erosion allowances along the coastline of the assessment area are up to 38 m from the horizontal shoreline datum today, up to 52 m in 2030, up to 76 m in 2050, up to 107 m in 2070, up to 144 m in 2090 and up to 202 m in 2120 and vary across the assessment area.

For the purposes of comparison, the erosion maps for 2070, 2090 and 2120 have an additional line plotted. This line considers the sea level rise allowance in accordance with DoT's recommendations in Bicknell (2010). This line is 5m, 10m and 19m seaward of the extent of the rare likelihood polygons for 2070, 2090 and 2120 respectively. Earlier time frames are not shown as the lines are the same for present, 2030 and offset only 2m for 2050.

Table 6-7 Total erosion allowance for almost certain likelihood for different profiles and planning timeframes

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**
1	9	9	9	0	8	2	**19**	9	0	20	6	**35**	9	0	33	10	**52**	9	0	46	14	**69**	9	0	67	20	**96**
2	2	2	2	1	8	2	**13**	2	3	20	6	**31**	2	5	33	10	**50**	2	7	46	14	**69**	2	10	67	20	**99**
3	17	17	17	1	8	2	**28**	17	3	20	6	**46**	17	5	33	10	**65**	17	7	46	14	**84**	17	10	67	20	**114**
4	14	14	14	1	8	2	**25**	14	3	20	6	**43**	14	5	33	10	**62**	14	7	46	14	**81**	14	10	67	20	**111**
5	10	10	10	3	8	2	**23**	10	8	20	6	**44**	10	13	33	10	**66**	10	18	46	14	**88**	10	25	67	20	**122**
6	8	8	8	1	8	2	**19**	8	3	20	6	**37**	8	5	33	10	**56**	8	7	46	14	**75**	8	10	67	20	**105**
7	0	0	0	0	8	2	**10**	0	0	20	6	**26**	0	0	33	10	**43**	0	0	46	14	**60**	0	0	67	20	**87**
8	0	0	0	1	8	2	**11**	0	3	20	6	**29**	0	5	33	10	**48**	0	7	46	14	**67**	0	10	67	20	**97**
9	0	0	0	0	8	2	**10**	0	0	20	6	**26**	0	0	33	10	**43**	0	0	46	14	**60**	0	0	67	20	**87**
10	5	5	5	0	8	2	**15**	5	0	20	6	**31**	5	0	33	10	**48**	5	0	46	14	**65**	5	0	67	20	**92**

Table 6-8 Total erosion allowance for possible likelihood for different profiles and planning timeframes

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**
1	22	**22**	22	0	8	2	**32**	22	0	20	6	**48**	22	0	35	10	**67**	22	0	55	14	**91**	22	0	85	20	**127**
2	29	**29**	29	1	8	2	**40**	29	3	20	6	**58**	29	5	35	10	**79**	29	7	55	14	**105**	29	10	85	20	**144**
3	33	**33**	33	1	8	2	**44**	33	3	20	6	**62**	33	5	35	10	**83**	33	7	55	14	**109**	33	10	85	20	**148**
4	21	**21**	21	1	8	2	**32**	21	3	20	6	**50**	21	5	35	10	**71**	21	7	55	14	**97**	21	10	85	20	**136**
5	35	**35**	35	3	8	2	**48**	35	8	20	6	**69**	35	13	35	10	**93**	35	18	55	14	**122**	35	25	85	20	**165**
6	15	**15**	15	1	8	2	**26**	15	3	20	6	**44**	15	5	35	10	**65**	15	7	55	14	**91**	15	10	85	20	**130**
7	12	**12**	12	0	8	2	**22**	12	0	20	6	**38**	12	0	35	10	**57**	12	0	55	14	**81**	12	0	85	20	**117**
8	0	**0**	0	1	8	2	**11**	0	3	20	6	**29**	0	5	35	10	**50**	0	7	55	14	**76**	0	10	85	20	**115**
9	4	**4**	4	0	8	2	**14**	4	0	20	6	**30**	4	0	35	10	**49**	4	0	55	14	**73**	4	0	85	20	**109**
10	13	**13**	13	0	8	2	**23**	13	0	20	6	**39**	13	0	35	10	**58**	13	0	55	14	**82**	13	0	85	20	**118**

Table 6-9 Total erosion allowance for rare likelihood for different profiles and planning timeframes

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**
1	22	**22**	22	0	9	2	**33**	22	0	24	6	**52**	22	0	46	10	**78**	22	0	74	14	**110**	22	0	119	20	**161**
2	31	**31**	31	1	9	2	**43**	31	3	24	6	**64**	31	5	46	10	**92**	31	7	74	14	**126**	31	10	119	20	**180**
3	37	**37**	37	1	9	2	**49**	37	3	24	6	**70**	37	5	46	10	**98**	37	7	74	14	**132**	37	10	119	20	**186**
4	24	**24**	24	1	9	2	**36**	24	3	24	6	**57**	24	5	46	10	**85**	24	7	74	14	**119**	24	10	119	20	**173**
5	38	**38**	38	3	9	2	**52**	38	8	24	6	**76**	38	13	46	10	**107**	38	18	74	14	**144**	38	25	119	20	**202**
6	17	**17**	17	1	9	2	**29**	17	3	24	6	**50**	17	5	46	10	**78**	17	7	74	14	**112**	17	10	119	20	**166**
7	12	**12**	12	0	9	2	**23**	12	0	24	6	**42**	12	0	46	10	**68**	12	0	74	14	**100**	12	0	119	20	**151**
8	0	**0**	0	1	9	2	**12**	0	3	24	6	**33**	0	5	46	10	**61**	0	7	74	14	**95**	0	10	119	20	**149**
9	6	**6**	6	0	9	2	**17**	6	0	24	6	**36**	6	0	46	10	**62**	6	0	74	14	**94**	6	0	119	20	**145**
10	13	**13**	13	0	9	2	**24**	13	0	24	6	**43**	13	0	46	10	**69**	13	0	74	14	**101**	13	0	119	20	**152**

Table 6-10 Total erosion allowance for planning purposes in 2120 (SPP2.6).

Zone	S1	S2	S3	Au	Total
1	22	0	100	20	**142**
2	31	10	100	20	**161**
3	37	10	100	20	**167**
4	24	10	100	20	**154**
5	38	25	100	20	**183**
6	17	10	100	20	**147**
7	12	0	100	20	**132**
8	0	10	100	20	**130**
9	6	0	100	20	**126**
10	13	0	100	20	**133**

6.4 Allowance for Storm Surge Inundation (S4)

The S4 inundation allowances adopted for Horrocks were derived as described in Section 5.2. The same water level was adopted across the entire assessment area for each of the three likelihoods for each planning timeframe. Future planning timeframes included an allowance for sea level rise as previously discussed. The total S4 inundation levels for each likelihood and planning timeframe are presented in Table 6-11.

The inundation levels are up to +3.6 mAHD today, and are predicted to increase to up to +3.7 mAHD in 2030, up to +3.8 mAHD in 2050, up to +4.1 mAHD in 2070, up to +4.3 mAHD in 2090 and up to +4.8 mAHD in 2120 as presented below.

Table 6-11 S4 inundation levels for Horrocks (m AHD)

Likelihood	2019 (Present Day)	2030	2050	2070	2090	2120
Almost Certain	+1.6	+1.7	+1.8	+1.9	+2.1	+2.3
Possible	+1.8	+1.9	+2.0	+2.2	+2.4	+2.7
Rare	+3.6	+3.7	+3.8	+4.1	+4.3	+4.8

6.5 Erosion and Inundation Hazard Mapping

Spatial mapping of the erosion and inundation hazard areas is a visual representation of the results in Sections 6.3 and 6.4, and is presented in **Error! Reference source not found.**.

One of the key limitations of mapping future inundation potential on present day topography is that it does not take into consideration potential changes in the beach profiles that could result from erosion. The inundation maps have been prepared to represent a bath tub model, and do not take into account connectivity pathways. The maps have been prepared in this manner as loss of foredunes from erosion could result in a change in connectivity to these areas in the future. E.g., inundation may be possible in the future in areas where there is a natural or constructed swale behind smaller foredunes.

7. Conclusions

The coastal hazards of erosion and inundation have been evaluated for Horrocks at timeframes of 2019, 2030, 2050, 2070, 2090 and 2120.

The mapping of erosion hazards in the short term (2019 to 2030) identified the greatest affects in the central and northern sections of the study area. In the medium (2050 – 2070) and long term (2090 to 2120), when erosion hazards are expected to be more strongly influenced by historical shoreline movement trends and sea level rise, mapping indicated that the areas impacted will be more uniform across the study area.

The mapping of inundation hazards identified the southern beach car park off Glance Street, and the first few rows of houses north of the car park behind Glance Street are within present day rare inundation zones with the area increasing across all time frames, but the likelihood remains at rare. Inundation of swales between the primary and secondary dunes in the northern part of the town site and northern part of the study area is possible, particularly if erosion of foredunes occurs. The rare inundation plane is a conservative level however mapping and review of topographic contours indicate potential inundation pathways into developed areas of Horrocks that should be considered in the Coastal Adaptation Plan.

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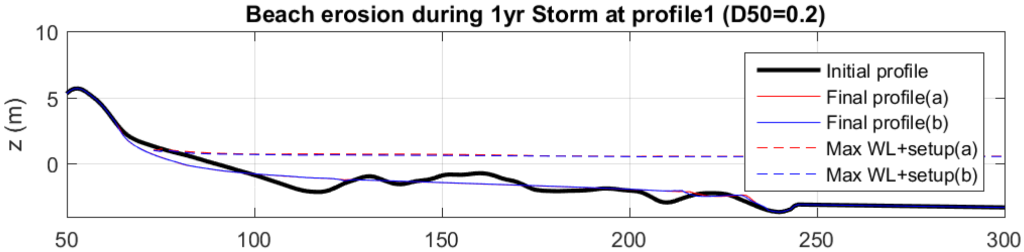
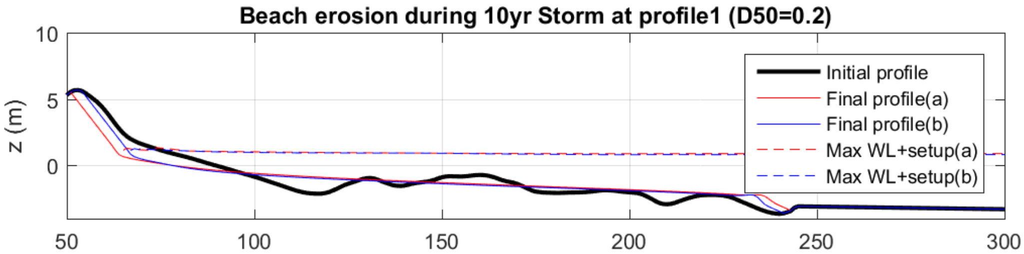
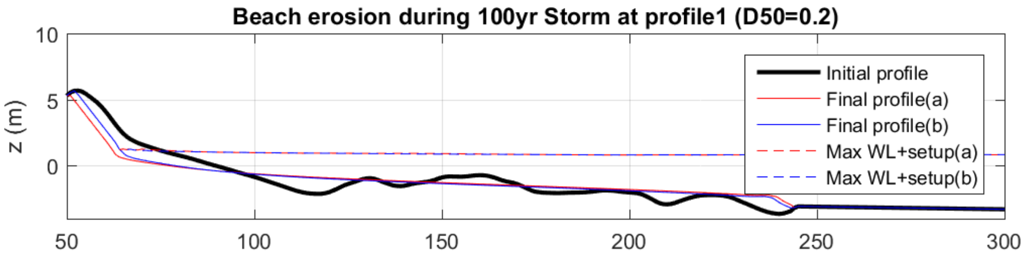
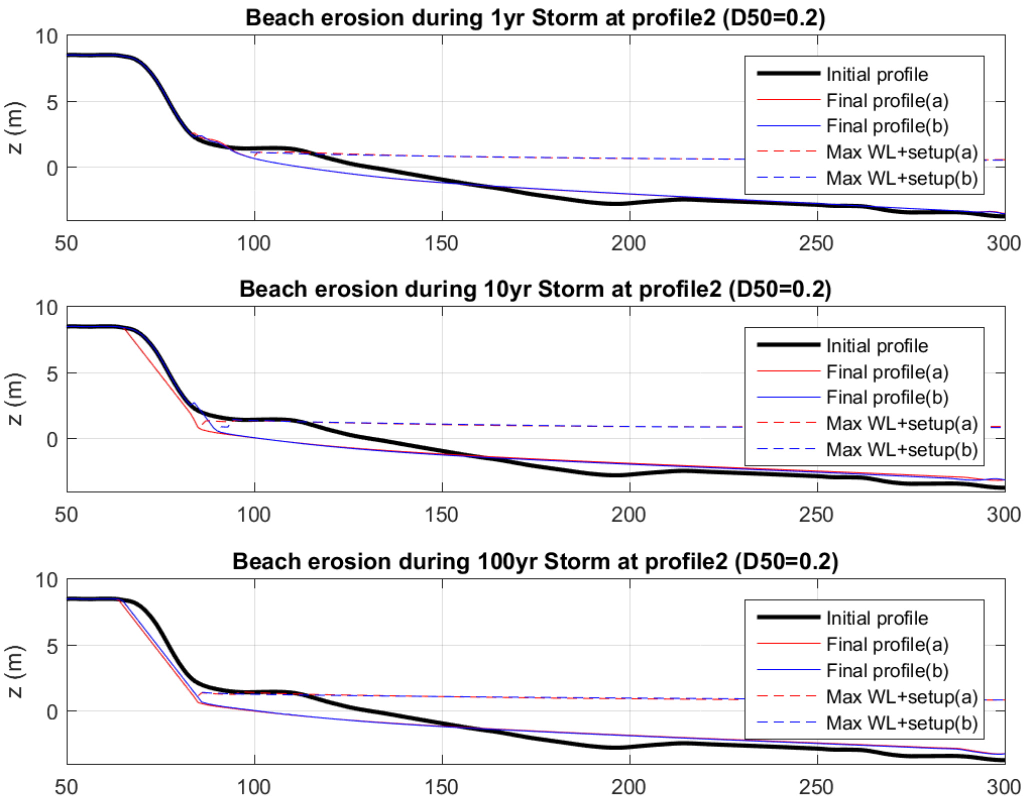
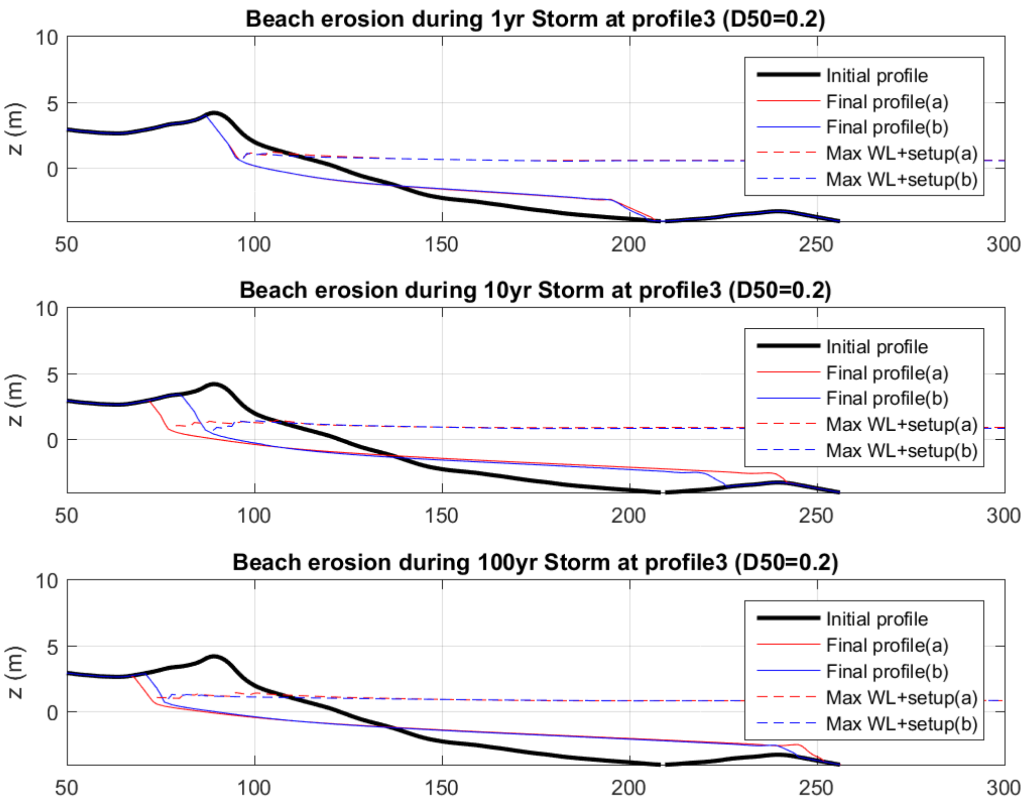
Appendix A - SBEACH Result Figures








Beach erosion during 1yr Storm at profile2 (D50=0.2)
Beach erosion during 10yr Storm at profile2 (D50=0.2)
Beach erosion during 100yr Storm at profile2 (D50=0.2)
z (m)
10
5
0
50
100
150
200
250
300
Initial profile
Final profile(a)
Final profile(b)
Max WL+setup(a)
Max WL+setup(b)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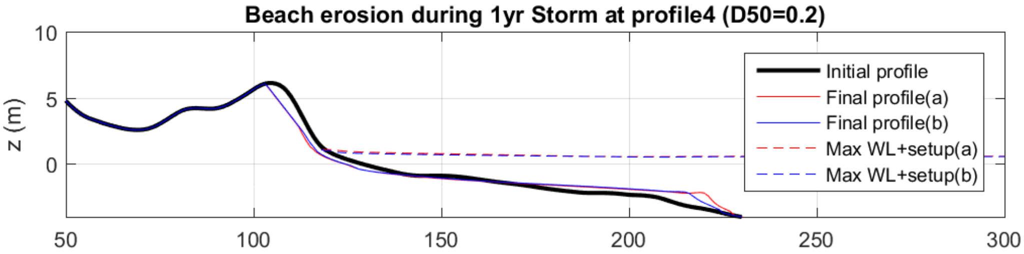
Beach erosion during 10yr Storm at profile3 (D50=0.2)
Beach erosion during 100yr Storm at profile3 (D50=0.2)
z (m)
10
5
0
50
100
150
200
250
300
Initial profile
Final profile(a)
Final profile(b)
Max WL+setup(a)
Max WL+setup(b)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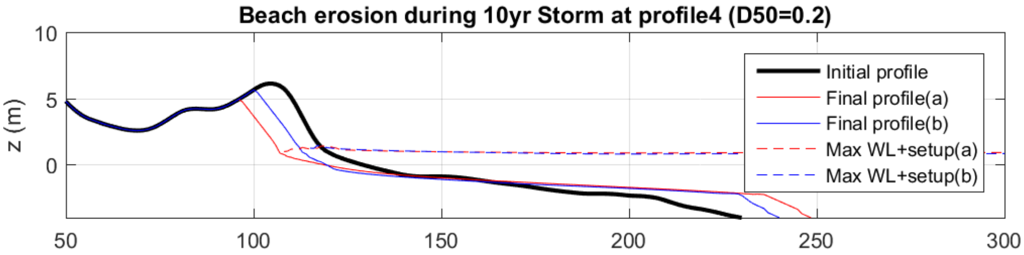
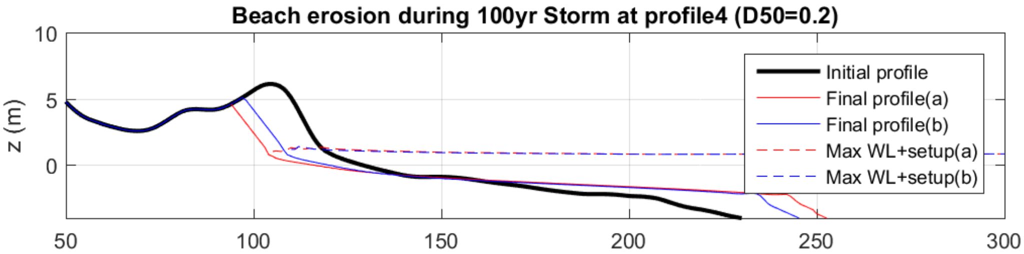
z (m)
Initial profile
Final profile(a)
Final profile(b)
Max WL+setup(a)
Max WL+setup(b)


Beach erosion during 10yr Storm at profile4 (D50=0.2)
z (m)
Initial profile
Final profile(a)
Final profile(b)
Max WL+setup(a)
Max WL+setup(b)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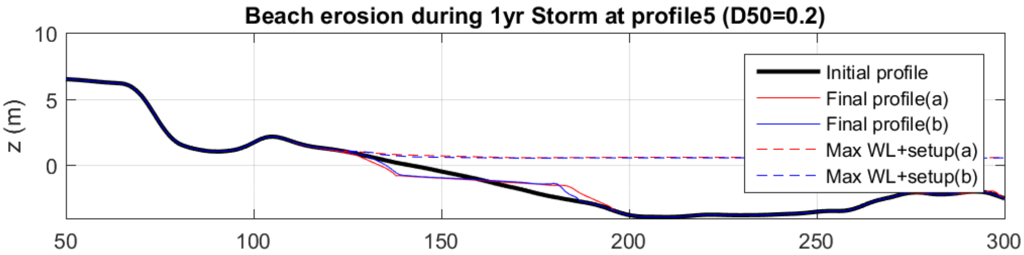
z (m)
Initial profile
Final profile(a)
Final profile(b)
Max WL+setup(a)
Max WL+setup(b)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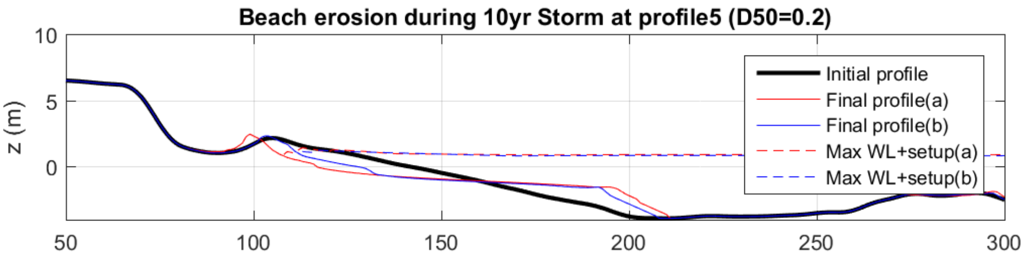
z (m)
Initial profile
Final profile(a)
Final profile(b)
Max WL+setup(a)
Max WL+setup(b)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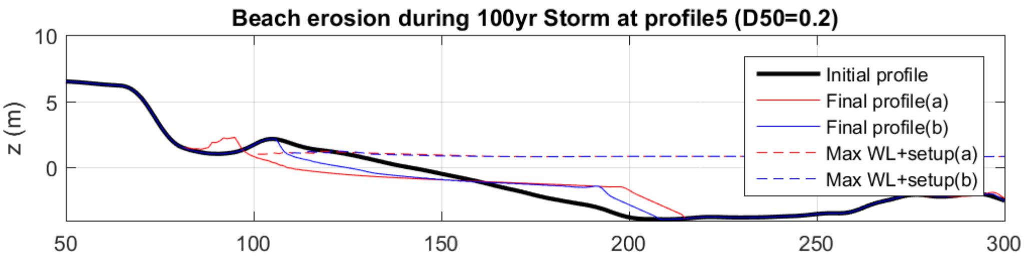
z (m)
Initial profile
Final profile(a)
Final profile(b)
Max WL+setup(a)
Max WL+setup(b)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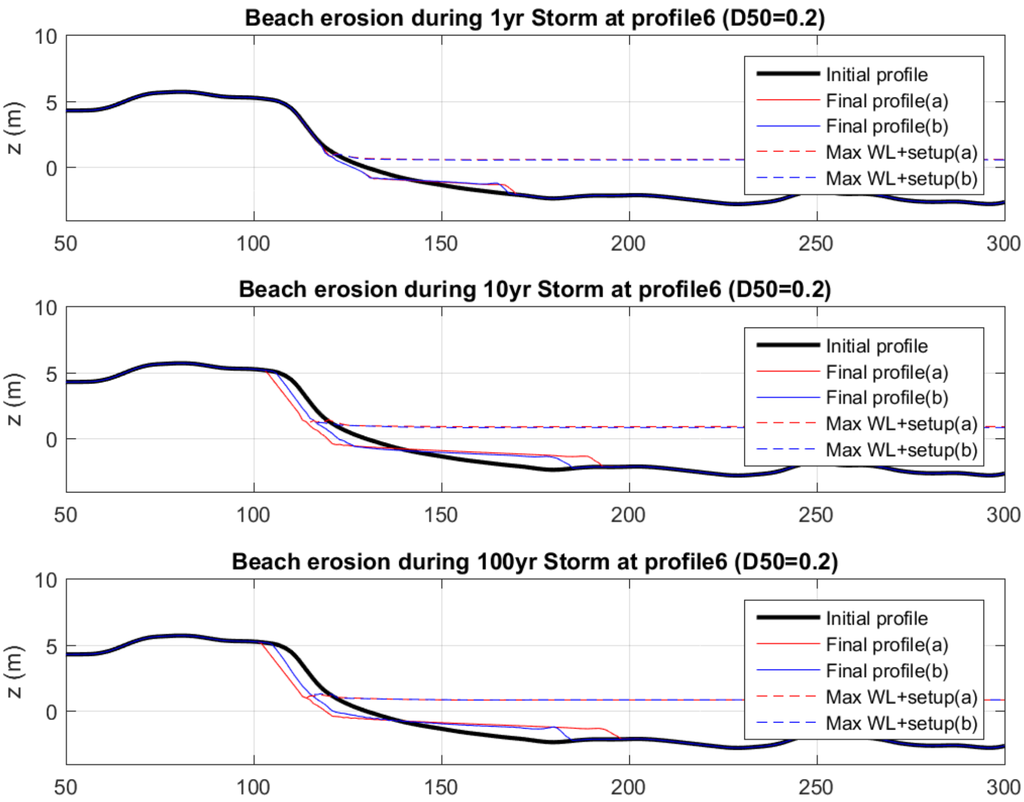
z (m)
Initial profile
Final profile(a)
Final profile(b)
Max WL+setup(a)
Max WL+setup(b)


Beach erosion during 1yr Storm at profile6 (D50=0.2)
Beach erosion during 10yr Storm at profile6 (D50=0.2)
Beach erosion during 100yr Storm at profile6 (D50=0.2)
z (m)
Initial profile
Final profile(a)
Final profile(b)
Max WL+setup(a)
Max WL+setup(b)
10
5
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200
250
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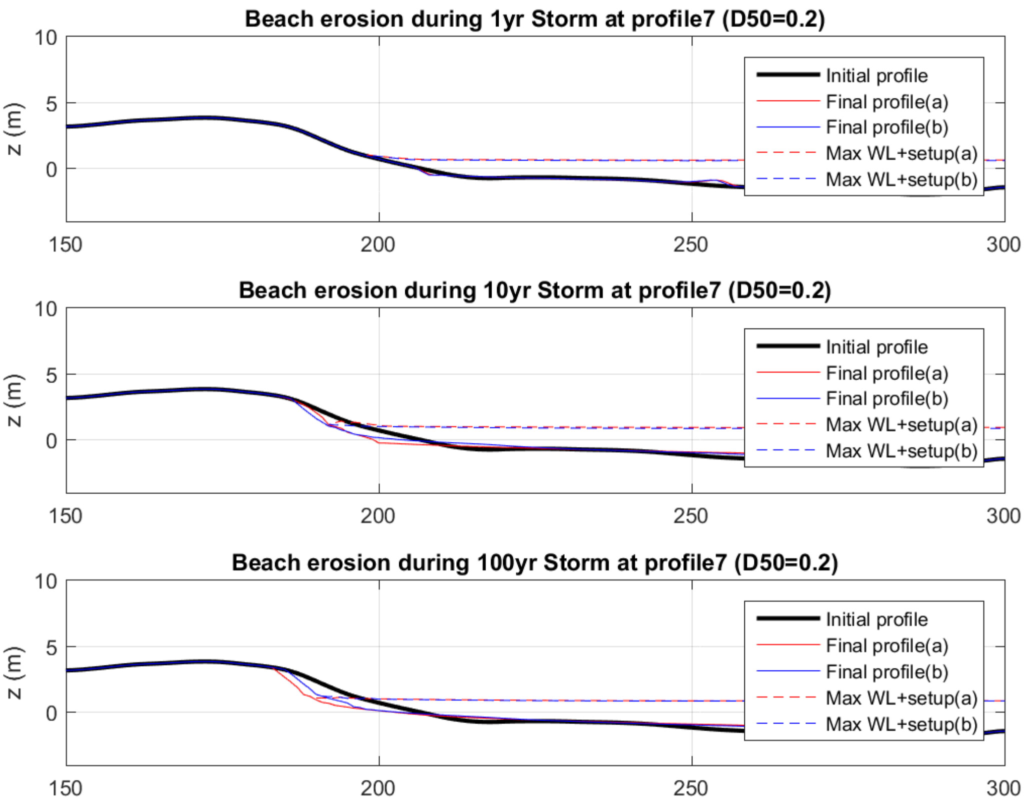
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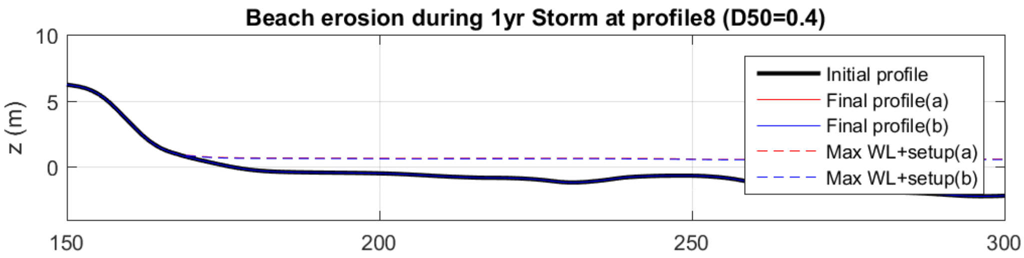
Beach erosion during 10yr Storm at profile7 (D50=0.2)
Beach erosion during 100yr Storm at profile7 (D50=0.2)
z (m)
Initial profile
Final profile(a)
Final profile(b)
Max WL+setup(a)
Max WL+setup(b)
10
5
0
150
200
250
300


Beach erosion during 1yr Storm at profile8 (D50=0.4)
z (m)
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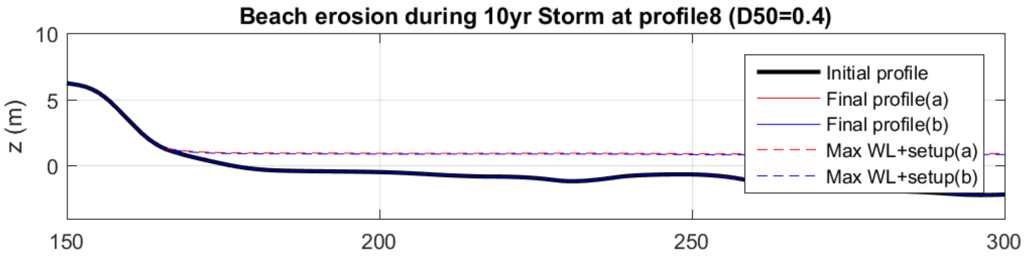
5
0
150
200
250
300
Initial profile
Final profile(a)
Final profile(b)
Max WL+setup(a)
Max WL+setup(b)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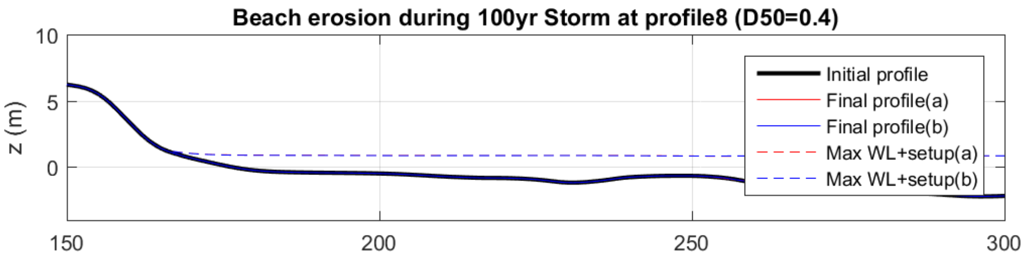
z (m)
10
5
0
150
200
250
300
Initial profile
Final profile(a)
Final profile(b)
Max WL+setup(a)
Max WL+setup(b)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z (m)
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150
200
250
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Initial profile
Final profile(a)
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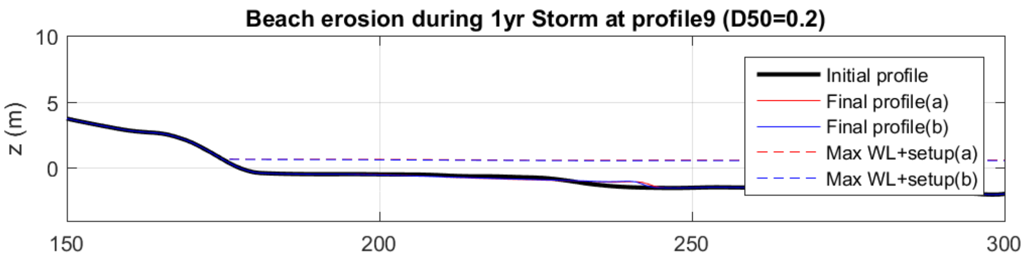
Max WL+setup(b)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z (m)
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Initial profile
Final profile(a)
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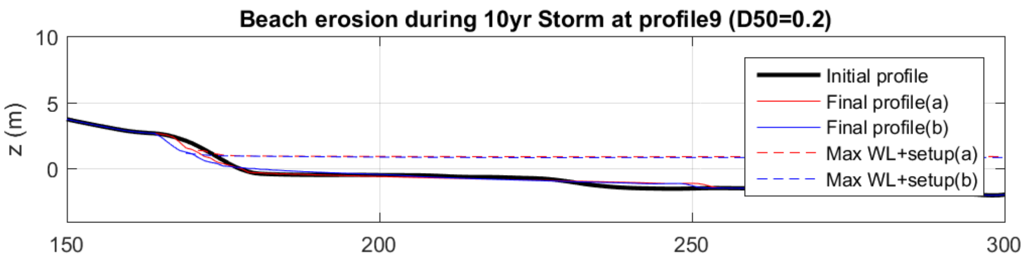
Max WL+setup(b)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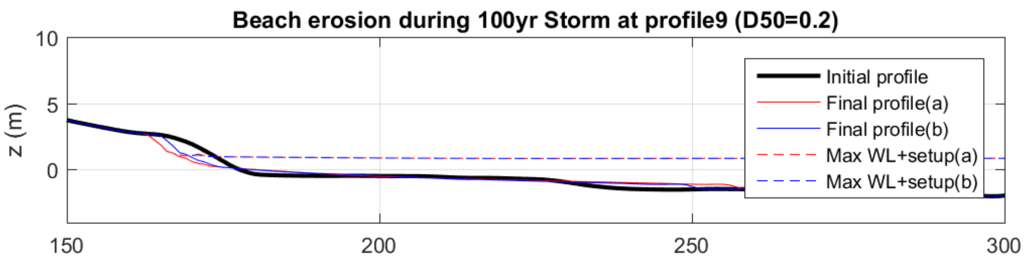
Initial profile
Final profile(a)
Final profile(b)
Max WL+setup(a)
Max WL+setup(b)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z (m)
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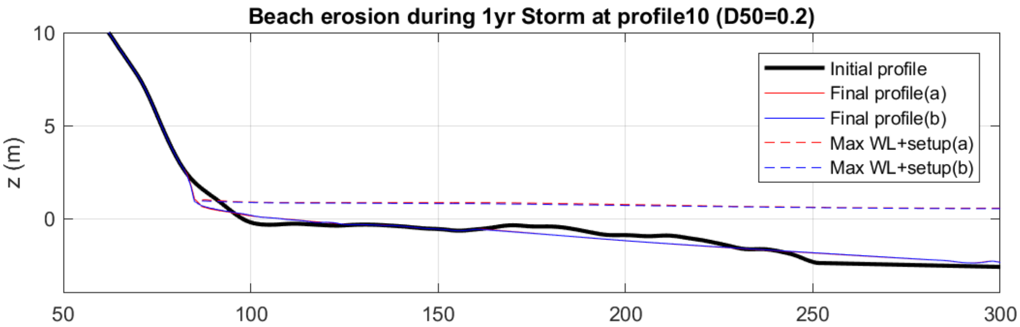
Initial profile
Final profile(a)
Final profile(b)
Max WL+setup(a)
Max WL+setup(b)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z (m)
Initial profile
Final profile(a)
Final profile(b)
Max WL+setup(a)
Max WL+setup(b)
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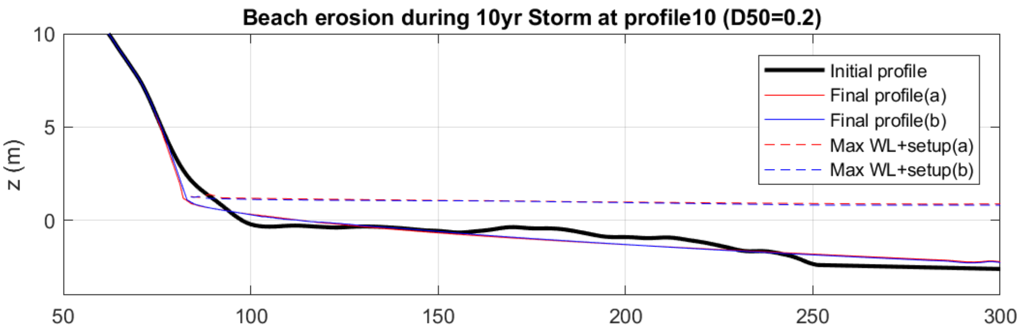
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z (m)
Initial profile
Final profile(a)
Final profile(b)
Max WL+setup(a)
Max WL+setup(b)
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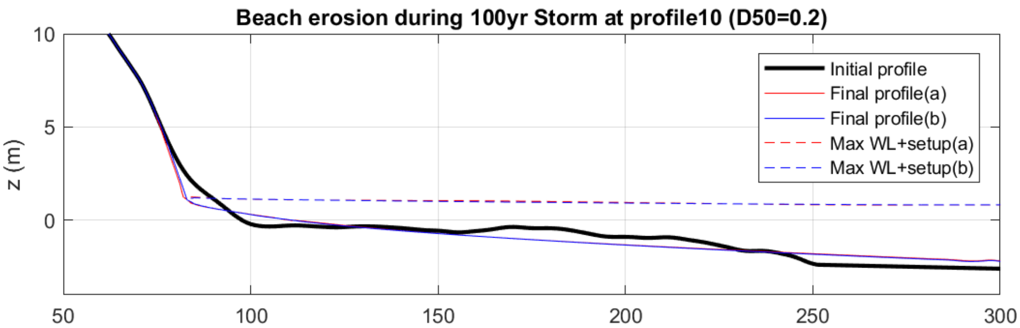
Beach erosion during 100yr Storm at profile10 (D50=0.2)
z (m)
Initial profile
Final profile(a)
Final profile(b)
Max WL+setup(a)
Max WL+setup(b)
10
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Appendix B – DSAS Results Table

Hazard Zone		Zone 1					Zone 2				
Transect		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Linear Regression Rate 1943-2016		0.02	0.05	0.09	0.12	0.03	-0.08	-0.08	-0.02	0.05	-0.02
Linear Regression Rate 1995-2016		0.5	0.33	0.44	0.32	-0.03	-0.11	-0.13	-0.1	0.06	0.02
Incremental shoreline movement rate	Oct-43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Jun-56	0.09	0.12	0.20	1.06	0.26	-0.71	0.00	-0.35	-0.25	-0.11
	Oct-65	-0.17	0.07	0.52	-0.32	0.09	0.75	-0.09	0.45	0.49	-0.10
	Nov-70	-0.91	-1.25	-1.60	-1.28	-1.96	-1.88	-1.35	-1.64	-1.05	0.26
	Jan-80	0.38	0.33	0.37	0.30	0.53	-0.01	0.28	0.39	0.11	-0.51
	Nov-90	-0.09	0.24	0.14	0.22	-0.25	0.43	0.04	0.11	0.12	0.06
	Dec-95	-0.79	-0.60	-0.68	-0.88	0.73	-0.24	0.08	0.04	0.48	0.79
	Mar-02				2.01	1.40	0.74	0.41	0.65	0.35	-0.02
	Mar-04	0.76	0.51	0.63	-4.15	-4.83	-3.98	-2.67	-2.34	-0.79	-1.18
	Oct-08	0.58	-0.06	0.39	1.19	0.78	-0.55	-0.45	-0.51	-1.10	-0.28
	Jan-16	0.13	0.43	0.26	-0.25	-0.23	0.89	0.56	0.42	1.10	0.69
	Minimum	-0.91	-1.25	-1.60	-4.15	-4.83	-3.98	-2.67	-2.34	-1.10	-1.18

Hazard Zone		Zone 3					Zone 4				Zone 5			Zone 6	
Transect		**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Linear Regression Rate 1943-2016		-0.03	-0.03	-0.01	-0.05	-0.07	-0.03	-0.03	-0.02	-0.08	-0.2	-0.23	-0.1	-0.03	-0.01
Linear Regression Rate 1995-2016		-0.2	-0.26	-0.26	-0.6	-0.59	-0.81	-0.73	-0.58	-0.6	-0.68	-0.79	-0.57	-0.35	-0.39
Incremental shoreline movement rate	Oct-43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Jun-56	-0.38	-0.24	-0.48	-0.66	-0.29	-0.04	-0.08	-0.55	0.14	-0.30	-0.64	-0.40	-0.23	-0.17
	Oct-65	0.23	0.13	0.31	0.34	0.28	0.33	-0.05	0.49	-0.75	-0.78	-0.33	0.53	0.66	0.34
	Nov-70	-0.22	0.32	0.05	0.77	0.79	0.69	0.68	0.48	0.53	0.46	0.14	0.28	-0.11	0.18
	Jan-80	-0.33	-0.34	-0.33	-0.28	-0.21	-0.51	-0.18	-0.19	-0.24	-0.22	-0.12	0.10	-0.15	-0.16
	Nov-90	0.29	0.22	0.32	-0.13	-0.20	-0.07	-0.03	-0.10	-0.02	-0.15	-0.05	0.07	0.31	0.36
	Dec-95	0.11	0.02	0.08	0.80	0.24	1.70	1.50	1.30	1.37	1.37	1.82	0.18	-0.11	-0.30
	Mar-02	0.57	0.45	0.59	-0.33	0.12	-0.98	-0.72	-0.62	-0.78	-1.24	-3.13	-1.83	-1.06	-0.40
	Mar-04	-2.37	-2.56	-2.15	2.19	1.03	-0.02	-1.34	-0.73	-0.07	0.17	3.84	0.27	1.25	1.31
	Oct-08	-0.47	-0.52	-0.48	-2.31	-2.71	-1.04	-1.42	-0.64	-0.04	-0.35	-0.48	0.00	-0.77	-1.35
	Jan-16	0.13	0.18	-0.10	-0.29	0.10	-0.74	0.06	-0.46	-1.10	-0.79	-0.76	-0.33	0.02	-0.13
	Minimum	-2.37	-2.56	-2.15	-2.31	-2.71	-1.04	-1.42	-0.73	-1.10	-1.24	-3.13	-1.83	-1.06	-1.35

Hazard Zone		Zone 7		Zone 8			Zone 9	Zone 10						
Transect		**25**	**26**	**27**	**28**	**29**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**
Linear Regression Rate 1943-2016		0	0.02	-0.02	-0.04	0		0	-0.01	0.01	0	0.05	0.07	0.05
Linear Regression Rate 1995-2016		-0.6	-0.63	-0.52	-0.35	-0.11		-0.17	-0.12	-0.19	-0.24	-0.05	-0.21	0.07
Incremental shoreline movement rate	Oct-43	0.00	0.00	0.00	0.00									
	Jun-56	-0.17	-0.54	-0.59	-0.68	0.00		-0.04	0.00	0.00	0.00	0.00	0.00	0.00
	Oct-65	0.19	0.23	0.15	-0.04	-0.15		0.05	0.11	0.05	0.19	0.19	0.48	0.17
	Nov-70	-0.67	-0.77	-0.81	-0.87	-0.61		1.39	0.52	1.06	1.17	0.77	0.11	1.06
	Jan-80	0.29	0.65	0.48	0.92	0.41		0.00	-0.28	-0.18	-0.29	-0.10	0.04	-0.58
	Nov-90	0.07	0.08	-0.12	-0.39	-0.14		-0.37	-0.24	-0.12	-0.49	-0.48	-0.28	-0.13
	Dec-95	1.85	1.66	1.97	1.29	0.36		0.71	0.86	0.38	1.24	1.58	1.76	0.70
	Mar-02	-1.65	-1.61	-1.46	-0.91	-0.43		0.25	-0.30	-0.32	-0.30	-0.55	-1.15	
	Mar-04	0.35	1.02	0.82	0.13	0.81		-0.85	-0.55	0.05	-0.50	-0.68	0.71	-0.10
	Oct-08	-0.51	-0.32	0.31	0.61	1.19		-0.46	0.40	-0.33	0.18	-0.09	0.42	0.64
	Jan-16	-0.18	-0.69	-0.93	-0.87	-1.25		-0.04	-0.27	-0.04	-0.46	0.59	-0.32	-0.19
	Minimum	-1.65	-1.61	-1.46	-0.91	-1.25		-0.85	-0.55	-0.33	-0.50	-0.68	-1.15	-0.58

Appendix C – Erosion and Inundation Hazard Maps

Paper Size ISO A3

0 100 200 300

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

GHD

Shire of Northampton
Horrocks Beach Coastal Hazard Risk Management and Adaptation Plan

Project No.	**61-37817**
Revision No.	**B**
Date	**12/06/2019**

Erosion Likelihoods (2019)

FIGURE 1

G:\61\37817\GIS\Maps\Working\Figures\6137817_001_Erosion_2019_RevB.mxd
Print date: 12 Jun 2019 - 10:51

Data source: GHD: Landgate: Suburbs - 20180319, Imagery (Accessed) - 20190611; Landgate: Locality - 20180319; MRWA: Road - 20171211; Erosion Likelihood - 20190611. Created by: slei

Paper Size ISO A3

0 100 200 300

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

GHD

Shire of Northampton
Horrocks Beach Coastal Hazard Risk Management and Adaptation Plan

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Date **12/06/2019**

Erosion Likelihoods (2030)

FIGURE 2

G:\61\37817\GIS\Maps\Working\Figures\6137817_002_Erosion_2030_RevB.mxd
Print date: 12 Jun 2019 - 10:51

Data source: GHD: Landgate: Suburbs - 20180319, Imagery (Accessed) - 20190611; Landgate: Locality - 20180319; MRWA: Road - 20171211; Erosion Likelihood - 20190611. Created by: slei

Paper Size ISO A3

0 100 200 300

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

GHD

Shire of Northampton
Horrocks Beach Coastal Hazard Risk Management and Adaptation Plan

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Date	12/06/2019

Erosion Likelihoods (2050)

FIGURE 3

G:\61\37817\GIS\Maps\Working\Figures\6137817_003_Erosion_2050_RevB.mxd
Print date: 12 Jun 2019 - 10:52

Data source: GHD: Landgate: Suburbs - 20180319, Imagery (Accessed) - 20190611; Landgate: Locality - 20180319; MRWA: Road - 20171211; Erosion Likelihood - 20190611. Created by: slei

Paper Size ISO A3

0 100 200 300

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

Shire of Northampton
Horrocks Beach Coastal Hazard Risk Management and Adaptation Plan

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Erosion Likelihoods (2070)

FIGURE 4

G:\61\37817\GIS\Maps\Working\Figures\6137817_004_Erosion_2070_RevB.mxd
Print date: 12 Jun 2019 - 12:43

Data source: GHD: Landgate: Suburbs - 20180319, Imagery (Accessed) - 20190611; Landgate: Locality - 20180319; MRWA: Road - 20171211; Erosion Likelihood - 20190611. Created by: slei

Paper Size ISO A3

0 100 200 300

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

GHD

Shire of Northampton
Horrocks Beach Coastal Hazard Risk Management and Adaptation Plan

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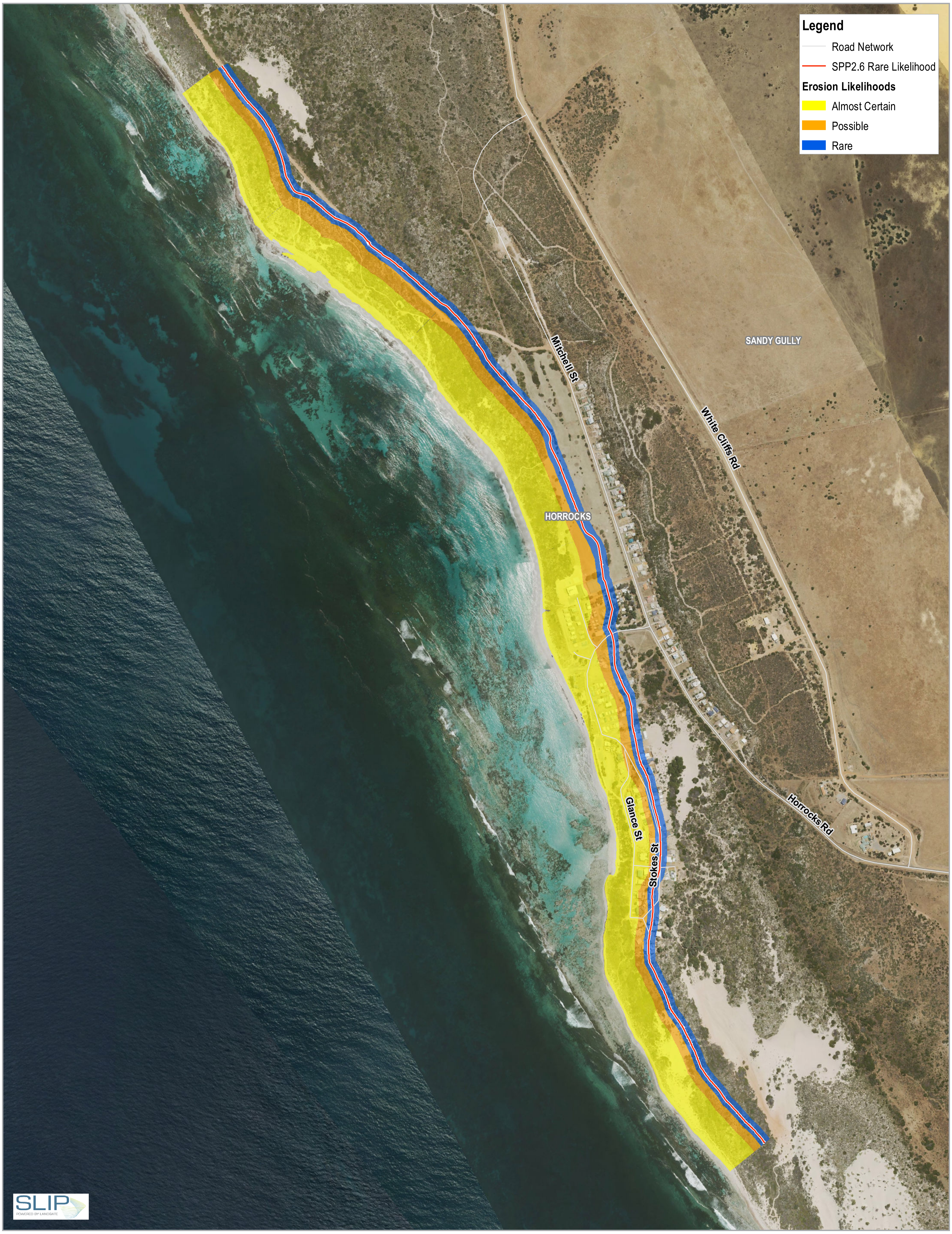
Date **12/06/2019**

Erosion Likelihoods (2090)

FIGURE 5

G:\61\37817\GIS\Maps\Working\Figures\6137817_005_Erosion_2090_RevB.mxd
Print date: 12 Jun 2019 - 12:44

Data source: GHD: Landgate: Suburbs - 20180319, Imagery (Accessed) - 20190611; Landgate: Locality - 20180319; MRWA: Road - 20171211; Erosion Likelihood - 20190611. Created by: slei



Paper Size ISO A3

0 100 200 300

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

Shire of Northampton
Horrocks Beach Coastal Hazard Risk Management and Adaptation Plan

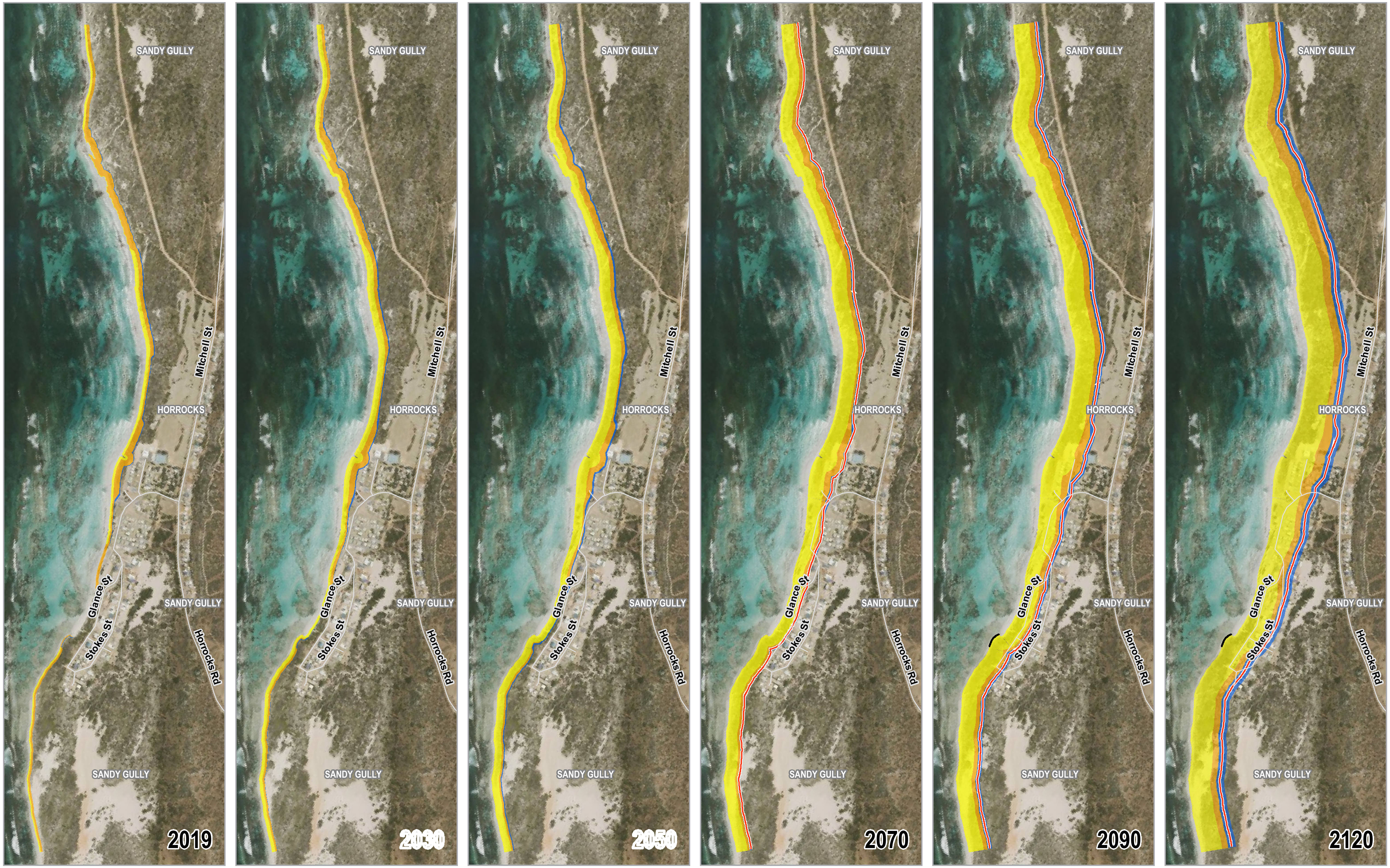
Erosion Likelihoods (2120)

Project No.	**61-37817**
Revision No.	**B**
Date	**12/06/2019**

FIGURE 6

G:\61\37817\GIS\Maps\Working\Figures\6137817_006_Erosion_2120_RevB.mxd
Print date: 12 Jun 2019 - 12:44

Data source: GHD: Landgate: Suburbs - 20180319, Imagery (Accessed) - 20190611; Landgate: Locality - 20180319; MRWA: Road - 20171211; Erosion Likelihood - 20190611. Created by: slei



Legend

Road Network
SPP 2.6 Rare Likelihood

Erosion Likelihoods

Almost Certain
Possible
Rare

Paper Size ISO A3
0 100 200 300
Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

Shire of Northampton
Horrocks Beach Coastal Hazard Risk Management and Adaptation Plan

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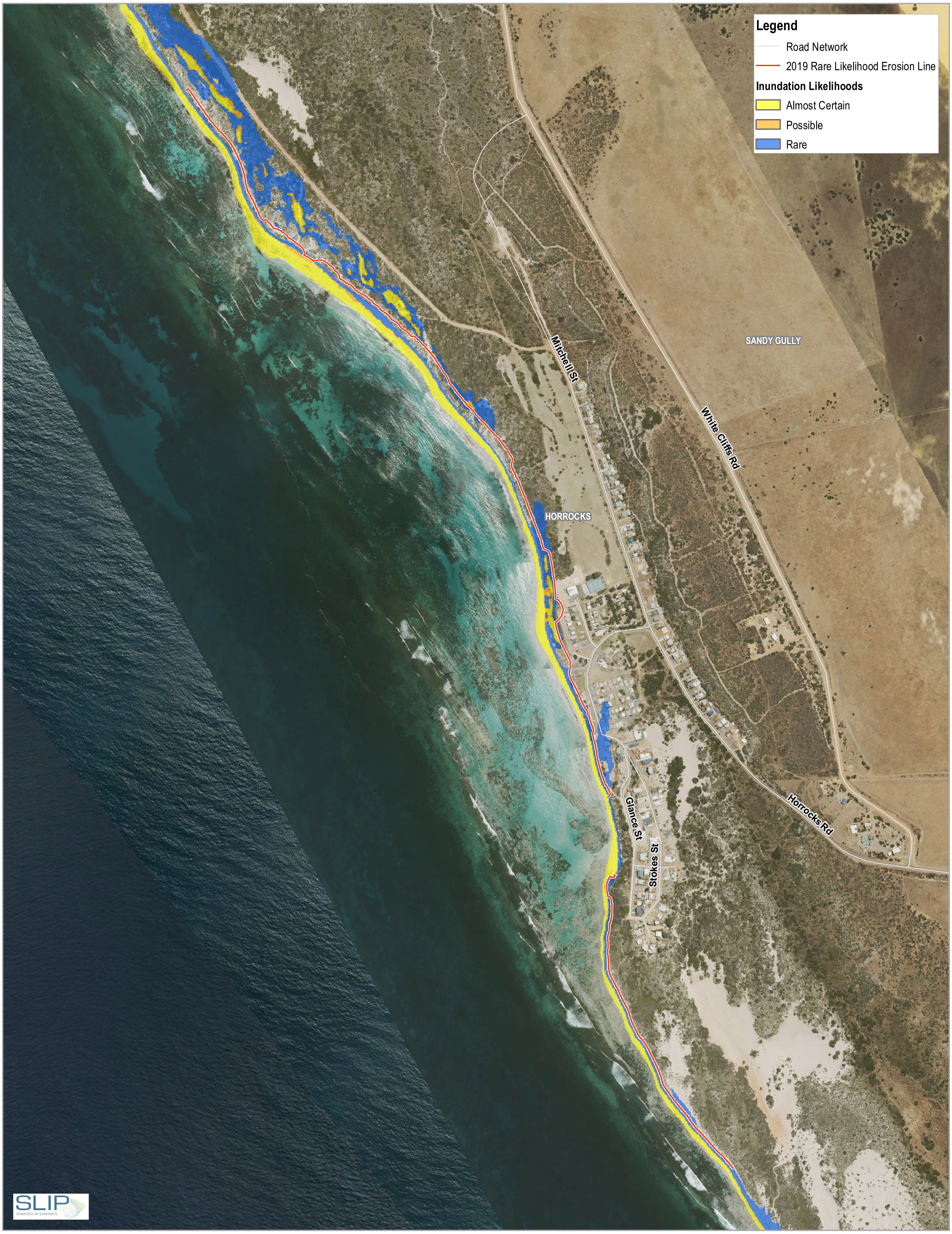
Erosion Likelihoods

FIGURE B.1

G:\61\37817\GIS\Maps\Working\Figures\6137817_B1_Erosion_Landscape6Yrs_RevA.mxd
Print date: 12 Jun 2019 - 12:47

Data source: GHD: Landgate: Suburbs - 20180319, Imagery (Accessed) - 20190426; Landgate: Locality - 20180319; MRWA: Road - 20171211; Erosion Likelihoods, SPP 2.6 Rare Likelihood - 20190611.
Created by: slei



Paper Size ISO A3

0 100 200 300

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

GHD

Shire of Northampton
Horrocks Beach Coastal Hazard Risk Management and Adaptation Plan

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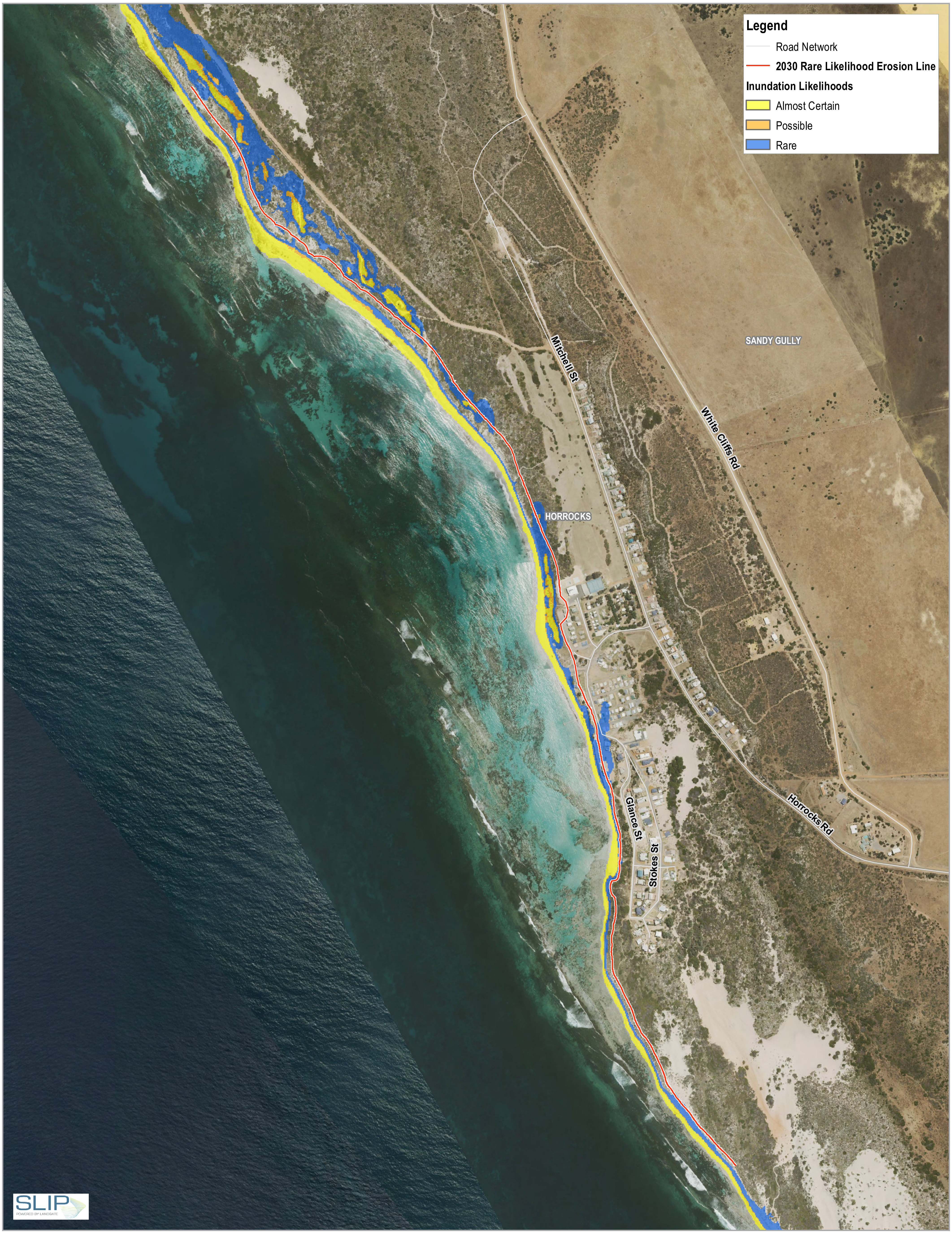
Date	**12/06/2019**

Inundation Likelihoods (2019)

FIGURE 7

G:\61\37817\GIS\Maps\Working\Figures\6137817_007_Inundation_2019_RevB.mxd
Print date: 12 Jun 2019 - 12:45

Data source: GHD: Landgate: Suburbs - 20180319, Imagery (Accessed) - 20190611; Landgate: Locality - 20180319; MRWA: Road - 20171211; Inundation Likelihood - 20190426, Rare Likelihood Erosion Line - 20190611. Created by: slei



Paper Size ISO A3

0 100 200 300

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

Shire of Northampton
Horrocks Beach Coastal Hazard Risk Management and Adaptation Plan

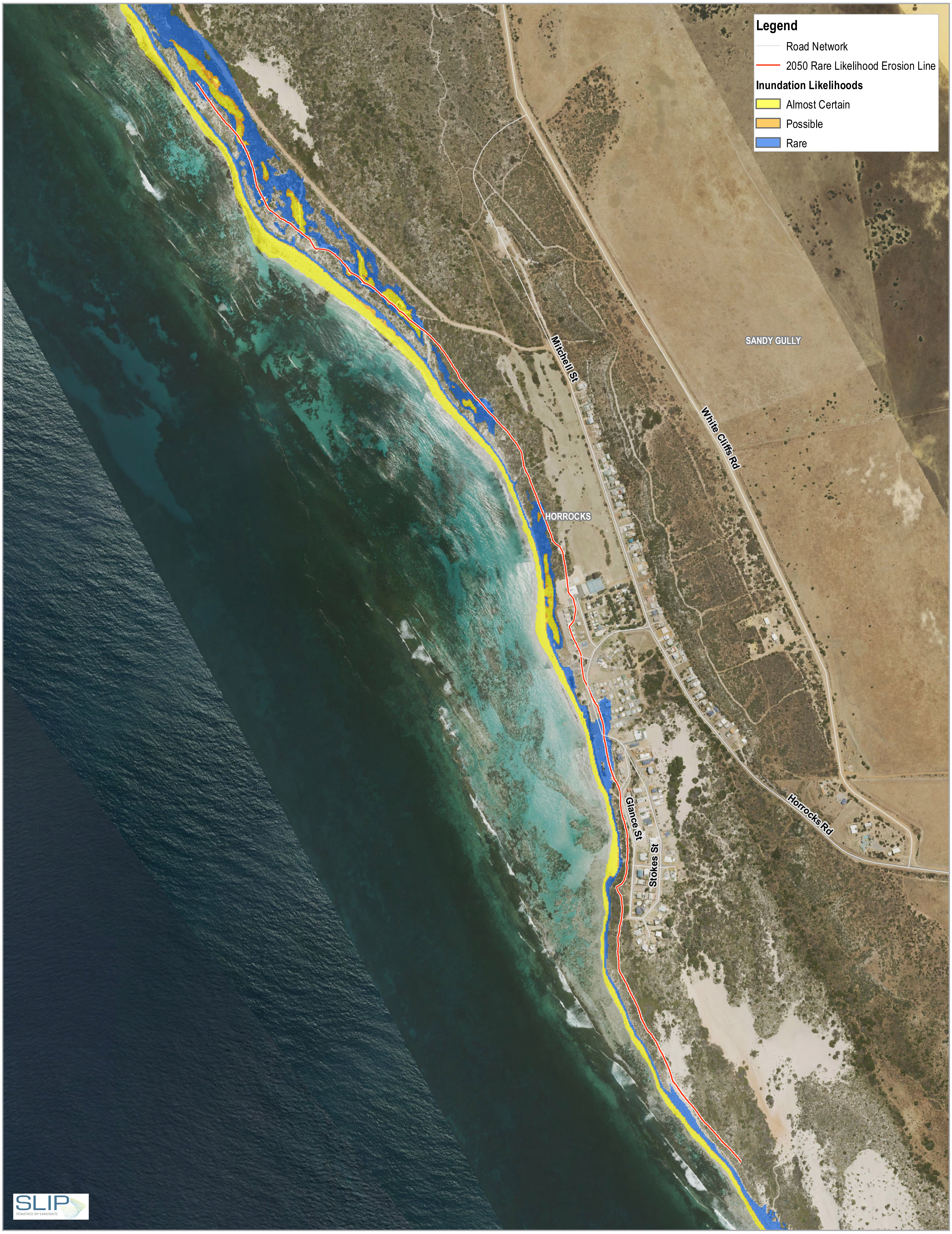
Project No. 61-37817
Revision No. B
Date 12/06/2019

Inundation Likelihoods (2030)

FIGURE 8

G:\61\37817\GIS\Maps\Working\Figures\6137817_008_Inundation_2030_RevA.mxd
Print date: 12 Jun 2019 - 12:45

Data source: GHD: Landgate: Suburbs - 20180319, Imagery (Accessed) - 20190426; Landgate: Locality - 20180319; MRWA: Road - 20171211; Inundation Likelihood - 20190426. Created by: slei



Paper Size ISO A3

0 100 200 300

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

GHD

Shire of Northampton
Horrocks Beach Coastal Hazard Risk Management and Adaptation Plan

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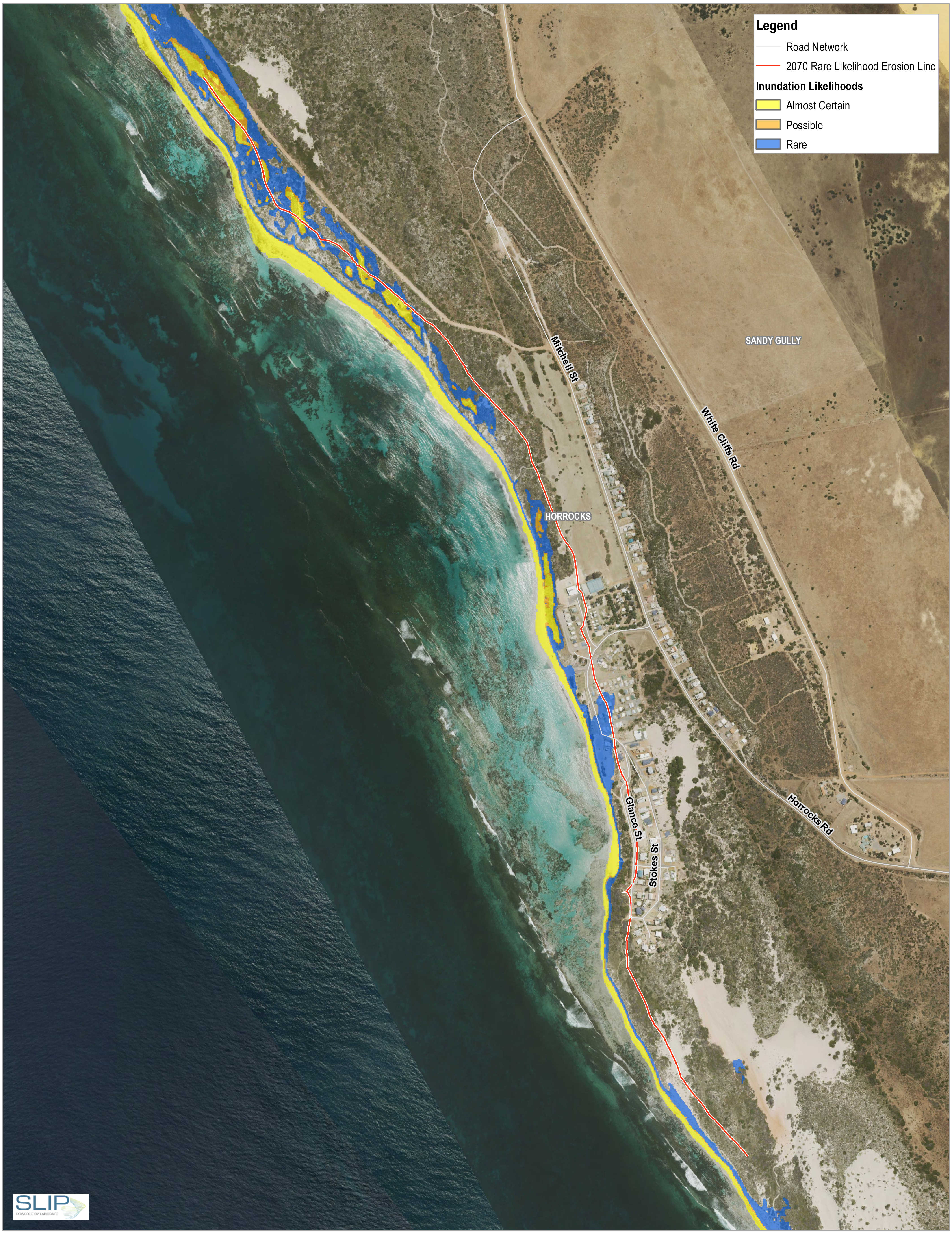
Date	**12/06/2019**

Inundation Likelihoods (2050)

FIGURE 9

G:\61\37817\GIS\Maps\Working\Figures\6137817_009_Inundation_2050_RevB.mxd
Print date: 12 Jun 2019 - 12:45

Data source: GHD: Landgate: Suburbs - 20180319, Imagery (Accessed) - 20190611; Landgate: Locality - 20180319; MRWA: Road - 20171211; Inundation Likelihood - 20190426, Rare Likelihood Erosion Line - 20190611. Created by: slei



Paper Size ISO A3

0 100 200 300

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

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Shire of Northampton
Horrocks Beach Coastal Hazard Risk Management and Adaptation Plan

Inundation Likelihoods (2070)

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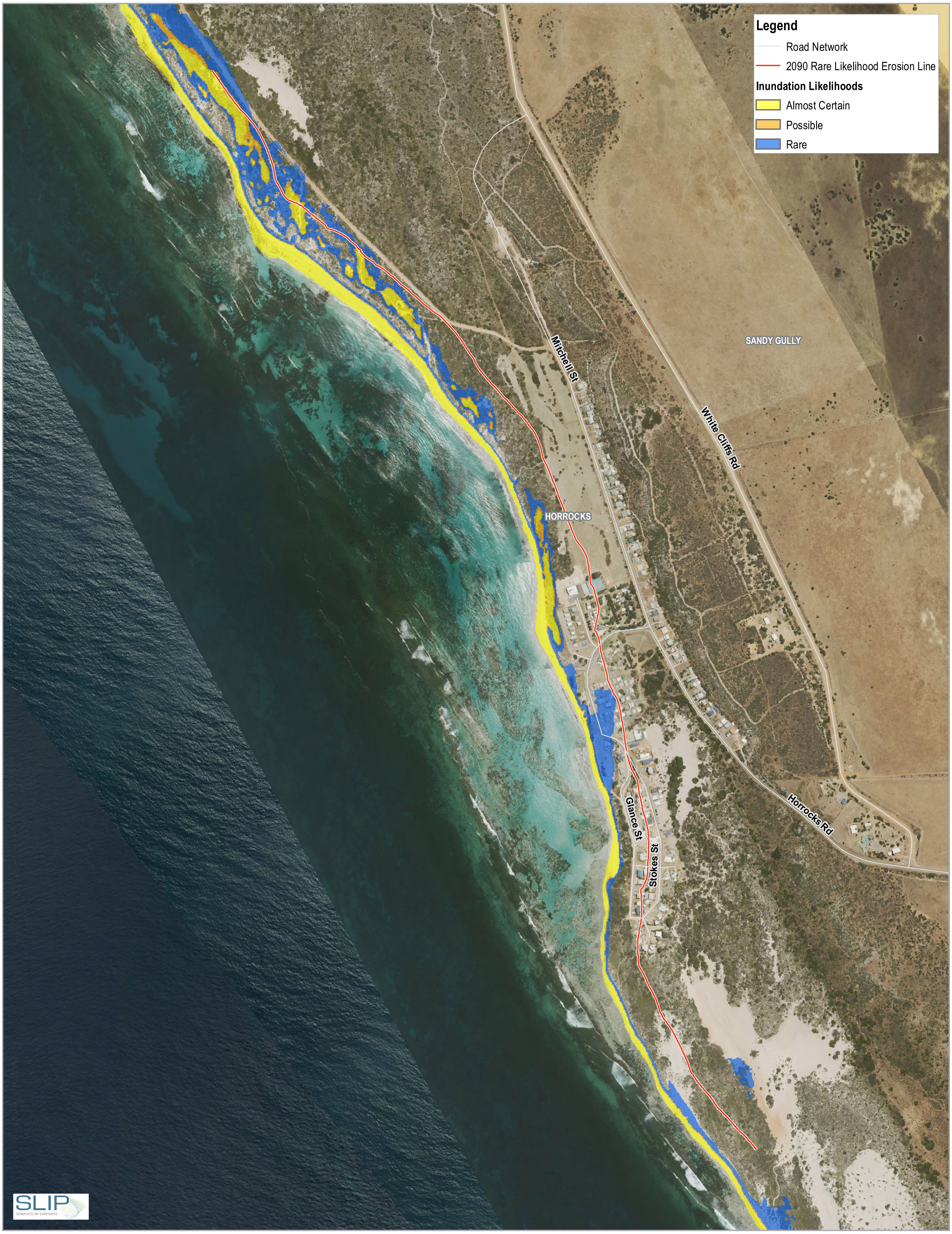
Revision No. **B**
Date **12/06/2019**

FIGURE 10

G:\61\37817\GIS\Maps\Working\Figures\6137817_010_Inundation_2070_RevA.mxd
Print date: 12 Jun 2019 - 12:46

Data source: GHD: Landgate: Suburbs - 20180319, Imagery (Accessed) - 20190611; Landgate: Locality - 20180319; MRWA: Road - 20171211; Inundation Likelihood - 20190426, Rare Likelihood Erosion Line - 20190611. Created by: slei



Paper Size ISO A3

0 100 200 300

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

Shire of Northampton
Horrocks Beach Coastal Hazard Risk Management and Adaptation Plan

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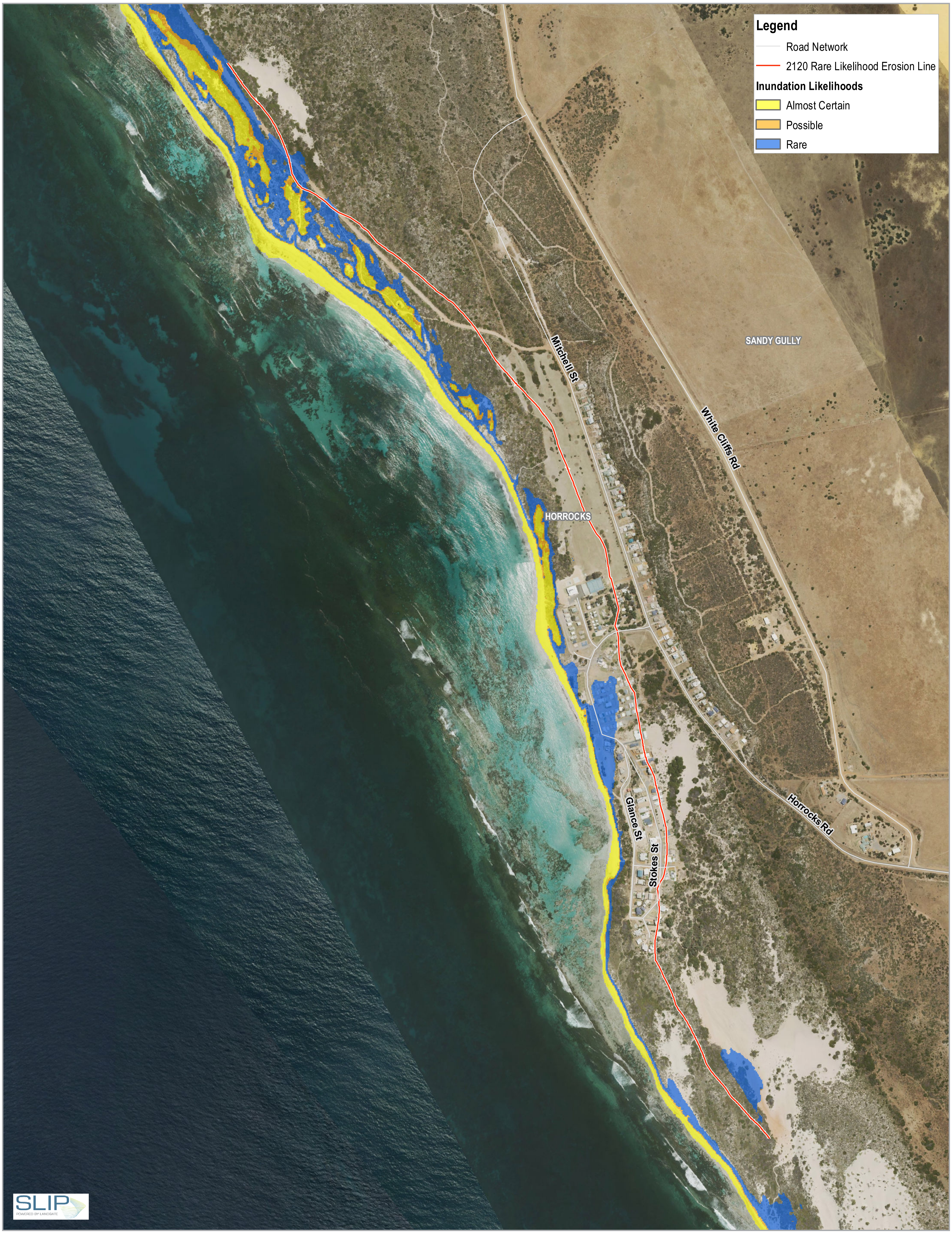
Date	12/06/2019

Inundation Likelihoods (2090)

FIGURE 11

G:\61\37817\GIS\Maps\Working\Figures\6137817_011_Inundation_2090_RevA.mxd
Print date: 12 Jun 2019 - 12:46

Data source: GHD: Landgate: Suburbs - 20180319, Imagery (Accessed) - 20190611; Landgate: Locality - 20180319; MRWA: Road - 20171211; Inundation Likelihood - 20190426, Rare Likelihood Erosion Line - 20190611. Created by: slei



Paper Size ISO A3

0 100 200 300

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

Shire of Northampton
Horrocks Beach Coastal Hazard Risk Management and Adaptation Plan

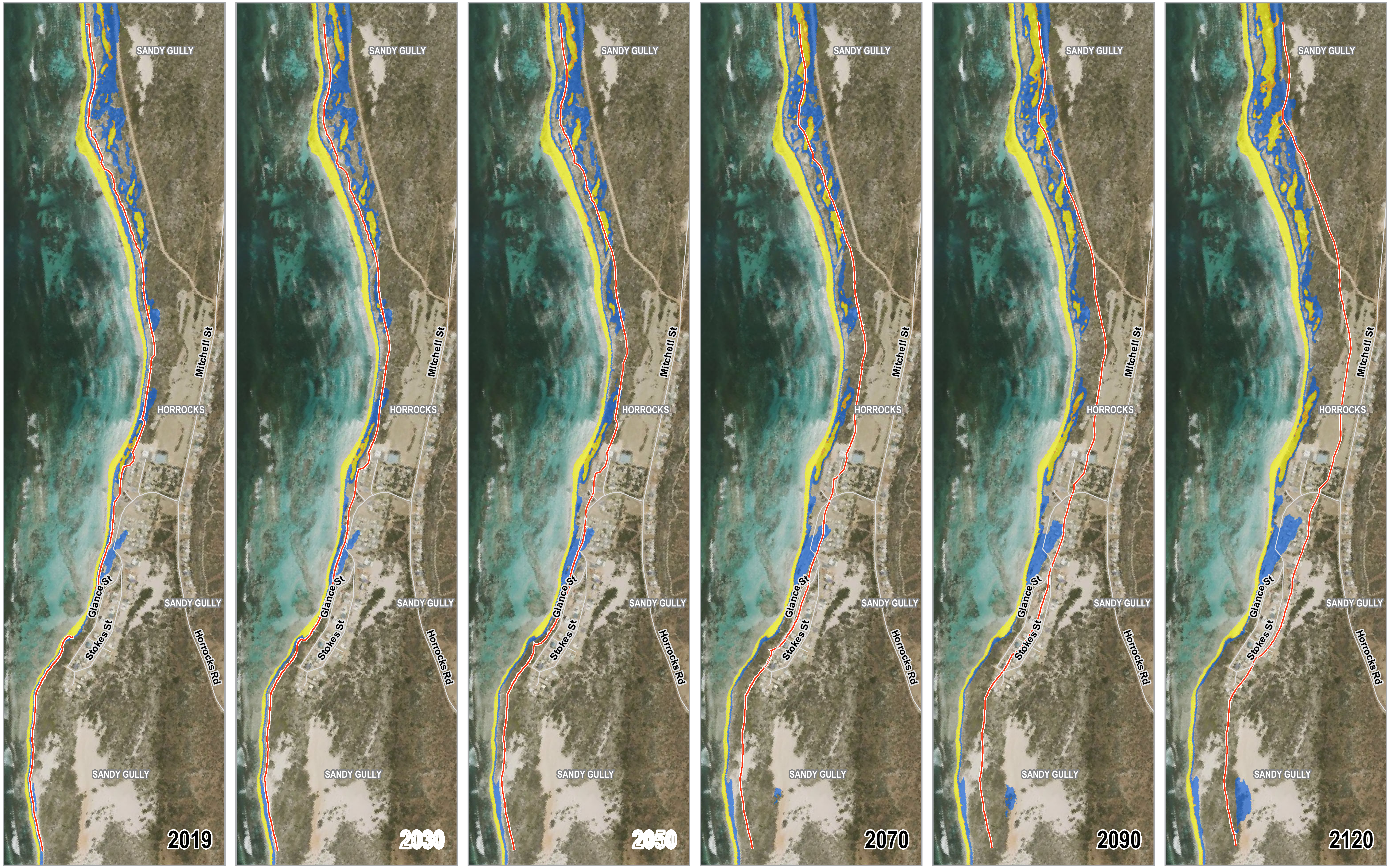
Project No. **61-37817**
Revision No. **B**
Date **12/06/2019**

Inundation Likelihoods (2120)

FIGURE 12

G:\61\37817\GIS\Maps\Working\Figures\6137817_012_Inundation_2120_RevB.mxd
Print date: 12 Jun 2019 - 12:47

Data source: GHD: Landgate: Suburbs - 20180319, Imagery (Accessed) - 20190611; Landgate: Locality - 20180319; MRWA: Road - 20171211; Inundation Likelihood - 20190426, Rare Likelihood Erosion Line - 20190611. Created by: slei



Legend

Road Network

Rare Likelihood Erosion Line

Inundation Likelihoods

Almost Certain

Possible

Rare

Paper Size ISO A3

0 100 200 300

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

Shire of Northampton
Horrocks Beach Coastal Hazard Risk Management and Adaptation Plan

Project No. **61-37817**
Revision No. **B**
Date **12/06/2019**

Inundation Likelihoods

FIGURE B.2

G:\61\37817\GIS\Maps\Working\Figures\6137817_B2_Inundation_Landscape6Yrs_RevA.mxd
Print date: 12 Jun 2019 - 12:47

Data source: GHD: Landgate: Suburbs - 20180319, Imagery (Accessed) - 20190426; Landgate: Locality - 20180319; MRWA: Road - 20171211; Inundation Likelihoods - 20190426, Rare Erosion Likelihood Line - 20190611. Created by: slei

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6137817-48416/https://projects.ghd.com/oc/WesternAustralia1/horrocksbeachchrmap/Delivery/Documents/6137817-REP_Coastal Hazard Assessment.docx

Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
Draft A	C Hart	G Bertrand	On file	A Krause	On file	
Draft B	G Bertrand	H O'Keeffe	On file	A Krause	On file	14.02.2020
Rev 0	G Bertrand	H O'Keefe		A Krause		13.10.2020

Appendix D - Vulnerability and Risk Assessment

Shire of Northampton

Horrocks Beach CHRMAP

Vulnerability and Risk Assessment

October 2020

Table of contents

Table index

Figure index

1. Introduction

The purpose of this Coastal Vulnerability & Risk Assessment (CVRA) is to summarise the assumptions, methodology and results of the vulnerability and risk assessment component of the Horrocks Beach Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) (GHD, In Prep). This CVRA is a supporting technical document to the Horrocks Beach CHRMAP which should be read in conjunction with the overarching CHRMAP (GHD, In Prep) including the Coastal Hazard Assessment (CHA). This CVRA follows the framework outlined in the Coastal Hazard Risk Management and Adaptation Planning Guidelines (WAPC 2019).

1.1 Risk

The risk level to an asset or land use is the product of the "likelihood" of a coastal hazard impacting that asset or land use and the "consequence" of that impact. Different assets and land uses support different values which trigger appropriate risk levels as determined by the risk matrix, refer to Table 1. To determine the specific risk levels to assets and land uses in the Horrocks Beach area, likelihood and consequence values were developed in the context of the values assessment of the project area.

Table 1 Risk Level Matrix

Likelihood	Risk Level				
Almost Certain	Moderate	High	High	Extreme	Extreme
Possible	Low	Moderate	High	High	Extreme
Rare	Low	Low	Moderate	High	High
	Insignificant	Minor	Moderate	Major	Catastrophic
	Consequence				

1.1.1 Likelihood

Analysis of the coastal hazards (refer the CHA) identified erosion and inundation risks to the Horrocks Beach project area at six time periods (Present Day (2019), 2030, 2050, 2070, 2090 and 2120). Likelihood is the chance of a coastal hazard occurring and is therefore linked to expected frequency of a coastal hazard occurring.

For each time period, three likelihood levels (almost certain, possible and rare) were defined for both erosion and inundation as identified in the CHA[1].

1.1.2 Consequence

Consequence is the impact of a coastal hazard on an asset or land use and its values. Consequences relate not only to the direct impact or damage to an asset but also the effect on related social, economic and environment values (WAPC 2014). The consequence scale is used to identify the sensitivity of an asset to coastal hazards (WAPC, 2019). The scale of consequence ranges from insignificant to catastrophic and is considered for each impacted

[1] Note: Although likelihood were defined in the CHA for all six time periods, the vulnerability assessment is only applied to 2019, 2050 and 2120

value. Where an asset has varying consequence levels to more than one value, the value with the highest consequence was used to determine the consequence level for that asset.

Community values, as outlined in the values chapter (section 3 of the CHRMAP document) and the survey summary (see Appendix B – Values Survey of the CHRMAP document), were taken into account when defining the level of consequence coastal hazards would have on an asset.

The risk assessment defined consequences for the value types that had been identified in the study area: social & heritage, economic and environmental. The consequence scale of safety, whilst frequently used in hazard risk assessments, was not assessed in this study because during coastal events likely to result in erosion and/or inundation, the community generally seeks shelter, beach areas should be closed and during more severe events the community is recommended or requested to evacuate to safer areas and is not allowed to return until safety has been assessed.

The scale of consequence for the different values was selected to represent the range of potential consequences relevant to the context of the study area. For example, the social consequence scale ranges from local to regional, as both local residents in Horrocks and people across the greater area of the Shire of Northampton and people travelling through use and value social services and experiences unique to the area. Setting the consequence levels to cover the expected scale of potential impacts is important as it assists decision makers to prioritise risks requiring mitigation. Use of state-wide or national scales for some categories would not allow identification of risks appropriate to the scale of this project. The scale of consequences for this project is detailed in Table 2.

The environmental consequence scale was based on the potential damage to the local environment, the proportion of the environmental value impacted in relation to the consequence threshold, the ability for the damage to be offset and identification of alternate habitat areas.

For example, if the erosion hazard affects only a small percentage of a foreshore reserve (typically undeveloped reserved areas of vegetated dunes) and is below the consequence threshold, the consequence would be considered to be insignificant, particularly if there is similar habitat unaffected nearby. If the percentage of the passive parks and recreation reserve impacted however is above the consequence threshold, and other passive parks and recreation reserves are impacted also, the consequence would be moderate. Refer to sections 2.1, 2.2.5 and 2.3.5 for asset and land use consequence scales for erosion and inundation, respectively.

Table 2 Scale of Consequence

		Category		
		Social & Heritage	**Economic**	**Environment**
5	Catastrophic	Loss of vital social or heritage values, experiences and/or sites of both local and regional significance. No alternative exists.	Damage to local economy, public or private infrastructure or loss of land value greater than $25 million.	Irreversible damage to local environmental asset(s) that would compromise its viability. No alternate habitat(s) exist.
4	Major	Loss of important social or heritage values, experiences and/or sites that would impair quality of life of the local community. No convenient alternative exists.	Damage to local economy, public or private infrastructure or loss of land value $5 million to $25 million.	Major damage to local environmental asset(s) that would compromise its viability. No alternate habitat exists.
3	Moderate	Loss of social or heritage values, experiences and/or sites that would somewhat impair quality of life of the local community. No convenient alternative exists. **Permanent or regular inundation.**	Damage to local economy, public or private infrastructure or loss of land value $500,000 to $5 million.	Moderate damage to local environmental asset that could be reversed or offset. Local alternate habitats exist. **Permanent or regular inundation.**
2	Minor	Loss of social or heritage values, experiences and/or sites that would have minimal impact on the quality of life of the local community. Alternative sites exist. **Temporary or infrequent inundation**	Damage to local economy, public or private infrastructure or loss of land value $100,000 to $500,000.	Minor environmental damage to local environmental asset(s) that could be reversed or offset. Local or regional alternate habitat exists. **Temporary or infrequent inundation**
1	Insignificant	Loss of social or heritage values, experiences and/or sites that would have little to no impact on quality of life of the local community. Many alternatives exist.	Damage to local economy, public or private infrastructure or loss of land value less than $100,000.	Insignificant damage to local environmental asset(s); recovery may take less than six months

1.1.3 Asset Risk

Risk levels for assets impacted by coastal hazards is identified from the consequence and likelihood scales (Table 1). Extreme risks are intolerable requiring immediate implementation of risk management measures. High risks are the most severe that can be tolerated and need monitoring in the short term. Medium risks can be tolerated and need to be monitored in the short to medium term. Low risks can be accepted without risk management measures in the short to medium term other than monitoring (WAPC, 2019).

1.1.4 Risk Tolerance

To identify the areas, assets and land uses that require risk management or remediation, the tolerance to the risk needs to be determined. Risk tolerance is a function of the risk level and the vulnerability (for erosion) or adaptive capacity (for inundation) of an asset or value. Risk tolerances for erosion and inundation in Horrocks are discussed further in Section 2.

It is important to define the level(s) at which risk is deemed acceptable, tolerable or intolerable, where intolerable risks require risk management measures as a priority (particularly in terms of changing risk across timeframes). For example, a risk that is rated under current conditions as low may simply be acceptable, requiring no further risk management measures other than monitoring. However, if the risk is identified as currently being high or extreme or will reach these levels before the end of the planning timeframes being considered in the CHRMAP, then these risks are likely to require more short-term or immediate risk management measures to reduce the risk back to tolerable or acceptable levels (WAPC, 2019). Specific examples relating to Horrocks are provided as part of the assessment in Section 2.

A risk tolerance scale has been developed to inform which risk and assets require risk management measures as a priority. The scale is used to determine action once tolerance has been calculated.

Table 3 Risk tolerance scale

Risk level	Action required	Acceptance/tolerance
Extreme-High	Immediate action required to eliminate or reduce risk to acceptable levels	Intolerable
High-Medium	Immediate to short-term action required	Tolerable
Medium	Short to medium term action required	Tolerable/Acceptable
Low	Accept risk	Acceptable

1.2 Vulnerability

Different assets and land uses have varying abilities to respond to coastal hazard risks. The most marked differences are observed between built assets with defined extents that cannot adapt to changes in the coastal environment versus natural assets that have the ability to respond and react to such changes. Therefore, when an asset or value is defined to be within a risk zone, it is important that we also understand whether it is vulnerable. Vulnerability is a function of three overlapping elements: exposure, sensitivity and adaptive capacity of an asset. Potential impacts are a function of exposure and sensitivity while vulnerability is a function of potential impacts and adaptive capacity (WAPC 2019, Figure 1). Each of these elements is described further below.

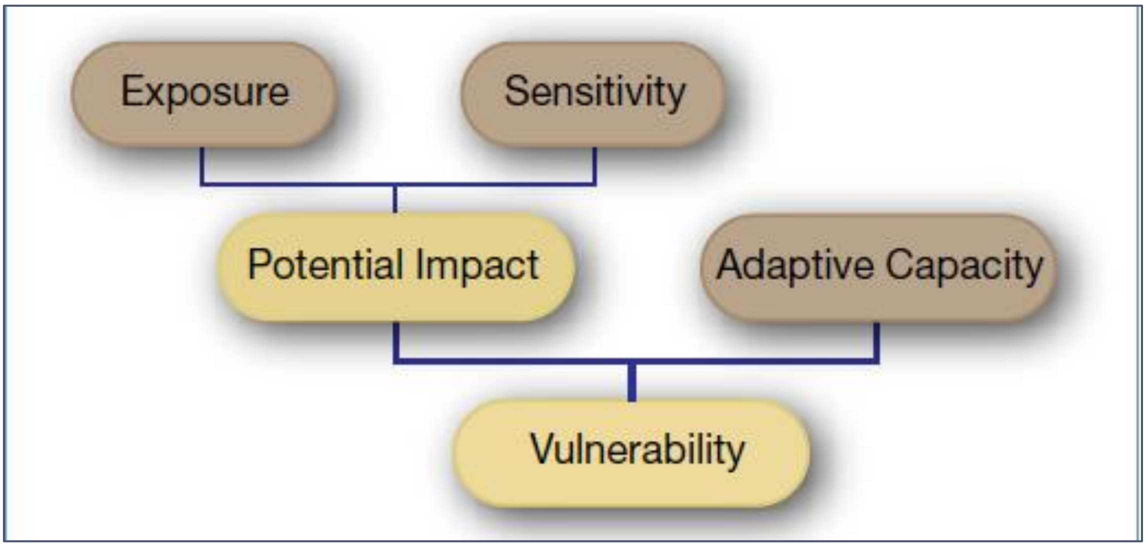

Figure 1 Vulnerability assessment flowchart (Source: Allen Consulting Group 2005 in WAPC 2019)

1.2.1 Exposure

Asset exposure is defined from the erosion hazard likelihood areas which overlap with an asset or land-use for each timeframe. Exposure for each asset or asset group has been assessed as either Not Applicable (N/A) (outside hazard likelihood area), almost certain, possible or rare.

1.2.2 Sensitivity

Sensitivity level reflects the responsiveness of the assets or land uses to the effects of coastal hazards. Sensitive assets are highly responsive to coastal hazard effects (WAPC 2019). The nature of the impact is based on area at risk and the immediacy of the impact. It is also important to understand the thresholds at which an asset begins to exhibit changes in response to coastal hazard effects, which may change sensitivity over time.

A summary of the sensitivity ratings is provided below:

Table 4 Sensitivity rating summary

Sensitivity	Reasoning
Low	Asset use not affected
Medium	Asset use not significantly impacted/is recoverable
High	Asset use impacted, asset can no longer be used

1.2.3 Potential impact

Potential impacts combine level of risk of all potential impacts that may occur to assets due to the effects of coastal hazards with sensitivity and likelihood. Potential impacts correlate to risk level and planned risk management measures are not included in their determination.

Different assets and land uses have varying abilities to respond to coastal hazard risks. The most marked differences are observed between built assets with defined extents that cannot adapt to changes in the coastal environment versus natural assets that have the ability to respond and react to such changes. Therefore, when an asset or value is defined to be within a risk zone, it is important to also understand whether it is vulnerable. Vulnerability is an important metric to consider in the CHRMAP process, as the same risks to different assets or land uses will affect those assets or land uses in different ways. Vulnerability is a function of three overlapping elements: exposure, sensitivity and adaptive capacity of an asset (WAPC 2019).

Table 5 Potential Impact Matrix

Sensitivity / Exposure	Low	Medium	High
Low	Low	Low	Medium
Medium	Low	Medium	High
High	Medium	High	High

Table 6 Vulnerability Matrix

Potential Impact / Adaptive Capacity	Low	Medium	High
High	Low	Low	Medium
Medium	Low	Medium	High
Low	Medium	High	High

1.2.4 Adaptive Capacity

Adaptive capacity is the measure of an assets capacity to adapt in response to erosion or inundation and recover. In the form of a man-made asset, this is normally assessed as the ability for and the cost for the asset to be modified or relocated and if it is designed to be sacrificial or have a short design life. Examples of assets with different adaptive capacities include:

- Wood post and wire fencing is a low-cost asset with a short design life that is easily relocatable and not restricted to a specific location so would be rated as highly adaptive.
- Dune vegetation, which can retreat if the dune field moves inland due to erosion (provided there is adequate land to retreat to) would also be rated as highly adaptive. A thin strip of dune vegetation between the beach and a road may not have the space to adapt to erosion, so would be assessed as low or medium adaptive capacity, depending on the level of constraint.
- A building which cannot be moved and to which erosion would cause structural damage would be have low adaptive capacity.

1.3 Assumptions

There are six assumptions which are fundamental to the outcomes of this CVRA:

1. The seawall was not considered as part of the CHA, however, the vulnerability assessment considers the seawall where appropriate, for example when identifying possible risks in the current term.
2. The community kitchen and playground have been highly valued by the local community in terms of social and recreational values. This area has low adaptive capacity and is therefore vulnerable to erosion hazard.

3. Beach and dune areas have been assumed to have medium sensitivity and high adaptive capacity, with the exception of the beach area adjacent to the jetty which has been assigned medium adaptive capacity (in the medium term) and high adaptive capacity (in the long term) as it is spatially constrained.
4. The Community Recreation Centre and residences are highly sensitive to loss of land and therefore erosion or permanent inundation. They have been assumed to have a low adaptive capacity to erosion, but a medium adaptive capacity to inundation.
5. Residential areas have been considered as approved development.
6. Roads – when considering roads as an asset, this also includes services and typical features included within the road reserve such as footpaths, drainage, water, electricity and communications. The consequence of loss of road reserve considers the broader impacts of the loss of the road reserve including the access they provide.

2. Methodology and Results

2.1 Asset Type and Grouping

Aerial interrogation, town planning scheme maps, cadastre information and a site visit have identified an asset listing for the Horrocks Beach project area. Eight assets have been identified in Planning Area 1 with 25 assets in Planning Area 2 (Figure 2).

Figure 2 Asset mapping within the Horrocks Beach study area

2.2 Erosion

2.2.1 Sensitivity Response

Assets and land uses were classified as having a low to high sensitivity to erosion as described in Section 1.2.2. Sensitivity changes over time for certain assets in response to how the asset can respond to the effects of coastal hazards. For example, a beach may recover to some extent following an erosion event where dunes and foreshore reserve are present, if this buffer disappears, the beach is more sensitive to erosion. Assets such as the boat launches have high sensitivity as their use is impacted and they have no ability to recover from an event.

Table 7 Assets sensitivity to erosion

	Asset #	Asset name	Sensitivity		
			Present Day	2050	2120
Planning Area 1	1	Sandy beach	Medium	Medium	High
	2	Coastal foreshore	Medium	Medium	Medium
	3	Golf course	No impact	No impact	Medium
	4	Beach access tracks	Medium	Medium	High
	5	Rural zoned bushland	No impact	No impact	Medium
	6	Little Bay Road	No impact	No impact	High
	7	Mitchell Street	No impact	No impact	No Impact
	8	Residences on Mitchell Street	No impact	No impact	No impact
Planning Area 2	9	Community centre	No impact	High	High
	10	Tennis courts	No impact	No Impact	High
	11	Caravan park	No impact	No Impact	High
	12	Residential houses	No impact	High	High
	13	Lookout	High	High	High
	14	Boat launch	High	High	High
	15	Foreshore reserve - picnic area	No impact	High	High
	16	Community centre beach	Medium	Medium	High
	17	Seawall	Medium	High	High
	18	Glance Cove	Medium	High	High
	19	Community kitchen	No impact	High	High
	20	Toilet block	High	High	High
	21	Playground	No impact	High	High
	22	BBQ/picnic area	High	High	High
	23	Jetty	Medium	Medium	High
	24	Jetty beach	Medium	Medium	High
	25	Holiday cottages	No impact	No impact	Medium
	26	Coastal path	No impact	High	High
	27	Carpark	No impact	High	High
	28	Revegetation infrastructure	Medium	Medium	High
	29	Boat launch 2	Medium	High	High
	30	Coastal foreshore	Medium	Medium	High
	31	Southern beach	Medium	Medium	High
	32	Universal beach access	High	High	High
	33	Whiting Pool	No impact	Medium	High
	34	Glance Street	No impact	High	High
	35	Glance Street residences	No impact	No impact	High

2.2.2 Erosion Likelihood (Exposure)

In the erosion hazard assessment (see CHA for details), eighteen polygons were generated representing the three likelihood levels at the four different timeframes. To assess the erosion likelihood for each asset, GHD mapped each asset within the Horrocks Beach study area and used judgement to determine level of impact as a result of the erosion hazard scenario. The basis of the erosion likelihood scenarios is detailed in the CHA.

The CVRA uses the results of the CHA assessment within the 2019 (present day), 2050 and 2120 timeframes, the likelihood of erosion was defined by interrogation of assets using aerial photography overlaid with hazard lines from the CHA:

- If any part of the asset was located within the almost certain erosion likelihood polygon, the asset was defined as exposed to an almost certain erosion likelihood.
- If none of the asset was within the almost certain polygon, but any part of the asset was located within the possible erosion likelihood polygon, the asset was defined as exposed to a possible erosion likelihood.
- If none of the asset was within the almost certain or possible polygons, but any part of the asset was located within the rare erosion likelihood polygon, the asset was defined as exposed to a rare erosion likelihood.
- If the asset was landward of all the erosion polygons, it was defined as not exposed to erosion.

The erosion likelihood for each asset is summarised in Figure 3 and incorporated in the risk assessment to calculate asset vulnerability and tolerance to erosion risk presented in Section 2.2.6.

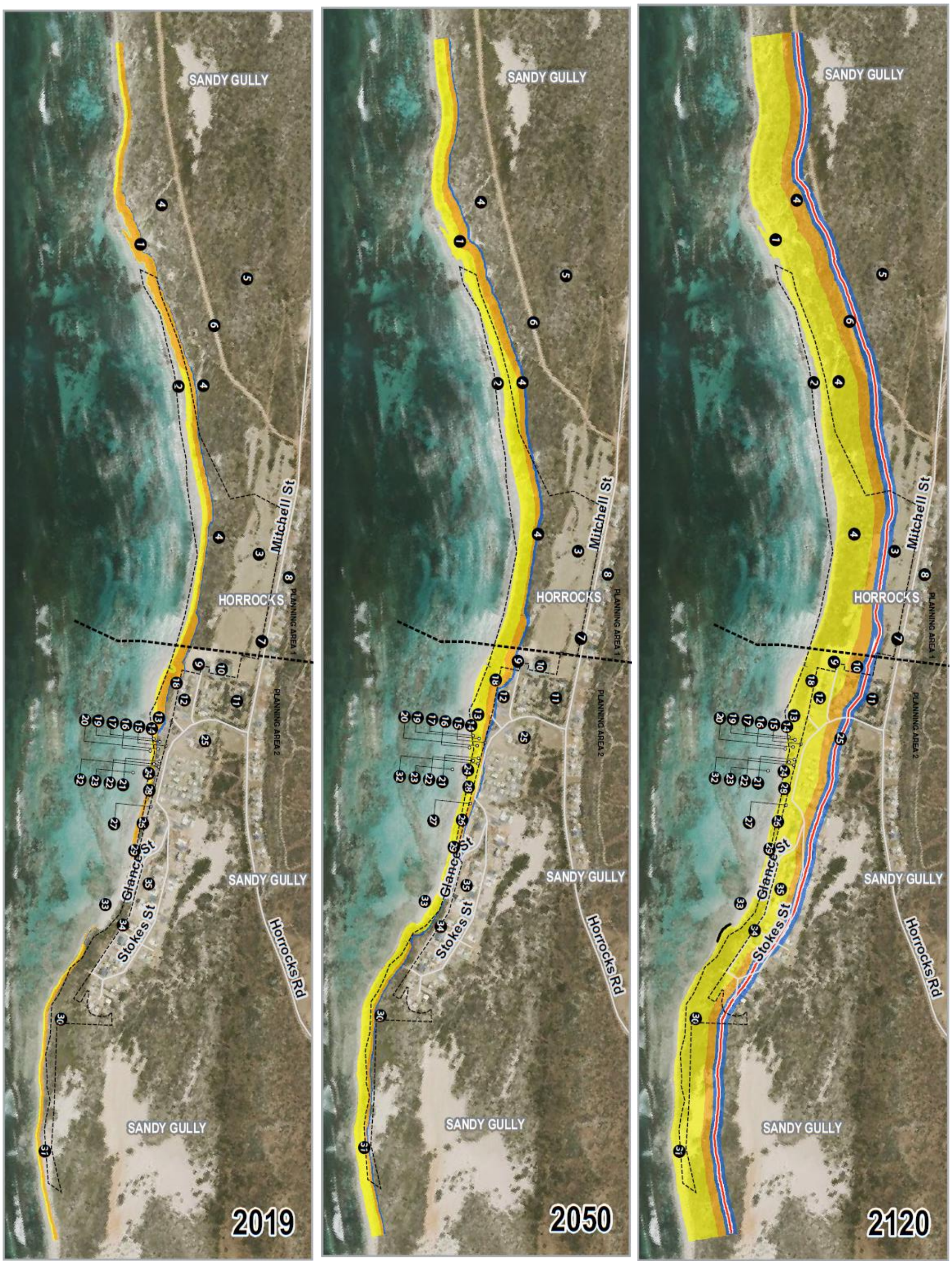

Figure 3 Erosion likelihoods over time (GHD, 2019) (for asset legend, refer to Figure 2)

2.2.3 Potential Impacts

Using the likelihood of erosion and the sensitivity of those assets to erosion, potential impact on assets identified has been established for each timeframe within the CVRA. As potential impacts correlate to risk levels (WAPC, 2019), existing risk management measures such as the seawall in front of the community kitchen have not been included as there is no guarantee that it will remain in place over the planning timeframe (discussed further in Section 2.2.6). Potential impacts of erosion are presented in Table 8.

Table 8 Potential impact of erosion to identified assets in Horrocks Beach

	Asset #	Asset name	Potential impacts from erosion risk		
			Present Day	2050	2120
Planning Area 1	1	Sandy beach	High	High	High
	2	Coastal foreshore	Medium	Medium	High
	3	Golf course	No impact	No impact	Medium
	4	Beach access tracks	Medium	Medium	High
	5	Rural zoned bushland	No impact	No impact	Medium
	6	Little Bay Road	No impact	No impact	High
	7	Mitchell Street	No impact	No impact	No Impact
	8	Residences on Mitchell Street	No impact	No impact	No impact
Planning Area 2	9	Community centre	No impact	Medium	High
	10	Tennis courts	No impact	No Impact	High
	11	Caravan park	No impact	No Impact	High
	12	Residential houses	No impact	High	High
	13	Lookout	High	High	High
	14	Boat launch	High	High	High
	15	Foreshore reserve - picnic area	No impact	High	High
	16	Community centre beach	Medium	High	High
	17	Seawall	Medium	High	High
	18	Glance Cove	Medium	High	High
	19	Community kitchen	High	High	High
	20	Toilet block	Medium	High	High
	21	Playground	No impact	High	High
	22	BBQ/picnic area	High	High	High
	23	Jetty	High	High	High
	24	Jetty beach	High	High	High
	25	Holiday cottages	No impact	No Impact	Medium
	26	Coastal path	No impact	High	High
	27	Carpark	No impact	High	High
	28	Revegetation infrastructure	Medium	High	High
	29	Boat ramp 2	Medium	High	High
	30	Coastal foreshore	Medium	High	High
	31	Southern beach	High	High	High
	32	Universal beach access	High	High	High
	33	Whiting Pool	No impact	High	High
	34	Glance Street	No impact	High	High
	35	Glance Street residences	No impact	High	High

2.2.4 Adaptive Capacity

Adaptive capacity (refer to section 1.2.4) of different asset types to erosion was determined by based on the nature of the asset and a judgement of how it would respond to the erosion hazard. A high adaptive capacity means that the asset is either able to respond to erosion by itself or with a low-cost intervention. An asset with a low adaptive capacity means that it is unable to change by itself in response to erosion hazard or would require significant costs and intervention to do so.

Adaptive capacity for assets within the Horrocks Beach study area are presented in Table 9. Adaptive capacity of an asset may change over time. For example the coastal foreshore to the north of the study area is comprised of vegetated dunes – in the short-term there is natural capacity to adjust and recover from erosion events resulting in a "high" adaptive capacity rating in the present day. However, by 2120, the adaptive capacity is reduced to "low" as it is expected that erosion events will have reduced the width of the foreshore reserve, limiting the ability to recover without encroaching onto land zoned for rural use.

Table 9 Adaptive Capacity to Erosion over time

	Asset #	Asset name	Adaptive capacity		
			Present Day	2050	2120
Planning Area 1	1	Sandy beach	High	High	Low
	2	Coastal foreshore	High	High	Low
	3	Golf course	No impact	No impact	Medium
	4	Beach access tracks	Medium	Medium	Low
	5	Rural zoned bushland	No impact	No impact	Low
	6	Little Bay Road	No impact	No impact	Low
	7	Mitchell Street	No impact	No impact	No Impact
	8	Residences on Mitchell Street	No impact	No impact	No impact
Planning Area 2	9	Community centre	No impact	Low	Low
	10	Tennis courts	No impact	No Impact	Low
	11	Caravan park	No impact	No Impact	Medium
	12	Residential houses	No impact	Low	Low
	13	Lookout	Low	Low	Low
	14	Boat launch	Low	Low	Low
	15	Foreshore reserve - picnic area	No impact	Medium	Low
	16	Community centre beach	Medium	Medium	Medium
	17	Seawall	Medium	Medium	Medium
	18	Glance Cove	Low	Low	Low
	19	Community kitchen	No impact	Medium	Low
	20	Toilet block	Medium	Medium	Low
	21	Playground	No impact	Medium	Medium
	22	BBQ/picnic area	Low	Low	Low
	23	Jetty	Low	Low	Low
	24	Jetty beach	Medium	Medium	Low
	25	Holiday cottages	No impact	No impact	Medium
	26	Coastal path	No impact	Medium	Low
	27	Carpark	No impact	Medium	Low
	28	Revegetation infrastructure	Medium	Medium	Medium
	29	Boat launch 2	Low	Low	Low
	30	Coastal foreshore	High	High	High
	31	Southern beach	High	High	Low
	32	Universal beach access	Medium	Medium	Low
	33	Whiting Pool	No impact	Medium	Low
	34	Glance Street	No impact	Low	Low
	35	Glance Street residences	No impact	Low	Low

2.2.5 Consequences

The consequence scale in Table 2 details the criteria used to assign consequence in this vulnerability and risk assessment.

The social consequence scale was defined through the results of the community values survey (see section 3 of the overarching CHRMAP document). The importance of social values in a particular place were measured by two key elements – access and impact. The impact that value/experience has on someone's quality or way of life, and their ability to access that value/experience.

Access

- Very important – cannot be conveniently accessed elsewhere;
- Somewhat important – can be conveniently accessed elsewhere, but with a preference to access it in this location; and
- Not important – can conveniently accessed elsewhere.

Impact

- Very important (significant impact) – the loss of the value/experience would significantly impair my way of life;
- Somewhat important (some impact) – the loss of the value/experience would impair my way of life, but I could live without it; and
- Not important (negligible impact) – the loss of the value/experience would not impair my way of life.

To undertake the risk assessment, a consequence level was selected for each asset in the assessment area affected by coastal hazards. For most consequence types, this definition was quantifiable. For social values, the consequence level was determined based on the effect on access and impact which was informed by the values survey. The consequence assigned to each of the assets at each timeframe is presented in the results section of this report (Section 2.4).

Table 10 Erosion Consequences to Identified Assets

	Name	Associated values	Consequence of Erosion)		
			Present Day	2050	2120
Planning Area 1	Sandy beach	Social, environmental, potential economic (tourism)	Insignificant	Insignificant	Major
	Coastal foreshore	Environmental	Insignificant	Insignificant	Major
	Golf course	Social, potential economic (tourism)	Not impacted	Not impacted	Moderate
	Beach access tracks	Social, potential economic (tourism)	Insignificant	Insignificant	Moderate
	Rural zoned bushland	Environmental	Not impacted	Not impacted	Moderate
	Little Bay Road	Infrastructure	Not impacted	Not impacted	Moderate
	Mitchell Street	Infrastructure	Not impacted	Not impacted	Not impacted
	Residences on Mitchell Street	Social, economic	Not impacted	Not impacted	Not impacted

	Name	Associated values	Consequence of Erosion)		
			Present Day	2050	2120
Planning Area	Community centre	Social, economic	Not impacted	Moderate	Major
	Tennis courts	Social, economic	Not impacted	Not impacted	Major
	Caravan park	Social, economic	Not impacted	Not impacted	Moderate
	Residential houses	Social, economic	Not impacted	Moderate	Catastrophic
	Lookout	Social, economic	Insignificant	Insignificant	Minor
	Boat ramp	Social, economic	Minor	Moderate	Major
	Foreshore reserve - picnic area	Social, economic	Not impacted	Moderate	Moderate
	Community centre beach	Social, economic, environmental	Minor	Minor	Moderate
	Seawall	Infrastructure	Moderate	Moderate	Moderate
	Glance Cove	Infrastructure	Minor	Minor	Major
	Community kitchen	Social, economic	Not impacted	Moderate	Moderate
	Toilet block	Social, economic	Minor	Minor	Moderate
	Playground	Social, economic	Not impacted	Minor	Moderate
	BBQ/picnic area	Social, economic	Insignificant	Insignificant	Moderate
	Jetty	Social, economic	Not impacted	Not impacted	Moderate
	Jetty beach	Social, economic, environmental	Insignificant	Moderate	Moderate
	Holiday cottages	Economic	Not impacted	Not impacted	Major
	Coastal path	Social, economic	Not impacted	Minor	Moderate
	Carpark	Social, economic	Not impacted	Minor	Major
	Revegetation infrastructure	Environmental	Minor	Minor	Minor
	Boat ramp 2	Social, economic	Minor	Minor	Moderate
	Coastal foreshore	Environmental	Insignificant	Insignificant	Moderate
	Southern beach	Social, environmental	Insignificant	Insignificant	Moderate
	Universal beach access	Social	Moderate	Moderate	Moderate
	Whiting Pool	Social, environmental	Not impacted	Insignificant	Moderate
	Glance Street	Infrastructure	Not impacted	Moderate	Major
	Glance Street residences	Social, economic	Not impacted	Moderate	Catastrophic

2.2.6 Asset Vulnerability and Erosion Tolerance

As discussed in Section 1.1.4, erosion tolerability is determined by the product of erosion risk and erosion vulnerability, refer Table 11.

Table 11 Erosion tolerance matrix

Risk Level \ Vulnerability	Low	Medium	High
Low	Acceptable	Acceptable	Tolerable
Medium	Acceptable	Tolerable	Intolerable
High	Tolerable	Intolerable	Intolerable
Extreme	Tolerable	Intolerable	Intolerable

Erosion tolerance has been calculated for each asset in the study area. Action required to reduce risk is then determined using the scale provided in Section 1.1.4.

In the immediate planning timeframe, assets identified as being at intolerable risk through the application of the vulnerability assessment include:

- Boat launch
- Glance Cove (road infrastructure)
- Boat launch 2
- Universal access path

These are the assets that are identified as requiring immediate action to reduce risk to acceptable levels. The two boat launches are actively managed by the Shire which reduces risks to these assets to acceptable levels.

The risk tolerance to the universal access path is intolerable due to lack of an alternative, however, in reality active management will only be required if the asset is damaged, which should be undertaken immediately if it can no longer be used safely.

Discussions with the Shire suggest that the sensitivity to erosion in the present term associated with the seawall is medium. As the impact of erosion increases over time, the sensitivity (or ability of the seawall to withstand the events) reduces, increasing sensitivity. This alters the tolerance of this to erosion over time – in the present term risks are tolerable but by 2050, they have become intolerable.

In the medium and long term many assets are at intolerable risk from erosion. The adaptation options relating to this are discussed in the CHRMAP report.

Table 12 Erosion risk tolerance for Horrocks assets

	Name	2019			2050			2120		
		Vulnerability	Risk level	Tolerance	Vulnerability	Risk level	Tolerance	Vulnerability	Risk level	Tolerance
Planning Area 1	Sandy beach	Medium	Medium	Tolerable	Medium	Medium	Tolerable	Medium	Extreme	Intolerable
	Coastal foreshore	Low	Low	Acceptable	Low	Low	Acceptable	Low	Extreme	Intolerable
	Golf course	No impact	No impact	No impact	No impact	No impact	No impact	No impact	High	Intolerable
	Beach access tracks	Medium	Low	Acceptable	Medium	Low	Acceptable	Medium	High	Intolerable
	Rural zoned bushland	No impact	No impact	No impact	No impact	No impact	No impact	No impact	High	Intolerable
	Little Bay Road	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
	Mitchell Street	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
	Residences on Mitchell Street	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
Planning Area 2	Community centre	No impact	No impact	No impact	High	Medium	Intolerable	High	Extreme	Intolerable
	Tennis courts	No impact	No impact	No impact	No impact	No Impact	No impact	High	Extreme	Intolerable
	Caravan park	No impact	No impact	No impact	No impact	No Impact	No impact	High	High	Intolerable
	Residential houses	No impact	No impact	No impact	High	High	Intolerable	High	Extreme	Intolerable
	Lookout	High	Low	Tolerable	High	Medium	Intolerable	High	High	Intolerable
	Boat launch	High	High	Intolerable	High	High	Intolerable	High	Extreme	Intolerable
	Foreshore reserve - picnic area	No impact	No impact	No impact	High	High	Intolerable	High	High	Intolerable
	Community centre beach	Medium	Medium	Tolerable	High	High	Intolerable	High	High	Intolerable
	Seawall	High	Medium	Tolerable*	High	High	Intolerable	High	High	Intolerable
	Glance Cove	High	Medium	Intolerable	High	Medium	Intolerable	High	Extreme	Intolerable
	Community kitchen	No impact	No impact	No impact	High	High	Intolerable	High	High	Intolerable

	Name	2019			2050			2120		
		Vulnerability	Risk level	Tolerance	Vulnerability	Risk level	Tolerance	Vulnerability	Risk level	Tolerance
	Toilet block	High	Low	Tolerable	High	High	Intolerable	High	High	Intolerable
	Playground	No impact	No impact	No impact	High	High	Intolerable	High	High	Intolerable
	BBQ/picnic area	High	Low	Tolerable	High	Medium	Intolerable	High	High	Intolerable
	Jetty	High	No impact	No impact	No impact	No Impact	No impact	High	High	Intolerable
	Jetty beach	High	Medium	Intolerable	High	High	Intolerable	High	High	Intolerable
	Holiday cottages	No impact	No impact	No impact	No impact	No Impact	No impact	Medium	High	Intolerable
	Coastal path	No impact	No impact	No impact	High	High	Intolerable	High	High	Intolerable
	Carpark	No impact	No impact	No impact	High	Medium	Intolerable	High	Extreme	Intolerable
	Revegetation infrastructure	Medium	Medium	Tolerable	High	High	Intolerable	High	High	Intolerable
	Boat launch 2	High	Medium	Intolerable	High	High	Intolerable	High	High	Intolerable
	Coastal foreshore	Low	Low	Acceptable	Medium	Medium	Tolerable	Medium	High	Intolerable
	Southern beach	Medium	Medium	Tolerable	Medium	Medium	Tolerable	High	High	Intolerable
	Universal beach access	High	High	Intolerable	High	High	Intolerable	High	High	Intolerable
	Whiting Pool	No impact	No impact	No impact	High	Medium	Intolerable	High	High	Intolerable
	Glance Street	No impact	No impact	No impact	High	High	Intolerable	High	Extreme	Intolerable
	Glance Street residences	No impact	No impact	No impact	High	High	Intolerable	High	No Impact	Intolerable

* Manual adjustment to allow for Shire's tolerance to current risks

2.3 Inundation

2.3.1 Sensitivity Response

Assets and land uses were classified as having a low to high sensitivity (as described in Section 1.2.2) to inundation. Unlike with sensitivity to erosion, the sensitivity responses are constant over time as the sensitivity of response is independent of exposure/likelihood. It therefore remains consistent across the planning timeframes.

Table 13 Asset sensitivity to inundation

	Asset #	Asset name	Sensitivity		
			Present Day	2050	2120
Planning Area 1	1	Sandy beach	Low	Low	Low
	2	Coastal foreshore	Low	Low	Low
	3	Golf course	No impact	No impact	No impact
	4	Beach access tracks	Low	Low	Low
	5	Rural zoned bushland	Low	Low	Low
	6	Little Bay Road	Medium	Medium	Medium
	7	Mitchell Street	No impact	No impact	No Impact
	8	Residences on Mitchell Street	No impact	No impact	No impact
Planning Area 2	9	Community centre	No impact	No impact	No impact
	10	Tennis courts	No impact	No impact	No impact
	11	Caravan park	No impact	No impact	No impact
	12	Residential houses	High	High	High
	13	Lookout	No impact	No impact	No impact
	14	Boat launch	Low	Low	Low
	15	Foreshore reserve - picnic area	Medium	Medium	Medium
	16	Community centre beach	Low	Low	Low
	17	Seawall	Medium	Medium	Medium
	18	Glance Cove	Medium	Medium	Medium
	19	Community kitchen	Medium	Medium	Medium
	20	Toilet block	Medium	Medium	Medium
	21	Playground	No impact	No impact	No impact
	22	BBQ/picnic area	Medium	Medium	Medium
	23	Jetty	No impact	No impact	No impact
	24	Jetty beach	Low	Low	Low
	25	Holiday cottages	No impact	No impact	No impact
	26	Coastal path	Medium	Medium	Medium
	27	Carpark	Medium	Medium	Medium
	28	Revegetation infrastructure	Medium	Medium	Medium
	29	Boat launch 2	Low	Low	Low
	30	Coastal foreshore	Low	Low	Low
	31	Southern beach	Low	Low	Low
	32	Universal beach access	Medium	Medium	Medium
	33	Whiting Pool	Low	Low	Low
	34	Glance Street	High	High	High

	35	Glance Street residences	High	High	High

2.3.2 Inundation Likelihood

The CHA identified a consistent water level at each of the three likelihoods (almost certain, possible or rare) across the entire assessment area. The identified water level for each likelihood has been applied for each planning timeframe (Present Day (2018), 2030, 2070 and 2120) for each section of the CHRMAP area.

The inundation levels are up to +3.6 mAHD today, and are predicted to increase to up to +3.7 mAHD in 2030, up to +3.8 mAHD in 2050, up to +4.1 mAHD in 2070, up to +4.3 mAHD in 2090 and up to +4.8 mAHD in 2120 as presented below (Table 14).

This vulnerability and risk assessment applied the same inundation levels as the hazard maps in the CHA to the 2019, 2050 and 2120 planning timeframes (Figure 4). Polygons of the inundation likelihood areas were derived as part of the hazard mapping during the CHA. The likelihood of inundation of each asset for each timeframe was determined by interrogating aerial photography and determining the overlap between the inundation likelihood polygons and each asset through visual assessment.

Table 14 S4 Inundation levels for Horrocks Beach (m AHD) (GHD, 2019)

Likelihood	2018 (Present Day)	2030	2050	2070	2090	2120
Almost Certain	+1.6	+1.7	+1.8	+1.9	+2.1	+2.3
Possible	+1.8	+1.9	+2.0	+2.2	+2.4	+2.7
Rare	+3.6	+3.7	+3.8	+4.1	+4.3	+4.8

2.3.3 Potential impacts

Using the likelihood of inundation and the sensitivity of those assets to inundation, potential impact on assets identified has been established for each timeframe within the CVRA. As potential impacts correlate to risk levels (WAPC, 2019), existing risk management measures have not been included. Potential impacts of erosion are presented in Table 15.

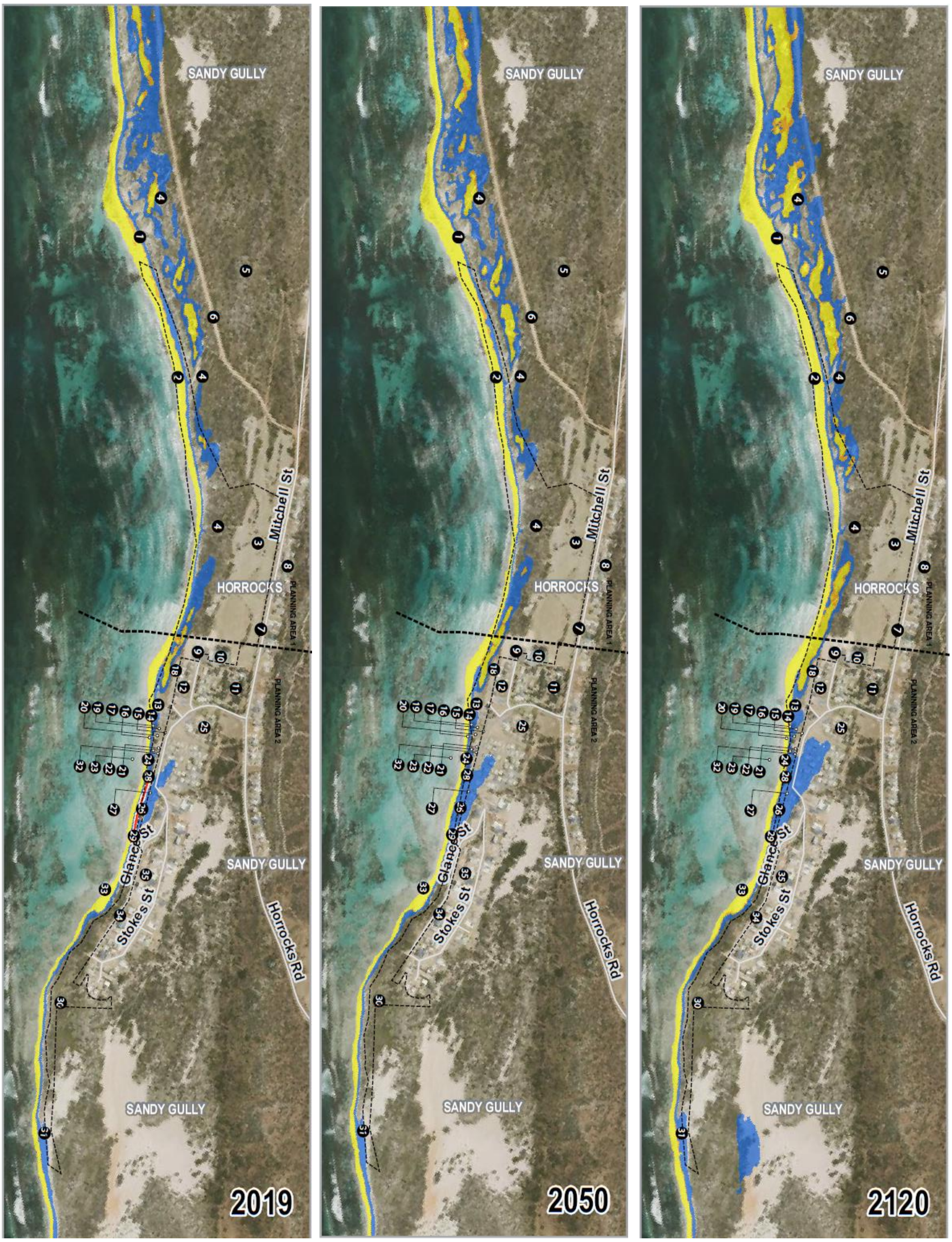

Figure 4 Inundation likelihood over time (GHD, 2019) (for asset legend, refer to Figure 2)

Table 15 Potential impact of inundation to identified assets in Horrocks Beach

	Asset #	Asset name	Potential impacts from inundation risk		
			Present Day	2050	2120
Planning Area 1	1	Sandy beach	Medium	Medium	Medium
	2	Coastal foreshore	Medium	Medium	Medium
	3	Golf course	No impact	No impact	No impact
	4	Beach access tracks	Medium	Medium	Medium
	5	Rural zoned bushland	Medium	Medium	Medium
	6	Little Bay Road	Low	Low	Low
	7	Mitchell Street	No impact	No impact	No Impact
	8	Residences on Mitchell Street	No impact	No impact	No impact
Planning Area 2	9	Community centre	No impact	No impact	No impact
	10	Tennis courts	No impact	No Impact	No Impact
	11	Caravan park	No impact	No Impact	No Impact
	12	Residential houses	Medium	Medium	Medium
	13	Lookout	No impact	No impact	No impact
	14	Boat launch	Medium	Medium	Medium
	15	Foreshore reserve - picnic area	Low	Low	Low
	16	Community centre beach	Low	Low	Medium
	17	Seawall	Low	Low	Medium
	18	Glance Cove	Low	Low	Low
	19	Community kitchen	No impact	No impact	Low
	20	Toilet block	Low	Low	Low
	21	Playground	No impact	No impact	No impact
	22	BBQ/picnic area	Low	Low	Low
	23	Jetty	No impact	No impact	No impact
	24	Jetty beach	Medium	Medium	Medium
	25	Holiday cottages	No impact	No impact	No impact
	26	Coastal path	Low	Low	Low
	27	Carpark	Low	Low	Low
	28	Revegetation infrastructure	Low	Low	High
	29	Boat ramp 2	Medium	Medium	Medium
	30	Coastal foreshore	Medium	Medium	Medium
	31	Southern beach	Medium	Medium	Medium
	32	Universal beach access	Low	Low	Medium
	33	Whiting Pool	Medium	Medium	Medium
	34	Glance Street	Medium	Medium	Medium
	35	Glance Street residences	Medium	Medium	Medium

2.3.4 Adaptive capacity

Adaptive capacity of different asset types to inundation was based on the nature of the asset and a judgement of how it would respond to the inundation hazard. A high adaptive capacity means that the asset is either able to respond to inundation by itself or with a low cost intervention. An asset with a low adaptive capacity means that it is unable to change by itself in response to inundation hazard or would require significant costs and/or intervention to do so.

The adaptive capacity of an asset or land use may be different for erosion and inundation. An example of an asset with high adaptive capacity to inundation in the Horrocks Beach study area are the beaches. The beach may become inundated during certain events but will recover as water recedes. Residential houses have a medium adaptive capacity to inundation as although they may flood in certain events, the impacts are unlikely to permanently alter the use of the building. Adaptive capacity to inundation for assets within the Horrocks Beach study area are presented in Table 16.

Table 16 Adaptive Capacity of assets to Inundation

	Asset #	Asset name	Adaptive capacity		
			Present Day	2050	2120
Planning Area 1	1	Sandy beach	High	High	Low
	2	Coastal foreshore	High	High	Low
	3	Golf course	No impact	No impact	Medium
	4	Beach access tracks	Medium	Medium	Low
	5	Rural zoned bushland	High	High	Low
	6	Little Bay Road	Medium	Medium	Low
	7	Mitchell Street	No impact	No impact	No Impact
	8	Residences on Mitchell Street	No impact	No impact	No impact
Planning Area 2	9	Community centre	No impact	No impact	No impact
	10	Tennis courts	No impact	No impact	No impact
	11	Caravan park	No impact	No impact	No impact
	12	Residential houses	Medium	Medium	Medium
	13	Lookout	No impact	No impact	No impact
	14	Boat launch	High	Medium	Medium
	15	Foreshore reserve - picnic area	Medium	Medium	Medium
	16	Community centre beach	High	High	High
	17	Seawall	Medium	Medium	Medium
	18	Glance Cove	Medium	Medium	Medium
	19	Community kitchen	Medium	Medium	Medium
	20	Toilet block	Medium	Medium	Medium
	21	Playground	No impact	No impact	No impact
	22	BBQ/picnic area	Medium	Medium	Medium
	23	Jetty	No impact	No impact	No impact
	24	Jetty beach	High	High	High
	25	Holiday cottages	No impact	No impact	No impact
	26	Coastal path	High	High	High
	27	Carpark	High	High	High
	28	Revegetation infrastructure	High	High	High
	29	Boat launch 2	High	Medium	Medium
	30	Coastal foreshore	High	High	High
	31	Southern beach	High	High	High
	32	Universal beach access	High	High	High
	33	Whiting Pool	High	High	High
	34	Glance Street	Medium	Medium	Medium
	35	Glance Street residences	Medium	Medium	Medium

2.3.5 Consequences

The consequence of inundation was rated in a similar matter to erosion i.e., from insignificant to catastrophic for the each value type identified e.g. social & heritage, economic and environmental. The consequences of inundation were rated on the basis of asset types and impacted values with details summarised in Table 17. Where an asset has varying consequence levels to more than one value, the value with the highest consequence was selected.

Consequence levels assigned for each time period were dependent upon whether the asset was impacted temporarily (possible or rare likelihood) or regularly (almost certain likelihood) by inundation.

Table 17 Consequences of Inundation to Assets

	Name	Associated values	Consequence of Inundation		
			Present Day	2050	2120
Planning Area 1	Sandy beach	Social, environmental, potential economic (tourism)	Insignificant	Insignificant	Insignificant
	Coastal foreshore	Environmental	Insignificant	Insignificant	Insignificant
	Golf course	Social, potential economic (tourism)	Not impacted	Not impacted	Not impacted
	Beach access tracks	Social, potential economic (tourism)	Insignificant	Insignificant	Insignificant
	Rural zoned bushland	Environmental	Insignificant	Insignificant	Insignificant
	Little Bay Road	Infrastructure	Insignificant	Insignificant	Insignificant
	Mitchell Street	Infrastructure	Not impacted	Not impacted	Not impacted
	Residences on Mitchell Street	Social, economic	Not impacted	Not impacted	Not impacted
Planning Area	Community centre	Social, economic	Not impacted	Not impacted	Not impacted
	Tennis courts	Social, economic	Not impacted	Not impacted	Not impacted
	Caravan park	Social, economic	Not impacted	Not impacted	Not impacted
	Residential houses	Social, economic	Minor	Minor	Minor
	Lookout	Social, economic	Not impacted	Not impacted	Not impacted
	Boat ramp	Social, economic	Insignificant	Insignificant	Insignificant
	Foreshore reserve - picnic area	Social, economic	Insignificant	Insignificant	Insignificant
	Community centre beach	Social, economic, environmental	Insignificant	Insignificant	Insignificant
	Seawall	Infrastructure	Insignificant	Insignificant	Insignificant
	Glance Cove	Infrastructure	Insignificant	Insignificant	Insignificant
	Community kitchen	Social, economic	Insignificant	Insignificant	Insignificant
	Toilet block	Social, economic	Insignificant	Insignificant	Insignificant

	Name	Associated values	Consequence of Inundation		
			Present Day	2050	2120
	Playground	Social, economic	Not impacted	Not impacted	Not impacted
	BBQ/picnic area	Social, economic	Minor	Minor	Minor
	Jetty	Social, economic	Not impacted	Not impacted	Not impacted
	Jetty beach	Social, economic, environmental	Insignificant	Insignificant	Insignificant
	Holiday cottages	Economic	Not impacted	Not impacted	Not impacted
	Coastal path	Social, economic	Insignificant	Insignificant	Insignificant
	Carpark	Social, economic	Insignificant	Insignificant	Insignificant
	Revegetation infrastructure	Environmental	Insignificant	Insignificant	Insignificant
	Boat ramp 2	Social, economic	Insignificant	Insignificant	Insignificant
	Coastal foreshore	Environmental	Insignificant	Insignificant	Insignificant
	Southern beach	Social, environmental	Insignificant	Insignificant	Insignificant
	Universal beach access	Social	Insignificant	Insignificant	Insignificant
	Whiting Pool	Social, environmental	Insignificant	Insignificant	Insignificant
	Glance Street	Infrastructure	Minor	Minor	Minor
	Glance Street residences	Social, economic	Minor	Minor	Minor

2.3.6 Inundation Risk and Tolerance

The calculation of the risk level to an asset or land used is the product of "likelihood" of a coastal inundation hazard impacting an asset or land use and the "consequence" of that impact. Different assets and land uses support different values which trigger appropriate risk levels as determined by the risk matrix. The inundation risk of each asset can be determined by the same risk assessment matrix as erosion (refer Table 1).

Asset tolerance to inundation is determined by the product of inundation risk and adaptive capacity (Table 18).

Table 18 Inundation tolerance matrix

Adaptive Capacity / Risk Level	Low	Medium	High
Low	Tolerable	Acceptable	Acceptable
Medium	Intolerable	Tolerable	Acceptable
High	Intolerable	Intolerable	Tolerable
Extreme	Intolerable	Intolerable	Tolerable

Inundation tolerance has been calculated for each asset in the study area. Action required to reduce risk is then determined using the scale provided in Section 1.1.4.

Table 19 Inundation risk tolerance for Horrocks assets

	Name	2019			2050			2120		
		Adaptive capacity	Risk level	Tolerance	Adaptive capacity	Risk level	Tolerance	Adaptive capacity	Risk level	Tolerance
Planning Area 1	Sandy beach	High	Medium	Acceptable	High	Medium	Acceptable	Low	Medium	Acceptable
	Coastal foreshore	High	Medium	Acceptable	High	Medium	Acceptable	Low	Medium	Acceptable
	Golf course	No impact	No impact	No impact	No impact	No impact	No impact	Medium	No impact	No impact
	Beach access tracks	Medium	Medium	Tolerable	Medium	Medium	Tolerable	Low	Medium	Tolerable
	Rural zoned bushland	High	Medium	Acceptable	High	Medium	Acceptable	Low	Medium	Acceptable
	Little Bay Road	Medium	Low	Acceptable	Medium	Low	Acceptable	Low	Low	Acceptable
	Mitchell Street	No impact	No impact	No impact	No impact	No impact	No impact	No Impact	No impact	No impact
	Residences on Mitchell Street	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
Planning Area 2	Community centre	No impact	No Impact	No Impact	No impact	No Impact	No Impact	No impact	No Impact	No Impact
	Tennis courts	No impact	No Impact	No Impact	No impact	No Impact	No Impact	No impact	No Impact	No Impact
	Caravan park	No impact	No Impact	No Impact	No impact	No Impact	No Impact	No impact	No Impact	No Impact
	Residential houses	Medium	Low	Acceptable	Medium	Low	Acceptable	Medium	Low	Acceptable
	Lookout	No impact	No Impact	No Impact	No impact	No Impact	No Impact	No impact	No Impact	No Impact
	Boat launch	High	Medium	Acceptable	Medium	Medium	Acceptable	Medium	Medium	Tolerable
	Foreshore reserve - picnic area	Medium	Low	Acceptable	Medium	Low	Acceptable	Medium	Low	Acceptable
	Community centre beach	High	Medium	Acceptable	High	Medium	Acceptable	High	Medium	Acceptable
	Seawall	Medium	Low	Acceptable	Medium	Low	Acceptable	Medium	Low	Acceptable
	Glance Cove	Medium	Low	Acceptable	Medium	Low	Acceptable	Medium	No Impact	No Impact

	Name	2019			2050			2120		
		Adaptive capacity	Risk level	Tolerance	Adaptive capacity	Risk level	Tolerance	Adaptive capacity	Risk level	Tolerance
	Community kitchen	Medium	Low	Acceptable	Medium	Low	Acceptable	Medium	Low	Acceptable
	Toilet block	Medium	Low	Acceptable	Medium	Low	Acceptable	Medium	Low	Acceptable
	Playground	No impact	No Impact	No Impact	No impact	No Impact	No Impact	No impact	No Impact	No Impact
	BBQ/picnic area	Medium	Low	Acceptable	Medium	Low	Acceptable	Medium	Low	Acceptable
	Jetty	No impact	No Impact	No Impact	No impact	No Impact	No Impact	No impact	No Impact	No Impact
	Jetty beach	High	Moderate	Acceptable	High	Moderate	Acceptable	High	Medium	Acceptable
	Holiday cottages	No impact	No Impact	No Impact	No impact	No Impact	No Impact	No impact	No Impact	No Impact
	Coastal path	High	Low	Acceptable	High	Low	Acceptable	High	Low	Acceptable
	Carpark	High	Low	Acceptable	High	Low	Acceptable	High	Low	Acceptable
	Revegetation infrastructure	High	Low	Acceptable	High	Low	Acceptable	High	Medium	Tolerable
	Boat launch 2	High	Medium	Acceptable	Medium	Medium	Acceptable	Medium	Medium	Tolerable
	Coastal foreshore	High	Medium	Acceptable	High	Medium	Acceptable	High	Medium	Acceptable
	Southern beach	High	Medium	Acceptable	High	Medium	Acceptable	High	Medium	Acceptable
	Universal beach access	High	Low	Acceptable	High	Low	Acceptable	High	Low	Acceptable
	Whiting Pool	High	Medium	Acceptable	High	Medium	Acceptable	High	Medium	Acceptable
	Glance Street	Medium	Low	Acceptable	Medium	Low	Acceptable	Medium	Low	Acceptable
	Glance Street residences	Medium	Low	Acceptable	Medium	Low	Acceptable	Medium	Low	Acceptable

2.4 Summary of Results

Detailed results presented in Section 2 indicate that there are no risks from inundation that are intolerable in the immediate, medium or long term. For example, Glance Street and associated housing is known to flood in rare events currently, impacts of flooding are managed once flood waters retreat.

There are, however, intolerable risks from erosion in the immediate (2019), medium (2050) and long term (2120) and this should be the focus of adaptive planning and risk treatment options. This will be presented as part of the overall CHRMAP document.

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Appendix E - Evaluation of Adaptation Options

Shire of Northampton

Horrocks Beach CHRMAP
Adaptation Options Assessment

October 2020

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Appendices

1. Introduction

1.1 Purpose of this Report

This document is to be read in conjunction with the Horrocks Beach Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) and is not a standalone report. The purpose of this report is to assess the adaptation options identified in the CHRMAP and develop a coastal adaptation plan for Horrocks Beach. The adaptation options have been assessed against their respective benefits and impacts to social, environmental and economical values and services.

1.2 Multi Criteria Analysis (MCA) Process overview

The following Multi Criteria Analysis (MCA) process and methodology has been informed by the Department for Communities and Local Government: London (2009) and was used when developing the MCA process for this project:

1. Establish the decision context
   - Define the project objectives
   - Establish aims of the MCA Process
   - Develop the socio-technical system
   - Define the context of the appraisal
2. Identify the options to be appraised
3. Identify the objectives and criteria
   - Identify criteria for assessing the consequences of each option
4. 'Weight' the criteria to reflect their relative importance to the decision
5. 'Score' each option in respect of each criteria.
6. Combine the scores and weights to derive an overall weighted score and rank the options and
7. Sensitivity testing – Assessing how sensitive the final scoring or ranking of the options is to changes in the weightings assigned to the criteria.

A key understanding required of the outcomes of the MCA process is that the MCA does not necessarily include an assessment of feasibility. Thus the options taken through an MCA process must be adequately developed and refined, possibly through multiple MCA rounds to identify the preferred ranking of the options.

1.3 Limitations of the MCA Process

The MCA process is a tool to building a model of different options and criteria when the number of options and criteria is beyond what we can easily assess in our heads. MCA is a tool to help us simplify the complex issues of assessing the benefits and impacts of different options. Options assessed in the MCA have been developed based on engineering and planning judgement. The MCA results do not indicate if options are actually viable or feasible to implement or acceptable to the community and stakeholders. As such, a degree of caution and judgement needs to be applied to the outcomes of an MCA process and the MCA process needs to be viewed as a tool only to identifying the best option to achieve the objectives. The best practice is to limit options to those which would not be considered to have passed an initial feasibility test.

1.4 Scope and Limitations

This report: has been prepared by GHD for Shire of Northampton and may only be used and relied on by Shire of Northampton for the purpose agreed between GHD and the Shire of Northampton as set out in section 1.1 of this report.

GHD otherwise disclaims responsibility to any person other than Shire of Northampton arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Shire of Northampton and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

GHD has prepared order of magnitude cost estimates using information reasonably available to the GHD employees who prepared this report; and based on assumptions and judgments made by GHD including the dates of implementation, lineal construction cost rates and, maintenance costs from similar projects and other assumptions detailed below in section 1.5.

The estimated costs for the options are order of magnitude estimates prepared for the comparison of options in the MCA process only. Actual prices, costs and other variables may be different to those used to prepare the estimated costs and may change. Unless as otherwise specified in this report, no detailed quotation has been obtained for actions identified in this report. GHD does not represent, warrant or guarantee that the works can or will be undertaken at a cost which is the same or less than the estimated costs.

Where estimates of potential costs are provided with an indicated level of confidence, notwithstanding the conservatism of the level of confidence selected as the planning level, there remains a chance that the cost will be greater than the planning estimate, and any funding would not be adequate. The confidence level considered to be most appropriate for planning purposes will vary depending on the conservatism of the user and the nature of the project. The user should therefore select appropriate confidence levels to suit their particular risk profile.

1.5 Assumptions

A number of assumptions were made in relation to developing adaptation option scenarios and assessing these scenarios against the criteria, including the development of Net Present Value order of magnitude estimates for the implementation of the adaptation options. These are outlined below:

- Managed retreat requires the relocation of public assets and land through acquisition of private property. Therefore there are no impacts on parkland, beach or community services.
- Unmanaged retreat however considers a scenario where there are no attempts to acquire properties, and therefore results in the loss of all land uses and their associated values (parks and recreation reserve, residential property, commercial property).
- Interim protection options are implemented prior to hazard affecting private land, therefore land-based public land and assets are also protected.
- Managed retreat/avoid costs apply to residential land value lost.
- Costing and Criteria Assumptions:
  - All costs have been calculated using a net present value calculation that considers a discount rate of 2.10% per annum[1].

[1] 2.1 % is the Garnaut Climate Review Figure for Gross National Product in the 21st Century

- Implementation costs include: loss of land value (delayed by protection), land development costs (delayed by protection), capital costs, maintenance costs and decommissioning costs.
- Impacts were assessed for erosion adaptation options only as inundation impacts are more tolerable for possible and rare events and are more temporary in nature.
- Dune and parklands impacts for the different interim protection considers the proportion of the parks and recreation reserve that may be lost or impacted by the rare event when the adaptation options are in place. Eg: implementation of seawalls would have a construction footprint impacting on the dune and parkland reserve along the full length of the protected area and a rare erosion event with a seawall in place should protect the remainder of the dune and parklands behind it, but groynes and sand replenishment would likely result in 25 to 50% loss of dune and parklands.
- Beach impacts for the different interim protection considers the length of beach foreshore that would be lost as a result of a rare event when the adaptation options are in place. In the case of managed retreat, it is assumed the area of retreat and expansion of the foreshore reserve will be wide enough for the beach to retreat inland in response to the rare event.
- After the first round of the MCA, where two different pathways were ranked closely e.g. managed retreat and interim protection, a second round may be required. This has not been undertaken as requires further input from Council and community. In these situations, land acquisition and foreshore restoration costs may be considered with land acquisition costs being based on current day sale values for properties in Horrocks and foreshore restoration costs being based on a recent foreshore redevelopment cost in regional WA.

2. Multi Criteria Analysis

2.1 Overview

A MCA was undertaken to assist identifying the preferred foreshore stabilisation option or options. An MCA is a decision-making tool used to assist in the comparison of options. An MCA evaluates the benefits and impacts of options based on the relative importance of several criteria. A MCA however is not a tool to identify fatal flaws. The MCA outcomes provide a ranking of options against a set of criteria.

The criteria used in the MCA should not double count similar aspects to prevent bias towards or against an option. For example, the volume of materials required for construction usually has a strong bearing on the construction cost. Therefore either the volume of materials required or construction cost but not both should be used as criteria. More criteria are not necessarily better, as this is more likely to result in double counting of similar aspects. The criteria should reflect the values and the feasibility factors that are important in decision making. Where possible the criteria scores for each option should be quantitative inputs over qualitative. For example, instead of saying one option is better on a scale of 1 to 5 than another because one option will impact on a greater plan area of dune and parkland, estimate the potential plan area of dune and parkland likely to be impacted by implementation of each of the adaptation options instead. Options scores are normalised to allow a combined raw score to be calculated.

The MCA process scores each option against the criteria. Each criteria is weighted or assigned a different percentage, based on its relative importance. This weighting should be considered in isolation. Options are then ranked based on their weighted scores.

2.1.1 Adaptation context and assumptions

The objective of this report is to determine the most feasible immediate actions and current planning adaptation options for the Horrocks Beach townsite when considering social, economic, environmental and infrastructure impacts as a result of erosion over the 100 year planning period.

The adaptation pathways approach includes a transition from immediate actions to current planning measures to long term retreat which will be used to compare to the option of retreating now versus a combination of interim protection and accommodation with deferred managed retreat.

Therefore in essence, the MCA process is being undertaken to identify the best of the options between the adaptation measures and retreating at the time of the trigger.

Interim protection measures are based on the assumption that they will provide a 50 year design life, after which retreat will occur (unless future triggers recommend further interim protection).

The time-period for comparison of the adaptation options will consider the costs to be incurred over the life span of the option. For example, for interim protection in the current planning period – construction costs will be considered in 2020, with ongoing annual maintenance costs for the following 50 years, until which point decommissioning costs and deferred retreat loss of land values are incurred. The implementation timeframe for protection of the beach adjacent to the Jetty Beach geotextile sand container seawall has been delayed until the end of the design life of the existing interim protection structure (approximately 2035).

MCA's have only been undertaken for coastal assets or asset groupings where a decision needs to be made in either the immediate (2020) or current (to 2050) planning to determine the adaptation pathway.

2.2 Coastal Adaptation Pathway

The coastal adaptation options were identified and developed depending on the timeframe of intolerable risk as identified in Table 1 in line with the hierarchy of adaptation solutions and GHD's principles to coastal adaptation, refer to Appendix A of the CHRMAP. A MCA was only required for Planning Area 2 as there were no intolerable risks in the immediate or current planning period for Planning Area 1.

For assets or asset groupings where a Trigger 3A has been reached for the immediate time period, an MCA was undertaken for the immediate time period only. When a Trigger 3 was identified in both the immediate and current planning period, a decision on the adaptation pathway needs to be implemented by approximately 2030, so the MCA was undertaken for the current planning period. When a Trigger 3 was reached in the current planning period but not the immediate a strategic decision was made as to whether an MCA was required based on the potential value of the assets at risk.

[2] 2050 is considered to be the current planning timeframe as planning should occur between now and then to properly prepare for the expected 2050 erosion risks.

Table 1: Erosion Risk to Horrocks coastal infrastrucutre and assets

	Name	2019 Tolerance	2050 Tolerance	2120 Tolerance
Planning Area 1	Sandy beach	Tolerable (Trigger 1)	Tolerable (Trigger 1)	Intolerable (Trigger 3A or 4)
	Coastal foreshore	Acceptable	Acceptable	Intolerable (Trigger 3A or 4)
	Golf course	No impact	No impact	Intolerable (Trigger 3A or 4)
	Beach access tracks	Acceptable	Acceptable	Intolerable (Trigger 3A or 4)
	Rural zoned bushland	No impact	No impact	Intolerable (Trigger 3A or 4)
	Little Bay Road	No impact	No impact	Intolerable (Trigger 3A or 4)
	Mitchell Street	No impact	No impact	No impact
	Residences on Mitchell Street	No impact	No impact	No impact
Planning Area 2	Community centre	No impact	Intolerable (Trigger 3A)	Intolerable
	Tennis courts	No impact	No impact	Intolerable
	Caravan park	No impact	No impact	Intolerable
	Residential houses	No impact	Intolerable (Trigger 3A)	Intolerable
	Lookout	Tolerable (Trigger 1)	Intolerable (Trigger 4)	Intolerable
	Boat launch	Intolerable (Trigger 3)	Intolerable (Trigger 3A)	Intolerable
	Foreshore reserve - picnic area	No impact	Intolerable (Trigger 3A)	Intolerable
	Community centre beach	Tolerable (Trigger 1)	Intolerable (Trigger 3A)	Intolerable
	Seawall	Tolerable (Trigger 1)	Intolerable (Trigger 3A)	Intolerable
	Glance Cove	Intolerable (Trigger 3A)	Intolerable (Trigger 3A)	Intolerable
	Community kitchen	No impact	Intolerable (Trigger 3A)	Intolerable
	Toilet block	Tolerable (Trigger 1)	Intolerable (Trigger 3A)	Intolerable
	Playground	No impact	Intolerable (Trigger 3A)	Intolerable
	BBQ/picnic area	Tolerable (Trigger 1)	Intolerable (Trigger 3A)	Intolerable
	Jetty	No impact	No impact	Intolerable
	Jetty beach	Intolerable (Trigger 3)	Intolerable (Trigger 3A)	Intolerable
	Holiday cottages	No impact	No impact	Intolerable
	Coastal path	No impact	Intolerable (Trigger 3A)	Intolerable
	Carpark	No impact	Intolerable (Trigger 3A)	Intolerable
	Revegetation infrastructure	Tolerable (Trigger 1)	Intolerable (Trigger 3A)	Intolerable
	Boat launch 2	Intolerable (Trigger 3)	Intolerable (Trigger 3A)	Intolerable
	Coastal foreshore	Acceptable	Tolerable	Intolerable
	Southern beach	Tolerable (Trigger 1)	Tolerable	Intolerable
	Universal beach access	Intolerable (Trigger 3)	Intolerable (Trigger 3A)	Intolerable
	Whiting Pool	No impact	Intolerable (Trigger 3A)	Intolerable
	Glance Street	No impact	Intolerable (Trigger 3A)	Intolerable
	Glance Street residences	No impact	Intolerable (Trigger 3A)	Intolerable
	Informal carpark	Acceptable	Intolerable (Trigger 3A)	Intolerable

2.1 Managed vs Unmanaged Retreat

Retreat can be achieved through either managed retreat or unmanaged retreat.

Managed retreat is defined as reducing or ceasing private land uses, including strategic acquisition of land, expansion of the foreshore reserve (for erosion hazard areas), and relocation of public infrastructure to maintain the existing public values of the foreshore/area at risk.

Unmanaged retreat or the 'do nothing' treatment option involves no government intervention or expenditure in coastal adaptation. There is no legal responsibility for government to protect private property from natural hazards or provide compensation where land is lost to erosion. If private property becomes uninhabitable or presents a public risk as a result of erosion, government can intervene and enforce eviction. Unmanaged retreat therefore involves the progressive loss of the public foreshore reserve before private property is abandoned due to safety. This shifts the cost (losses) onto coastal property owners and would result in the loss of social and environmental values associated with the coastal foreshore reserve.

As described in the following section, only adaptation options that retain values that triggered intolerable risk were considered in the evaluation process. Adaptation options that were clearly inconsistent with values of importance were not progressed into the MCA, and were discounted through a fatal flaw assessment. Unmanaged retreat was included as an option in the MCA as it also reflects a "do nothing" pathway should implementation not occur. The MCA results therefore illustrate how poorly this option performs against the scored criteria to justify the need for investment.

2.2 Option Identification and Fatal Flaw Assessment

The risk treatment options for erosion risks have been considered for the entire area and for specific assets/asset groupings. Assets were identified as part of entire CHRMAP (Figure 5 of main CHRMAP document).

2.2.1 Entire study area

Offshore breakwaters developed in the gaps of the offshore reef chain could be used to protect the entire study area from erosion. However this option was not considered suitable in this location due to implications this would have on the navigation channel and the impact on boating, which is highly valued by the community. Maintaining access to the marine environment was highlighted as the second most important aspect in Horrocks to maintain and is an important part of how people recreate at Horrocks.

The options that cover the entire area therefore include unmanaged and managed retreat. Values/asset specific options, such as sand replenishment and seawalls, allow for protection of these assets in the current term and support the retention of specific values. Protection of assets allows more time to determine how retreat should occur in the long term. Managed and unmanaged retreat are presented for each asset/asset grouping to allow comparison against other location specific options. An MCA for the entire area has therefore not been undertaken.

2.2.2 Glance Cove and Community Centre – Road, Residential Housing and Community Infrastructure (Assets 9, 12, 18)

The erosion risks to the assets associated with Glance Cove (including the road, residences and community centre) have been considered together as the risk treatment options would apply to all assets.

Groynes with sand replenishment were not considered to be a feasible solution to implement in this location due to potential interference with navigation, impacts to longshore sediment transport and impacts to social values. Erosion risks that were assessed in the MCA are summarised in Table 2.

Table 2 Glance Cove and Community Centre Erosion trigger points and adaptation options

Trigger Level	Justification
3	Immediate hazard risks to road. Interim protection may be feasible to also protect housing and community infrastructure
Adaptation Options	
Unmanaged retreat	
Managed retreat through land acquisition and foreshore expansion	
Interim protection – Dune stabilisation and sand replenishment – to provide an erosion buffer	
Interim protection – Seawall and sand replenishment	

2.2.3 Boat launches (Assets 14 and 29)

The erosion risks to the two boat launch areas have been considered together as treatment options are the same (although required in both locations). Erosion risks that were assessed in the MCA are summarised in Table 3. Groynes and seawalls with sand replenishment were not considered to be a feasible solution to implement to these assets due to the changes in sedimentation around the structures likely to significantly impact on functional use of the boat launching infrastructure. A series of offshore breakwaters could protect the entire study area and therefore this infrastructure, however as described in 2.2.1, are likely to impact on access to deep water via navigational channels.

Table 3 Boat launches - Erosion trigger points and adaptation options

Trigger Level	Justification
3	Immediate hazard risks
Adaptation Options	
Unmanaged retreat	
Managed retreat into adjacent foreshore reserve and or	
Interim protection – Launch/beach stabilisation - gravel replenishment – to stabilise structure and provide an erosion buffer	

2.2.1 Jetty Beach, existing GSC Seawall, community kitchen, toilet block, playground, BBQ, picnic areas, Glance Street, Glance Street residences, coastal path and carpark (assets 15, 17, 19, 20, 21, 22, 24, 26, 28, 34, 35)

The beach surrounding the jetty, the existing seawall, the community kitchen, the toilet block, playground, barbeques, picnic areas, Glance Street, Glance Street residences, coastal path and associated parking have been considered together as risk treatment options apply to the whole area. The erosion risks to the area are known. The trigger level is currently 2, as a decision to undertake interim protection was undertaken in 2010 when a GSS seawall was constructed. Given the design life of the structure and its design for a 1 in 50 event there are still some residual risks, however, the Shire considers these to be acceptable. The seawall has been complimented with sand replenishment and revegetation and stabilisation of the adjacent dune. At the end of the design life of the structure (approximately 2035), trigger 3A will be reached as it will still be feasible to undertake interim protection in this area. The relocation of the toilet block, community kitchen, playground, barbeques and car parking should be considered at the end of their life. Replacement of the seawall at the end of its design life has been compared against acquisition of the Glance Street properties (managed retreat) which would allow the foreshore reserve to be expanded. Groynes were considered as an alternative option to the GSS seawall, however, were not carried through to the MCA due to the impact on the functional use of the jetty and the impact to social values associated with the area. Interim protection at the end of the design life of the existing GSS seawall should include consideration of the erosion risks to the road (Glance Street) and private residences, i.e. is an extension/relocation required.

Table 4 Jetty Beach Area- Erosion trigger points and adaptation options

Trigger Level	Justification
2	Trigger 3A will be reached within the current planning period
Adaptation Options	
Unmanaged retreat	
Managed retreat through land acquisition and foreshore expansion	
Interim protection – Replace and extend seawall and undertake sand replenishment	
Interim protection – Dune stabilisation and sand replenishment – to provide an erosion buffer	

2.2.2 Universal beach access (asset 32)

The universal beach access track is at almost certain risk of erosion. This is most apparent at the end of the track which is not always at the beach level and would restrict usage. This is considered to be an intolerable risk as there is no alternative universal access, however, in reality the condition is likely to change with sand movement and it would be difficult to manage.

Table 5 Universal Beach Access – Erosion trigger points and adaption options

Trigger Level	Justification
3	Immediate hazard risks
Adaptation Options	
Unmanaged retreat	
Managed retreat – redesign/upgrade access at end of design life (utilise existing reserve)	
Managed retreat – accommodate through relocation (potentially as part of land acquisition and foreshore expansion proposed as part of Jetty Beach managed retreat option)	
Interim protection – Sand replenishment and path stabilisation	

2.2.3 Informal parking (asset 27)

There is a more informal area for parking at the southern end of the study area. This area is at possible risk in the short term and reaches almost certain risk by 2050. Dune stabilisation and revegetation is not a feasible interim protection option to this asset as there is not suitable width to implement this option without impacting on the informal parking area.

Table 6 Erosion trigger points - Informal parking area

Trigger Level	Justification
3	Current hazard risks
Adaptation Options	
Unmanaged retreat	
Managed retreat – relocate parking	
Interim protection – Seawall and sand replenishment	

2.2.4 Whiting Pool (asset 33)

Whiting Pool appears to be accreting sand in the immediate term, however, the effects of shoreline retreat due to sea level rise indicate that the potential erosion hazard area will continue to increase over time. This area has sufficient coastal foreshore to accommodate the potential for erosion in the short term and although the beach is likely to retreat landward, it can still be utilised and enjoyed by the community. The actions relating to this area involve monitoring and sand replenishment if required. No MCA has been conducted for this area, however, protection to this area may be a secondary consequence of interim protection measures elsewhere.

2.3 MCA Criteria

The selection criteria to assess the coastal adaptation options have been adapted from the MCA criteria developed for the Port Hedland Townsite CHRMAP (GHD, 2019) and reflect the different land use compositions and values which are specific to this region. Erosion and inundation both impact Horrocks Beach, assets and values in different ways and this is reflected in the identification of the planning areas and the criteria used to reflect the potential benefits and impacts that the different coastal adaptation options may have on social, economic and environmental values.

Whilst inundation risk is likely to affect Horrocks Beach, due to the impacts being tolerable, only erosion risks have been considered in the MCA.

A summary of the criteria, what they are a measurement of, and the specific purpose of inclusion of the criteria in the MCA process is shown in **Error! Reference source not found.**.

Criteria	units	Relates to	Metric for Scoring
Feasibility of implementation			
C1 Public implementation Cost	$M	Implementation cost includes: Do nothing or asset relocation costs Interim protection costs Strategic retreat costs Accommodation costs	Cost of implementation of the adaptation solution measured over the next 100 years considering. Asset replacement costs ($) Capital, maintenance and decommissioning - discounted costs ($) Loss of land value – (discounted cost) Cost impact on private landowners
Social, environmental and economic values			
C2 – Dune and parkland impacts, including social spaces	m^2	Local economy (tourism) Recreation Social places and interaction Cultural value Ecosystem and biodiversity (dune vegetation)	Area of foreshore reserve/public open space affected by hazard with the implementation option.
C3 – Beach impacts	m	Local economy (tourism) Recreation Character, sense of place, scenery Ecosystem and biodiversity (intertidal zone)	Lineal metres of beach affected by hazard with the implementation option in place
C4 –Residential impacts	Number of residences	Land supply in Horrocks Personal wealth Infrastructure and servicing	Number of residential lots (existing or potential) affected by hazard with the implementation option.
C5 – Community service impacts	m^2	Loss of community infrastructure Social spaces and interaction Servicing	Area of community service land affected by hazard or due to implementation option
C5 – Safe access to water	Scale 1-5	Accessing the water Local economy	Scale 1-5
Safety and risk			
C8 – Residual risk to property	Scale of 1-5	Safety and risk management	Scale of 1-5

2.4 Criteria weighting

The criteria used in this analysis, how they were scored and the weightings assigned are summarised below in Table 7. The weightings to the options were discussed and assigned by Council in a Private Councillor Briefing facilitated by GHD.

GHD project staff attended a Shire of Northampton Councillor meeting to provide briefing on the project and to gain an understanding/ weighting of the criteria from the Councillors. The councillors were asked to individually rank the relative importance of each criterion for each planning area and asset on a scale of 1 (least important) to 5 (most important). Councillor consideration was partially informed by community perspectives gleaned from survey responses; these are reported in Appendix B of the CHRMAP document.

However, as the overall community weightings were quite different to the Councillor rankings, community weightings were also developed using the results of the community values survey and used to undertake sensitivity testing (cost and residential impact ranked more highly in the Council rankings and loss of social spaces, beach and ensure safe access to the water was much more important to the community).

The same Councillor and community rankings were used across all assets subject to the MCA process, however, as some criteria were not relevant, weightings were increased accordingly.

The average ranking for each criterion was used to calculate a relative weighting for each criterion, so that the total of the criterion summed to 1. The rankings applied to MCA criterion and used to determine weightings for each asset/asset grouping are summarised in Table 7.

Table 7 Criterion ranking

Criteria	Councillor rank	Community rank
Public implementation cost	5	5
Dune and parkland impacts	3	5
Beach impacts	2	3
Residential impacts	4	2
Community service impacts	3	3
Safe access to water	1	5
Residual risk	1	1

3. MCA Results

Full results of the scoring, weighting and ranking of the options is detailed in **Error! Reference source not found.**.

3.1 Glance Cove and Community Centre – Road, Residential Housing and Community Infrastructure

The results of the MCA for Glance Cove, the Horrocks Community Centre and associated residences indicate that interim protection ranks most favourably. Dune stabilisation and revegetation has been included as an interim protection option, however, a significant storm event may demolish this effort affecting its practical feasibility. The option of a seawall has therefore also been provided as an alternative interim protection measure and may be more viable in the longer term. The differing Councillor and community rankings and resultant weightings produce different preferences for the options. Interim retreat is equally favourable to the seawall when using the community rankings compared to the Councillor rankings. This is due to the different priority given to residential housing protection (Table 8 and Table 9). This should be further investigated.

Dune stabilisation may help to delay the decision point, however, it is important that Council decide an approach to retreat in this area as soon as possible.

Criteria in the MCA included consideration of cost, loss of housing and loss of community infrastructure.

Table 8 MCA Results – Glance Cove and Community Centre (Councillor weightings)

Adaptation Option	Normalised Score	Weighted Score	Rank
Unmanaged retreat	5.0	0.72	**4**
Managed retreat through land acquisition and foreshore expansion	2.62	0.56	**3**
Interim protection – Dune stabilisation and revegetation	2.62	0.39	**1**
Interim protection – Seawall	2.83	0.49	**2**

Table 9 MCA Results – Glance Cove and Community Centre (Community weightings)

Adaptation Option	Normalised Score	Weighted Score	Rank
Unmanaged retreat	5.0	0.74	**4**
Managed retreat through land acquisition and foreshore expansion	2.62	0.43	**=1**
Interim protection – Dune stabilisation and revegetation	2.62	0.43	**=1**
Interim protection – Seawall	2.83	0.57	**3**

3.2 Boat launches

The results of the MCA for the two boat launches indicates that managed retreat rank most favourably. However, this options assumes the launches would no longer be available. Given the community values associated with this infrastructure it is therefore suggested that the Shire should continue its current approach to protection until conditions or cost no longer allow. Application of the community and council weightings made minimal impact on the results (Table 10 and Table 11).

Table 10 MCA Results – Boat launches (Council weightings)

Adaptation Option	Normalised Score	Weighted Score	Rank
Unmanaged retreat	3.0	0.50	**=2**
Managed retreat through retreat into the foreshore reserve	1.0	0.30	**1**
Protect – beach/launch stabilisation	1.0	0.50	**=2**

Table 11 MCA Results – Boat launches (Community weightings)

Adaptation Option	Normalised Score	Weighted Score	Rank
Unmanaged retreat	3.0	0.64	**3**
Managed retreat through retreat into the foreshore reserve	1.0	0.21	**1**
Protect – beach/launch stabilisation	1.0	0.36	**2**

3.3 Jetty Beach and Surrounding Dunes and Parkland

Results of the MCA indicate that interim protection via dune stabilisation and revegetation, ranks most highly followed by protection via seawall and sand replenishment (Table 12 and Table 13). Managed retreat is however scored very similarly to protection via seawall. This indicates that when the existing seawall is at the end of its design life, the whole area should be reconsidered using a values based approach to ensure protection is the most favourable option (compared to managed retreat). This infrastructure is also providing protection to the parkland assets, Glance Street and residences on Glance Street.

The Shire will be required to undertake community consultation to determine in more detail how acceptable the reality of sacrificing private residences actually is compared to public acquisition (this applies to the study area in its entirety). A preferred approach to private land should be determined prior to interim protection being no longer feasible.

Differences in scoring are due to Councillors placing a higher weighting on residential impacts and the value placed on the parkland area by the community. The community weightings show that after dune stabilisation and revegetation, managed retreat scores very closely to replace and extend seawall and undertake sand replenishment, but under the Council weighting, these options are not scored as closely.

Table 12 MCA Results – Jetty beach and surrounds (Council weightings)

Adaptation Option	Normalised Score	Weighted Score	Rank
Unmanaged retreat	5.0	0.72	**4**
Managed retreat through retreat acquisition and foreshore	3.03	0.56	**3**
Protect – replace and extend seawall and undertake sand replenishment	2.33	0.44	**2**
Protect – dune stabilisation and revegetation	1.67	0.27	**1**

Table 13 MCA Results – Jetty beach and surrounds (Community weightings)

Adaptation Option	Normalised Score	Weighted Score	Rank
Unmanaged retreat	5.0	0.74	**4**
Managed retreat through retreat acquisition and foreshore	3.03	0.53	**3**
Protect – replace and extend seawall and undertake sand replenishment	2.33	0.51	**2**
Protect – dune stabilisation and revegetation	1.67	0.28	**1**

3.4 Universal Beach Access

It has been assumed that current management practices will continue until the end of the design life of the asset and interim protection (sand replenishment and path stabilisation) has not been included in the MCA.

The most favourable option for treatment of the universal access is to redesign/upgrade at the end of its design life to achieve improved functionality (and less management of erosion impacts). At the end of the design life of this infrastructure it is therefore recommended alternative designs and solutions be considered to allow continued provision of this infrastructure and improve functionality.

Table 14 MCA Results – Universal Beach Access (Council weightings)

Adaptation Option	Normalised Score	Weighted Score	Rank
Unmanaged retreat	2.0	0.33	**2**
Accommodate through redesign/upgrade at end of design life	0.54	0.22	**1**
Accommodate through relocation	2.0	0.67	**3**

Table 15 MCA Results – Universal Beach Access (Community weightings)

Adaptation Option	Normalised Score	Weighted Score	Rank
Unmanaged retreat	2.0	0.29	**2**
Accommodate through redesign/upgrade at end of design life	0.54	0.19	**1**
Accommodate through relocation	2.0	0.71	**3**

3.5 Informal Parking

The most favourable treatment options for the informal parking area is managed retreat which would involve relocation of parking into adjacent streets. However, managed retreat involving the sacrifice of this parking area means that the adjacent residences will be at risk. The protect option would also protect these residences.

The Councillor weightings rank the options of a seawall more highly than the community as they valued protection of residences more highly than the community. If managed retreat is taken in this area private land is likely to be sacrificed in the 30-50 year timeframe and community consultation to prepare for this is required.

Table 16 MCA Results – Informal parking (Council weightings)

Adaptation Option	Normalised Score	Weighted Score	Rank
Unmanaged retreat	4.0	0.67	**3**
Managed retreat through parking relocation and acquisition	1.12	0.31	**1**
Protect –seawall	2.0	0.47	**2**

Table 17 MCA Results – Informal parking (Community weightings)

Adaptation Option	Normalised Score	Weighted Score	Rank
Unmanaged retreat	4.0	0.64	**3**
Managed retreat through parking relocation and acquisition	1.12	0.22	**1**
Protect –seawall	2.0	0.57	**2**

3.1 Summary

MCA’s have been completed for the identified assets/asset groupings where decisions need to be made that will impact on the current and long term adaptation pathways. The MCA’s are a tool to provide guidance of the options to consider in more detail, but they are limited by the assumptions made in the scoring and weighting of the options. Where options are not strongly separated by weighted scores it is recommended that further investigations are undertaken to make better informed decisions.

The results presented by the MCA indicate that costing of the adaptation options, the residential impacts and the residual risk allocated to the options are the most influential factors when determining the weighted scores and ranks. Because the cost estimates are order of magnitude cost estimates only and the effectiveness of the different protection options have not been tested, it is strongly recommended that further economic and coastal engineering assessment of the adaptation options are undertaken prior to implementing a specific option for each location.

4. References

Department for Communities and Local Government: London (2009), Multi-Criteria Assessment: a Manual.

Appendices

Appendix A – Detailed MCA Scoring and Results

Glance Cove and Community Centre - council ranks

CRITERIA	Applied rank	%	Weight	ADAPTATION OPTIONS	Unmanaged retreat	Managed retreat through acquisition and foreshore	Protect - Dune Stablisation and Sand Nourishment	Protect - seawall and sand replenishment	Units	Unmanaged retreat	Managed retreat through acquisition and foreshore	Protect - Dune Stablisation and Sand Nourishment	Protect - seawall and sand replenishment
					Normalised Scores					Criteria Scores			
Public implementation cost	5	28	0.28		0.00	0.62	0.87	1.00	$M	$ -	$ 3.30	$ 4.62	$ 5.33
Dune and parkland impacts	3	17	0.17		1.00	0.00	0.25	0.50	m^2	9500	0	2375	4750
Beach impacts	2	11	0.11		1.00	0.00	0.50	1.00	m	260	0	130	260
Residential impacts	4	22	0.22		1.00	1.00	0.00	0.00	No. residences	15	15	0	0
Community service impacts	3	17	0.17		1.00	1.00	0.00	0.00	m^2	6800	6800	0	0
Residual impacts	1	6	0.06		1.00	0.00	1.00	0.33	Scale 1-5	4	1	4	2
		100		Sum	5.00	2.62	2.62	2.83					
				Weighted Sum	0.72	0.56	0.39	0.49					
				Rank	4	3	1	2					

Glance Cove and Community Centre - community ranks

CRITERIA	Applied rank	%	Weight	ADAPTATION OPTIONS	Unmanaged retreat	Managed retreat through acquisition and foreshore	Protect - Dune Stablisation and Sand Nourishment	Protect - seawall and sand replenishment	Units	Unmanaged retreat	Managed retreat through acquisition and foreshore	Protect - Dune Stablisation and Sand Nourishment	Protect - seawall and sand replenishment
					Normalised Scores					Criteria Scores			
Public implementation cost	5	26.3	0.26		0.00	0.62	0.87	1.00	$M	$ -	$ 3.30	$ 4.62	$ 5.33
Dune and parkland impacts	5	26.3	0.26		1.00	0.00	0.25	0.50	m^2	9500	0	2375	4750
Beach impacts	3	15.8	0.16		1.00	0.00	0.50	1.00	m	260	0	130	260
Residential impacts	2	10.5	0.11		1.00	1.00	0.00	0.00	No. residences	15	15	0	0
Community service impacts	3	15.8	0.16		1.00	1.00	0.00	0.00	m^2	6800	6800	0	0
Residual impacts	1	5.3	0.05		1.00	0.00	1.00	0.33	Scale 1-5	4	1	4	2
		100		Sum	5.00	2.62	2.62	2.83					
				Weighted Sum	0.74	0.43	0.43	0.57					
				Rank	4	1	1	3					

Boat launches - Council weightings

CRITERIA	Applied rank	%	Weight		Unmanaged retreat	Managed retreat into foreshore reserve	Protect - beach/launch stabilisation	Units	Unmanaged retreat	Managed retreat into foreshore reserve	Protect - beach/launch stabilisation
				ADAPTATION OPTIONS	Normalised Scores				Criteria Scores		
Public implementation cost	5	50	0.50		0.00	0.00	1.00	$M	$ -	$ -	$ 0.01
Community service impacts	3	30	0.30		1.00	1.00	0.00	Area reserve lost m2	400	400	0
Safe access to water	1	10	0.10		1.00	0.00	0.00	Scale 1-5	5	2	2
Residual impacts	1	10	0.10		1.00	0.00	0.00	Scale 1-5	5	2	2
		100		Sum	3.00	1.00	1.00				
				Weighted Sum	0.50	0.30	0.50				
				Rank	2	1	2				

Boat launches - Community weightings

CRITERIA	Applied rank	%	Weight		Unmanaged retreat	Managed retreat into foreshore reserve	Protect - beach/launch stabilisation	Units	Unmanaged retreat	Managed retreat into foreshore reserve	Protect - beach/launch stabilisation
				ADAPTATION OPTIONS		.			Criteria Scores		
Public implementation cost	5	36	0.36		0.00	0.00	1.00	$M	$ -	$ -	$ 0.01
Community service impacts	3	21	0.21		1.00	1.00	0.00	Area reserve lost m2	400	400	0
Safe access to water	5	36	0.36		1.00	0.00	0.00	Scale 1-5	5	2	2
Residual impacts	1	7	0.07		1.00	0.00	0.00	Scale 1-5	5	2	2
		100		Sum	3.00	1.00	1.00				
				Weighted Sum	0.64	0.21	0.36				
				Rank	3	1	2				

Jetty Beach and Surrounds - Council Weightings

CRITERIA	Applied rank	%	Final Weight
Public implementation cost	5	28	0.28
Dune and parkland impacts	3	17	0.17
Beach impacts	2	11	0.11
Residential impacts	4	22	0.22
Community service impacts	3	17	0.17
Residual impacts	1	6	0.06
		100	1

ADAPTATION OPTIONS	Unmanaged retreat	Managed Retreat through acquisition and foreshore	Seawall and sand replenishment	Dune stabilisation and revegetation
Normalised Scores				
	0.00	0.28	1.00	0.67
	1.00	1.00	0.33	0.00
	1.00	0.00	1.00	0.50
	1.00	1.00	0.00	0.00
	1.00	0.50	0.00	0.00
	1.00	0.25	0.00	0.50
Sum	5.00	3.03	2.33	1.67
Weighted Sum	0.72	0.56	0.44	0.27
Rank	4	3	2	1

	Unmanaged retreat	Managed Retreat through acquisition and foreshore	Seawall and sand replenishment	Dune stabilisation and revegetation
Criteria Scores				
	$ -	$ 1.02	$ 3.67	$ 2.47
	6400.00	6400.00	3200.00	$ 1,600.00
	170.00	0.00	170.00	$ 85.00
	6.00	6.00	0.00	$ -
	3000.00	1500.00	0.00	$ -
	5.00	2.00	1.00	$ 3.00

Jetty Beach and Surrounds - Community Ranks

CRITERIA	Applied rank	%	Final Weight
Public implementation cost	5	26	0.26
Dune and parkland impacts	5	26	0.26
Beach impacts	3	16	0.16
Residential impacts	2	11	0.11
Community service impacts	3	16	0.16
Residual impacts	1	5	0.05
		100	

ADAPTATION OPTIONS	Unmanaged retreat	Managed Retreat through acquisition and foreshore	Seawall and sand replenishment	Dune stabilisation and revegetation
Normalised Scores				
	0.00	0.28	1.00	0.67
	1.00	1.00	0.33	0.00
	1.00	0.00	1.00	0.50
	1.00	1.00	0.00	0.00
	1.00	0.50	0.00	0.00
	1.00	0.25	0.00	0.50
Sum	5.00	3.03	2.33	1.67
Weighted Sum	0.74	0.53	0.51	0.28
Rank	4	3	2	1

	Unmanaged retreat	Managed Retreat through acquisition and foreshore	Seawall and sand replenishment	Dune stabilisation and revegetation
Criteria Scores				
	$ -	$ 1.02	$ 3.67	$ 2.47
	6400.00	6400.00	3200.00	$ 1,600.00
	170.00	0.00	170.00	$ 85.00
	6.00	6.00	0.00	$ -
	3000.00	1500.00	0.00	$ -
	5.00	2.00	1.00	$ 3.00

Universal beach access - Council weightings

CRITERIA	Applied rank	%	Weight
Public implementation cost	5	42	0.42
Dune and parkland impacts	3	25	0.25
Community service impacts	3	25	0.25
Residual impacts	1	8	0.08
		100	

ADAPTATION OPTIONS

	Unmanaged retreat	Accomodate through redesign/upgrade at end of design life	Accommodate through relocation elsewhere
Normalised Scores			
	0.00	0.54	1.00
	0.00	0.00	1.00
	1.00	0.00	0.00
	1.00	0.00	0.00
Sum	2.00	0.54	2.00
Weighted Sum	0.33	0.22	0.67
Rank	2	1	3

Unmanaged retreat	Accomodate through redesign/upgrade at end of design life	Accommodate through relocation elsewhere
Criteria Scores		
$ -	$ 0.00	$ 0.00
1.00	1.00	3.00
30.00	0.00	0.00
5.00	2.00	2.00

Universal beach access - Community weightings

CRITERIA	Applied rank	Weight	Final Weight
Public implementation cost	5	36	0.36
Dune and parkland impacts	5	36	0.36
Community service impacts	3	21	0.21
Residual impacts	1	7	0.07
		100	

ADAPTATION OPTIONS

	Unmanaged retreat	Accomodate through redesign/upgrade at end of design life	Accommodate
Normalised Scores			
	0.00	0.54	1.00
	0.00	0.00	1.00
	1.00	0.00	0.00
	1.00	0.00	0.00
Sum	2.00	0.54	2.00
Weighted Sum	0.29	0.19	0.71
Rank	2	1	3

Unmanaged retreat	Accomodate through redesign/upgrade at end of design life	Accommodate
Criteria Scores		
$ -	$ 0.00	$ 0.00
1.00	1.00	3.00
30.00	0.00	0.00
5.00	2.00	2.00

Informal parking - Council weightings

CRITERIA	Applied rank	Weight	Final Weight
Public implementation cost	5	33	0.33
Beach impacts	2	13	0.13
Residential impacts	4	27	0.27
Community service impacts	3	20	0.20
Residual impacts	1	7	0.07
		100	

ADAPTATION OPTIONS — Normalised Scores

	Unmanaged Retreat	Managed Retreat through parking relocation	Protect - Seawall
Public implementation cost	0.00	0.12	1.00
Beach impacts	1.00	0.00	1.00
Residential impacts	1.00	1.00	0.00
Community service impacts	1.00	0.00	0.00
Residual impacts	1.00	0.00	0.00
Sum	4.00	1.12	2.00
Weighted Sum	0.67	0.31	0.47
Rank	3	1	2

Criteria Scores

	Unmanaged Retreat	Managed Retreat through parking relocation	Protect - Seawall
Public implementation cost	$ -	$ 0.30	$ 2.41
Beach impacts	150.00	0.00	150.00
Residential impacts	1.00	1.00	0.00
Community service impacts	2500.00	0.00	0.00
Residual impacts	5.00	1.00	1.00

Informal parking - Community weightings

CRITERIA	Applied rank	Weight	Final Weight
Public implementation cost	5	36	0.36
Beach impacts	3	21	0.21
Residential impacts	2	14	0.14
Community service impacts	3	21	0.21
Residual impacts	1	7	0.07
		100	

ADAPTATION OPTIONS — Normalised Scores

	Unmanaged Retreat	Managed Retreat through parking relocation	Protect - Seawall
Public implementation cost	0.00	0.21	1.00
Beach impacts	1.00	0.00	1.00
Residential impacts	1.00	1.00	0.00
Community service impacts	1.00	0.00	0.00
Residual impacts	1.00	0.00	0.00
Sum	4.00	1.21	2.00
Weighted Sum	0.64	0.22	0.57
Rank	3	1	2

Criteria Scores

	Unmanaged Retreat	Managed Retreat through parking relocation	Protect - Seawall
	$ -	$ -	$ -
Public implementation cost	0.00	0.30	1.40
Beach impacts	150.00	0.00	150.00
Residential impacts	1.00	1.00	0.00
Community service impacts	2500.00	0.00	0.00
Residual impacts	5.00	1.00	1.00

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