Appendix J - Coastal Hazard Risk Management and Adaptation Plan

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R1258 Rev 3

November 2020

Northwest Resorts Pty Ltd

Ningaloo Lighthouse Holiday Park
Coastal Hazard Risk Management & Adaptation Plan

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Table of Contents

Table of Figures

Table of Tables

1. Introduction

The proposed Ningaloo Lighthouse Holiday Park (Holiday Park) site is located on the Western Australian coastline approximately 1,200 km north of Perth. The Holiday Park site encompasses Lots 2 and 557 Yardie Creek Road, North West Cape and is situated within the Shire of Exmouth (Shire). The locality of the Holiday Park is shown in Figure 1.1 below.

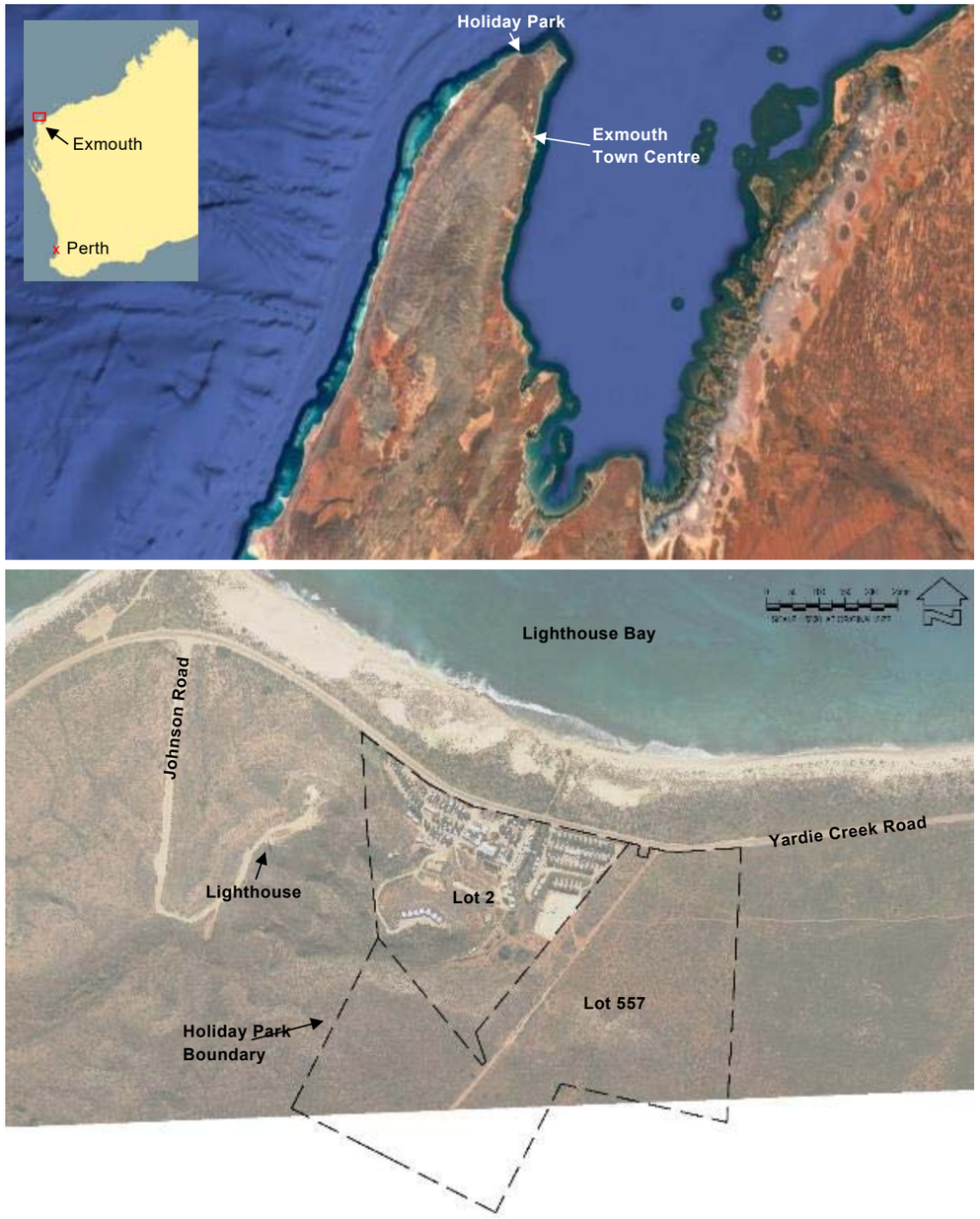

Figure 1.1 Holiday Park Location Plan

Lot 2 contains the existing Ningaloo Lighthouse Holiday Park which has been operating for over 30 years. The existing Park comprises a mix of camping and caravan park areas, cabin-based guest accommodation and associated facilities and amenities. The adjacent Lot 557 however, is vacant with the exception of unsealed vehicle tracks.

An image of the existing Holiday Park site, showing the seaward edge of both Lots 2 and 557, is provided below as Figure 1.2.

Figure 1.2 Existing Holiday Park Site

Exmouth is located close to the Ningaloo Marine Park and Cape Range National Park which are well known tourist destinations, with visitors travelling from all over Australia and the world to experience their beauty and natural wonder. As such, the Ningaloo Coast has been recognised with a UNESCO World Heritage listing based on both its marine and terrestrial qualities that need to be preserved. The extract of the Ningaloo Coast World Heritage area that includes the coastline adjacent to the Holiday Park site is shown below in Figure 1.3.

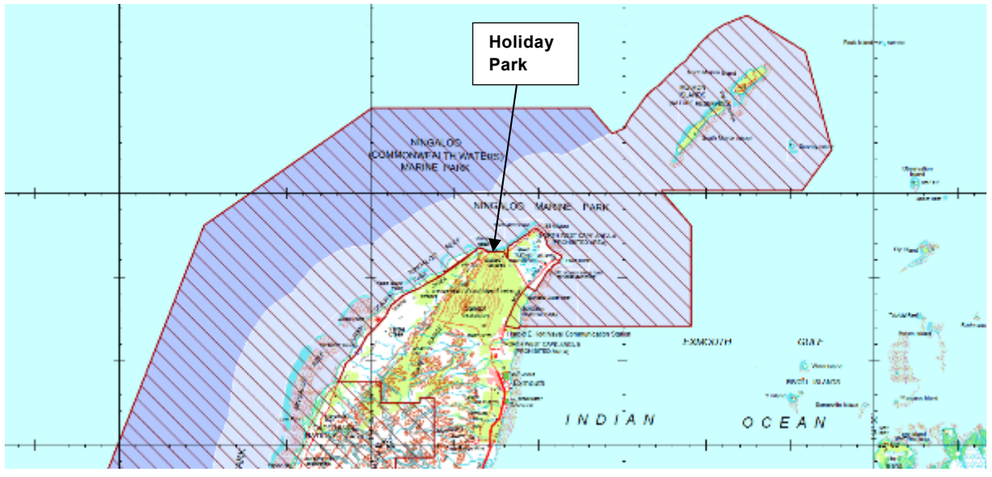

Figure 1.3 Ningaloo Coast World Heritage Area

Northwest Resorts Pty Ltd recognise the opportunity to support and enhance the growing tourism within the region and in 2017 purchased Lots 2 and 557 Yardie Creek Road. The Holiday Park site is perfectly situated to provide access to the highly valued Ningaloo Marine Park and Cape Range National Park. Northwest Resorts Pty Ltd intend to develop the site into a contemporary Holiday Park that enables a diverse range of visitors to experience and enjoy the amazing natural area that surrounds. The development of the Holiday Park will help drive sustained economic growth in Exmouth by creating year-round job opportunities, attracting long-term residents and creating opportunities for new and existing local businesses.

The vision for the Holiday Park is to create an iconic and memorable destination that protects and enhances the existing natural and social values as well as character of the coastal site. The current plans for the Holiday Park feature a wide range of accommodation types, function and retail spaces, a pool, playground and various recreational areas. It is intended that the Holiday Park will:

- Support the high standard of marine and terrestrial activities available in the region to encourage length of stay.
- Provide a range of accommodation types for families and domestic and international visitors.
- Provide large landscaped areas and open spaces for guests to relax and play.
- Be capable of satisfying high end escorted coach travellers, fly-in guests and weddings/functions.

The relevant seaward extract of the draft drawing plan for the Resort Development Approval (DA) submission, completed by Kerry Hill Architects (2019), is shown in the following Figure 1.4.

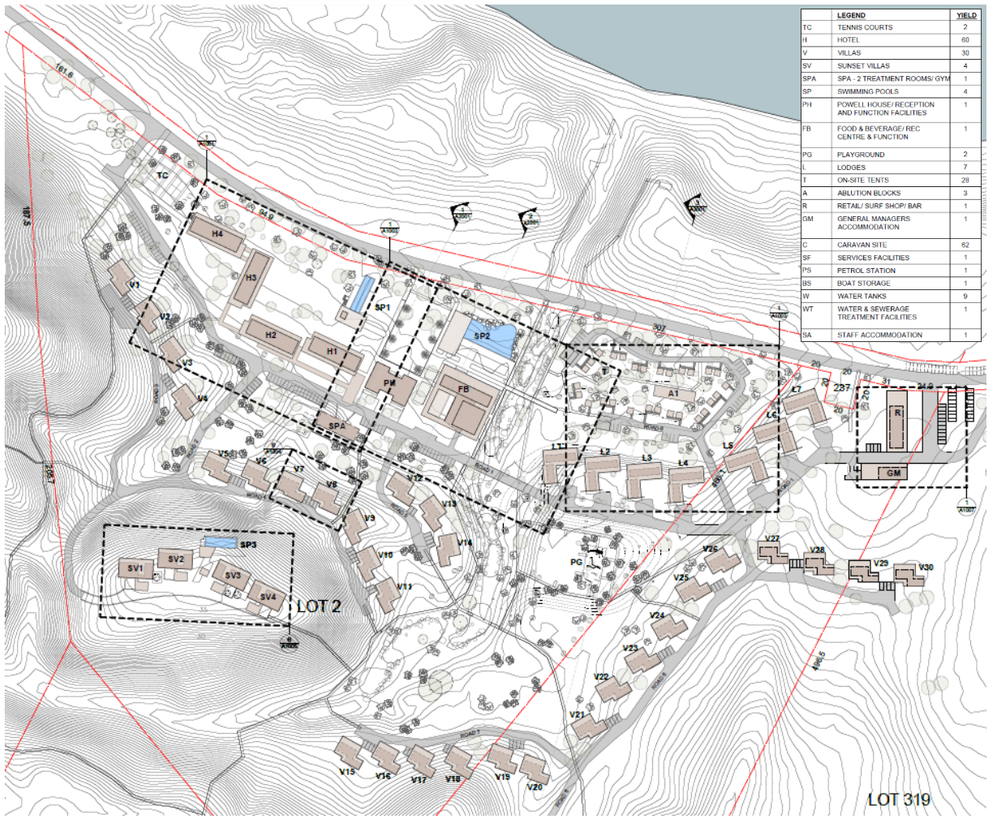

Figure 1.4 Holiday Park Draft Plan for DA Approval (Kerry Hill Architects 2019)

An architectural render is also shown in the figure below to provide context to the following sections of the report.

Figure 1.5 Architectural Render of Design (Kerry Hill Architects 2019)

As the Holiday Park site has a coastal frontage, the risks posed to the site from coastal hazards need to be considered both now and into the future. Notwithstanding the potential risks, Northwest Resorts Pty Ltd is committed to pursuing the development of the Holiday Park if it is economically feasible. Development at this location will provide a world class destination with accommodation and amenities suitable for a diverse range of tourists and visitors and help boost the Western Australian tourism industry.

1.1 Coastal Hazard Assessment Requirements

Within Western Australia, State Planning Policy 2.6: State Coastal Planning Policy (SPP2.6; WAPC 2013) provides guidance on the assessment of coastal hazard risks for assets or infrastructure located near to the coast. The objectives of SPP2.6 are wide ranging, however a key component of SPP2.6 is to provide focused areas of the coast for use by the public to access and enjoy the coastal amenity that is inherent to the Western Australian lifestyle. This includes allowing for tourism developments at appropriate locations through the provision of access to the foreshore reserve in these areas. Table 1.1 provides further details of how the proposed Holiday Park is consistent with the stated objectives of SPP2.6.

Table 1.1 Alignment of the Holiday Park with SPP2.6 Objectives

SPP2.6 Policy Objective	Details of Proposed Holiday Park Development
1. Ensure that development and the location of coastal facilities takes into account coastal processes, landform stability, coastal hazards, climate change and biophysical criteria.	The design of the Holiday Park has considered the coastal processes, landform stability, coastal hazards, climate change and biophysical criteria related to the adjacent shoreline at Lighthouse Bay. This has included ensuring that the buildings and assets of a more permanent nature within the Holiday Park are located above and behind the potential inundation levels and coastal erosion hazard allowances respectively.
2. Ensure the identification of appropriate areas for the sustainable use of the coast for housing, tourism, recreation, ocean access, maritime industry, commercial and other activities.	The adjacent Ningaloo Coast has a UNESCO World Heritage listing based on both its marine and terrestrial qualities. Furthermore, the Holiday Park site is connected with the Australia Coral Coast tourism brand (extending from Cervantes to Ningaloo) and has experiences available to enjoy the abundant wildlife and natural landscapes. These include swimming with whale sharks and manta rays, viewing the seasonal wildflowers, sighting emus, kangaroos, birds and reptiles, snorkelling, fishing and enjoying the beaches to name a few. As such, Exmouth and the surrounding region is an extremely popular tourism destination, with the local Shire generating the greatest tourist annual expenditure (approximately $151 million in 2017; Tourism Research Australia) within Western Australia. The existing development within Lot 2 has existed (Ningaloo Lighthouse Holiday Park) and operated as a tourism destination for over 30 years. With the sustained growth of this region, Northwest Resorts Pty Ltd has recognised the opportunities to redevelop Lots 2 and 557 into a contemporary Holiday Park, create a world class destination and improve the diversity and accessibility of the region.
3. Provide for public coastal foreshore reserves and access to them on the coast.	The plans for the Holiday Park include retaining the existing foreshore reserve and the access to the shoreline from Yardie Creek Road.
4. Protect, conserve and enhance coastal zone values, particularly in areas of landscape, biodiversity and ecosystem integrity, indigenous and cultural significance.	The Holiday Park design recognises the strong support for retaining public access to the beaches and foreshore reserve as well as preserving the surrounding natural environment for future generations.

The guidance on the assessment of coastal hazard risk is provided within SPP2.6 in the form of a methodology to assess the potential extent of coastal hazard impacts, as well as for the development of a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP). Further details in this regard are also provided in the CHRMAP Guidelines (WAPC 2014).

The key requirement of a CHRMAP is to develop a risk based adaptation framework for assets or infrastructure that could be at risk of impact from coastal hazards over the relevant planning

timeframe. Importantly, the balance of these risks needs to be considered in conjunction with the expected lifetime of the assets or infrastructure.

To provide guidance regarding the risks posed by coastal hazards, Northwest Resorts Pty Ltd engaged specialist coastal and port engineers, M P Rogers & Associates Pty Ltd (MRA), to complete a CHRMAP for the proposed Holiday Park development. This CHRMAP covers the following key items:

- Establishment of context.
- Coastal hazard assessment and vulnerability.
- Risk analysis and evaluation.
- Risk management and adaptation planning.
- Implementation planning.

Details regarding each of these items will be provided in this report.

2. Context

2.1 Purpose

The potential vulnerability of the coastline and the subsequent risk to the community, economy and environment needs to be considered for any coastal development.

SPP2.6 requires that the responsible management authority or development proponent prepares a CHRMAP where an existing or proposed development may be at risk from coastal hazards over the planning timeframe. The main purpose of the CHRMAP is to define areas of the coastline which could be vulnerable to coastal hazards and to outline the preferred approach for the monitoring and management of these hazards where required.

A CHRMAP can be a powerful planning tool to help provide clarity to existing and future developers, users, managers or custodians of the coastline. This is done by defining levels of risk exposure, management practices and adaptation techniques that the development proponent, with agreement from the appropriate management authority, considers acceptable in response to the present and future risks posed by coastal hazards.

Specifically, the purpose of this CHRMAP is as follows.

- Determine the specific extent of coastal hazards in relation to the proposed Holiday Park development.
- Determine the coastal hazard risks associated with the Holiday Park development and how these risks may change over time.
- Establish the basis for present and future risk management and adaptation, which will be used to inform the proposed Holiday Park development.
- Provide guidance on appropriate management and adaptation planning for the future, including monitoring.

2.2 Objectives

The key objectives of this plan are as follows.

- Inform the Holiday Park development plan by providing appropriate guidance to the proponents and key stakeholders with respect to the management of coastal hazards.
- Ensure that the proponent and key stakeholders understand the potential likelihood of assets within the proposed Holiday Park development being impacted by coastal hazards over each planning horizon.
- Outline the required coastal adaptation approach in a project specific implementation plan for the proponent and that is acceptable to key stakeholders.

2.3 Scope

The *CHRMAP Guidelines* (WAPC 2014) provide a specific framework for the preparation of a CHRMAP. This is outlined in the flowchart presented in Figure 2.1, which shows the risk management and adaptation process.

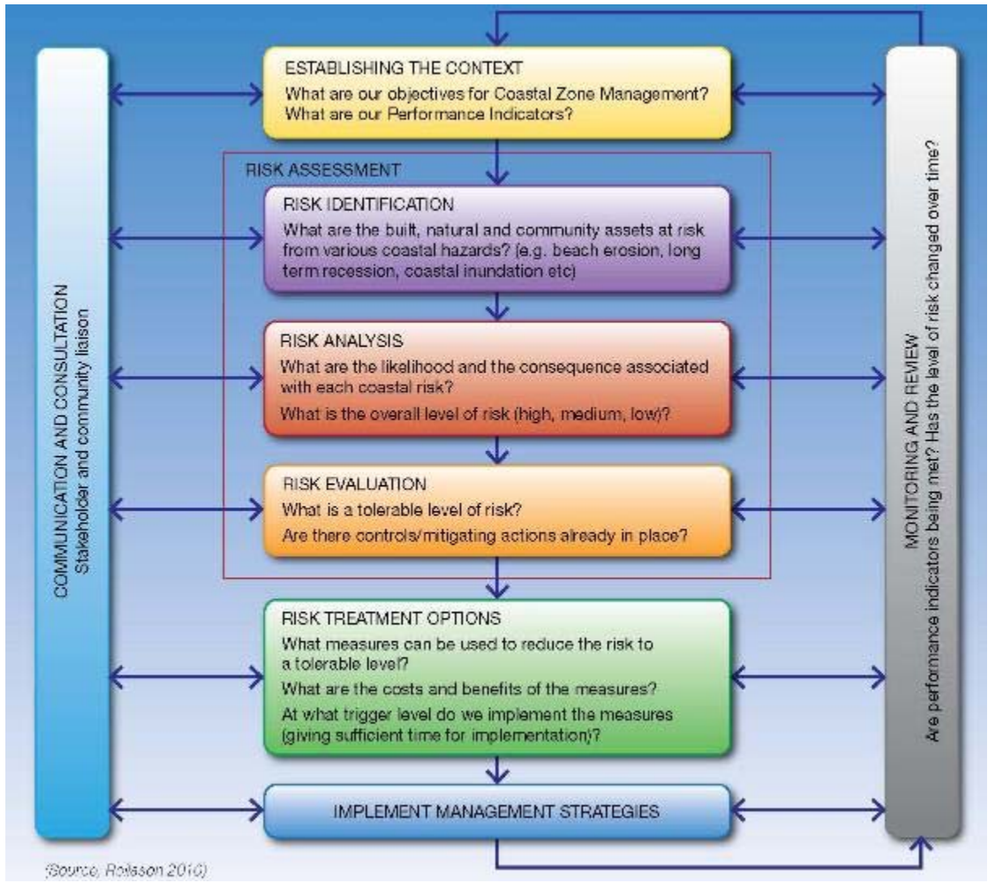

Figure 2.1 Risk Management & Adaptation Process Flowchart (WAPC 2014)

As presented in the flowchart, the process for the development of a meaningful CHRMAP requires a number of fundamental inputs. These inputs enable the assessment and analysis of risk, which should ultimately be informed by input received from key stakeholders, to help shape the subsequent adaptation strategies.

The management of coastal hazard risk associated with the proposed Holiday Park development will be required to present a proposed adaptation plan that is acceptable to the stakeholders. As a result, the approach that has been taken for this plan is to develop a management methodology that allows for flexibility into the future.

The development of the adaptation plan will be informed by the assessment of the coastal erosion and inundation hazards at the site. The identification of the coastal erosion and inundation hazards for the proposed Holiday Park development is presented within Section 3 of this report.

This CHRMAP will consider the potential risks posed by coastal hazards over a range of horizons covering the 100 year planning timeframe. This planning timeframe is required by SPP2.6 for development on the coast.

Intermediate planning horizons will also be considered in order to assess how risk profiles may change in the future and to inform the requirement for adaptation strategies. The intermediate planning horizons that will be considered in this CHRMAP are listed below.

- Present day (2019).
- 25 years to 2044.
- 50 years to 2069.
- 75 years to 2094.
- 100 years to 2119.

Based on the results of the risk assessment, risk mitigation strategies will be developed, where required, in order to provide a framework for future management. However, it is important to realise that the risk assessment will be based on the outcomes of the coastal vulnerability assessment, which, by their nature, are justifiably conservative. This is due to the uncertainty around coastal dynamics when predicting impacts over long timeframes. As a result, the framework for future risk management strategies should be considered to be a guide of future requirements.

The actual requirement for implementation of these management actions should ultimately be informed by a coastal monitoring regime. The purpose of this coastal monitoring regime is to identify changes in the shoreline or sea level that could alter, either positively or negatively, the risk exposure of the proposed assets and infrastructure. A recommended coastal monitoring regime is included within the implementation plan, presented within Section 8 of this report.

2.4 The Site

The Holiday Park site is located approximately 16 km north of the Exmouth town centre and near the northernmost tip of the North West Cape peninsula, adjacent to Vlamingh Head. The land immediately behind Vlamingh Head, termed Lighthouse Hill, reaches over 60 mAHD in elevation approximately 500 m south of the shoreline and features the Vlamingh Lighthouse near its peak. Vlamingh Hill slopes down to a shoreline which is fringed by low beachrock bluffs and fringing reefs that extend around 200 to 300 m offshore (Short 2006).

To the east, the shoreline fronting the Holiday Park site is characterised by low beachrock bluffs with a foredune generally above 10 mAHD at the back of the beach that runs parallel to the site boundary. Waves averaging about 0.5 m arrive at the beach after transgressing the offshore fringing reefs (Short 2006) and the Vlamingh Head lefthand surfing break is located on the outer edge of the reef adjacent the head.

Images of the shoreline fronting the Holiday Park are provided in the following Figures 2.2 and 2.3 and show several of the beachrock bluffs along the shoreline.

Figure 2.2 Shoreline Fronting the Holiday Park Site (Google 2007)

Figure 2.3 Shoreline Fronting the Holiday Park Site Taken in May 2011 (Gozzard 2012)

The Nautical Chart (WA 900) for Exmouth also shows the shoreline fronting the Holiday Park site as “reef that covers and uncovers.” The relevant extract of the Nautical Chart (WA 900) containing the Holiday Park site is shown in Figure 2.4 below.

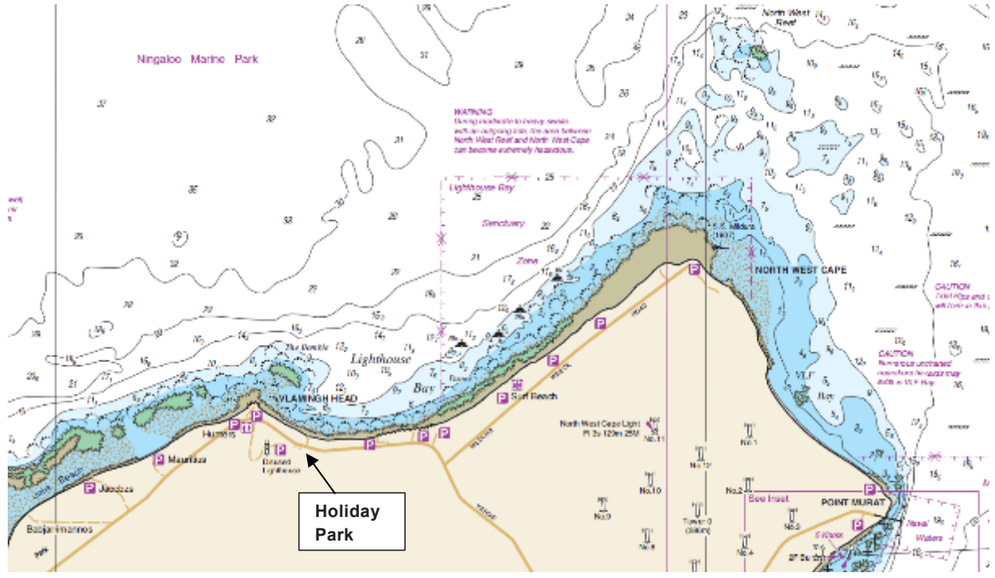

Figure 2.4 Nautical Chart (WA 900) Extract

The Coast Adapt shoreline explorer, one of the tools developed by the Australian Government to assist with coastal planning and decision making, also shows the shoreline fronting the site as being “dominantly hard rock with low erodibility.” The extract of the shoreline explorer showing the beach adjacent to the Holiday Park site is provided in Figure 2.5.

Figure 2.5 CoastAdapt Shoreline Explorer Extract

Based on the available survey information and aerial imagery for the Holiday Park site, the fronting rocky outcrops along the shoreline are generally visible between around 0.5 and 1 mAHD. This has been applied to the hydrodynamic modelling completed to simulate the shoreline response during severe events at the site, as detailed in Section 3 of this report.

A *Preliminary Geotechnical Investigation* (Douglas Partners 2019) has also been completed for a portion of the Holiday Park site to investigate the feasibility of excavating some of the underlying material. Douglas Partners (2019) outlines that the Onslow 1:250,000 scale Environmental Geology sheet shows the following geological units along the seaward portion of Lots 2 and 557, Yardie Creek Road.

- Bundera Calcarenite (Tantabiddi Member, Qbt): Including calcarenite and calcirudite, coralgal reef deposits, shallow marine and minor eolian.
- Vlamming Sandstone (Tv): Including well sorted, medium grained crossbedded quartzose calcarenite and calcrete soils and eolian.
- Longitudinal and network dunes and residual sand plains (Qe): Including reddish brown to yellowish quartz sand.

Consistent with the above geology, Douglas Partners (2019) discusses and shows various rocky outcrops throughout the site, including those shown in the following figure near the landward edge of Lot 2.

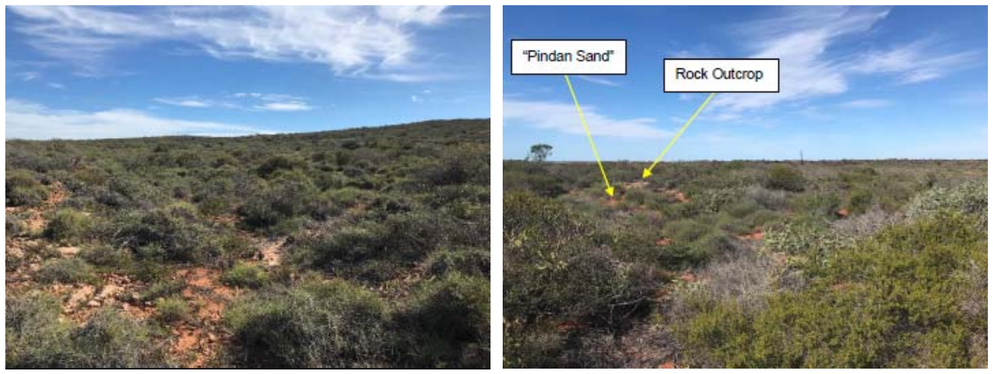

Figure 2.6 Rocky Outcrops Near Landward Edge of Lot 2 (Douglas Partners 2019)

Douglas Partners also carried out 16 Dynamic Cone Penetrometer tests within Lots 2 and 557 in locations outside the visible rocky outcrops to measure in-situ density of shallow soils and to provide an indication on possible depth to rock. The results indicate shallow underlying rock of varying strength at a number of locations within both Lots 2 and 557.

Given that the rock throughout the Holiday Park site hasn't been confirmed as continuous by the geotechnical investigations completed, the Holiday Park shoreline is to be assessed as a sandy coast in accordance with SPP2.6.

The rock platforms fronting and throughout the Holiday Park site, are however likely to provide some level of protection compared to a typical sandy beach. Therefore, the outcomes of the coastal hazard assessment and subsequent risk analysis are considered to be conservative.

In 2012, the Department of Planning engaged Damara WA Pty Ltd to prepare a technical report on *The Coast of the Shires of Shark Bay to Exmouth, Gascoyne, Western Australia: Geology, Geomorphology and Vulnerability.* The key aim of the project was to determine the vulnerability of landforms along the Gascoyne coast to changing environmental conditions, including projected changes in climate. This considered primary (geological timescales), secondary (contemporary timescales) and tertiary (decadal timescales) sediment compartments (Damara 2012) between the Shires of Shark Bay and Exmouth as well as further delineated cells classified based on geology and geomorphology.

The Holiday Park site is situated within the Ningaloo primary compartment, the Winderabandi Point to North West Cape secondary compartment, the Vlamingh Head to North West Cape tertiary compartment (primary cell) and the Vlamingh Head to East Vlamingh secondary cell, as listed below in Figure 2.7 and shown in Figure 2.8.

Compartment			Cell
Primary	**Secondary**	**Tertiary**	**Primary**
NINGALOO: Alison Point to North West Cape	Winderabandi Point to North West Cape	Vlamingh Head to North West Cape	18. Secondary cell is Vlamingh Head to East Vlamingh ++ (Primary cell is Vlamingh Head to North West Cape)
		Low Point to Vlamingh Head	17. Secondary cell is Babjarrimannos to Vlamingh Head ++ (Primary cell is Vlamingh South to Vlamingh Head)
			Note. Further cells not delineated
		Osprey Bay to Low Point	
		Winderabandi Point to Osprey Bay	
	Point Cloates to Winderabandi Point	Point Cloates to Winderabandi Point	
	Point Maud to Point Cloates	Coast Hill to Point Cloates	
		Point Maud to Coast Hill	
	Alison Point to Point Maud	Alison Point to Point Maud	16. Purdy Point to Point Maud +
			15. Point Anderson to Purdy Point +
			Pelican Point to Point Anderson
			Alison Point to Pelican Point

Figure 2.7 Compartments & Sediment Cells for Holiday Park Site (Damara 2012)

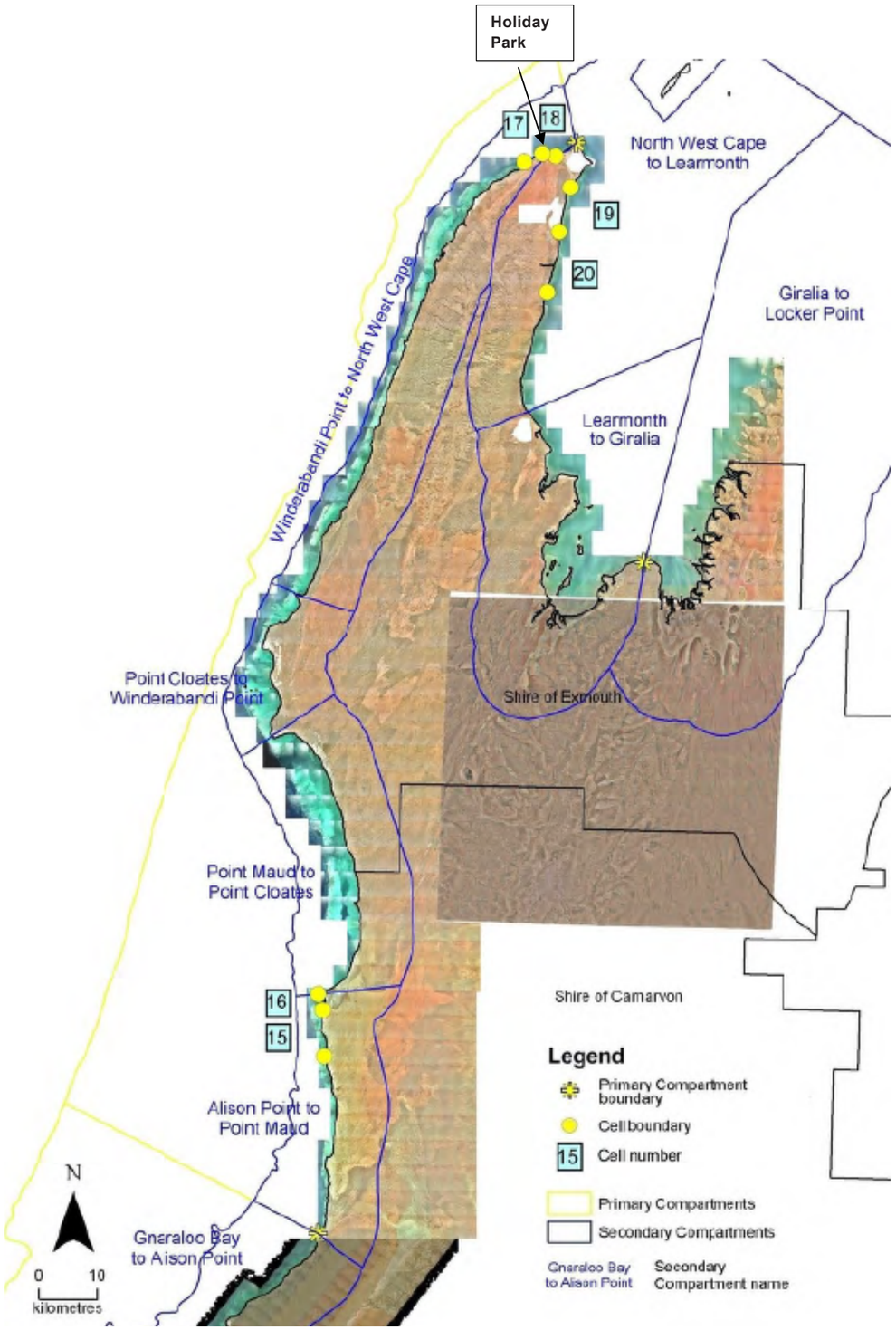

Figure 2.8 Compartments for Holiday Park Site (Damara 2012)

Based on comparisons of available aerial imagery, oblique aerial imagery, identified landforms and cell descriptions (Damara 2012), the susceptibility, instability and vulnerability of each primary cell was assessed. The relevant Vlamingh Head to East Vlamingh primary cell, encompassing the Holiday Park shoreline, was assessed as having a low susceptibility to change and a low instability. Subsequently, the cell was rated as having a low vulnerability, with coastal risk of inundation and flooding noted as being unlikely to constrain coastal management.

(Damara 2012) also recommended the following for the cell encompassing the Holiday Park:

- Development of a monitoring system that identifies:
  - Tropical Cyclones with the potential to threaten Vlamingh Head, and the predicted coincidental tidal conditions. Information available for such an assessment is held by the Bureau of Meteorology (BoM) and the Department of Transport (DoT), although this requires subsequent interpretation to identify the risk at Vlamingh Head.
  - Tsunami with the potential to threaten Vlamingh Head. The information for this assessment could be obtained by the Australian Tsunami Warning System, coordinated by the BoM, Geoscience Australia and Emergency Management Australia (EMA).
- Installation of signage at coastal car parks and/or distribution of safety information regarding tsunamis to inform the transient visitors to the area of the risk. This information is available from EMA.
- Definition and dissemination of an evacuation plan, particularly for the areas that may be at greater risk of flooding or inundation.

These recommendations as well as the relevant sediment compartments/cells will be considered in conjunction with the coastal hazard assessment and risk management and adaptation strategies discussed in Sections 3 and 7 of this report respectively.

2.5 Stakeholder Engagement

In February 2019, Element prepared a Local Development Plan on behalf of Northwest Resorts Pty Ltd, for the proposed development of Lots 2 and 557 Yardie Creek Road, North West Cape (Element 2019). The Local Development Plan went through an advertising period and 10 submissions were received from the public, local departments and local organisations.

Overall, the project has received positive feedback to date and stakeholder engagement and consultation will be ongoing through the subsequent Development Approval phase.

2.6 Planning Controls

The planning controls for the site are set out in the Shire Local Planning Scheme No. 4, and more specifically in the Local Development Plan referred to in Section 2.5 above.

2.7 Environmental Requirements

The environmental requirements for the Holiday Park are detailed within the documentation provided to support the Development Approval application. Information about the bushfire requirements, as it relates to access to and from the site which is provided via Yardie Creek Road, is outlined below.

2.7.1 Bushfire Prone Areas

The project area is designated as bushfire prone on the WA Map of Bush Fire Prone Areas due to native vegetation located within 100 m of the site that triggers bushfire planning requirements under State Planning Policy 3.7: Planning in Bushfire-Prone Areas. The necessary bushfire planning inputs have been prepared in support of the proposed development.

2.8 Key Assets

The proposed Holiday Park development is being prepared with the specific requirement to not impact the social and environmental values of the area, as to do so would be an unacceptable outcome to the key stakeholders and would detract from the tourism value of the site. As a result, the preservation of social and environmental values is considered to be inherent in the development of the relevant plans for the Holiday Park.

It has therefore been identified that a coastal adaptation strategy will need to be prepared to ensure that there is no impact on the social and environmental values of the area. This will require a coastal adaptation strategy that, incorporating the results of the coastal hazard assessment presented in Section 3, ensures the Holiday Park development assets are appropriately designed and managed to safeguard against any adverse impacts. This assessment will be completed with regard for the expected economic life of the facilities that will be constructed. For instance, it is envisaged that the design life of the structures within the Holiday Park will be limited to 50 years for buildings and more permanent infrastructure. On the other hand, facilities of a temporary nature within the foreshore reserve are expected to be limited to a 25 year design life. Beyond this period, it is expected that the condition of these assets would be such that they would need to be replaced.

In this regard, whilst the key environmental assets are included in Table 2.1 and discussed thereafter, the planning for the development has already addressed the risks associated with these assets.

The key assets within the proposed Holiday Park development were shown on the plan provided in Figure 1.4 and have also been summarised in Table 2.1 below. The risk assessment will focus on these assets in order to identify their vulnerability to coastal hazard impact and consequently the requirements for risk management.

It is understood that all of the existing assets within the Holiday Park boundary (Lots 2 and 557) will be replaced as part of the proposed development. As such, these assets are not included in the following Table 2.1 or assessed in this CHRMAP. There are no modifications proposed to the alignment of Yardie Creek Road which runs along the seaward boundary of the Holiday Park and it is therefore included in the risk analysis and assessment presented in Sections 5 and 6 of this report.

Table 2.1 Key Assets within Proposed Holiday Park Development

Key Assets	Elevation / Finished Floor Level (mAHD)
Environment	
Beach	N/A
Coastal Dunes	N/A
Social	
Retail/Surf Shop/Bar	>~ 12.5
Lodges	>~ 9.5
On-site Tents	>~ 8.5
Ablution Blocks	>~ 9.0
Villas	>~ 13.5
General Managers Accommodation	>~ 12.5
Playground	>~ 14.0
Food & Beverage/Rec Centre	>~ 9.0
Swimming Pools	>~ 8.0
Powell House/Reception & Function Facilities	>~ 9.5
Spa/Gym	>~ 11.0
Hotel	>~ 9.0
Sunset Villas	>~ 33.0
Tennis Courts	>~ 9.0
Economic	
Yardie Creek Road	>~ 6.5

Notes: 1. Based on the existing Holiday Park site levels.

2.9 Success Criteria

The success criteria for the CHRMAP will ultimately be as follows.

- To ensure the proponent and key stakeholders understand the potential extent of impact of coastal hazards on the proposed assets within the Holiday Park development.
- To ensure the proponent and key stakeholders understand the potential likelihood of assets within the proposed Holiday Park development being impacted by coastal hazards over the 100 year planning timeframe.
- To determine and advise on the level of risk to assets within the proposed Holiday Park development of being impacted by coastal hazards over the 100 year planning timeframe.
- Development of an acceptable risk management and adaptation strategy for the proposed Holiday Park development over the 100 year planning timeframe.
- Development of an implementation plan to outline the requirements and responsibilities over time.

The outcomes of the success criteria listed above are presented in the following sections of this report.

3. Coastal Hazard Assessment

3.1 Methodology

Exmouth is a region prone to tropical cyclones, which means that a tropical cyclone is likely to represent the critical 100 and 500 year ARI storm events required for consideration at the Holiday Park in accordance with SPP2.6. On average the northwest coast of Western Australia experiences an average of about 5 tropical cyclones per year. Of these, an average of about 2 cyclones cross the coast per year and one of these is severe, defined as being a category 3 or higher (BoM 2018).

Tropical cyclones in this region generally occur between November and April, however the chance of experiencing an intense category 4 or 5 cyclone is highest in March and April (BoM 2018). The effects of any one cyclone depends upon the intensity of the central pressure deficit, the radius to maximum wind and the actual track of the cyclone. Differences in these features result in significant variations between the physical effects of each event (wind and wave conditions, storm surge, etc).

Tropical cyclone tracks vary in response to weather patterns and surrounding environmental flows that occur at the time, though generally, tropical cyclones in the northwest follow a reasonably predictable path. Typically, after forming at lower latitudes, tropical cyclones are initially steered to the west-south-south before taking a more southerly track as they move south. If tropical cyclones move south beyond about 22°S, or cross the coastline, they tend to curve to the south-south-east (BoM 2018).

In 2018, Seashore published *Design Storms for Western Australian Coastal Planning: Tropical Cyclones*. The report identifies tropical cyclone scenarios for town sites along the Western Australian coast between Augusta and the Western Australia/Northern Territory border, which includes Exmouth. Review of region specific storm scenarios with varying characteristics such as cyclone intensity, frequency, scale and track was completed to develop design storms for each of the town sites. The study has been distributed by DoT and is intended to complement the SPP2.6 in determining coastal hazards, albeit the extreme water levels defined within the document are noted as being deliberately conservative.

As an indication of the potential surge that can be experienced during the passage of a severe event, recordings from the tide gauge at Exmouth (Figure 3.1 below) during the passage of Tropical Cyclone Vance in 1999 showed a 3.4 m residual above the predicted tidal level. This is the highest residual water level recorded within a tide gauge along the Western Australian coastline. However, Seashore (2018) note that tide gauge recordings are not always reliable in extreme events due to a variety of factors, such as damage to the gauge, choking by debris or exceedance of the vertical limit of gauge measurements.

Figure 3.1 Recording Device Locations (Google Earth)

It is important to understand the typical duration of peak storm surge. The water level record from Exmouth during the passage of Tropical Cyclone Vance illustrates the acuteness of this peak. As shown on Figure 3.2, the measured water level is significantly higher than the predicted tidal level for a period either side of the peak, however the more significant build up to the peak water level is less than 3 hours in total duration, with the actual peak water level in existence for less than around half an hour.

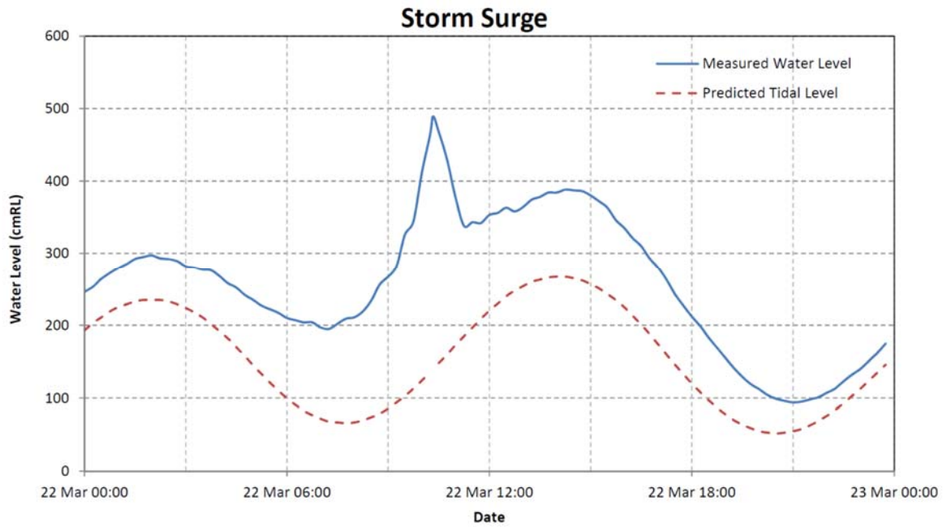

Figure 3.2 Exmouth Water Level Record for Tropical Cyclone Vance

Whilst differences in the duration of the peak water level are specific to each event with regard to the strength, proximity and speed of the cyclone, the general trend will be consistent with only short durations for the peak water level. This is an important consideration with regard to planning for development in cyclone effected areas, as discussed in later sections of this report.

Seashore (2018) provides a preliminary set of estimated ARI inundation levels, including for the Exmouth region. In the absence of targeted and more detailed modelling, the levels presented by Seashore are deliberatively conservative. The potential inundation levels for Exmouth provided for the 100 and 500 year ARI events are summarised in the following Table 3.1.

Table 3.1 Preliminary Inundation Levels (Seashore 2018)

ARI	Preliminary Inundation Level
100	4.0 mAHD
500	5.2 mAHD

As recommended by Seashore (2018), site specific coastal hazard modelling was completed for the Holiday Park site in order to refine these preliminary estimates.

MRA has previously setup, calibrated and validated a Delft3D hydrographic model for the North West Cape peninsula (MRA 2019). The model's ability to accurately represent conditions at the Holiday Park site can be demonstrated by the simulation of Tropical Cyclone Nicholas and comparison to the observed record.

The observed water level and wave record was obtained from the Exmouth tide gauge and Exmouth Waverider Buoy respectively (refer to Figure 3.1). A comparison between the observed record and the model outputs was undertaken for both wave and water levels. The following figures show the observed data record and the model outputs during Tropical Cyclone Nicholas at a comparable location during the event.

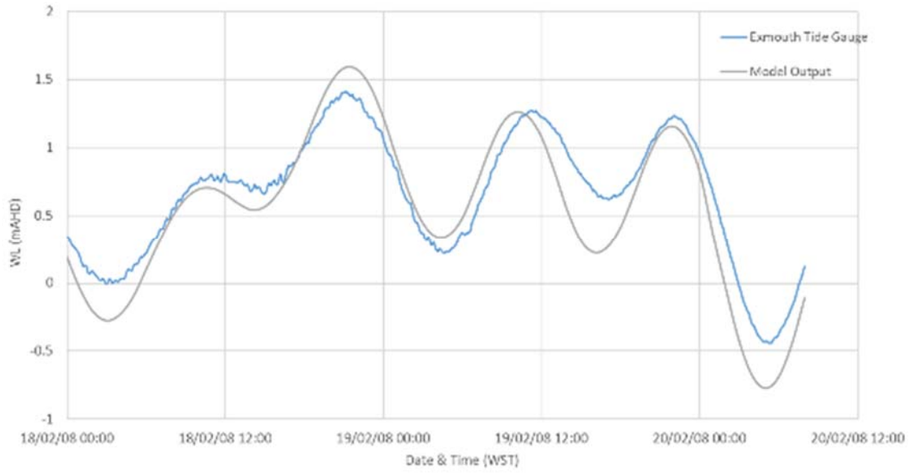

Figure 3.3 Water Level Comparison for Modelled Tropical Cyclone Nicholas

As shown, observations at the tide gauge are generally well reflected in the model, although the peak water level is slightly overestimated (conservative).

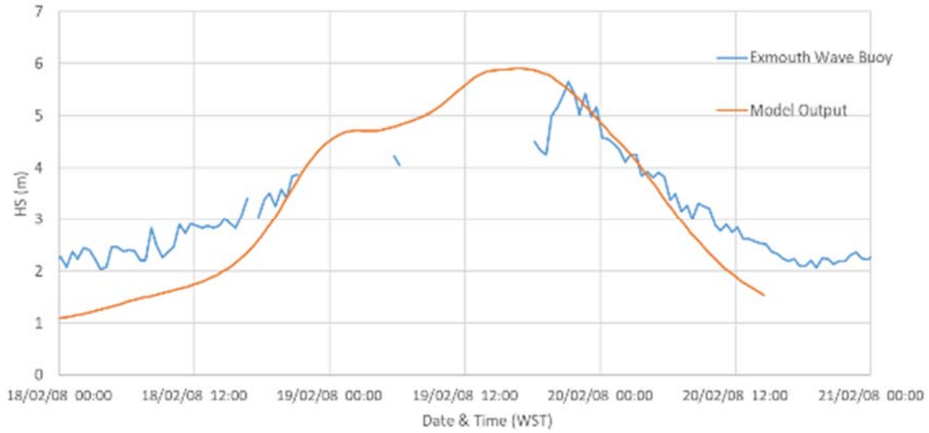

Figure 3.4 Wave Comparison for Modelled Tropical Cyclone Nicholas

The comparison generally demonstrates good agreement between the model outputs and the available data record, although the ability to compare the peaks of each dataset is limited by the missing data in the data record. As expected, the more ambient periods prior to and after the cyclone passing the site are under represented by the model. The model only generates waves resulting from the cyclone wind field. Therefore, parts of the wave spectrum dominated by background wave conditions would not be expected to be accurately reflected in the model.

Based on the comparison of the model outputs the model provides a reasonable, if slightly over-estimated (conservative) representation of the observed conditions.

Design events consistent with the requirements of SPP2.6 (100 and 500 year ARI) are required to simulate and assess coastal hazards at the Holiday Park site. To be suitably conservative, the design event must represent the 'worst case' conditions at the site for the chosen ARI. For the Holiday Park site, storm surge is a function of the following tropical cyclone parameters:

- Cyclone intensity, typically described by central pressure deficit;
- Proximity of the system centre to the point of observation;
- Radius of maximum winds; and
- Cyclone forward speed.

Seashore (2018) suggested that tracks corresponding to cyclones producing the highest measured surge at tidal stations around WA provided an indication of the track that should be considered for a 'worst-case' approach in the near vicinity of the station. These characteristics were used by Seashore to determine a set of design storm paths, based on historic storms, for each of the town sites of interest. For the Exmouth region, the cyclone that provides the 'worst case' approach is Tropical Cyclone Nicholas. The path of this cyclone is shown in Figure 3.5.

To determine appropriate scaling of central pressure and radius to maximum winds, Seashore (2018) also assessed characteristics of tropical cyclones along the Western Australian coast within 5º latitude-longitude cells. Within each cell the BoM tropical cyclone database was interrogated to evaluate distributions of cyclone central pressure and radius. The results of this were combined with the 'worst case' approach to define design cyclone events. The characteristics of the 100 year ARI (erosion case) and 500 year ARI (inundation case) design cyclones given for the site are shown in the figure below.

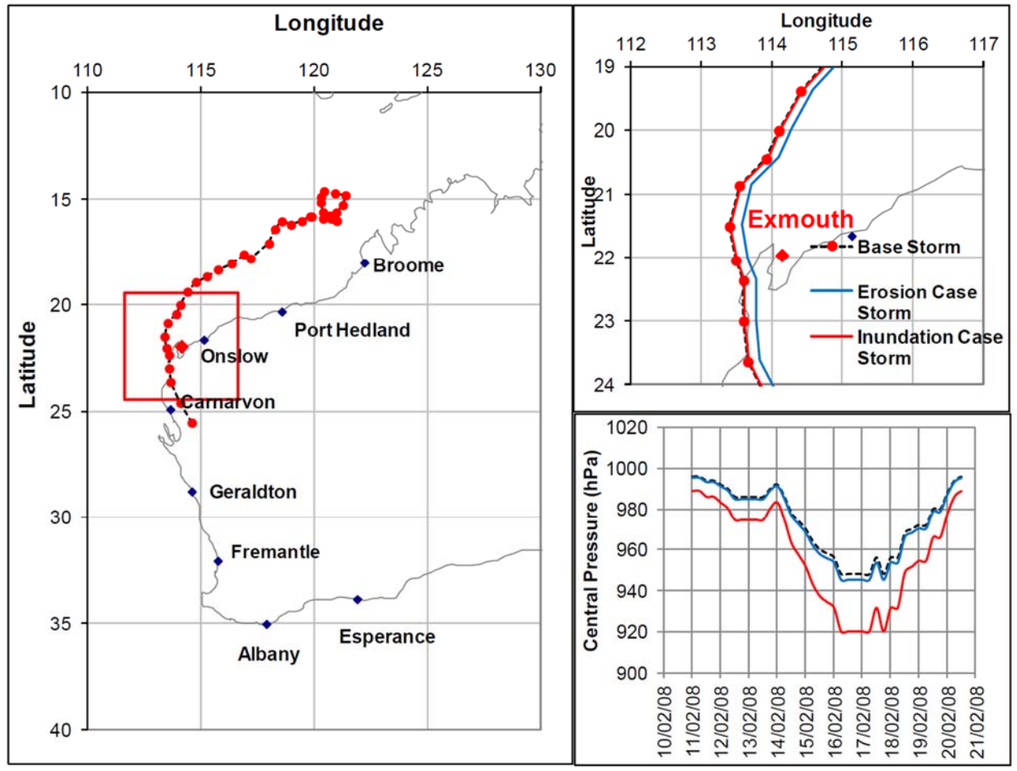

Figure 3.5 Design Events Based on Tropical Cyclone Nicholas

The design cyclones shown in Figure 3.5 were simulated using the calibrated and validated Delft3D model to assess the erosion and inundation hazards, in accordance with the recommendations of SPP2.6. These results are discussed further in the following sections of this report.

3.2 Coastal Erosion Hazard Identification

Schedule One of SPP2.6 presents the recommended methodology for the calculation of coastal erosion hazards. For sandy coasts, as adopted for the Holiday Park shoreline (refer to Section 2.4), the assessment methodology requires that consideration is given to the potential impacts of each of the following.

- Severe storm erosion associated with the 100 year ARI event (termed the S1 Allowance).
- Long term shoreline movement (termed the S2 Allowance).
- Sea level rise (termed the S3 Allowance).
- An allowance of 0.2 m/year for uncertainty.

The calculations of these erosion allowances are presented in the following sections.

3.2.1 S1 Erosion Allowance – Severe Storm Erosion

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. These two factors acting in concert allow waves to erode the upper parts of the beach not normally vulnerable to wave attack.

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, beach berm and sometimes the dunes. The eroded sand is consequently transported offshore with the return water flow to form offshore bars. As these bars grow, they can cause incoming waves to break further offshore, decreasing the wave energy available to attack the beach. This is shown diagrammatically in Figure 3.6 for a sandy coastline.

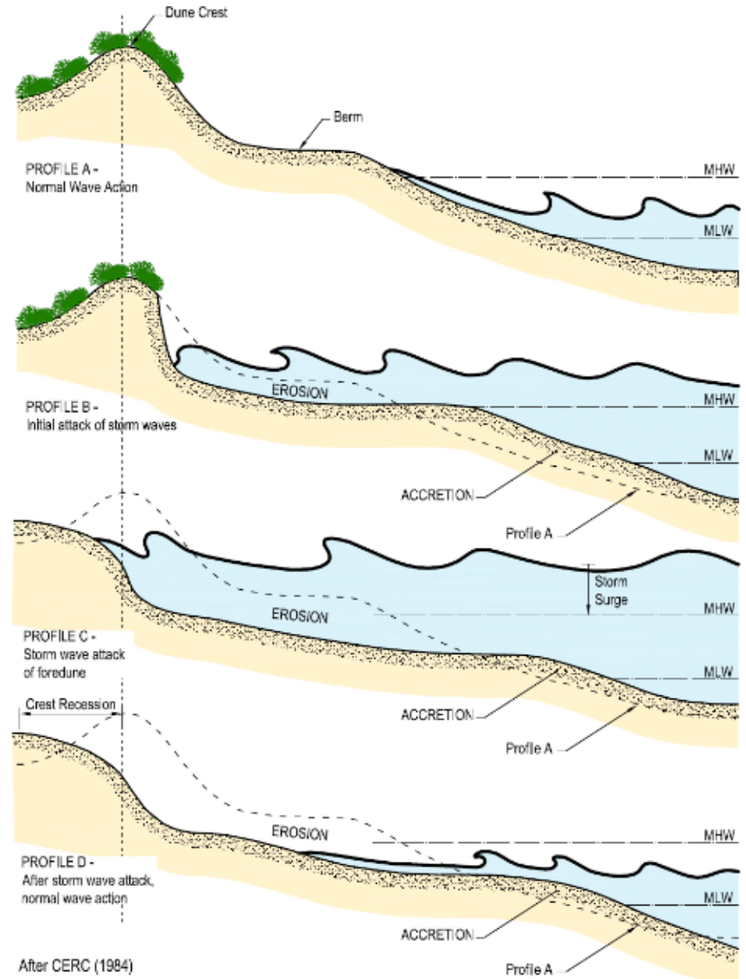

Figure 3.6 Storm Wave Attack

SPP2.6 recommends that potential cross shore erosion be determined by modelling the impact of an appropriate storm sequence using acceptable models such as SBEACH (WAPC 2013). It is also specified that the modelled storm should have an annual exceedance probability (AEP) of 1% with regard to beach erosion. This is equivalent to a storm with an ARI of 100 years.

A representative profile to simulate the response at the shoreline fronting the Holiday Park site was developed using the following data and is shown in Figure 3.7.

- Topographic data based on a contour survey of the Holiday Park site and foreshore area, completed in November 2011.
- Hydrographic survey from DoT extending offshore to -25 mAHD.
- A hard rock bottom between 0.5 and 1 mAHD, based on the visible rock at the shoreline fronting the Holiday Park (discussed previously in Section 2.4).

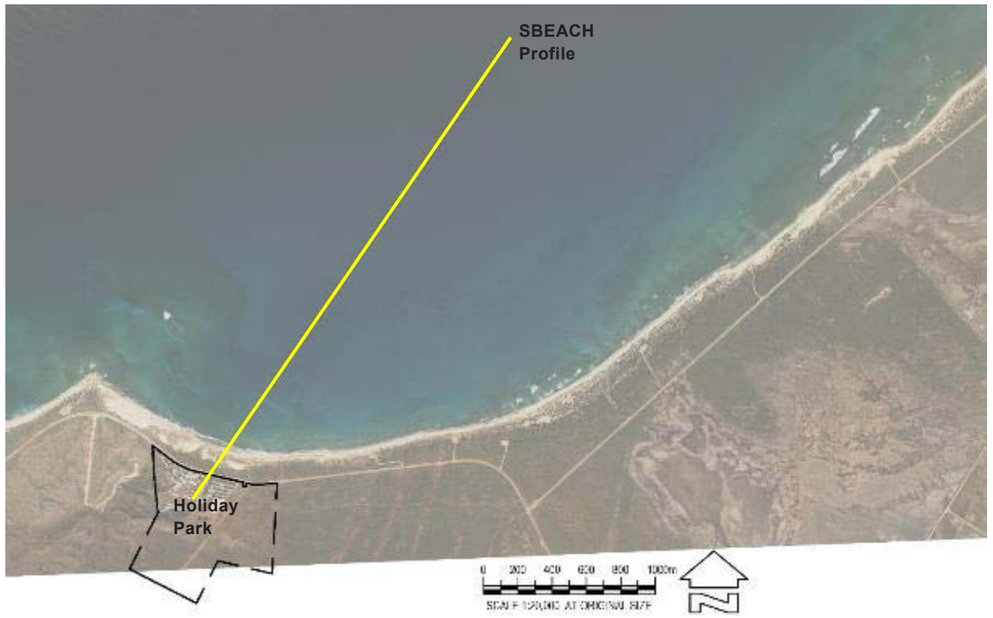

Figure 3.7 Holiday Park SBEACH Profile Location

Inputs for the SBEACH model were derived from the Delft3D cyclone and hydrodynamic modelling of the 100 year ARI event based on Tropical Cyclone Nicholas and provided by Seashore (2018), as discussed previously in Section 3.1.

The design cyclone was simulated within the domain using the previously calibrated and validated Delft 3D model. The background water level for the simulation was Mean High Water Springs (MHWS; 0.95 mAHD). This is consistent with the approach recommended in Seashore (2018).

Wave and water level conditions from the model were extracted at the offshore end of the SBEACH profile. As per SPP 2.6, three repeats of these conditions were used as boundary conditions for SBEACH modelling. A time series of the boundary conditions is shown in Figure 3.8.

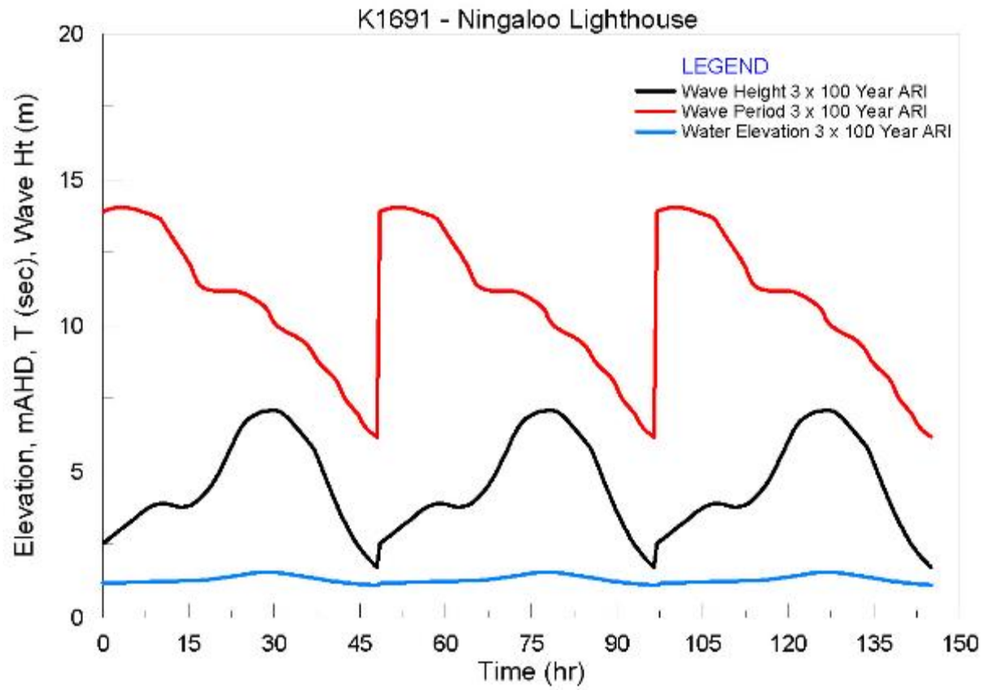

Figure 3.8 100 Year ARI SBEACH Boundary Conditions

A sediment size (d_{50}) was determined from the laboratory analysis of a sediment sample completed previously for a nearby section of shoreline in Exmouth. The Particle Size Distribution Graph of this sample is shown below in Figure 3.9 and shows that a d_{50} of 0.3 mm is appropriate for use at the Holiday Park.

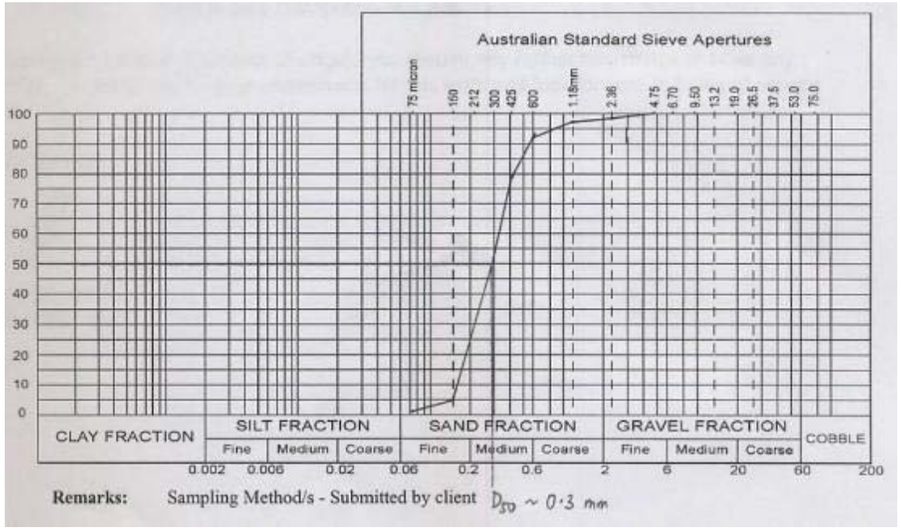

Figure 3.9 Particle Size Distribution Graph for Exmouth Sediment Sample

For this assessment, a stable slope profile of 30 degrees from the horizontal was also adopted in accordance with the SPP2.6 recommendations. The model output from the SBEACH simulation of the cyclone conditions is provided in Figures 3.10. The SBEACH model report is provided in Appendix A.

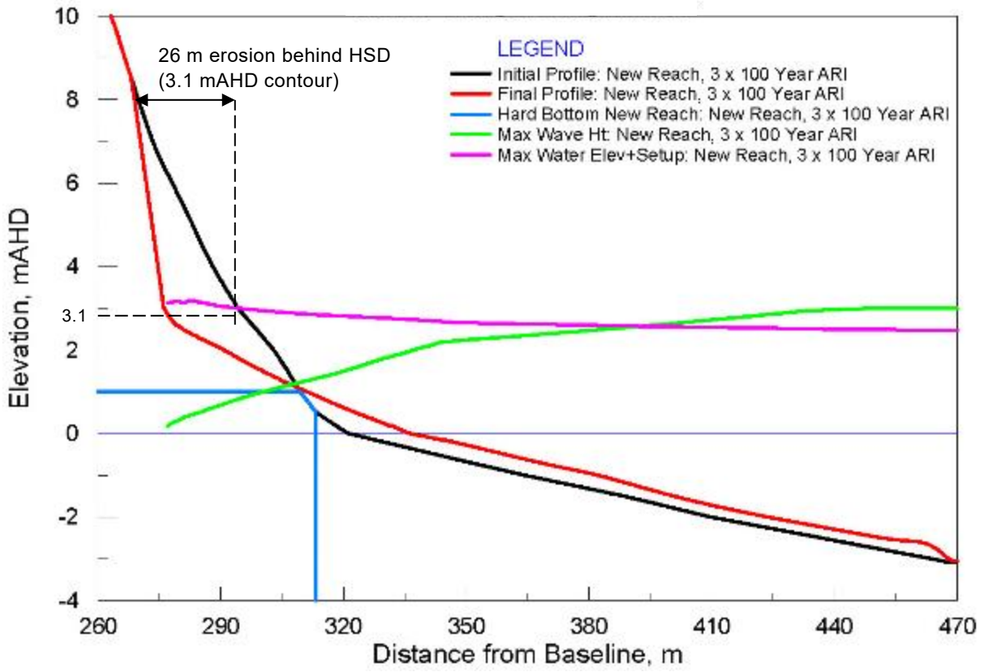

Figure 3.10 Outputs from SBEACH Simulation of Adjacent Shoreline

Figure 3.10 shows 26 m of erosion behind the 3.1 mAHD HSD to the shoreline fronting the Holiday Park during the design event. Therefore, a 26 m storm erosion allowance is required for S1.

3.2.2 S2 Erosion Allowance – Long Term Shoreline Movement

Historically, changes in shorelines occur on varying timescales from storm to post storm, seasonal and longer term (Short 1999). The S1 Erosion allowance accounts for the short term storm timescale of beach change. The S2 Erosion allowance is intended to account for the longer term movement of the shoreline that may occur within the planning horizon. To determine the S2 Erosion allowance, historical shoreline movement trends are examined and likely future shoreline movements predicted.

Shoreline Movement Analysis

SPP2.6 recommends that shoreline movement trends be based on the review of available shoreline records. This can include analysis of historical aerial photography, High Water Mark (HWM) surveys or previously extracted coastal vegetation lines available from DoT.

Available aerial photographs extend back 50 years to 1969, although are at limited intervals. The following aerial photographs were purchased, rectified and the vegetation line extracted.

- 1969.
- 2000.
- 2004.
- 2007.
- 2014.

The coastal vegetation lines were extracted from the aerial photographs using the methodology outlined in DoT (2009). The accuracy of the photogrammetry technique is expected to be in the order of ± 5 m. The position of the vegetation line was analysed for the entire Vlamingh Head to North West Cape tertiary compartment (primary cell; Damara 2012). This is illustrated by the shoreline movement plan provided as Appendix B. Figure 3.11 shows the chainage plan for the shoreline movement analysis. The Holiday Park shoreline extends between approximately chainage 100 and 1000 m.

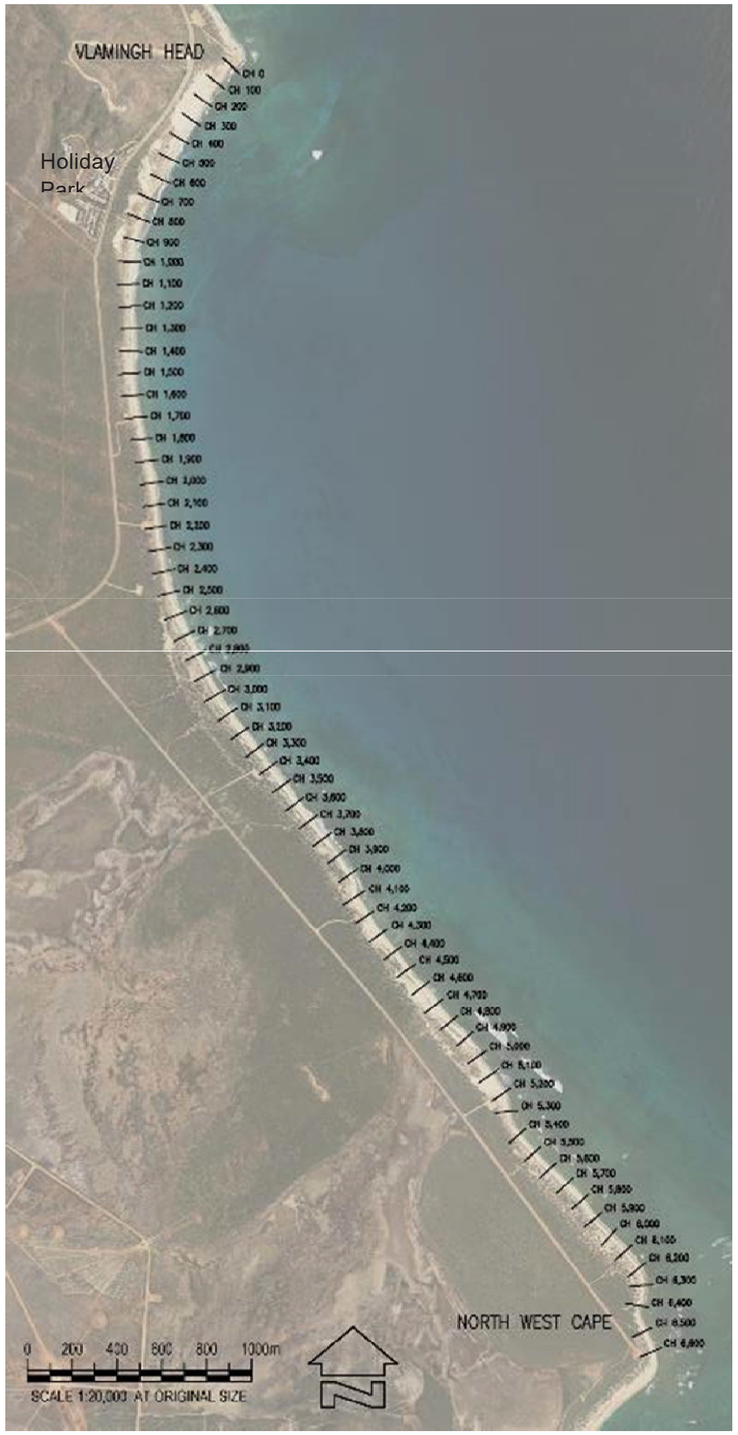

Figure 3.11 Chainage Plan for Shoreline Movement Analysis

The movements of the shoreline relative to the 1969 coastal vegetation line were estimated at each of the chainages and are presented in Figures 3.12 and 3.13. The rates of shoreline movement per year were also calculated at each of the chainages and are presented in Figures 3.14 and 3.15.

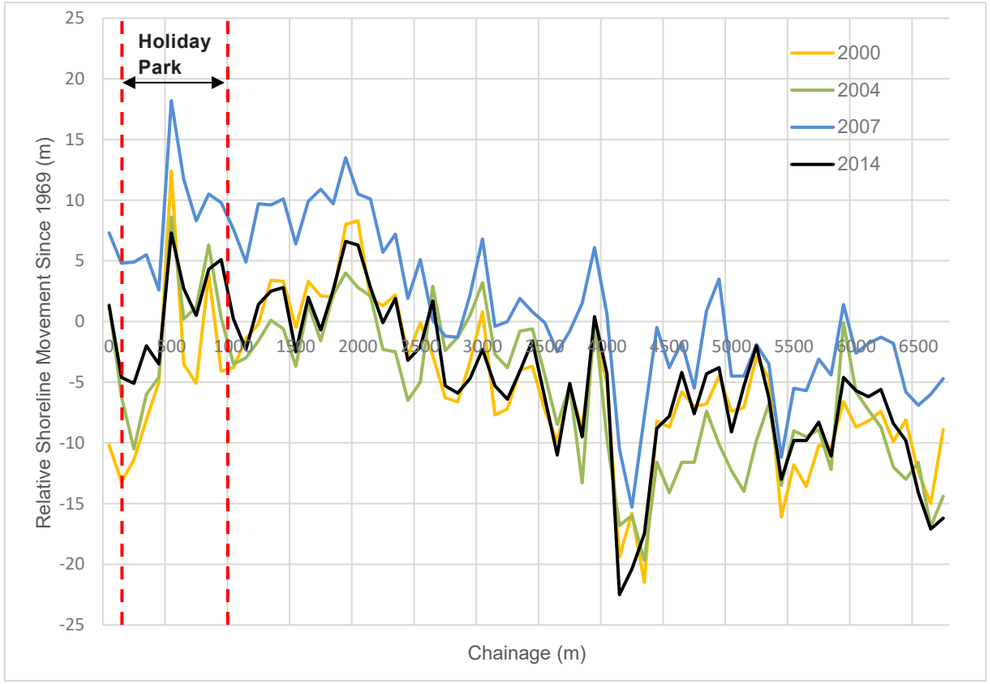

Figure 3.12 Shoreline Position Relative to 1969

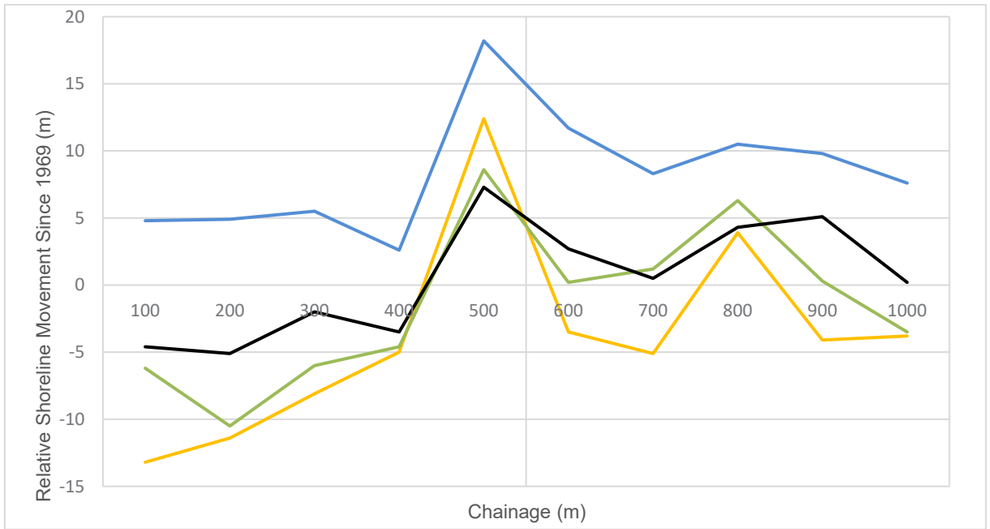

Figure 3.13 Shoreline Position Relative to 1969 Fronting Holiday Park

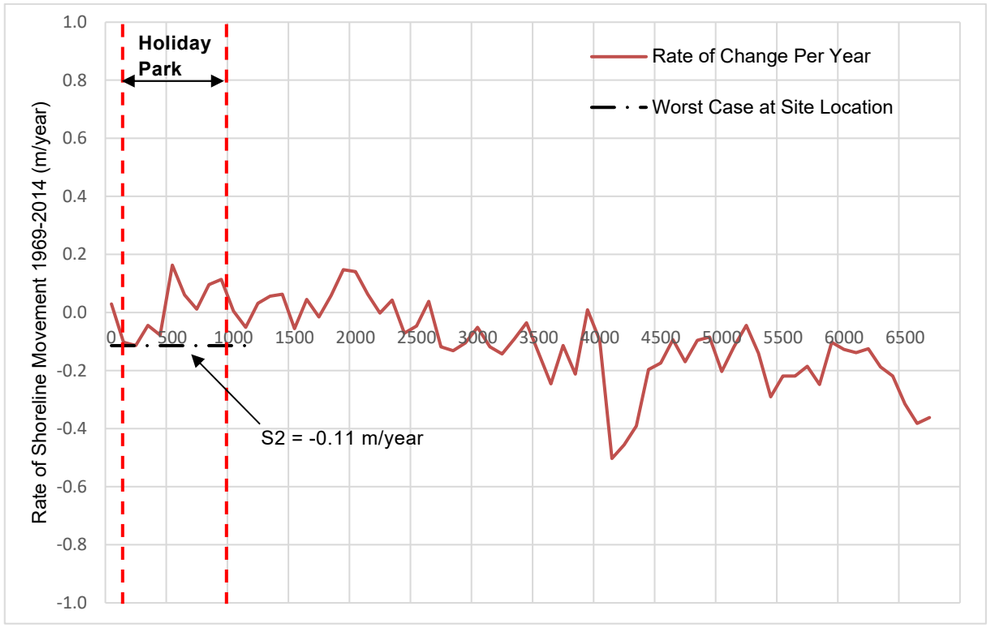

Figure 3.14 Annual Shoreline Movement Rates From 1969 to 2014

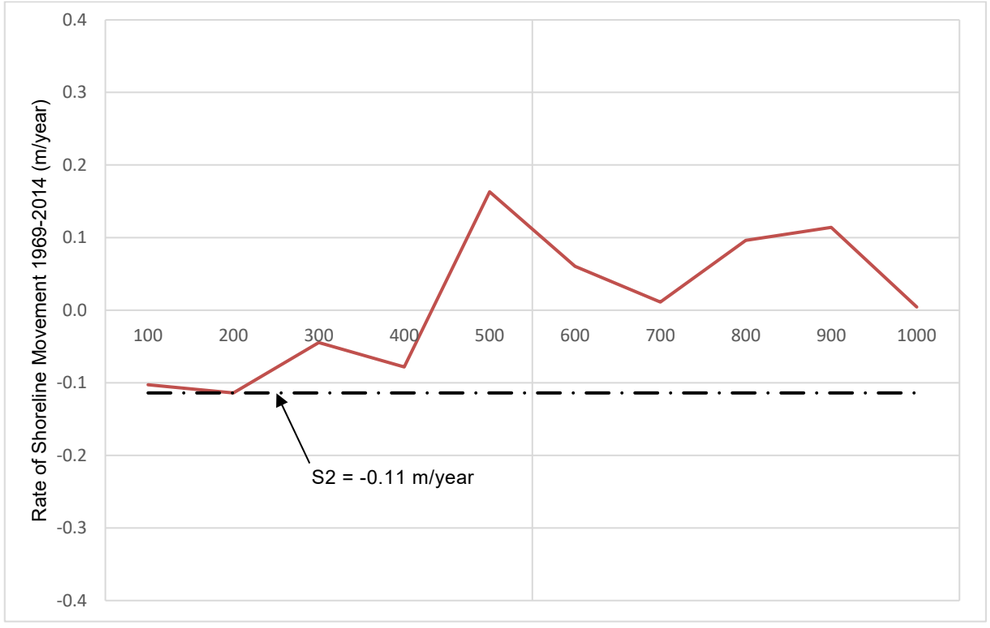

Figure 3.15 Annual Shoreline Movement Rates From 1969 to 2014 Fronting Holiday Park

The maximum rate of annual erosion observed for the section of shoreline fronting the Holiday Park, between chainages 100 m to 1000 m, was 0.11 m/year. Therefore, an S2 erosion allowance

of 0.11 m/year is recommended to determine the coastal erosion hazard allowances for the Holiday Park.

3.2.3 S3 Erosion Allowance – Sea Level Rise

The Intergovernmental Panel on Climate Change (IPCC) has presented various scenarios of possible climate change and the resultant sea level rise in the coming century. The range of these projections is shown in Figure 3.16 (IPCC 2013).

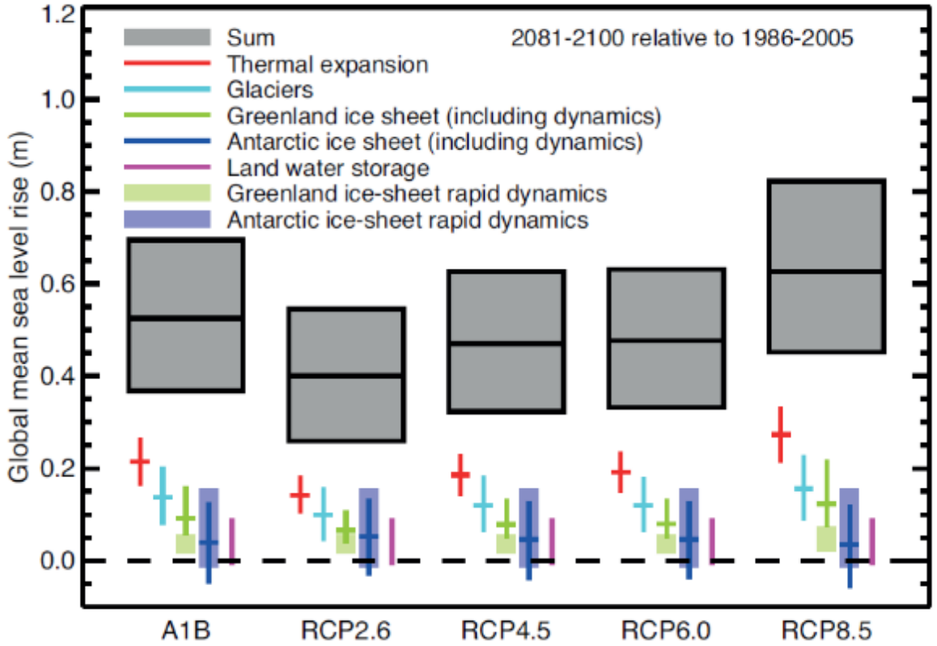

Figure 3.16 IPCC Scenarios for Sea Level Rise (IPCC 2013)

The results of the on-going increase in sea level and the anticipated impacts of accelerated increases are difficult to predict. Nevertheless, such increases in global sea level are likely to lead to beach erosion, as a sea level rise usually results in deepening of nearshore waters, allowing larger waves to reach the shore and erode the beach face (Bird 2000).

Komar (1998) provides a reasonable treatment for sandy shores, including examination of the Bruun Rule (Bruun 1962). The Bruun Rule relates the recession of the shoreline to the sea level rise and slope of the nearshore sediment bed:

$$R = \frac{1}{\tan(\theta)} S$$

where: R = recession of the shore.

θ = average slope of the nearshore sediment bed.

S = sea level rise.

The basic notion behind the Bruun Rule is that a sea level rise would cause erosion of the upper beach, and transference of sand from the beach to the adjacent sea floor. In due course, this process would restore the previous transverse profile in relation to the higher sea level, albeit at a more landward location (Bird 2000; Komar 1998).

DoT (2010) completed an assessment of the potential increase in sea level that could be experienced on the Western Australian coast in the coming 100 years. This assessment extrapolated work by Hunter (2009) to provide sea level rise values based on the IPCC (2007) A1FI climate change scenario projections to the year 2110. The derived sea level rise scenario was subsequently adopted by the Western Australian Planning Commission (and SPP2.6) for use in coastal planning along the Western Australian coast. This is the sea level rise scenario adopted for this assessment and is presented in Figure 3.17.

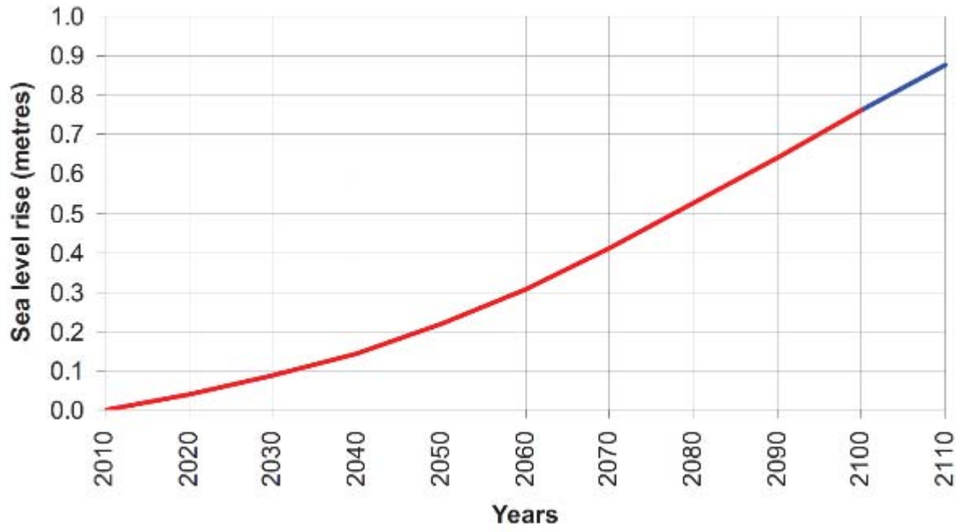

Figure 3.17 Recommended Sea Level Rise Scenario for Coastal Planning in Western Australia (DoT 2010)

SPP2.6 notes that the allowance for erosion caused by future sea level rise on a sandy coast should be calculated as 100 times the adopted sea level rise value of 0.9 m over a 100-year planning horizon, or 90 m. Table 3.2 summarises the sea level rise values and subsequent S3 Erosion allowances for the range of previously presented planning horizons.

Table 3.2 Sea Level Rise Allowances

Planning Horizon	Potential Sea Level Rise (m)	S3 Erosion Allowance (m)
Present Day (2019)	0	0
2044	0.14	14
2069	0.37	37
2094	0.65	65
2119	0.9	90

Notes: 1. Based on recommendations in DoT (2010) with a 2019 base year.

3.2.4 Summary of Erosion Allowances

Each of the erosion allowances were determined over the planning horizons to 2044, 2069, 2094 and 2119. A present day scenario was also considered. The allowances are combined with a 0.2 m/year allowance for uncertainty to create a coastal erosion hazard line for each planning horizon. Table 3.3 presents the results of these combinations for the relevant shoreline fronting the Holiday Park.

Table 3.3 Summary of Coastal Erosion Allowances Over Each Planning Horizon

Year	Planning Horizon	S1 (m)	S2 (m)	S3 (m)	Allowance for Uncertainty (m)	Total
2019	Present Day	26	0	0	0	26
2044	25	26	3	14	5	48
2069	50	26	6	37	10	79
2094	75	26	8	65	15	114
2119	100	26	11	90	20	147

Notes: 1. The total coastal erosion hazard allowance is to be measured in a landward direction from the HSD, which is the 3.1 mAHD contour for the 100 year ARI event (as shown previously in Figure 3.10).

The coastal erosion hazard lines are presented in Appendix C, which also shows the proposed Holiday Park development assets.

It is important to understand that these coastal erosion hazard lines are not intended to be predictions of the future shoreline location, but rather to provide conservative estimates of possible future shoreline retreat that are appropriate for consideration in coastal planning. For instance, assessment of aerial photography at the site since 1969 has shown that there has been very little movement of the shoreline, despite having been around 15 cyclone events that would have affected the area over the period. This provides an indication of the stability of the shoreline over the longer term. This was further assessed, based on the local geology and geomorphology, by Damara (2012) and it was determined that the relevant Vlamingh Head to East Vlamingh

primary cell, encompassing the Holiday Park shoreline, has a low susceptibility to change, a low instability and subsequently a low vulnerability.

Nevertheless, the coastal hazard lines shown in Appendix C will be used in this CHRMAP plan to inform the potential future risk associated with the development and operation of the Holiday Park.

3.3 Coastal Inundation Hazard Identification

SPP2.6 requires that the allowance for inundation (termed the S4 Allowance) be taken as the maximum extent of inundation experienced during a water level event with a 0.2% AEP (500 year ARI) plus the appropriate allowance for sea level rise. This is the critical aspect when considering public safety and significant assets, however for tourist based areas where public safety is managed, consideration of less severe inundation events could be appropriate.

Assessment of the inundation levels requires consideration of peak storm surge, including wave setup. A storm surge occurs when a storm with high winds and low pressures approaches the coastline (refer Figure 3.18). The strong, onshore winds and large waves push water against the coastline (wind and wave setup) and the barometric pressure difference creates a region of higher water levels. These factors acting in concert create the storm surge. The size of the storm surge is influenced by the following factors.

- Wind strength and direction.
- Pressure gradient.
- Seafloor bathymetry.
- Coastal topography.

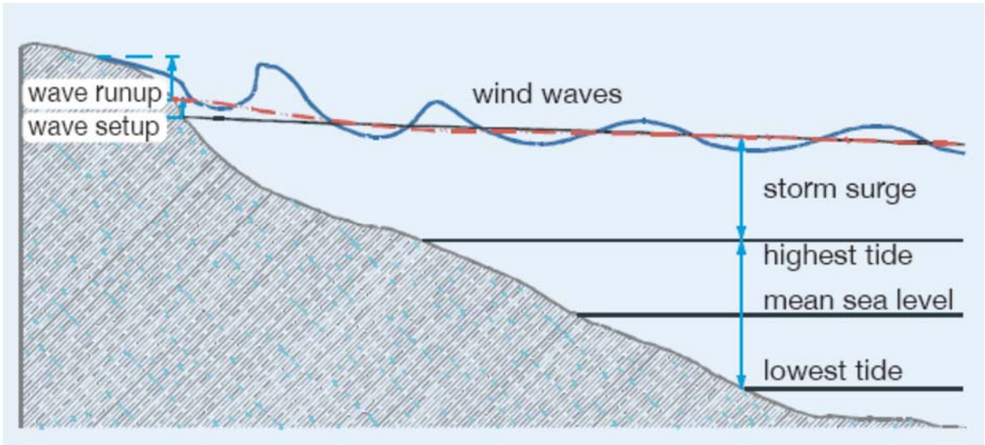

Figure 3.18 Storm Surge Components

As discussed previously, Seashore (2018) recently published preliminary HSD levels which included a 500 year ARI water level of 5.2 mAHD at Exmouth. As these projected levels are given for the shoreline, they are assumed to include the nearshore wind and wave setup during the events. It is again noted that these inundation levels are stated as being deliberately conservative.

Based on this 500 year ARI water level, the resulting inundation levels for each of the planning horizons are provided in Table 3.4, including appropriate allowances for sea level rise previously introduced in in Figure 3.17.

Table 3.4 S4 Inundation Levels

Planning Horizon	Potential Sea Level Rise Allowance (m)	500 year ARI Water Level (mAHD)	Inundation Level (mAHD)
Present Day (2019)	0	5.2	5.2
2044	0.14	5.2	5.3
2069	0.37	5.2	5.6
2094	0.65	5.2	5.9
2119	0.9	5.2	6.1

These potential inundation levels will be considered as part of the CHRMAP in order to comply with the requirements of SPP2.6.

4. Coastal Vulnerability

The vulnerability of the proposed Holiday Park assets is related to their level of exposure to coastal hazards, as well as their sensitivity to the impacts caused by these hazards and their ability to respond to them (termed adaptive capacity). With the exception of the environmental assets, which will essentially be left to naturally respond to the impacts of coastal hazards, the assets that are being considered are built form assets. Therefore, whilst for instance any assets within the foreshore reserve will be constructed in a way that will allow easy migration in the future if the coastal hazards are realised beyond the trigger values determined, the level of vulnerability of these assets will ultimately be linked to their level of exposure. This will be considered for the risk assessment and future management and adaptation strategies proposed for these assets. Details of the risk assessment completed and the future management and adaptation strategies proposed are presented in the following sections of this report.

5. Risk Analysis

In accordance with WAPC (2014), a risk based approach will be used to assess the hazards and required mitigation and adaptation options for the proposed Holiday Park development. As coastal hazards are the focus of this assessment, it is the likelihood and consequences of these coastal hazards that need to be considered. As stated previously, it is inherent in the development plan that there be no negative social or environmental impacts as a result of the Holiday Park, with mitigation strategies already highlighted to address these issues.

5.1 Likelihood

Likelihood is defined as the chance of something happening (AS/NZS ISO 31000:2009). WAPC (2014) defines the likelihood as the chance of erosion or storm surge inundation occurring or how often they impact on existing and future assets and values. This requires consideration of the frequency and probability of the event occurring over a given planning timeframe.

The probability of an event occurring is often related to the AEP or the ARI. The use of the AEP to define impacts of coastal hazards over the planning timeframe assumes that events have the same probability of occurring each year. In the case of climate change and sea level rise, which has a large influence on the assessed coastal hazard risk, this is not true. In addition, there is insufficient data available to properly quantify the probability of occurrence. A scale of likelihood has therefore been developed, which follows the Australian Standard Risk Management Principles and Guidelines (AS/NZS ISO 31000:2009). This is presented in Table 5.1.

Table 5.1 Scale of Likelihood

Rating	Description/Frequency
Almost certain	There is a high possibility the event will occur as there is a history of frequent occurrence 90-100% probability of occurring over the timeframe.
Likely	It is likely the event will occur as there is a history of casual occurrence 60-90% probability of occurring over the timeframe.
Possible	The event may occur 40-60% probability of occurring over the timeframe.
Unlikely	There is a low possibility that the event will occur 10-40% probability of occurring over the timeframe.
Rare	It is highly unlikely that the event will occur, except in extreme/exceptional circumstances. 0-10% probability of occurring over the timeframe.

The likelihood and consequences of coastal hazards are different for erosion and inundation. As a result, the likelihood and consequence of erosion and inundation should be considered separately. The likelihood of coastal erosion and inundation hazard impact is discussed separately in the following sections.

5.1.1 Coastal Erosion

The likelihood ratings given to the relevant assets are based on the coastal erosion hazard lines presented in Appendix C and the consideration of the probabilities of each of the allowances occurring within the respective planning horizons.

It is important to note that the hazard lines reaching a particular asset at the end of the planning horizon do not necessarily mean that this will occur. This is due to the fact that it requires all of the following to occur.

- Continuation of the maximum erosion trend identified for the shoreline fronting the Holiday Park site, plus the additional allowance for uncertainty.
- The upper estimate of erosion caused by sea level rise.
- The severe storm event to be experienced at the end of the planning timeframe (ie when the other allowances have been realised).

Only if all of these occur will the erosion hazard lines be realised. This has been considered in the assessment of likelihood for the relevant assets.

The proposed Holiday Park development assets located landward of the 2119 erosion hazard line **avoid** the risks associated with erosion hazards. This is discussed by the risk adaptation and mitigation strategies in Section 7.

The assessment of the relative likelihood of each of the remaining identified key assets (refer to Table 2.1), located seaward of the 2119 erosion hazard line and therefore potentially impacted by erosion hazards over the 100 year planning timeframe, is presented in Table 5.2.

Table 5.2 Assessment of Likelihood of Coastal Erosion Impact

Key Assets	Present Day (2019)	2044	2069	2094	2119
Yardie Creek Road	Rare	Rare	Rare	Unlikely	Possible

Notes: 1. Based on most exposed location of each asset group.

The assessment of the likelihood of coastal erosion impact shows the following.

- Coastal erosion is unlikely to impact any of the Holiday Park development assets at the present day in 2019.
- It is Possible that Yardie Creek Road will be impacted over the 100 year planning timeframe to 2119.

5.1.2 Coastal Inundation

The likelihood of inundation of the proposed Holiday Park assets was considered based on the 500 year ARI storm surge inundation allowance of 6.1 mAHD, at the end of the 100 year planning timeframe with the appropriate allowances for sea level rise, as presented in Section 3.

5.2 Consequence

The second part of the risk assessment is determining the consequence of the coastal erosion hazards on the proposed assets. A scale of consequence has been developed which provides a range of impacts and is generally consistent with the Australian Standard Risk Management Principles and Guidelines (ISO 31000:2009).

Table 5.3 Scale of Consequence

Rating	Social	Economic	Environment
Catastrophic	Loss of life and serious injury. Large long term or permanent loss of services, employment wellbeing, finances or culture (75% of community affected), international loss, no suitable alternative sites exist	Damage to property, infrastructure or local economy > $20M	Major widespread loss of environmental amenity and progressive irrecoverable environmental damage
Major	Serious injury. Medium term disruption to services, employment wellbeing, finances or culture (<50% of community affected), national loss, limited alternative sites exist	Damage to property, infrastructure or local economy > $5M to $20M	Severe loss of environmental amenity and a danger of continuing environmental damage
Moderate	Minor injury. Major short or minor long term disruption to services, employment wellbeing, finances or culture (<25% of community affected), regional loss, many alternative sites exist	Damage to property, infrastructure or local economy > $500,000 to $5M	Isolated but significant instances of environmental damage that might be reversed with intensive efforts. Recovery may take several years.
Minor	Small to medium disruption to services, employment wellbeing, finances or culture (<10% of community affected), local loss, many alternative sites exist	Damage to property, infrastructure or local economy > $50,000 to $500,000	Minor instances of environmental damage that could be reversed. Consistent with seasonal variability, recovery may take one year.
Insignificant	Minimal short-term inconveniences to services, employment, wellbeing, finances or culture (<5% of community affected), neighbourhood loss, many alternative sites exist	Damage to property, infrastructure or local economy < $50,000	Minimal environmental damage, recovery may take less than 6 months.

The assessed consequences of coastal erosion for each of the planning horizons are outlined in Table 5.4. As shown in the table, the consequences of erosion vary for some key assets over different timeframes due to the potential effects of increased erosion.

Table 5.4 Assessment of Consequence of Coastal Erosion Impact

Key Assets	Present Day (2019)	2044	2069	2094	2119
Yardie Creek Road	Minor	Minor	Minor	Major	Major

Notes: 1. Assumes structures are appropriately designed to withstand coastal forces expected during design events as discussed in following sections.

Erosion is deemed to have a low consequence if the asset is landward of the coastal hazard line for the assessed planning horizon, since the extent of impact to the social, economic and environmental criteria is based on the extent of the potential erosion. For example, Yardie Creek Road a Minor consequence of erosion up to 2069, as it is landward of the 2069 coastal erosion hazard line. However, as portions of Yardie Creek Road are seaward of the 75 year erosion hazard line to 2094, the consequence increases to a Major thereafter based on the consequence scale presented in Table 5.3.

6. Risk Evaluation

6.1 Risk Evaluation Matrix

The risk rating from a risk assessment is defined as “likelihood” x “consequence.” A risk matrix defining the levels of risk from combinations of likelihood and consequence has therefore been developed for the coastal hazards. This risk matrix is generally consistent with WAPC (2014).

Table 6.1 Risk Matrix

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

A risk tolerance scale assists in determining which risks are acceptable, tolerable and unacceptable. The risk tolerance scale used for the assessment is presented in Table 6.2.

Table 6.2 Risk Tolerance Scale

Risk Level	Action Required	Tolerance
Extreme	Immediate action required to eliminate or reduce the risk to acceptable levels	Intolerable
High	Immediate to short term action required to eliminate or reduce risk to acceptable levels	Intolerable
Medium	Reduce the risk or accept the risk provided residual risk level is understood	Tolerable
Low	Accept the risk	Acceptable

The risk tolerance scale has been reviewed and accepted for use by the proponent. It shows that the extreme and high risks need to be managed.

6.2 Risk Assessment

The risk assessment for the study area will be completed in accordance with the recommendations of AS5334 (2013), which requires a detailed risk analysis to include a vulnerability analysis to thoroughly examine how coastal hazards and climate change may affect

the assets. This includes consideration of the adaptive capacity and vulnerability of the relevant assets, as discussed previously in Section 4 of this report.

Based on the results of the risk analysis completed previously, Table 6.3 presents the coastal erosion risk levels for each of the identified key assets potentially at risk over the 100 year planning timeframe. The order of the assessed risks in the table has been used to show the priority risk assets for each planning timeframe at the start of the table, with decreasing risk down the table.

Table 6.3 Assessment of Risk of Coastal Erosion Impact

Key Assets	Present Day (2019)	2044	2069	2094	2119
Yardie Creek Road	Low	Low	Low	Medium	Medium

The results of the risk assessment show that the proposed Holiday Park assets have a Low or Medium risk of being impacted by erosion over the 100 year planning timeframe to 2119. Based on Table 6.2, these risks are deemed to be tolerable, but steps should be taken to reduce these risks where possible.

Further consideration and discussion of the implications of these results are provided in the following section with regard to risk management.

7. Risk Adaptation & Mitigation Strategies

SPP2.6 outlines a hierarchy of risk adaptation and mitigation options, where options that allow for a wide range of future strategies are considered more favourably. This hierarchy of options is reproduced in Figure 7.1.

Figure 7.1 Risk Management & Adaptation Hierarchy

These options are generally outlined below:

- Avoid – avoid new development within the area impacted by coastal hazards.
- Retreat – the relocation or removal of assets within an area identified as likely to be subject to intolerable risk of damage from coastal hazards.
- Accommodation – measures which suitably address the identified risks.
- Protect – used to preserve the foreshore reserve, public access and public safety, property and infrastructure.

The assessment of options is generally done in a progressive manner, moving through the various options until an appropriate mitigation option is found.

7.1 Coastal Adaptation Approach

The potential future movement of the shoreline and the risks posed from coastal hazards necessitates the requirement for coastal adaptation and risk mitigation planning.

The requirement for coastal hazard risk mitigation strategies for the proposed Holiday Park development is ultimately informed by the respective asset owners. The proponent has acknowledged and accepted the coastal hazard risks for each of the proposed assets within the Holiday Park. This acceptance is on the basis that the risk management and adaptation principles, as previously mentioned and detailed herein, are put in place.

The proposed approach for the Holiday Park development is summarised below:

- The natural assets fronting the Holiday Park, including the Beach and Coastal Dunes, will be left to respond naturally to the impacts of coastal hazards.

- The majority of the built assets within the Holiday Park development **avoid** both inundation and erosion coastal hazard risks over the 100 year planning timeframe to 2119. As shown in Appendix C, the majority of the proposed built assets are located landward of the 100 year erosion hazard line. Furthermore, the finished floor levels of these assets are well above the 500 year ARI inundation level and behind the extent of expected inundation during the relevant cyclone event. These assets that **avoid** the coastal hazard risks are summarised below:

    - Retail/Surf Shop/Bar.
    - Lodges.
    - On-site Tents.
    - Ablution Blocks.
    - Villas.
    - General Managers Accommodation.
    - Playground.
    - Food & Beverage/Rec Centre.
    - Swimming Pools.
    - Powell House/Reception & Function Facilities.
    - Spa/Gym.
    - Hotel.
    - Sunset Villas.
    - Tennis Courts.

- The only public asset that has portions within the 100 year erosion hazard line and is therefore potentially at risk is Yardie Creek Road. The risk to this asset at the end of the 100 year planning horizon in 2119 was assessed as Medium. These risks are considered to be tolerable (Table 6.2), however an As Low As Reasonably Practicable (ALARP) approach is proposed to minimise any potential impacts, the following is recommended:

    - There are no modifications proposed to Yardie Creek Road which is a Shire asset. Given the Low risk over the 50 year planning timeframe to 2069, it isn't expected that Yardie Creek Road will require management or adaptation to deal with coastal hazard risks in the short term. However, in later timeframes over the 100 year planning horizon, the Shire may wish to implement management or adaptation strategies if the risks to Yardie Creek Road are determined as being intolerable. This will require the consideration of land tenure as well as the requirements for the provision of foreshore reserve. This would need to be completed in accordance with the requirements of SPP2.6 and based on the assessed coastal hazard risks at the time.

Implementation of the above strategies will help to manage the coastal hazard risks to the overall development. Furthermore, the implementation of coastal adaptation will also ensure that the social and environmental values of the area are maintained. It is important to note that monitoring of the shoreline will form a key part of the adaptation planning response. Monitoring of the shoreline is discussed in Section 8.4. This will enable changes to the shoreline and subsequent risk levels to be identified to inform the implementation of the above strategies.

7.1.1 Public Safety

As outlined previously, the risk ratings that were determined for the assets assessed, and consequently the risk mitigation strategies outlined above, are provided on the basis that public safety during severe cyclone events is already managed. The Department of Fire and Emergency Services' (DFES) management occurs along the entire coastline of Western Australia in response to cyclone events, which are the key contributor to coastal hazards at the Holiday Park site (refer to Section 3).

Essentially, to manage risks associated with cyclone inundation, DFES communicate with BoM to receive updates on the potential cyclone tracks and associated storm surge and areas of inundation. Evacuations are then completed as required in order to manage public safety prior to event impact. As a result of the evacuation policies that are already in place, the management of public safety due to coastal hazards is ensured.

It is also important to note that there would be some degree of self -management of these risks by patrons of the Holiday Park at the time of such events, as many travellers would be aware of the risks and would likely leave the area before conditions became too severe.

Nevertheless, despite the potential self-management by travellers and the management by DFES it is recommended that a site specific evacuation plan is developed for the Holiday Park. This was recommended by Damara (2012) for areas that may be at greater risk of flooding or inundation. Based on the existing contours at the site and the 500 year ARI water level of 6.1 mAHD at the end of the 100 year planning timeframe, this inundation would be limited to the beach and portions of the undeveloped foreshore area.

The plan should outline steps that should be taken as severe events approach, as well as evacuation pathways and routes to relevant evacuation centres. It is recommended that this plan is developed in consultation with DFES and the Shire. As a result of the evacuation policies that are already in place, as well as any further development of these policies that may be required specifically for the Holiday Park, the management of public safety due to coastal hazards is ensured.

8. Implementation

The risk mitigation and adaptation strategies outlined in Section 7 set out the general proposed coastal management approach for the Holiday Park development. Direct guidance on when, what, how and by who these processes will be completed is provided within this implementation plan. For ease of reference, these details have been broken down to outline the requirements for each stage of the project and/or asset life.

8.1 Planning & Initial Construction

Coastal planning for this development, largely informed by the findings of this CHRMAP, have identified that there are no coastal erosion hazard risks for the proposed Holiday Park Development.

8.2 Operation Over the Infrastructure Service Life

Over the service lives of the proposed assets, there will be a requirement to monitor the shoreline to ascertain whether coastal risks are increasing. Further details of the monitoring requirements are outlined in Section 8.4. This monitoring will be responsibility of the proponent.

8.3 Monitoring & Review

Coastal monitoring and review is essential in order to track changes to the shoreline over time. Whilst the results of the coastal hazard assessment (refer Section 3) provides an indication of the potential changes to the shoreline (and incorporate a justifiable level of conservatism), the system is inherently complex and the actual shoreline response could be different to that presented. Monitoring should therefore be completed to track changes over time and indicate whether the timing for risk mitigation should be adjusted.

The shoreline monitoring should be completed using a combination of onsite measurements and photo-monitoring as well as review of aerial photography captured by Landgate. Given the large buffer for erosion and minimal shoreline movement as outlined in Section 3 over the period analysed since 1969, it is recommended that shoreline monitoring is completed and assessed at ten yearly intervals.

If the rate of change in shoreline position observed during the monitoring is materially different from that allowed for in the coastal hazard assessment provided in Section 3, it would be recommended that the coastal hazard assessment and this CHRMAP be updated to quantify any changes to the risks posed by coastal hazards.

Likewise, should the State Government guidance for the determination of the required allowances change as a result of new information becoming available, the coastal hazard assessment and this CHRMAP should also be updated. This is especially the case for information regarding climate change and projected sea level rise, however may also apply for the calculation of severe storm erosion, shoreline movement erosion and inundation allowances. The responsibility for both of these actions would rest with the proponent.

A summary of the requirements for the monitoring and review is presented in Table 8.4.

Table 8.4 Implementation Plan – Monitoring & Review

Requirement	Timing	Responsibility
Shoreline monitoring	Ongoing – to be assessed on a 10 yearly basis	Proponent
Revision of coastal hazard assessment and CHRMAP	If shoreline behaviour changes substantially from that identified within the coastal hazard assessment OR If guidance changes on the determination of the required allowances as a result of new information becoming available	Proponent

9. Conclusions

This CHRMAP has been completed to provide guidance on required adaptation and management actions associated with proposed assets within the proposed Holiday Park development. The coastal hazard assessment completed and discussed in Section 3 as well as this CHRMAP report have been completed in line with the recommendations of SPP2.6 and WAPC (2014).

The completion of the coastal hazard risk assessment for the proposed development has shown that there is a risk of coastal hazard impact over the 100 year planning timeframe. However, these risks are limited to erosion impacts on Yardie Creek Road and were determined to be tolerable over the 100 year planning timeframe.

Despite the level of risk being acceptable to the proponent, the ALARP approach has been adopted for the proposed development and additional risk mitigation strategies have been proposed for implementation.

Notwithstanding the results of the coastal hazard assessment, it is again noted that aerial photography of the beach fronting the proposed development, documenting coastal processes since 1969 and covering a period when several cyclones and many severe storm events would have influenced the shoreline, indicates that this is a relatively stable coastal environment.

The risk analysis and assessment completed as part of this CHRMAP is balanced against the considerable benefit to the region created by the proposed Holiday Park development.

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11. Appendices

Appendix A SBeach Runs

K1691 - Ningaloo Lighthouse
Reach: New Reach Storm: 3 x 100 Year ARI

Report
Project: K1691 - Ningaloo Lighthouse
Reach: New Reach
Storm: 3 x 100 Year ARI
MODEL CONFIGURATION

INPUT UNITS (SI=1, AMERICAN CUST.=2): 1
NUMBER OF CALCULATION CELLS: 933
GRID TYPE (CONSTANT=0, VARIABLE=1): 1
NUMBER OF GRID CELL REGIONS: 2
NUMBER CELLS AND CELL WIDTH IN REGION 1: 499, 1.0
NUMBER CELLS AND CELL WIDTH IN REGION 2: 434, 5.0
NUMBER OF TIME STEPS AND VALUE OF TIME STEP IN MINUTES: 1728, 5.0
TIME STEP(S) OF INTERMEDIATE OUTPUT 1: 200
TIME STEP(S) OF INTERMEDIATE OUTPUT 2: 400
NO COMPARSION WITH MEASURED PROFILE.
PROFILE ELEVATION CONTOUR 1: -0.50
PROFILE ELEVATION CONTOUR 2: 0.00
PROFILE ELEVATION CONTOUR 3: 0.50
PROFILE EROSION DEPTH 1: 0.50
PROFILE EROSION DEPTH 2: 1.00
PROFILE EROSION DEPTH 3: 1.50
REFERENCE ELEVATION: 0.00
TRANSPORT RATE COEFFICIENT (m^4/N): 1.75E-6
COEFFICIENT FOR SLOPE DEPENDENT TERM (m^2/s): 0.0020
TRANSPORT RATE DECAY COEFFICIENT MULTIPLIER: 0.50
WATER TEMPERATURE IN DEGREES C : 20.0

WAVE TYPE (MONOCHROMATIC=1, IRREGULAR=2): 2
WAVE HEIGHT AND PERIOD INPUT (CONSTANT=0, VARIABLE=1): 1
TIME STEP OF VARIABLE WAVE HEIGHT AND PERIOD INPUT IN MINUTES: 30.0
WAVE ANGLE INPUT (CONSTANT=0, VARIABLE=1): 0
CONSTANT WAVE ANGLE: 0.0
WATER DEPTH OF INPUT WAVES (DEEP WATER = 0.0): 25.0
SEED VALUE FOR WAVE HEIGHT RANDOMIZER AND % VARIABILITY: 4567, 20.0
TOTAL WATER ELEVATION INPUT (CONSTANT=0, VARIABLE=1): 1
TIME STEP OF VARIABLE TOTAL WATER ELEVATION INPUT IN MINUTES: 60.0
WIND SPEED AND ANGLE INPUT (CONSTANT=0, VARIABLE=1): 0
CONSTANT WIND SPEED AND ANGLE: 0.0, 0.0

TYPE OF INPUT PROFILE (ARBITRARY=1, SCHEMATIZED=2): 1
DEPTH CORRESPONDING TO LANDWARD END OF SURF ZONE: 0.30
EFFECTIVE GRAIN SIZE DIAMETER IN MILLIMETERS: 0.35
MAXIMUM PROFILE SLOPE PRIOR TO AVALANCHING IN DEGREES: 45.0

NO BEACH FILL IS PRESENT.

NO SEAWALL IS PRESENT.

HARD BOTTOM IS PRESENT.

COMPUTED RESULTS

DIFFERENCE IN TOTAL VOLUME BETWEEN FINAL AND INITIAL PROFILES:
-11.1 m^3/m

-Page 1-

K1691 - Ningaloo Lighthouse
Reach: New Reach Storm: 3 x 100 Year ARI

MAXIMUM VALUE OF WATER ELEVATION + SETUP FOR SIMULATION
3.19 m

TIME STEP AND POSITION ON PROFILE AT WHICH MAXIMUM VALUE
OF WATER ELEVATION + SETUP OCCURRED
318, 283.0 m
MAXIMUM ESTIMATED RUNUP ELEVATION: 5.02 m
(REFERENCED TO VERTICAL DATUM)

POSITION OF LANDWARD MOST OCCURRENCE OF A 0.50 m EROSION DEPTH:
270.0 m

DISTANCE FROM POSITION OF REFERENCE ELEVATION ON INITIAL PROFILE
TO POSITION OF LANDWARD MOST OCCURRENCE OF A 0.50 m EROSION DEPTH:
51.0 m

POSITION OF LANDWARD MOST OCCURRENCE OF A 1.00 m EROSION DEPTH:
271.0 m

DISTANCE FROM POSITION OF REFERENCE ELEVATION ON INITIAL PROFILE
TO POSITION OF LANDWARD MOST OCCURRENCE OF A 1.00 m EROSION DEPTH:
50.0 m

POSITION OF LANDWARD MOST OCCURRENCE OF A 1.50 m EROSION DEPTH:
272.0 m

DISTANCE FROM POSITION OF REFERENCE ELEVATION ON INITIAL PROFILE
TO POSITION OF LANDWARD MOST OCCURRENCE OF A 1.50 m EROSION DEPTH:
49.0 m

MAXIMUM RECESSION OF THE -0.50 m ELEVATION CONTOUR:
0.40 m

THE 0.00 m CONTOUR DID NOT RECEDE

THE 0.50 m CONTOUR DID NOT RECEDE

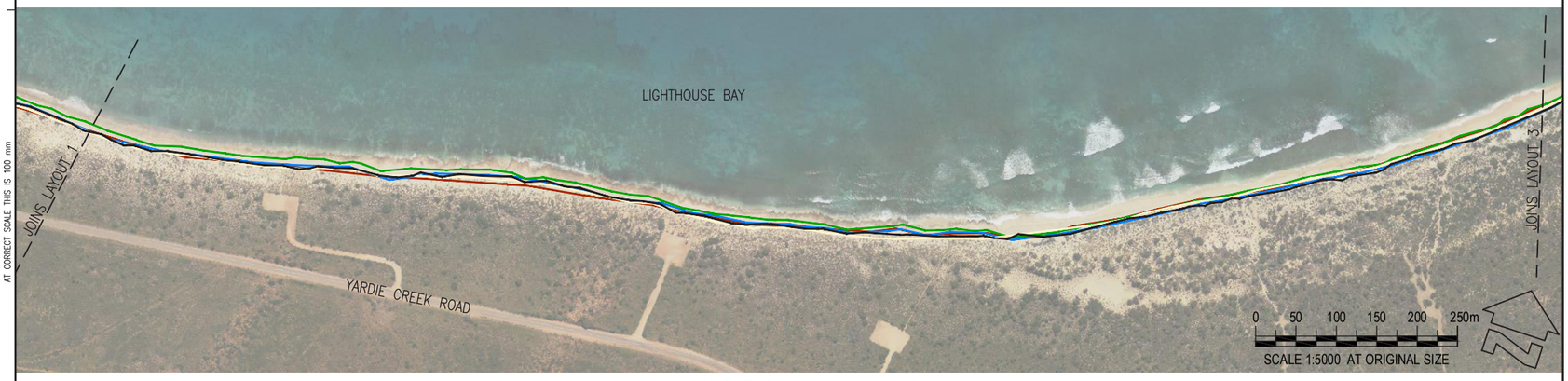
AT CORRECT SCALE THIS IS 100 mm

LAYOUT 1

LEGEND:

- 2014 VEGETATION LINE
- 2007 VEGETATION LINE
- 2004 VEGETATION LINE
- 2000 VEGETATION LINE
- 1969 VEGETATION LINE

AT CORRECT SCALE THIS IS 100 mm



LAYOUT 2

m p rogers & associates pl coastal and port engineers	Suite 1, 128 Main Street Osborne Park 6017 t: +61 8 9254 6600 Western Australia admin@coastsandports.com.au	DRAWN R BORJA CHECKED A CLAPIN	SHORELINE MOVEMENT PLAN - SHEET 1 OF 2 NORTHWEST RESORTS PTY LTD – NINGALOO LIGHTHOUSE RESORT	SCALE AT A3 1:5,000	SEPTEMBER 2019 SK1691–01–01A

P:\MRA Paying Jobs\K1691 CONF Minderoo – Ningaloo Lighthouse Resort\5 MRA Dwgs\Sketches\SK1691-01A Shoreline Movement Plan

AT CORRECT SCALE THIS IS 100 mm

LAYOUT 3

LEGEND:

- 2014 VEGETATION LINE
- 2007 VEGETATION LINE
- 2004 VEGETATION LINE
- 2000 VEGETATION LINE
- 1969 VEGETATION LINE

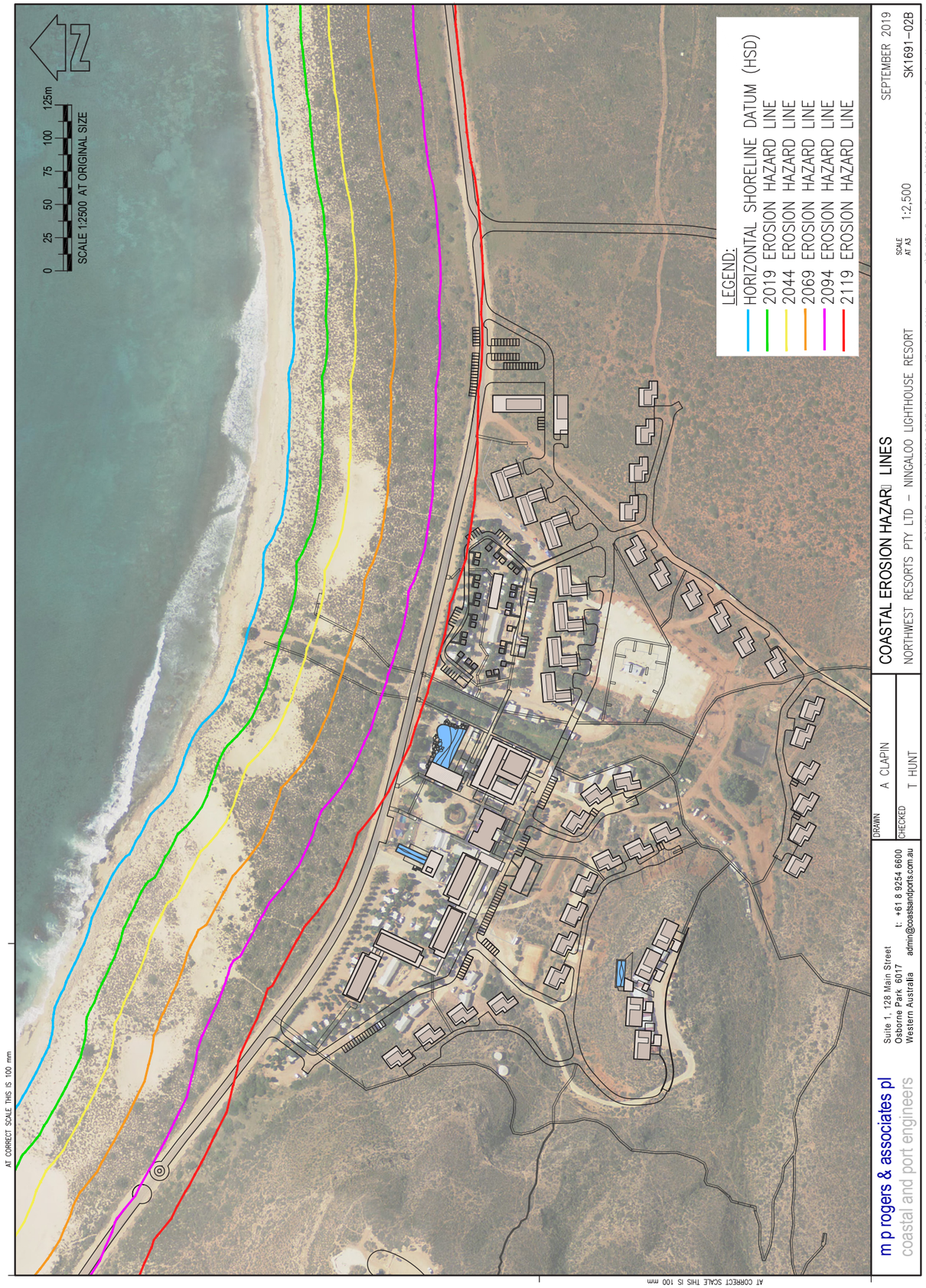
AT CORRECT SCALE THIS IS 100 mm

LAYOUT 4

m p rogers & associates pl coastal and port engineers	Suite 1, 128 Main Street Osborne Park 6017 t: +61 8 9254 6600 Western Australia admin@coastsandports.com.au	DRAWN R BORJA CHECKED A CLAPIN	SHORELINE MOVEMENT PLAN - SHEET 2 OF 2 NORTHWEST RESORTS PTY LTD – NINGALOO LIGHTHOUSE RESORT	SCALE AT A3 1:5,000	SEPTEMBER 2019 SK1691–01–02A

P:\MRA Paying Jobs\K1691 CONF Minderoo – Ningaloo Lighthouse Resort\5 MRA Dwgs\Sketches\SK1691-01A Shoreline Movement Plan

Appendix C Coastal Erosion Hazard Lines



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