Technical Report

Kangaroo Island Coastal Hazard Mapping Project

Kangaroo Island Council

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EXECUTIVE SUMMARY

Overview

The coastline of Kangaroo Island (KI) is highly varied, ranging for low lying coastal plains in the east to high cliffs in the west. These different coastlines are all subject to coastal processes and many of the lower-lying areas along the east of the island are subject to coastal inundation and erosion risks. These processes are likely to be exacerbated by climate change and associated increases in future sea level.

The coastal assets, public land and infrastructure within the vicinity of the coastline are subject to increased risk, and to date limited consideration has been given to the likely long-term management requirements to address this risk. Kangaroo Island Council has commissioned Seed Consulting and Water Technology to develop an Adaptation Strategy for the eastern end of Kangaroo Island to address these risks and set-out potential future priority action pathways.

The Local Government Association Coastal Adaptation Decision Pathways Investigative Framework as the overarching approach has been adopted for the study. The primary objective of the study is to understand and map the existing coastal hazards and the associated risk to coastal assets, public land and infrastructure and from this to develop coastal adaptation strategies across the affected communities for Council and other Stakeholders such as State Government and private landholders. This project focusses on delivering this information for the eastern section of the KI coastline, from Smith Bay in the north to Point Tinline in the south.

This report presents the supporting technical coastal hazard assessments undertaken for the project to support the development of adaptation strategies for the study area. Much of the information presented is also available via on online mapping portal, https://bit.ly/2NyJXdm, and will be provided to Council as a geodatabase on completion of the study

Coastal Hazard Mapping

Erosion Hazard Assessment

The Coastal Policy (Coast Protection Board, 2016) indicates coastal erosion should be assessed for a 100-year timeframe. The policy recommends consideration of local long-term erosion or accretion trends, potential storm erosion, as well as likely recession due to sea level rise. The assessment approach for each of these components and their applicability to a section of coast depends on the local coastal morphology, with sandy coasts responding differently to oceanographic (wind, wave and current) forces compared to steeper or more resistant coastlines.

This project has identified the different coastal morphologies across the study area and applied the most relevant approach to quantify the potential for coastal erosion under current and future conditions. The resultant coastal hazard zones have been presented in map form.

Inundation Hazard Assessment

Coastal inundation includes both long-term and short-term inundation conditions. Long-term inundation is likely to occur as a result of a change in the mean water level and tidal range as a result of sea level rise. Short-term inundation is associated with extreme water levels and waves, occurs under current mean sea level conditions, and will be increased as a result of sea level rise.

For this project both long-term and short-term and coastal inundation have been mapped across the study area to quantity the potential for coastal inundation under current and future conditions. As with the erosion hazards, inundation hazard zones have been presented in map form.

Groundwater Hazard Assessment

Although groundwater is generally not considered within the scope of a coastal hazard assessment, there are potential impacts to groundwater systems that may occur as a result of future changes in sea level. For this project an initial review of the groundwater systems within the study area has been undertaken to identify what the potential impacts may be in the future. Insufficient information is currently available to map future groundwater hazards. However, preliminary locations have been identified where further investigations into groundwater hazards may be warranted in the future

Asset and Infrastructure Risks

An analysis has been carried out to identify the assets that may be at risk from coastal inundation or erosion (whether in public or private ownership). The risk profiles developed will subsequently be used to identify priority areas to inform the adaptation strategy.

An asset and infrastructure database was developed by collating Council/Government GIS layers and assets identified from aerial imagery. The Council GIS layers included location information for pumping stations, drains/pipes, jetties and features of interest. Additional assets with social, cultural or economic significance were identified visually using aerial imagery.

Risk profiles have been developed for all assets by assigning scores to the consequence of each relevant coastal hazard and the likelihood of this coastal hazard impacting the asset over the planning periods being considered within this study. The risk profile is determined by applying the likelihood and consequence ratings to a risk matrix.

Key observations of the results of the public asset risk assessment include:

- The majority of wastewater pumping stations were not at risk of inundation or erosion hazards, however at American River and Brownlow Beach, there is a total of 8 and 6 stations at risk respectively. The number of at-risk pumping stations is represented as a percentage of the total number of pumping stations per area.
- The public assets at Penneshaw have a relatively low risk rating, however under the 2100 erosion scenario there is an extreme risk to the pipe/drain network.
- For pipes and drains, the number of assets identified was calculated in relation to the length of infrastructure, represented by a percentage of the total length within each area. There were no impacted pipes and drains in Emu Bay or D'Estrees Bay.

The percent of public roads at risk from coastal erosion or inundation hazards for each community were analysed. The roads included in the risk/consequence analysis were roads with specific costing data provided by the council and does not include all roads in each community. The roads were intersected with the erosion and inundation extents to calculate the percent of road that would be at risk. This percentage was used as a guide to estimate the value of the risk.

Key observations of the results of the public road risk assessment include:

- The majority of roads assessed are at extreme risk levels in the 2100 erosion and inundation scenarios.
- The major roads in American River are not impacted by any erosion scenarios.
- Frenchmans Terrace in Penneshaw is not impacted by any inundation scenarios.

- The worst affected road is Nepean Esplanade in Nepean Bay, which is at an extreme risk level in the 2050 and 2100 erosion and inundation scenarios, and a moderate and high risk level in the existing erosion and inundation scenarios respectively.
- All roads analysed, except Frenchmans Terrace in Penneshaw, are at moderate to extreme risk levels in the 2100 inundation scenario.

Potential impacts and risks to private assets were also assessed. The property parcel information provided by Council was compared to the erosion and inundation mapping for the existing, 2050 and 2100 sea level rise scenarios. For each private land parcel within a hazard extent, the percentage of the parcel affected by the hazard was then calculated.

From this information a financial value for the assets that have been identified as at risk to coastal erosion or inundation has been estimated. Where the value of the asset was unable to be obtained, these have been listed as data gaps. This information can be used to prioritise future adaptation strategies or responses and support applications for funding to undertake future assessments and projects.

GLOSSARY AND DEFINITIONS

Term	Definition
Accretion	Deposition and accumulation of sediment, either horizontally or vertically
AHD	Australian Height Datum. 0m AHD approximately corresponds to mean sea level
ARI	Average Recurrence Interval. A measure of the average frequency at which a storm of a given magnitude recurs (ideally based on statistical analysis of recorded historical storm data). Thus a 100 year ARI storm is one of a magnitude that statistically occurs every 100 years on average. Note however that this is a statistical average and not a measure of actual recurrence intervals. Thus it is entirely possible that two 100 year ARI storms could occur in the same year.
AEP	Annual Exceedance Probability: The measure of the likelihood (expressed as a probability) of an event equalling or exceeding a given magnitude in any given year.
Astronomical tide	Water level variations due to the combined effects of the Earth's rotation, the Moon's orbit around the Earth and the Earth's orbit around the Sun.
Brunn Factor	A multiplier used to define the amount of horizontal shoreline recession that results from a given sea-level rise. For example, a Bruun Factor of 100 means a shoreline recedes horizontally by 100 times the vertical rise in mean sea-level. The use of Bruun Factors is a highly simplified application of the Bruun Rule of erosion by sea-level rise.
DEM	Digital elevation model. A widely used GIS format which represents surfaces (e.g., of land) as a grid, each cell of which has a defined location and elevation.
Calcarenite	Sand-grade lithified sedimentary rock composed of cemented calcium carbonate grains (i.e., a type of limestone). On the Australian coast, many prominent calcarenite deposits are Holocene or Pleistocene coastal dunes of carbonate dominated sand cemented by groundwater processes. Calcarenites vary from very hard tough rocks to soft friable sandy rocks.
Erosion	Removal of material (e.g., from a sediment body or landform) by natural processes (e.g., wave action). Coastal erosion typically results in landwards recession of the shoreline, but in theory need not do so; e.g., wind erosion of coastal dunes need not necessarily lead to shoreline recession.
Exceedance Probability	The probability of an extreme event occurring at least once during a prescribed period of assessment is given by the exceedance probability. The probability of a 1 in 100 year event (1% AEP) occurring during the first 25 years is 22%, during the first 50 years the probability is 39% and over a 100 year asset life the probability is 63%.
Geomorphology	The study of landforms, their forms, genesis, development and processes.
HAT	Highest Astronomical Tide: the highest water level that can occur due to the effects of the astronomical tide in isolation from meteorological effects.
Holocene	Geological epoch beginning approximately 12,000 years ago. It is characterised by warming of the climate following the last glacial period and rapid increase in global sea levels to approximately present day levels.
Hydro-isostasy	Impact of addition or loss of water on the earth surface elevation.
Lacustrine	Geological term to describe sediments which are derived from a lake environment.

Term	Definition
LAT	Lowest Astronomical Tide. Defined as the lowest tide level which can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions.
LiDAR	Light Detection and Ranging; a contemporary method of high resolution topographic mapping using laser reflections off ground and other surfaces.
Lithified	Indurated, consolidated, cemented or rocky materials (generally hard, albeit some may be relatively soft by reason of being weathered or only semi-lithified).
MHHW	Mean Higher High Water: the mean of the higher of the two daily high waters over a long period of time. When only one high water occurs on a day this is taken as the higher high water.
MHWN	The average height of the high waters of neap tides
MHWS	Mean High Water Springs: the height of MHWS is the average, throughout a year when the average maximum declination of the moon is 23.5°, of the heights of two successive high waters during those periods of 24 hours when the range of the tide is greatest. Used when semi-diurnal tides are present.
MLWN	The average height of the low waters of neap tides
MLWS	The average height of all low waters of spring tides
Neap tides	The tides of decreased range occurring near the times of first and third quarter phases of the moon. The gravitational forces of the moon and the sun counteract each other. Since the combined tidal force is decreased the high tides are lower and the low tides are higher than average.
MSL	Mean Sea Level: the long-term average level of the sea surface.
Pleistocene	Geological epoch from 2.5 million to 12,000 years before present that spans the earth's recent period of repeated glaciations and large fluctuations in global sea levels.
Quaternary	Geological period beginning approximately 2.6 million years ago and continuing today. The Quaternary Period is sub-divided into the Pleistocene (older) and Holocene (recent) stages.
Recession	Landwards retreat of a shoreline resulting from repeated erosion events over a prolonged period of time
Significant Wave Height	The average of the highest one third of all waves.
SMARTLINE	A coastal data mapping format based on attributing a GIS polyline representing the coastline with multiple attributes describing a range of coastal characteristics which describe not just the physical location of the line itself, but also features and processes characterising the coastal area to landwards, seawards and beneath the line, and segmenting (dividing) the line where-ever any one of the attributes change in the alongshore direction.
Spring tide	The tides of increased range occurring near the times of full moon and new moon. The gravitational forces of the moon and the sun act to reinforce each other. Since the combined tidal force is increased the high tides are higher and the low tides are lower than average. Spring tides is a term which implies a welling up of the water and bears no relationship to the season of the year.
Storm bite	The amount of erosion that occurs during a single (usually storm) event.

Term	Definition
Storm surge	The meteorological component of the coastal water level variations associated with atmospheric pressure fluctuations and wind setup.
Storm tide	Coastal water level produced by the combination of astronomical and meteorological (storm surge) ocean water level forcing.
Substrate	An underlying stratum or layer of sedimentary rock / soil
Wave climate	The mix of swell and/or locally-generated wind waves received at a particular coastal location, including average wave heights and directions, and the degree of variability in these that is characteristic of the given coastal location.

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1 INTRODUCTION

Seed Consulting and Water Technology have been commissioned by Kangaroo Island Council to undertake a project to identify and evaluate sea level rise risks and adaptation options for coastal communities within the eastern extent of Kangaroo Island.

Kangaroo Island (KI) is located 13.5km south of mainland South Australia at its closest point. It encompasses an area of 4,400 square kilometres and has a resident population of approximately 4500 people, with an additional 200,000 visitors each year. These visitor numbers are steadily increasing.

Coastal communities such as those on KI are vulnerable to sea level rise, coastal inundation and flooding and dune recession in our changing climate. In responding to these risks, local councils must actively collect data that informs practical decision making, and provides the opportunity for capacity building amongst staff, community and other stakeholders in developing and delivering adaptation responses.

This project therefore focusses on delivering coastal hazard mapping and analysis for the eastern section of the KI coastline, from Smith Bay in the north to Point Tinline in the south as shown in Figure 1-1, to enable informed decision-making and future policy development.

The study area encompasses approximately 200km of coastline and numerous different landscape features such as bays, estuaries, sea cliffs, offshore reefs, dune systems, rock headlands and a large spit formation. Existing coastal settlements include:

- Emu Bay
- Kingscote
- Brownlow
- Nepean Bay
- American River
- Muston
- Island Beach
- Brown Beach
- Baudin Beach
- Penneshaw
- Antechamber Bay
- D'Estrees Bay

The study utilises the Local Government Association Coastal Adaptation Decision Pathways Investigative Framework in developing the overarching approach to the study. Based on this approach, the scope of works for the technical assessments detailed in this report includes:

- Collation and review of available coastal datasets and information,
- Assessment of the coastal processes relevant to the study area, with specific focus on the existing coastal settlements,
- Assessment and mapping the erosion and inundation hazards across the study area under existing and future conditions,

- Review of existing coastal protection structures and strategies,
- Profiling the risk to assets, public land and infrastructure as a result of erosion and inundation hazards.
- Determine the monetary value of the assets at risk.

This report presents the supporting technical coastal hazard assessments undertaken within this scope of work to support the development of adaptation strategies and action plans for the study area. Much of the information presented is also available via on online mapping portal, https://bit.ly/2NyJXdm, and will be provided to Council as a geodatabase on completion of the study.

FIGURE 1-1 STUDY AREA

1.1 Planning Horizons

The following planning horizons have been adopted when assessing coastal hazards in this study:

- 2018 – current state of play, identifying immediate risks,
- 2050 – provides a medium-long term (32 years) outlook of risks, allowing adequate time for adaptation strategies to be employed, while allowing the time to monitor and verify projected coastal hazard scenarios.
- 2100 – allows for transparency of potential risks by the end of the century, informing the decision-making process.

1.2 Sources and Pathways

In order to define the susceptibility of the coast to inundation and erosion it is important to identify the different forms these hazards may take and therefore how they may impact a particular coastal classification. The following table, Table 1-1, is provided as an overview of the short and long-term hazards that may affect the Kangaroo Island coastline and has been adapted from the Victorian Coastal Hazard Guide (DSE, 2012) and the Coastal Hazard Risk Management and Adaptation Planning Guidelines (WA Department of Planning, 2014). Each hazard has been described in terms of the **Source** of the hazard, and **Pathways** by which impacts of the hazard may be felt.

When identifying risks to coastal communities in the study area, the potential for various coastal hazards to be present has been considered as well as their potential impacts.

TABLE 1-1 COASTAL HAZARD SOURCES AND PATHWAYS

Hazard	Source	Pathways
Long term coastal inundation	▪ Sea level rise (tides) ▪ Waves ▪ River flows / rainfall ▪ Increased berm heights at estuaries/coastal lagoons	▪ Direct inundation of low-lying land especially in estuarine and coastal lagoons ▪ Inundation via rivers, streams or stormwater outlets.
Short term coastal inundation	▪ Sea level rise (tides, storm surge, climate change) ▪ Waves ▪ River flows / rainfall ▪ Climate cycles ▪ Wind	▪ Overtopping or breaching of dunes, coastal barriers or protection works ▪ Inundation via beach access points and boat ramps ▪ Inundation via rivers, streams or stormwater outlets.
Groundwater – saline intrusion	▪ Sea level rise ▪ Waves ▪ River flows / rainfall ▪ Climate cycles ▪ Wind	▪ Hydraulic connection to aquifer beds ▪ Flow along buried stream channels ▪ Flow through crushed rock in fault zones
Short term erosion	▪ Sea level rise ▪ Waves ▪ Interrupted sediment supply ▪ Catchment discharges ▪ Climate cycles ▪ Wind	▪ Short-term fluctuations/cycles ▪ River/coastal dynamics ▪ Human induced changes ▪ Can lead to long term continuous retreat especially for soft rock coasts
Long term erosion (soft shores)	▪ Sea level rise ▪ Waves ▪ Interrupted sediment supply ▪ Catchment discharges ▪ Increased berm heights at estuaries/coastal lagoons ▪ Climate cycles ▪ Wind	▪ Long-term continuous retreat ▪ Long-term fluctuating recession ▪ Human induced changes

Hazard	Source	Pathways
Long term erosion (Rock shores)	▪ Geological defects controls ▪ Sea level rise ▪ Waves ▪ Climate cycles ▪ Wind	▪ Slumping ▪ Undermining ▪ Removal of toe material ▪ Lowering of shore platform or fronting beach ▪ Internal factors (defects) ▪ Groundwater/surface water ▪ Weathering
Damage to engineered coasts	▪ Sea level rise ▪ Waves ▪ Interrupted sediment supply ▪ Catchment discharges	▪ Undermining ▪ Overtopping ▪ Outflanking ▪ Increased wave forces

2 DATA & INFORMATION REVIEW

The following data and information have been collated and reviewed for the purpose of informing the coastal hazard assessment.

2.1 Topographic Data

The South Australian Department of Environment, Water and Natural Resources (DEWNR) provided LiDAR elevation data for two areas within the eastern region of Kangaroo Island. The LiDAR was captured by RPS in May 2015 and covers most parts of the eastern end of the island, including all key areas of interest for this study. The LiDAR coverage is shown in Figure 2-2.

The LiDAR project was flown with an intended vertical accuracy of ±0.15m, and the measured accuracy when compared to 68 ground control survey points was well within this tolerance, with an average difference -0.032m. The LiDAR was provided as a complete 1m-resolution mosaicked raster which can be used directly as is.

In addition to the LiDAR datasets, the South Australian Coastal Protection Board also collects shoreline cross-section profile data at numerous locations across the state. The relevant data sets were sourced for the current project study area and included cross-section profiles for the sandy beaches of Emu Bay, Brownlow, Island Beach, Penneshaw and Antechamber Bay. The majority of these cross sections were first surveyed in 1985 and have been regular surveyed up until present.

2.2 Water Levels

Tidal water level data was sourced from the Australian National Tide Tables (ANTT, 2016), while extreme water level estimates were provided by the Coast Protection Board. This information is summarised in Section 3.1.

2.3 Sediment Data

The sediment size present on a beach influences the beach slope and adjacent dune characteristics. It is also an important factor in determining the beach response and potential for erosion during storm events. For instance, fine sediment is more readily mobilised by wind and waves. Sediment data for sandy shorelines within the study areas has therefore been sourced for this study.

Appendix 2 of the Short and Fotheringham (1986) report contains detailed analysis of sediment samples taken from site across Kangaroo Island. Data relevant to the current study area are summarised in Table 2-1.

TABLE 2-1 SEDIMENT SIZE DATA

Location	Sample Site	Mean Sediment Diameter (mm)
Brownlow	Dune	2.46
Brownlow	Beach	1.54
Morrison Beach	Swash	0.87
Red Cliffs	Swash	1.50
Island Beach	Swash	2.07

Location	Sample Site	Mean Sediment Diameter (mm)
Browne Beach	Swash	1.09
American Beach	Swash	1.76
Hog Bay	Swash	2.39
Hog Bay	Foredune	2.24
Antechamber Bay	Foredune	2.15
Antechamber Bay	Swash	2.29
D'Estrees Bay	Swash	2.48
Emu Bay	Dune	2.34
Emu Bay	Swash	2.68
Boxing Bay	Transgressive Dune	2.49
Boxing Bay	Foredune	2.41
Boxing Bay	Swash	2.42

2.4 Historic Aerial Imagery

The following historic aerial imagery was sourced from the DEWNR via Mapland. This imagery has been analysed to assess long term erosion or accretion trends along the coastline within the study area.

- Survey 5711, Frame 107 Date: 20.09.1999
- Survey 5722, Frame 130, Date: 01.10.1999
- Survey 4006, Frame 30, Date: 23.01.1989
- Survey 5936, Frame 43, Date: 30.03.2001
- Survey 5723, Frame 262, Date 11.10.1992
- Survey 5711, Frame 55, Date 20.09.1999
- Survey 5936, Frame 13, Date 30.03.2001
- Survey 5936, Frame 42, Date 30.03.2001

The images were selected to provide a reasonable coverage of the main areas of interest across the study area as shown in Figure 2-1and have been compared to more recently available (post 2015) imagery.

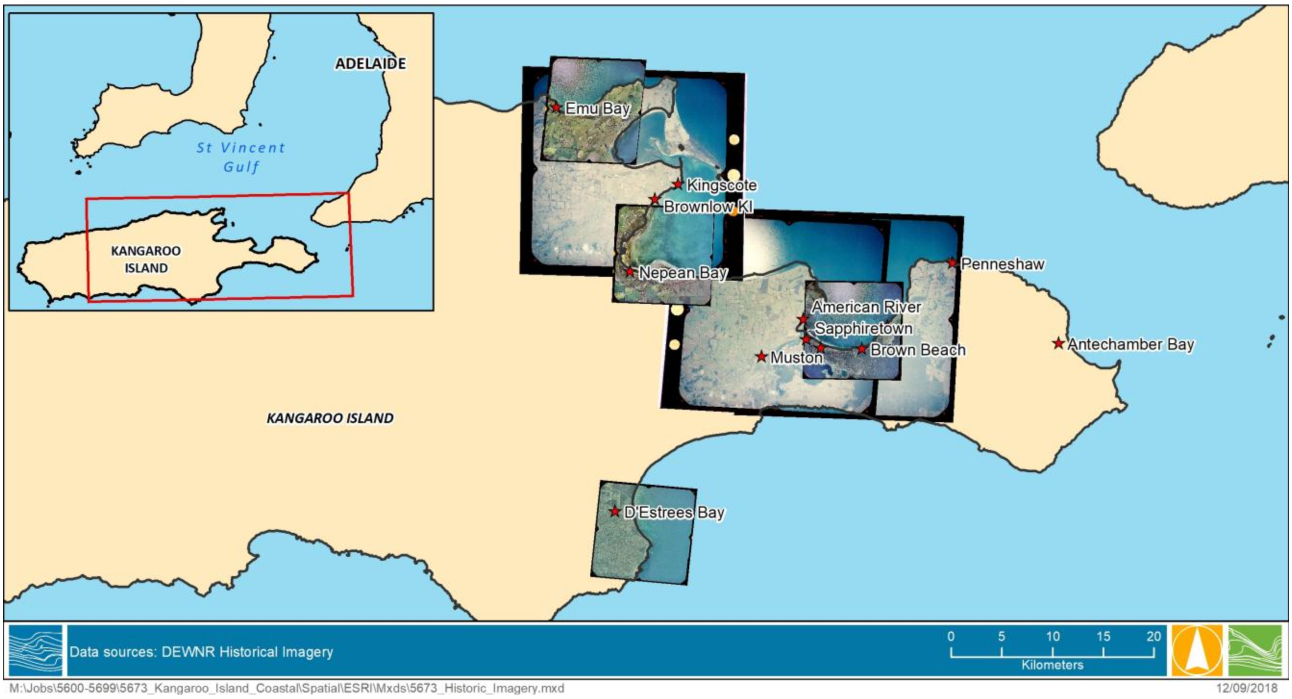

FIGURE 2-1 HISTORIC IMAGERY SOURCED FOR THE STUDY

2.5 Previous Studies

A range of previous studies on the coastal landscapes and coastal hazards of Kangaroo have been undertaken. The following reports were sourced and reviewed for this study:

- Womersley H.B.S. (1947). The Marine Algae of Kangaroo Island
- Dailey B., Milnes, A.R., Twidale, C.R., and Bourne, J. A., (1979). Geology and Geomorphology
- Oks (1986). Kangaroo Island Coast Protection District: Marine Biota, Working Paper
- Social and Ecological Assessment (1986). Flora and Fauna of the Kangaroo Island Coast
- Short and Fotheringham (1986). Morphodynamic, Hazard and Development Impact Assessment
- Edwards (1987). Kangaroo Island Coast Protection District Study Report
- Short and Fotheringham (2006). Coastal Morphodynamics and Holocene Evolution of the Kangaroo Island Coast, South Australia
- Bourman, Murray-Wallace and Harvey (2016). Coastal Landscapes of South Australia
- Mariani et al (2012). Generic Design Coastal Erosion Volumes and Setbacks for Australia

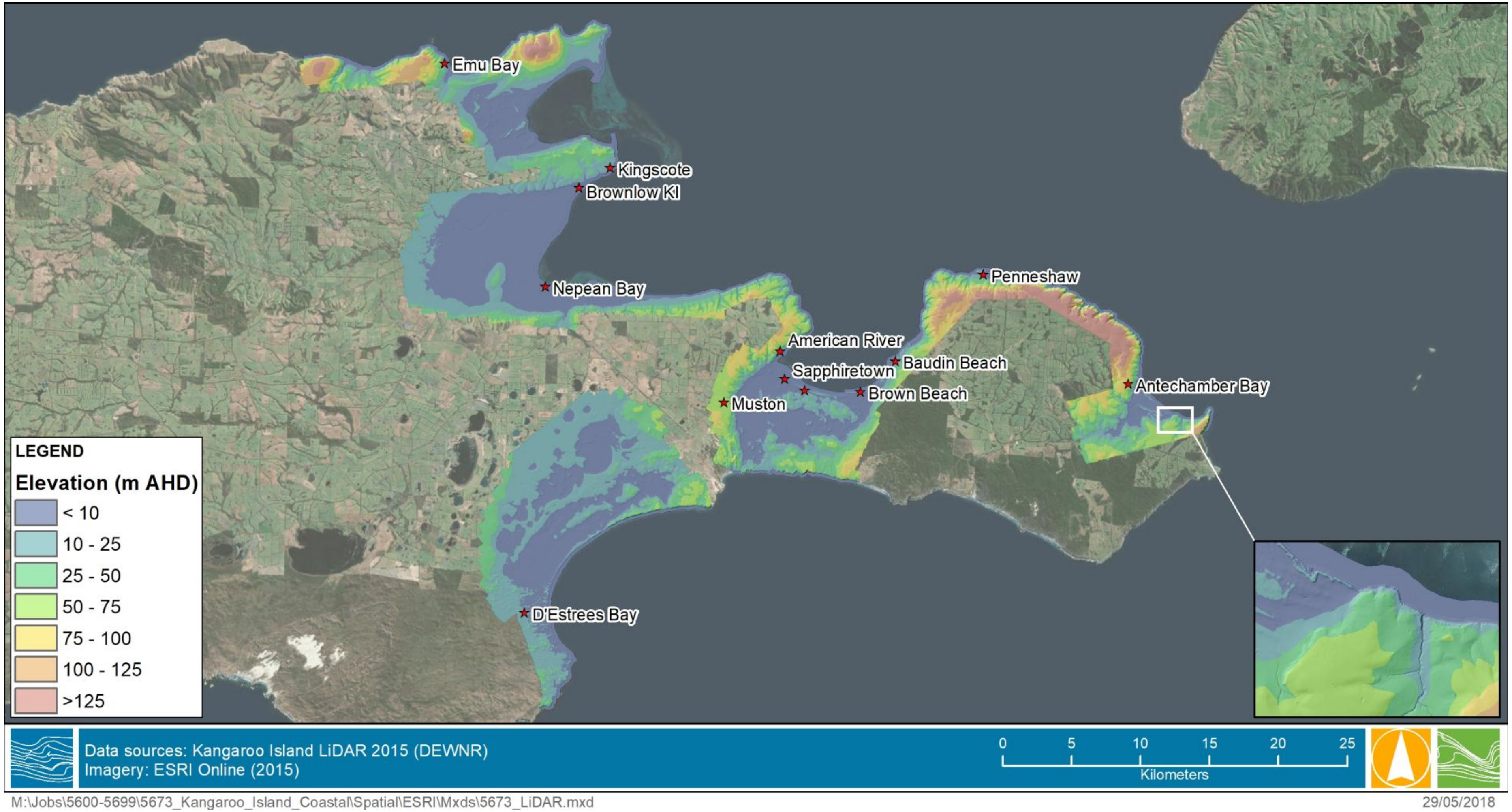

FIGURE 2-2 LIDAR DATA COVERAGE AND DETAIL

3 OCEANOGRAPHIC AND COASTAL PROCESSES

3.1 Oceanographic Conditions

The following section identified the magnitude and frequency of the main oceanographic processes impacting the coastline of Kangaroo Island within the study area under existing conditions and for the future planning horizons.

3.1.1 Mean Sea Level

Table 3-1 provides a summary of relevant sea level rise increments related to the planning horizons detailed in Section 1.1.

TABLE 3-1 SEA LEVEL RISE SCENARIOS

	Year and Sea Level Increment		
	Existing	2050	2100
Mean Sea Level Rise (m)	0.0	0.3	1.0

3.1.2 Astronomical Tide

Astronomical tide refers to the rise and fall of the sea surface due to the gravitational attraction between the earth, moon and sun. Water level variations in coastal areas due to the astronomical tide can be reliably predicted provided a reasonable length of continuous water level observations is available.

Tidal plane information for different locations within the study area, as listed in the Australian National Tide Tables (2016), is presented in Table 3-2. The Mean High-Water Springs (MHWS) and the Highest Astronomical Tide (HAT) has been combined with the required sea level rise increments described in Table 3-1 for each location and the resultant water levels are detailed in Table 3-3

Table 3-3. Note that the levels presented in these tables are referenced to the Australian Height Datum (m AHD). Tidal levels as presented in the Bureau of Meteorology Tide Tables or similar references are often referenced to different datums such as LAT. The Australian Height Datum has been adopted for this study as it is the reference datum for all the available topographic data and storm tide levels provided by the Coast Protection Board are also referenced to AHD.

This information has been used to inform the long-term inundation assessment, detailed in Section 5

TABLE 3-2 TIDAL PLANES FOR SITES ACROSS THE STUDY AREA (ANTT, 2016)

	Level (m AHD)				
Tidal Plane	**Emu Bay**	**Kingscote**	**American River**	**Vivonne Bay**	**Penneshaw**
Highest Astronomical Tide (HAT)	1.0	1.1	0.9	0.7	1.0
Mean High Water Springs (MHWS)	0.7	0.6	0.6	0.4	0.6
Mean High Water Neaps (MHWN)	0.2	0.1	0.2	0.1	0.1
Mean Low Water Neaps (MLWN)	-0.1	-0.2	-0.1	-0.1	-0.2
Mean Low Water Springs (MLWS)	-0.6	-0.7	-0.6	-0.4	-0.6
Lowest Astronomical Tide (LAT)	-0.8	-1.0	-0.8	-0.5	-0.8

TABLE 3-3 ESTIMATE OF HIGH WATER LEVELS FOR DIFFERENT SEA LEVEL RISE SCENARIOS

m AHD	Existing	2050 (+0.3m)	2100 (+1.0m)
Mean Sea Level Rise	-	0.3	1.0
Emu Bay			
MHWS	0.7	1.0	1.7
HAT	1.0	1.3	2.0
Kingscote			
MHWS	0.6	0.9	1.6
HAT	1.1	1.4	2.1
American River			
MHHW	0.6	0.9	1.6
HAT	0.9	1.2	1.9
Vivonne Bay			
MHHW	0.4	0.7	1.4
HAT	0.7	1.0	1.7
Penneshaw			
MHHW	0.6	0.9	1.6
HAT	1.0	1.3	2.0

3.1.3 Storm Tides

The term storm tide refers to coastal water levels produced by the combination of astronomical and meteorological ocean water level forcing. The meteorological component of the storm tide is commonly referred to as storm surge and collectively describes the variation in coastal water levels in response to atmospheric pressure fluctuations and wind setup. The storm tide and components are presented in Figure 3-1.

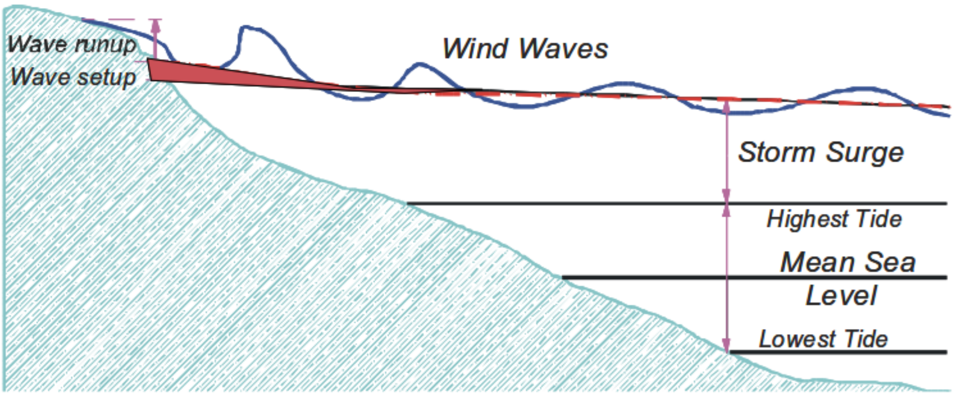

FIGURE 3-1 STORM TIDE COMPONENTS (CSIRO, 2009)

The Coast Protection Board establishes the 100-year Average Recurrence Interval (ARI) water level for the entire South Australian coastline. For the areas of interest within Kangaroo Island coastline the recommended 1 in 100-year ARI levels are detailed in Table 3-4.

TABLE 3-4 100 YEAR ARI STORM TIDE LEVELS

Location	Sea Level Rise Scenario	100-Year ARI Still Water Level (m AHD)	Wave Set Up (m)	Wave Run Up (m)	100-Year ARI Max Water Level (m AHD)
Emu Bay	Existing	1.75	0.20	0.35	2.3
	2050	2.05			2.6
	2100	2.75			3.3
Kingscote	Existing	1.80	0.2	0.4	2.4
	2050	2.1			2.7
	2100	2.8			3.4
Brownlow Beach	Existing	1.8	0.2	0.3	2.3
	2050	2.1			2.6
	2100	2.8			3.3
Nepean Bay American River Island Beach Penneshaw	Existing	1.8	0.2	0.2	2.2
	2050	2.1			2.5
	2100	2.8			3.2

Location	Sea Level Rise Scenario	100-Year ARI Still Water Level (m AHD)	Wave Set Up (m)	Wave Run Up (m)	100-Year ARI Max Water Level (m AHD)
Antechamber Bay	Existing	1.75	0.30	0.40	2.45
	2050	2.05			2.75
	2100	2.75			3.45
D'Estrees Bay	Existing	1.70	0.6	1.0	3.3
	2050	2.0			3.6
	2100	2.7			4.3

3.1.4 Winds and Waves

An overview of the wave climate for Kangaroo Island is presented in Figure 3-2 (from Oks, 1986). The south and western coasts experience the highest wave energy as they are directly exposed to the Southern Ocean. Waves refract around the northern section of Kangaroo Island and continue along the coast decreasing in wave energy as they propagate eastward to Point Marsden (Womersley, 1947). The coastline from Kangaroo Head to Point Marsden is sheltered resulting in a relatively low energy wave climate for the areas of Kingscote, Brownlow and Nepean Bay. The townships located within Eastern Cove which include American River, Sapphiretown, Muston, Island Beach, Brown Beach and Baudin Beach are sheltered to an even greater degree resulting in an even lower wave energy (Oks, 1986).

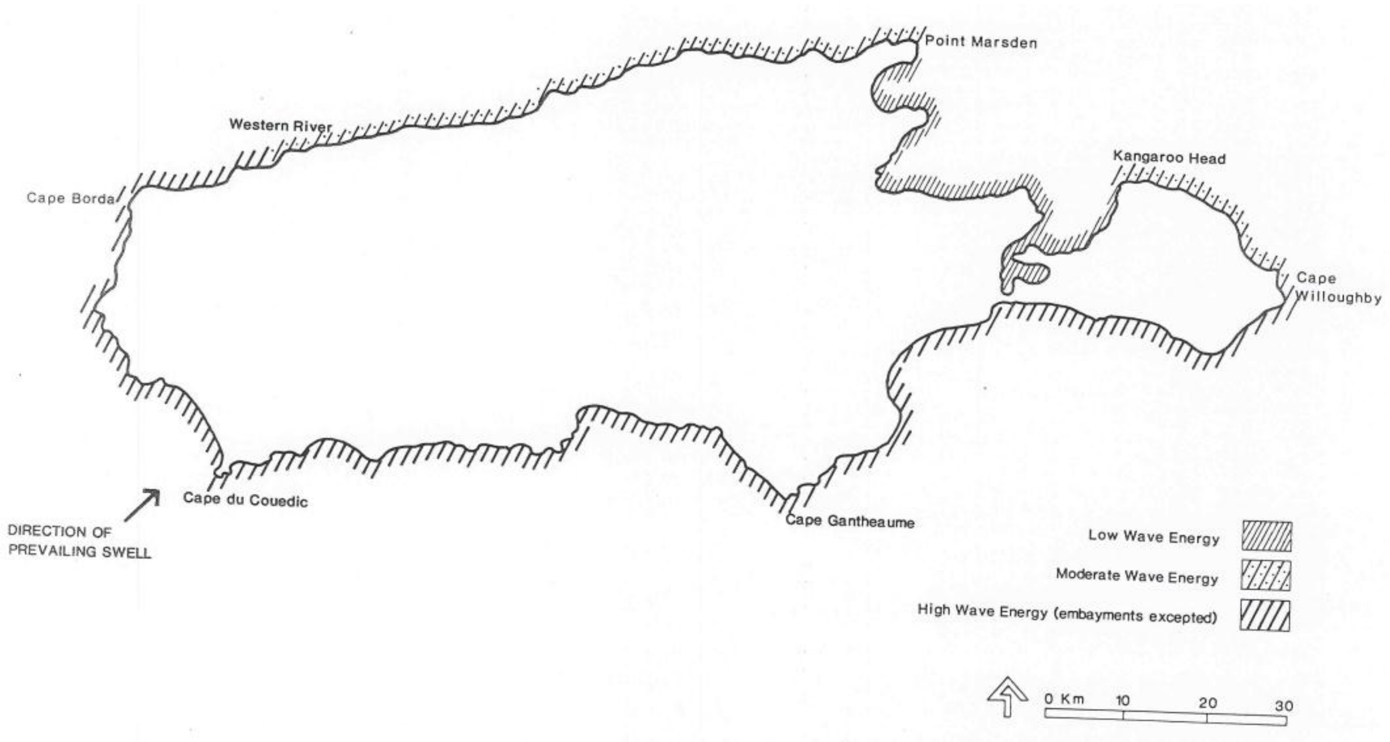

FIGURE 3-2 WAVE ENERGY DISTRIBUTION KANGAROO ISLAND (OKS 1986)

3.2 Coastal Processes

The following sections summarise existing knowledge and understanding of the geology, geomorphology and coastal processes influencing the dynamics of the shoreline around Kangaroo Island and in particular the study area. This information has been used to inform the selection of appropriate coastal hazard analysis tools and analysis approaches.

3.2.1 Geology

Short and Fotheringham (1986) provides a detailed overview of the geology of Kangaroo Island. Kangaroo Island is an extension of the mount lofty ranges which is part of the Adelaide Geosyncline and is made up of sedimentary rocks from the Late Cambrian (570 million years before present) and Early Palaeozoic periods (280 million years before present) (Dailey et al 1976). The shape of Kangaroo Island is framed for the most part by the pre-Quaternary bedrock which has over the last 20 million years has been cycled between being connected above sea level to the mainland and periods such as now when it has been cut off by the sea. This has resulted in large scale dune system containing carbonate shell fragments(sand) during periods of high water which are then lithified into calcarenite during periods when the sea-levels have receded (Short and Fotheringham, 1986).

When sea levels rose again, and waves began to erode the newly formed rock the formation of calcarenite sea cliffs is observed and can be seen within the southern and western regions of Kangaroo Island. These cliffs cover roughly 220km of shoreline (50 of the total shoreline length) and extend up 20km inland in certain regions as shown in Figure 3-3.

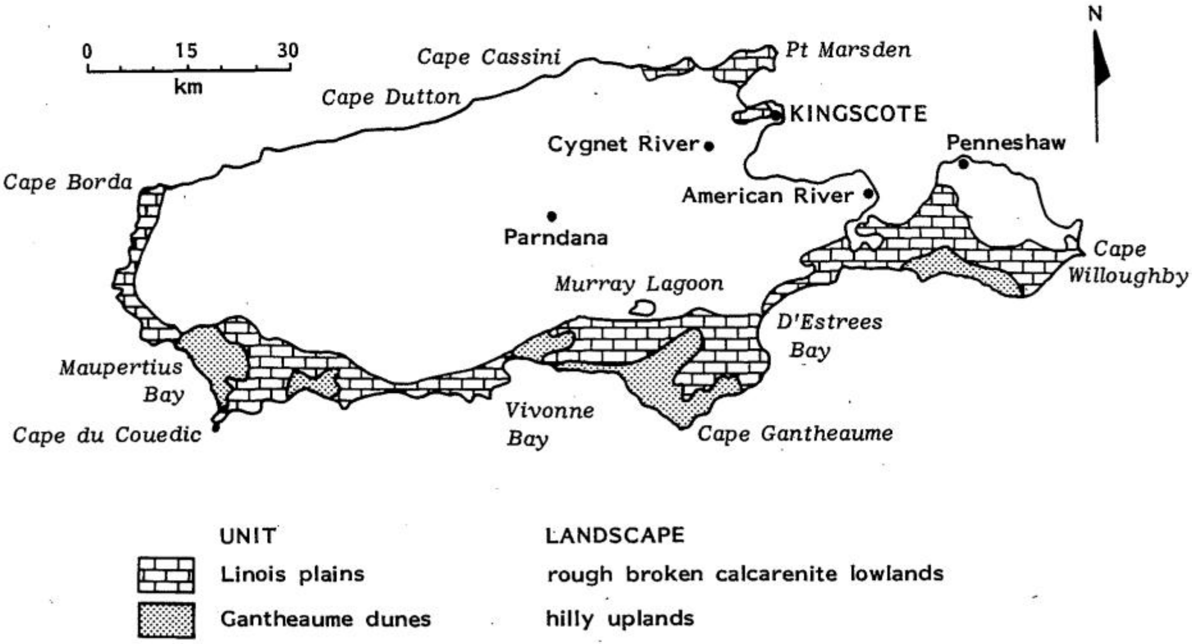

FIGURE 3-3 CALCARENITE DUNE DISTRIBUTION ACROSS KANGAROO ISLAND (SHORT AND FOTHERINGHAM 1986)

3.2.2 Geomorphology

The current study area encompasses predominantly the north east coast of Kangaroo Island. As detailed in Short and Fotheringham (1986), the north east coast is dominated by offshore winds and low waves.

Topographically three relatively shallow bays (Bay of Shoals, Nepean Bay (Inc. Western Cove) and Eastern Cove), separated by low to moderately high bedrock cliffs. The Quaternary sediment (1.8 million years before present) is restricted largely to the Holocene deposits (10,000 years before present) in the bays, consisting of low beach ridges and tidal flats composed of both marine and terrigenous material.

Much of the southern and western coastline is largely influenced by carbonate sand which is located as far as 20km inland, transported by wind. The resultant calcarenite sea cliffs such as within D'Estrees Bay are characteristic of this coastline.

Emu Bay is located on the northern coastline, which is largely controlled by the bedrock with a few small areas of drowned river valleys and bays which contain both marine and terrigenous sediments.

The general composition and erodibility of the shorelines within the study area, as detailed in Short and Fotheringham (1986) are summarised below:

- Emu Bay - The main portion of the Emu Bay township is located on coastline which is classified as hard rock and has low erosion potential. The sandy sections of coast within the region is for the most part located on top of bedrock meaning that coastal recession is limited to sandy layer atop of this rock surface. A section with high recession and erosion potential is the roughly 500m stretch of coastline south of Buick St which is classified as a sediment backed open sandy shoreline. Without the rock backing, the potential for erosion and coastal recession is not limited to the upper sediment layer as with the other coastlines in this region.
- Kingscote - The Kingscote coastline is dominated by hard rocky shores and has a low erosion potential. The western shoreline of Beatrice Point the has a high erosion potential along with a small 250m section of shoreline east of the intersection of Chapman Terrace and Cygnet Road.
- Brownlow - The shoreline at Brownlow can be separated into two main sections the hard rock shoreline with low erodibility to the north of Hanley Road and the sand dominated shoreline with a high erodibility potential in the south.
- Nepean Bay and Western Cove - The coastline of Western Cove is a predominantly sand dominated shoreline with a high erodibility potential. On the southern coastline in outer Nepean Bay the shoreline is dominated by more rocky substrates with both hard and soft rock observed.
- Eastern Cove - Within Eastern Cove, American River and Muston coastlines are predominately of low erodibility made up of hard rock shorelines. Within American River however the eastern facing tip of Buick Point is classified as a sand dominated shoreline with a high erosion potential. Sapphire Town, Island Beach and most of Brown Beach are dominated by highly erodible sandy shorelines. The coastline at Baudin Beach is made up of a soft rock shorelines respectively with a low to moderate erodibility.
- Penneshaw - Penneshaw is located on a hard rock section of coastline which runs from the northern eastern section of eastern cove to northern section of Antechamber Bay in the south. This coastline is defined by large cliff faces and a very low erodibility. There is a short section of erodible sandy shoreline located at Hog Bay, between the Ferry Terminal and The Frenchmans Rock.
- Antechamber Bay - The bay region is comprised of highly erodible sandy shorelines between the rocky cliffs roughly 700m north of the Chapman River mouth and rocky headland separating Antechamber Bay with Red House Bay in the south.
- D'Estrees Bay - This coastline is mainly comprised of soft rocky shorelines with a moderate erodibility. A small portion of hard rocky shoreline is also seen within the area which exhibits a very low erodibility.

The generalised coastal geomorphology of the study area is summarised in Figure 3-4, which presents the SMARTLINE dataset available on the CoastAdapt platform (http://coastadapt.com.au/coastadapt-interactive-map). This is based on the work of Sharples, Mount and Pederen (2009).

The broad classes shown in the SMARTLINE mapping reflect the fundamental differences in susceptibility to coastal erosion, namely:

- Predominantly sandy – typically sandy types of shorelines, most readily eroded but also very mobile and capable of accretion (growth) as well as erosion.
- Predominantly soft rock – generally cohesive clayey material which are more resistant to erosion than sandy shorelines, but not as resistant as well-lithified rock. These may erode slowly but significantly over time, and do not rebuild as sandy shores may.
- Predominantly hard rock – most resistant to noticeable erosion on human time-scales although steeper hard rock shores may be notably unstable. Moderately sloping hard rock shorelines are considered to have negligible erosion hazard based on the lack of historical-observed instability in this shoreline type.

FIGURE 3-4 COASTAL MORPHOLOGY AS DEFINED ON THE SMARTLINE DATASET AVAILABLE ON THE COASTADAPT PLATFORM

3.2.3 Coastal Processes

A brief overview of the coastal processes across the study are is provided below, based on Edwards (1987) and Short and Fotheringham (1986):

- Emu and Boxing Bays

Emu Bay is considered a low gradient, low wave energy beach which is backed by a 20 to 50m high scarped Pleistocene dune calcarenite. Despite the generally low wave energy environment, Emu Bay is subject to storm wave erosion and overwash. Boxing Bay is similar, although backed by pre-Quaternary bedrock.

- North East Coast – North Cape to Cape Willoughby

It is a leeward coast with the prevailing west to south-west winds blowing predominantly offshore, likewise the south-west swell only reaches the far eastern portions after refraction into Backstairs Passage. As a result, this is a modally low energy coast. However locally generated wind waves together with strong tidal and/or shelf current around North Cape and in Backstairs Passage, have moved and reworked substantial quantities of sediment.

- Bay of Shoals

The Bay of Shoals has 21 km of shoreline, dominated by the east facing U shaped bay and associated 20km of sandy shoals. The Bay represents the larges area of shallow marine sedimentation around Kangaroo Island. Most of the sediment appears to originate from the seafloor north and east of Port Marsden being reworked southward and shoreward by northerly wind waves and possibly tidal and/or wind generated currents. The sholas now effectively block the Bay from Gulf waves, resulting in a very low energy stable coastline, with Bay sedimentation being restricted to the flood tide delta and possible fine material in the Bay centre.

- Western Cove

Western Cove is an open, roughly U-shaped cove that faces the east-north-east. As such the prevailing winds blow offshore and the only apparent forms of marine energy are tides and low refracted northerly and westerly waves. The Cove has been a major sediment sink in the Holocene period with wave induced cliff erosion and littoral drift forming beach ridges, samphire flats and sandflats. Sedimentation is continuing along the southern shore. Whilst high ocean and Gulf waves can occasionally impact the southern shore, wave energy is low. Nevertheless, the southern shoreline is actively eroding.

- Eastern Cove

Eastern Cove though slightly higher wave energy than Western Cove, has experience far less Holocene sedimentation. The most substantial sedimentation is associated with the American River tidal delta and Pelican Lagoon intertidal and subtidal sediments.

- North-East Dudley Peninsula

Most of the coastline comprises stable bedrock cliffs and shore platforms, with the only significant area of Holocene sedimentation at Antechamber Bay and Hog Bay. The slightly more exposed wave climate along this coast allowing more movement of sediment as indicated by the intermittent closure of the Chapman River entrance by the sand berm.

- Cape Willoughby to D'Estrees Bay

This high wave energy coastline is characterised by bedrock headlands, extensive bedrock and/or calcarenite cliffs and shore platforms with a few Holocene beach deposits. All the beaches and cliffs are capped and backed by Pleistocene dune calcarenite and to a lesser degree Holocene dunes. Lower energy beach dune ridges only occur in east-facing D-Estrees Bay. This lower wave energy environment occurs as wave refract around cape Linois to Point Tinline and waves attenuate across the shallow bay flow.

4 EROSION HAZARD ASSESSMENT

4.1 Erosion Processes Overview

The following section summarises provides an overview of the erosion processes and current understanding of how different shorelines are likely to respond sea level rise.

4.1.1 Sandy Shorelines

Long Term Recession

Long term recession of a sandy shoreline is caused by a net loss of sediment at the beach. The net loss of sediment can be the result of imbalances in the longshore rate of sediment transport, including the introduction of structures such as a groyne, or a harbour, or can be associated with adjustment of the shoreline to incremental changes in mean sea level.

Incremental increases in the mean sea level on a sandy shore will lead to erosion, as wave action erodes the beach face, transporting sediment offshore. The sand transported offshore can then be redeposited onshore in the form of washovers (where wave action washes over the dune crest transporting sediment with it). Over time this process translates the shoreline profile shoreward and upward in response to the relative higher sea level. This process results in a redistribution of sediment across the profile but does not lead to net gain or loss of sediment.

Already eroding beaches may recede faster, while currently accreting (growing) breaches may continue to accrete more slowly, or switch to receding. The long-term trend of a shoreline in response to sea level change may be delayed or masked by episodic swell-driven beach recovery between storm events.

Short-Term Erosion

As described in Section 3.1.3, *storm tide* refers to extreme coastal water levels produced by the combination of astronomical and meteorological sea level forcing. As well as source of direct inundation of the coastal zone, individual storm events have the capacity to remove sand from beaches and erode soft rock shores.

Sand moved offshore in such an event may move back onshore during calm weather in a normal cycle. It may also be transported along the coast by longshore currents. Finer sediments, and some sand, may be lost from the system, taken offshore by currents and turbulence

Increases in mean water levels and storm tides elevations will allow storm waves to approach closer to the shore before breaking, resulting in greater energy to be dissipated over a smaller area. This will contribute to increased erosion of these shorelines and also potentially sand shoreward through increased overwashing of the dunes. The increased wave energy may also move sand further offshore, potentially removing the sediment from the adjacent beach system.

In the absence of significant swell or exposure to swell, such as in an estuary setting, there may be little or no recovery between erosion events, compared to episodic recovery that occurs on open sandy coasts. This is likely to be the case with Nepean Bay and the Bay of Shoals.

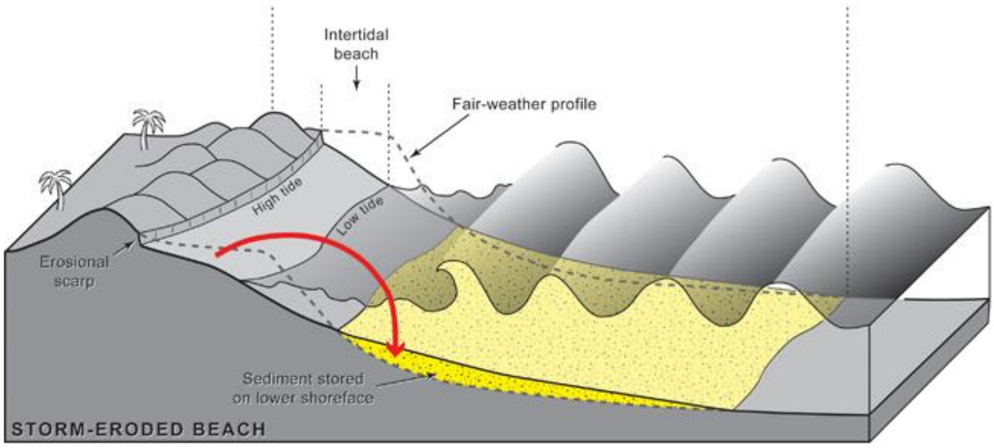

FIGURE 4-1 SHORE TERM STORM EROSION HAZARDS (USGS, 2008)

The underlying geology often provides a natural limit to recession of sandy shorelines, as illustrated in Figure 4-2 (Sharples, 2013). This figure shows recession back to the intersection of the underlying bedrock, and projected high-water mark. The second cross section provides an example of soft sediment overlying bedrock above the projected high-water mark (HWM).

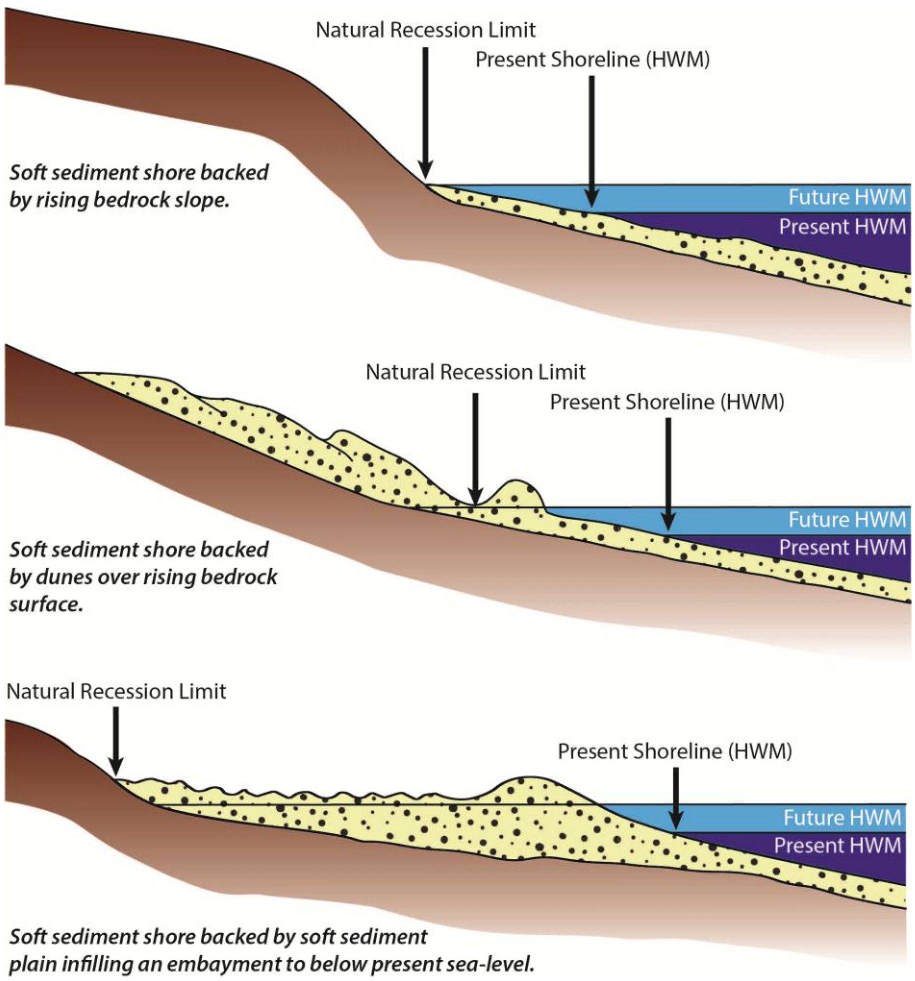

FIGURE 4-2 NATURAL RECESSION LIMITS OF SOFT SEDIMENT SHORELINES (ADAPTED FROM SHARPLES 2013)

4.1.2 Estuaries, Lagoons and Tidal Flats

Elevated water levels in estuaries and coastal lagoons will lead to increasingly saline water and an increase in wave action along the shoreline. Increasing salinity will likely result in dieback of more freshwater dependent fringing vegetation, which then exposes the softer estuarine sediments to waves. A more energetic wave climate in turn increases the rate of erosion of the soft shoreline material. There may be little or no recovery between erosion events, compared to episodic recovery that occurs on open sandy coasts. This is likely to be the case with Nepean Bay and Western Cove.

4.1.3 Soft Rock Shoreline

On a soft rock coast, once the material is eroded, these shorelines cannot recover to their former state as sandy beaches do. In some cases, large hard rocks eroded from a soft rock cliff can provide some protection to the toe of the cliff (DPaC 2016). This process is shown graphically in Figure 4-3.

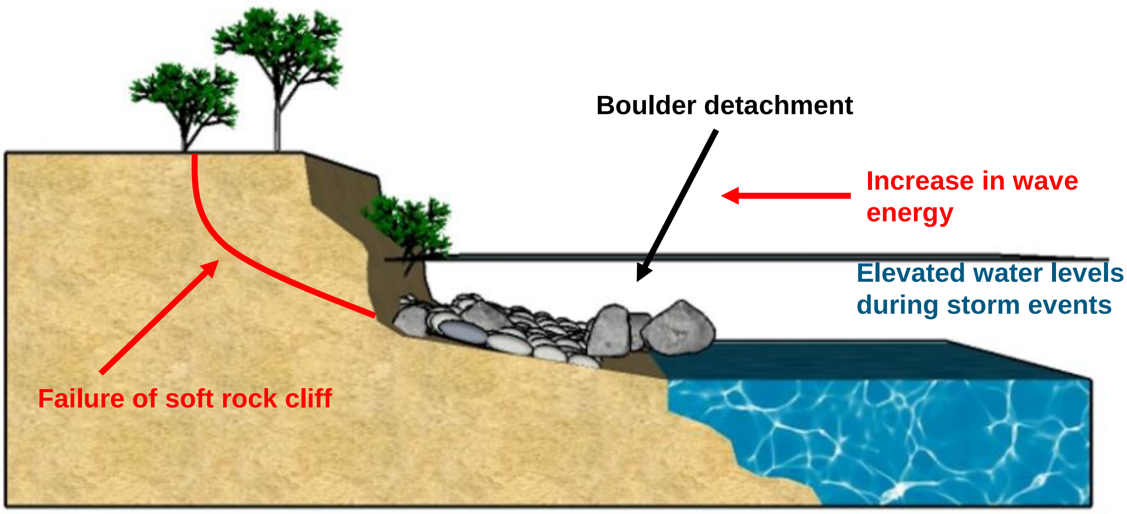

FIGURE 4-3 EROSION PROCESSES FOR SOFT ROCK CLIFFS

The frequency and severity of erosion on soft rock shorelines is likely to increase as a result of climate change. Increases in water level, associated with sea level rise, or storm events, may also expose less resistant portions of the profile to erosive forces.

Soft sediments within an estuarine or coastal lagoon environment are also susceptible to wave induced erosion. While this form of erosion can occur as a result of a coastal storm, it more typically occurs as longer-term recession of the shoreline due persistent wave action over long periods.

4.1.4 Hard Rock Shorelines

The rate of recession of rocky shorelines is determined by the following factors:

- Inherent properties of the substrate,
- Wave climate (magnitude and exposure),
- Accumulation and retention of slope-foot materials, and
- Presence of engineering structures (seawalls etc).

Hard rock shorelines are generally exposed, as their natural resistance to erosion allows them to persist as headlands while softer shorelines to the sides erode. Rock material is episodically detached from the slope and removed by wave action.

Hard rock shores are the least susceptible to erosion of the shoreline classes. Steeply sloping hard rock shorelines, such as hard bedrock cliffs, while highly erosion resistant, can be subject to block falls and slumping. These fallen rocks can act as a self-armouring mechanism providing some protection to the toe of the cliff. The rate of recession of hard rock shorelines is very low, however the risk associated with a failure can be high as significant portions break off.

Shorelines of steep to cliffed hard rock have been categorized as having potential for rock falls and slumping hazards, although the risk rating is low. More gradual sloped hard rock shorelines are not considered to represent an erosion hazard within existing coastal management time scales.

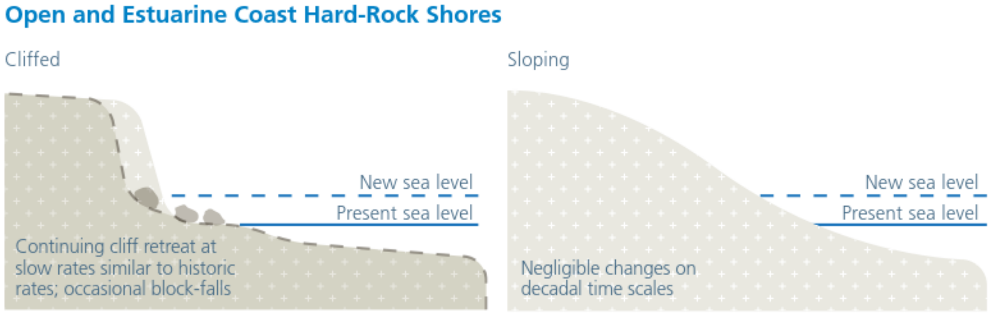

FIGURE 4-4 GENERALISED IMPACTS OF SEA LEVEL RISE ON ROCK SHORELINES (SOURCE: C. SHARPLES, UNIVERSITY OF TASMANIA; VICTORIA COASTAL HAZARD GUIDE, 2012)

4.2 Analysis Approach

The Coastal Policy (Coast Protection Board, 2016) indicates coastal erosion should be assessed for a 100-year timeframe. The policy recommends consideration of local long-term erosion or accretion trends, potential storm erosion, as well as likely recession due to sea level rise. The assessment approach for each of these components and their applicability to a section of coast depends on the local coastal morphology, with sandy coasts responding differently to oceanographic (wind, wave and current) forces compared to steeper or more resistant coastlines. Approaches to estimating the response of a shoreline to sea level rise include the Brunn Rule, however, this is only applicable to sandy shorelines. See Section 4.5 for a definition and further information on the Brunn Rule.

An overview of the analysis approaches to estimate the different aspects of coastal erosion are presented in Table 4-1. The long-term recession, short term erosion and shoreline response to sea level rise have been combined for specific locations to provide an estimate of the potential coastal erosion zone along the study area coastline. For example, for sandy shorelines the current rate of long-term erosion has been used to estimate the likely long-term erosion that will occur between now and 2050. To this value is added the predicted short-term erosion that could occur as a result of a 100-year ARI storm event, and the predicted coastal recession as a result of sea level rise (e.g. S1 + S2 + S3, where S1 S2 and S3 are defined in Table 4-1.

Due to the substantial length of the study areas shoreline, the resultant erosion extents have been presented as online maps, which can be accessed via the following link: https://bit.ly/2NyJXdm

TABLE 4-1 ANALYSIS APPROACH OVERVIEW

Coastal Hazard	Shoreline Type	Assessment Approach
Long-term Erosion or Accretion (S1)	Sandy	Estimates of the long-term erosion or accretion of sandy shorelines has been based on an analysis of cross-shore profiles captured at 13 locations across the study area by the Department of Environmental, Water and Natural Resources (DEWNR) over the past 30 years, although some profiles only have information for part of this period. The profiles have typically been every 5-7 years. The long-term recession rate is then extrapolated out over the planning period (2050 and 2100) to give the total long-term recession to that point in time. Where accretion was occurring the long-term recession, rate was set to zero. This is a conservative as it assumes that the current sediment transport processes contributing to accretion are no longer able to occur as a result of future sea level conditions.
	Estuaries, Lagoons and Tidal Flats	Not applicable for this shoreline type. Inundation hazards during storm events are typically more significant than erosion for this shoreline type.
	Soft Rock	Although there have been studies of coastal soft rock erosion and recession processes (e.g. Trenhaile, 2011) there are no widely accepted or used methods for generating generic (widely-applicable) soft rock coastal erosion susceptibility zones. Historical rates of soft rock shoreline recession are the best available indicators of potential future rates, albeit it is expected that ongoing sea-level rise will cause some acceleration of historical rates of soft rock shoreline recession. Comparison of historic aerial imagery was used to assess estimate historic recession rates.

Coastal Hazard	Shoreline Type	Assessment Approach
	Hard Rock – gentle to moderate slopes	As discussed in Sharples et al (2013), hard rock foreshores and backshores that slope up at gentle to moderate angles to landwards are regarded as having acceptable (i.e., negligible) erosion susceptibility. Although some may exhibit small erosion scarps (typically lower than 5 metres) backing a shore platform, these have generally developed on millennial time scales since the end of the last post-glacial marine transgression circa 6,500 years ago and are eroding at very slow rates which in most cases can be expected to be virtually un-noticeable over human time frames (Sharples et al, 2013). Since this shoreline category is classified as having negligible erosion or recession susceptibility over human time frames, no erosion prone area has been defined. Within the SMARTLINE dataset, moderate to steeply sloping is defined as 5° to 60°. For the purposes of this first pass assessment, gentle to moderately sloping hard rock shorelines where defined as those shorelines where the slope was less than 45 degrees. The slope angle was determined from the LiDAR dataset. This assumption could be further refined based on a steep slope criterion of 15 to 30 degrees.
	Hard Rock – moderate to steep slopes	Sharples et al (2013) notes "that steeply sloping to cliffed hard rock foreshores and backshores are normally much less susceptible to coastal erosion and recede at much slower rates than soft rock or soft sediment shores. Nonetheless their steepness is itself an indication that these are actively eroding landforms, and these shores may be prone to block falls and slumping on scales and event frequencies sufficient to be noticeable and problematical over human time frames. Many steep coastal slopes are mantled by bedrock talus blocks (unconsolidated slope deposits) derived from past instability and prone to ongoing slumping, while bedrock block falls from vertical faces will occur periodically in response to basal wave erosion gradually undermining the cliff base. It is therefore necessary to treat steep to cliffed hard rock shores as potentially susceptible to erosion and recession." Steeply sloping shorelines for this assessment were defined as where the slope was greater than 45 degrees. The slope angle was determined from the LiDAR dataset. This assumption could be further refined based on a steep slope criterion of 15 to 30 degrees. Hard – rock cliff regression (slumping) hazard zones have previously been estimated for NSW coastal hard rock cliffs by manually mapping a potential slump hazard zone extending the same distance horizontally landwards of the cliff top as the height of the cliff above its base, which generally approximates the High Water Mark (Patterson Britton 2005). This method created a hazard buffer landwards of sea cliffs by assuming a maximum slumping and instability angle of 45° rising landwards from the base of the cliff. This simplified approach has been adopted for this study. Alternative approaches to estimating cliff and steep slope recession are detailed in Sharples et al (2013)

Coastal Hazard	Shoreline Type	Assessment Approach
Short Term (Storm) Erosion (S2)	Sandy	The large waves, elevated water levels and strong winds generated by a storm can cause severe erosion on sandy foreshores. To determine the response of the local foreshore to the design storm event, the numerical model SBEACH has been applied. This Storm-induced BEAch CHange (SBEACH) model is a numerical simulation model of cross-shore beach, berm, and dune erosion produced by storm waves and elevated ocean water levels. This erosion is often referred to as the “storm bite”.
	Estuaries, Lagoons and Tidal Flats	Not applicable for this shoreline type. Inundation hazards during storm events are typically more significant than erosion for this shoreline type.
	Soft Rock	Individual storm bites as recorded and used for unconsolidated sediment shores are not as useful for soft rock shores. Soft rock erodes less in a given storm than soft sediments may, however it does not recover from erosion and so tends to exhibit notable recession rates over longer periods, representing the cumulative effect of repeated small storm bites. Therefore, the long-term recession rate is more useful to define coastal erosion hazards for soft rock coasts. In addition, no shoreline profile measurements are available for this shoreline type. No distinction for exposure to different wave climates has been made in this assessment due to the lack of appropriate modelling or analysis methods.
	Hard Rock	Not applicable for this shoreline type
Recession due to Sea Level Rise (S3)	Sandy	A Bruun factor was applied to provide a first pass assessment for setbacks due to sea level rise. On open coasts, the Bruun factor “rule of thumb” is typically in the range of 50 to 100 (Mariani et al, 2012). That is, coastal recession will be 50 to 100 times the predicted sea level rise magnitude. By adopting this “rule of thumb” approach it provides a conservative approach to identifying areas potentially at risk.
	Estuaries, Lagoons and Tidal Flats	The erosion prone extent for these areas is represented by the Mean High-Water Springs (MHWS), which defines the upper limit of the intertidal zone. The intertidal zone includes areas regularly but not permanently inundated and washed by waves. The future MHWS tidal planes have therefore been used to indicate the future shoreline location for these areas.

Coastal Hazard	Shoreline Type	Assessment Approach
	Soft Rock	Trenhaile (2011) provides evidence that soft rock shores tend to progressively erode and recede landwards at slow to moderate but fairly continuous rates under stable sea-levels. However, soft rock shoreline retreat rates are expected to increase with a rising sea-level, primarily because of reduced wave attenuation as water deepens over the near shore profile, allowing stronger wave attack. There is no data currently available to determine whether there has yet been any acceleration of soft rock shoreline retreat rates on South Australian coasts in response to the sea-level rise that has occurred over the last century. However, modelling of soft rock recession processes by Trenhaile (2011) suggests that with continuation of the sea-level rise acceleration now being observed, cliff recession rates in cohesive clay soft rock shores may be 1.5 to 2 times greater over the next century than they were in the last 100 years. In order to allow for expected acceleration of shoreline retreat rates with sea-level rise, a conservative allowance of 2 x historical recession rates has been applied. This is the approach adopted by Sharples et al (2013) when assessing soft rock coastal erosion hazards across Tasmania.
	Hard Rock	Hard-rock shores are considered to respond to sea-level changes by initially establishing a new equilibrium profile relative to any new sea-level but will then show only very slow change thereafter if sea-level remains constant (Trenhaile, 2011). It may therefore be expected that hard rock cliffs will begin to exhibit acceleration in their rates of erosional recession as they adjust to the rising sea-level. However, the lack of measured data makes it problematic to attempt to estimate accelerated retreat rates. For the purposes of this analysis no additional allowance has been made specifically for the acceleration of erosion rates on hard rock cliffs due to sea level rise. A buffer to account for this potential uncertainty could be included in future.

4.3 Long Term Recession and Accretion

Long term recession and accretion trends have been assessed used the following approached, as discussed in Table 4-1:

- Profile analysis: for Sandy shorelines where profile data was available from the Coast Protection Board.
- Aerial imagery analysis: for other Sandy and Soft Rock shorelines where historic aerial imagery is available.
- Slope analysis: for Hard Rock shorelines to differentiate between moderate and steeply sloping coastlines.

4.3.1 Profile Analysis

Cross sections were provided by the South Australian Coastal Protection Board for the sandy beaches of Emu Bay, Brownlow, Island Beach, Penneshaw and Antechamber. The majority of these cross sections were first surveyed in 1985 and have been regular surveyed ever since. For the purpose of this analysis profiles have been presented at roughly a 5-year interval to estimate the rate of coastal recession or accretion over the last 32 years.

Emu Bay

Data is available for three profiles within the Emu Bay region, the locations shown in Figure 4-5. The northernmost profile (815003) is stable across the 32 years of survey (see Figure 4-6). This is because this section of coastline is comprised of predominantly of rock.

The other two profiles show a pattern of accretion over the 32-year period. Profile 815004 has accreted roughly 10m between 2m AHD and 3m AHD at a rate of 0.31 m/year, as shown within Figure 4-7. The foredune height has also increased by roughly 1m, along with the volume of sand on the beach itself.

The eastern profile (815016) has only been measured since 2007 and the measurements show only a slight change within the profile, with accretion of roughly 10m (1 m/year) between the 1m AHD and 1.5m AHD contours (see Figure 4-8). The beach berm located at 1m AHD has accreted by 20m at a rate of 2 m/year. The smaller time scale over which profile 815016 has been sampled however may mean that these changes reflect shorter term fluctuations due to seasonal or storm events. As noted in Table 4-1, where a shoreline is accreting, for the purposes of the coastal hazard assessment the long-term recession value is set to zero.

This is a conservative assumption given the uncertainty in future sediment transport rates with sea level rise and in line with the approach adopted in the following guidance document:

- SPP2.6 (Western Australia) states that *"Where the historic annual rate of shoreline movement is accretion less than 0.2 metres per year the allowance for historic shoreline movement trends should be zero. Where the historic annual rate of shoreline movement is continuous accretion in excess of 0.2 metres per year and there is compelling evidence that accretion is likely to continue at the same rate for at least the next 50 years the allowance for historic shoreline movement trends should be calculated as minus 50 times the historic longer-term annual rate of accretion."*

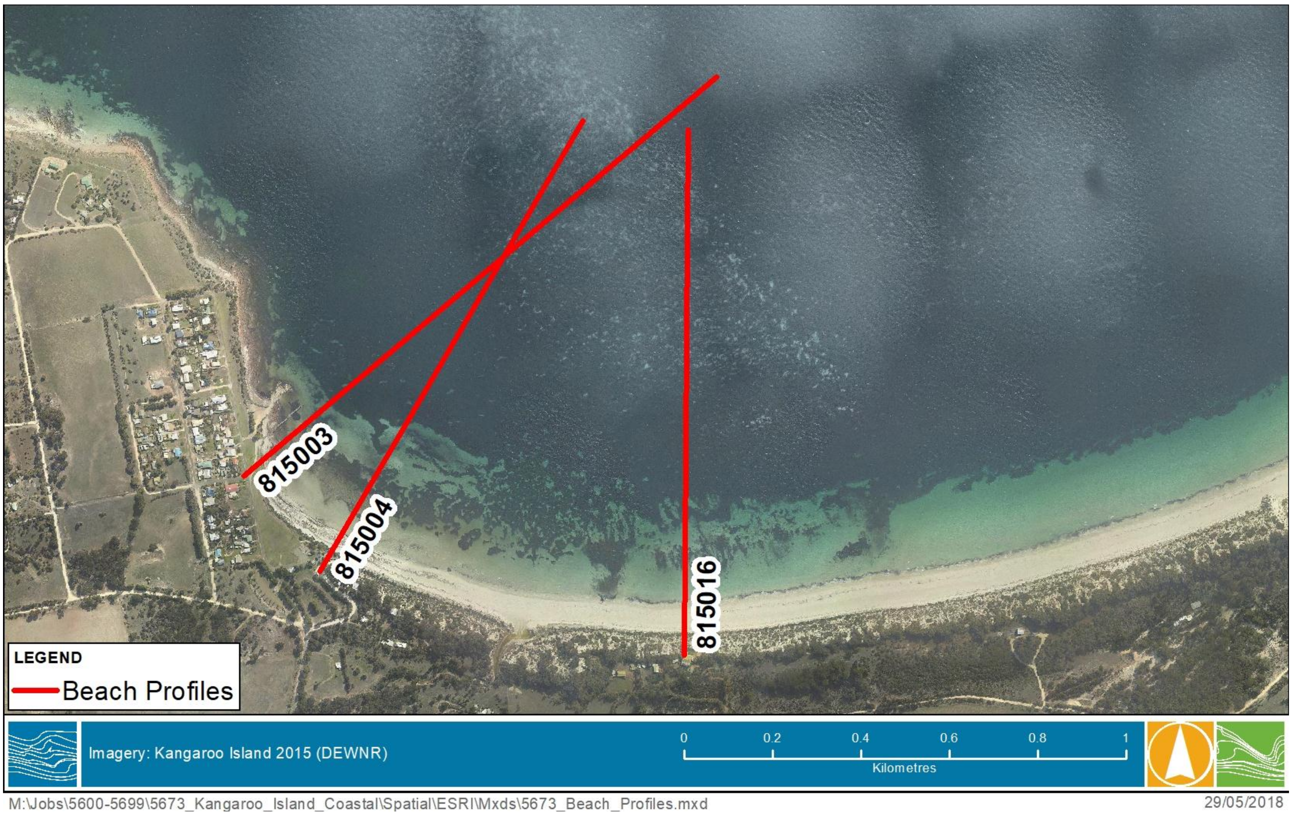

FIGURE 4-5 EMU BAY CROSS SHORE PROFILE LOCATIONS

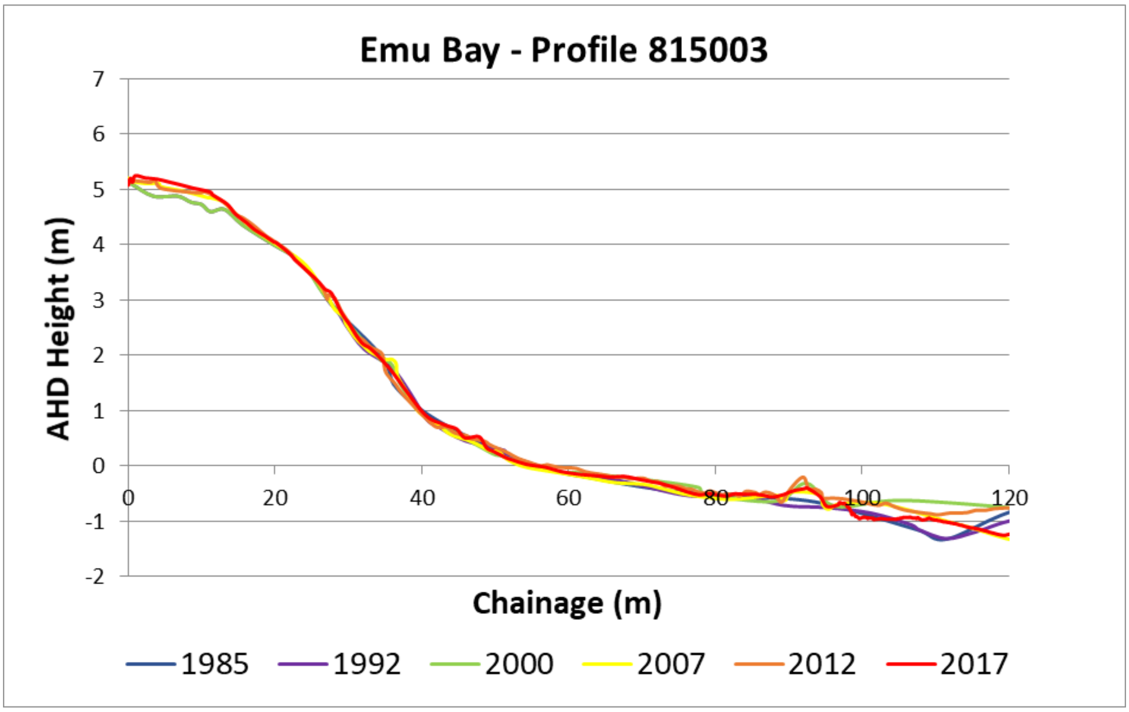

FIGURE 4-6 EMU BAY BEACH CROSS SECTION - 815003

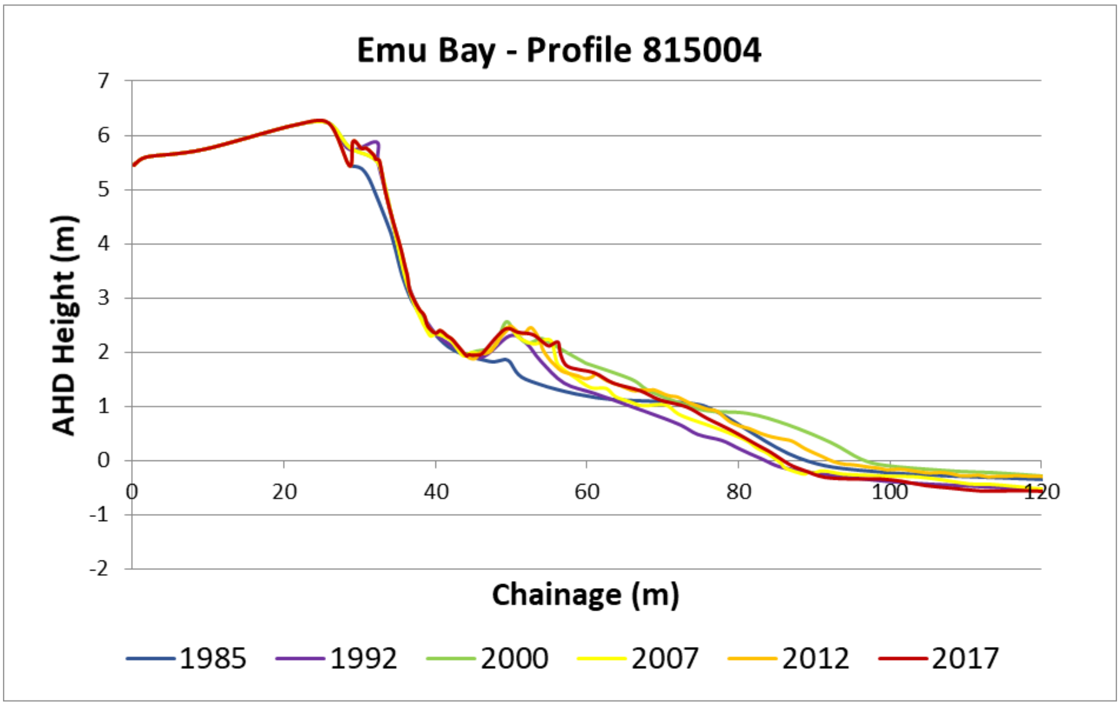

FIGURE 4-7 EMU BAY BEACH CROSS SECTION - 815004

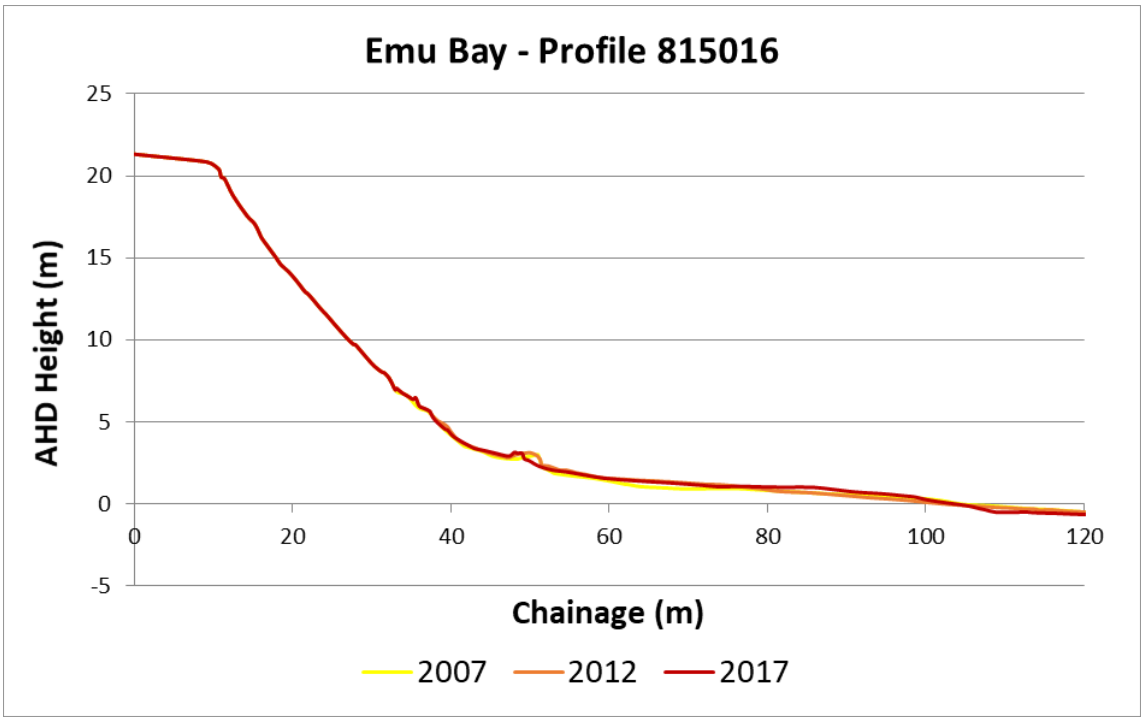

FIGURE 4-8 EMU BAY BEACH CROSS SECTION - 815016

Brownlow Beach

The two profiles at Brownlow Beach, as shown in Figure 4-9 exhibit two very different long-term trends. There is accretion at the northern profile (815001) and recession at the southern profile (815002). Due to the inland extent of profile 815001, it has been plotted from The Parade (approximately chainage 200) to the offshore extent.

Between the 0m AHD and 2m AHD contours profile 851001 has remained relatively stable over the last 32 years (Figure 4-10). Between chainages 250 and 290 however there has been significant increase in the height of the levee/foredune by between 0.75 to 1m. This change occurred in between the 1992 and 2000 measurements.

The southern profile (851002) is shown in Figure 4-11. At this location there has been a horizontal recession of the levee/foredune by 4.2m over the past 32 years, which is a rate of 0.13 m/year. The measurements also show a reduction in foredune crest height of around 0.75m across the same period.

The earlier analysis by Short and Fotheringham (1986) suggested that longshore transport from eroding bluffs such as Rolls Point and east of Red Point, was the dominant sand source in this area rather than onshore sediment supplies.

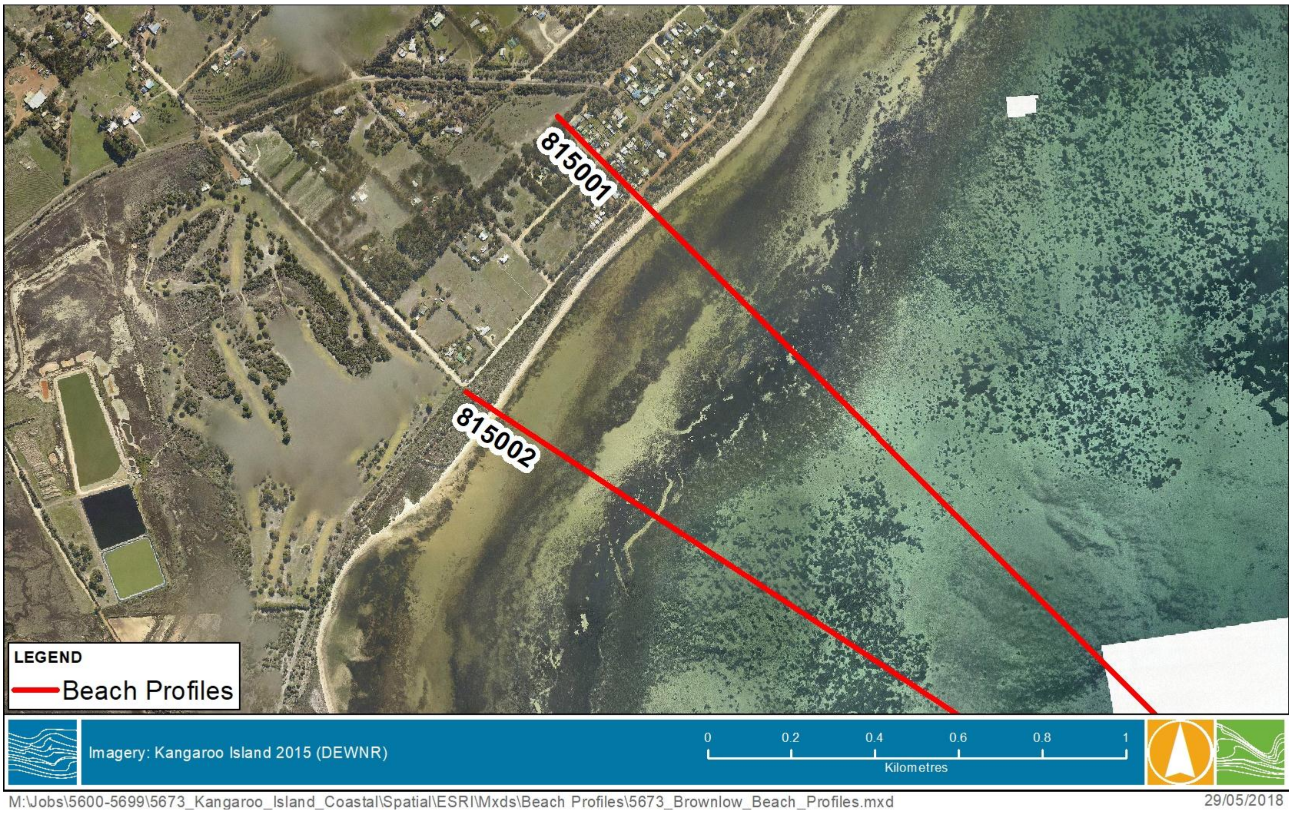

FIGURE 4-9 BROWNLOW BEACH CROSS SHORE PROFILE LOCATIONS

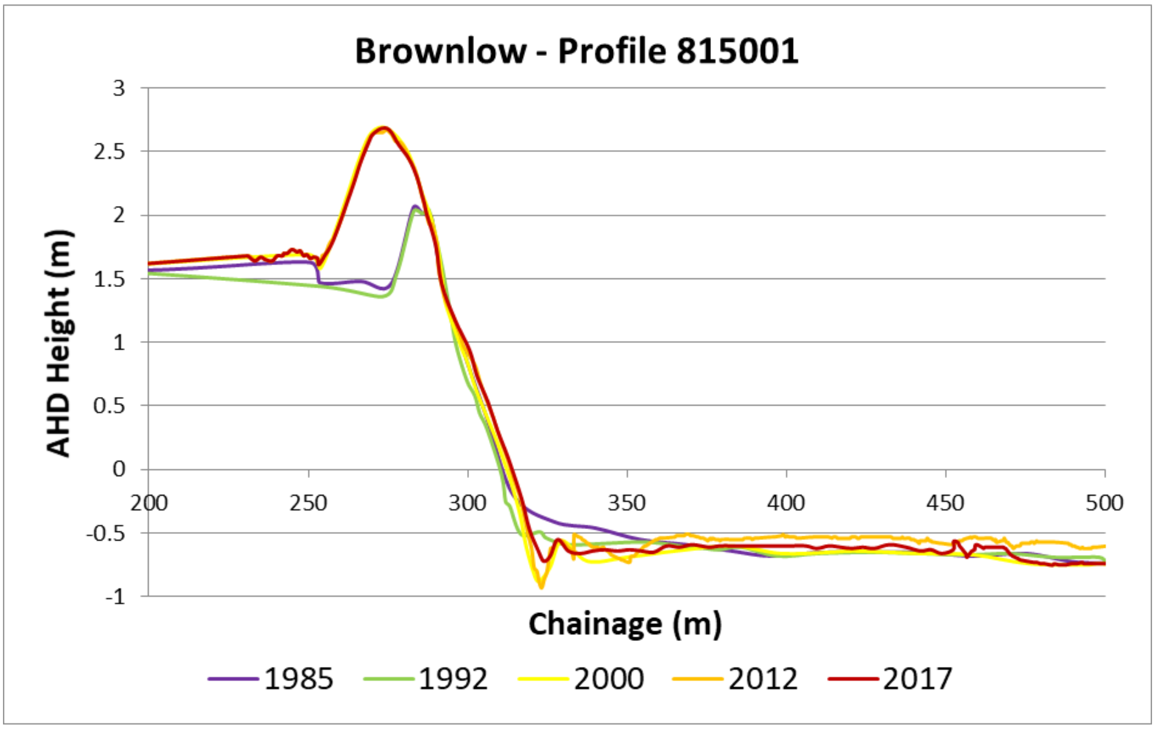

FIGURE 4-10 BROWNLOW BEACH CROSS SECTION - 815001

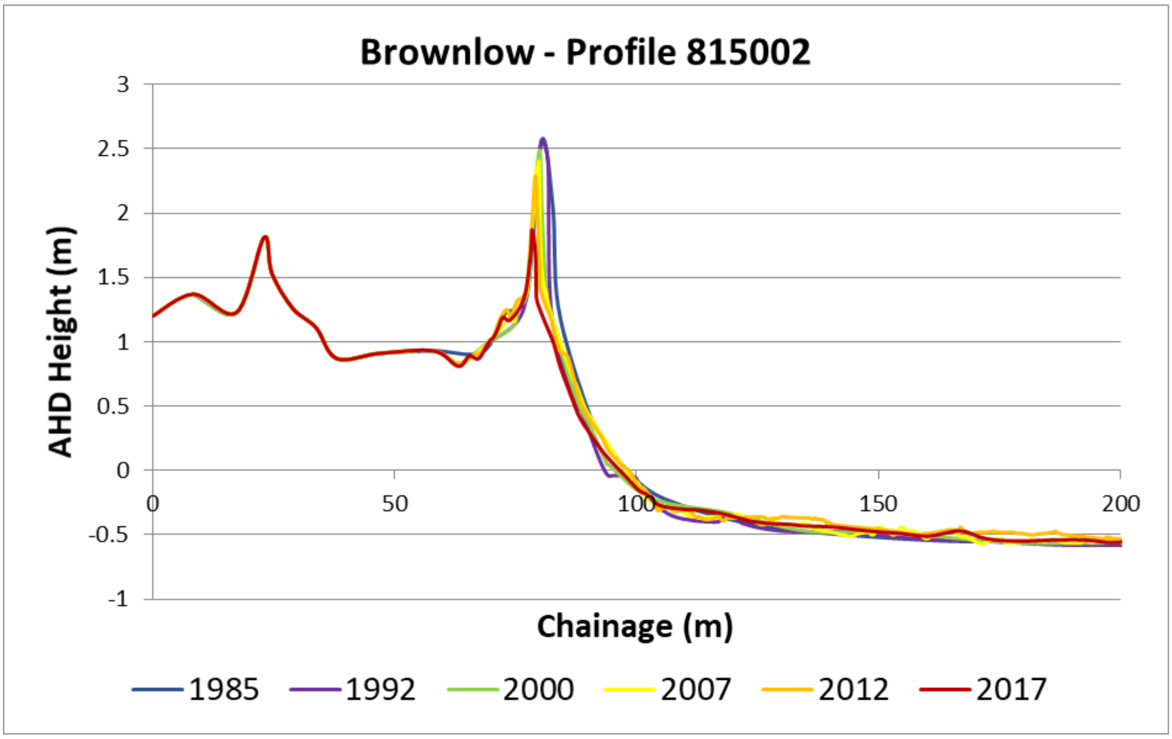

FIGURE 4-11 BROWNLOW BEACH CROSS SECTION - 815001

Island Beach

The profiles at Island Beach show a consistent trend of accretion across the three locations (81004, 81005 and 81006), shown in Figure 4-12. All profiles show accretion trends both horizontally and vertically at both the mean sea level (0m AHD) and at around the 2.5m AHD contour, which represents the foredune crest.

The western profile (810004) shows accretion at a rate of 0.63 m/year at the 1m AHD contour, which reflects the location of the beach berm (see Figure 4-13). The foredune crest has increased in height by roughly 0.2m and has also accreted seaward by 5m at a rate of 0.17 m/year. The beach profile volume has increased with the majority of the profile increasing in height by around 0.75m between chainages 100 and 125.

The middle profile (810005) has seen an increase in foredune crest height of 0.5m and accretion at the base of the foredune of roughly 10m at a rate of 0.31 m/year (see Figure 4-14).

The eastern profile (81006) shows accretion on average of around 7m across the profile over the past 32 years at a rate of 0.22 m/year (see Figure 4-15).

As noted at Emu Bay, where a shoreline is accreting, for the purposes of the coastal hazard assessment the long-term recession value has been set to zero.

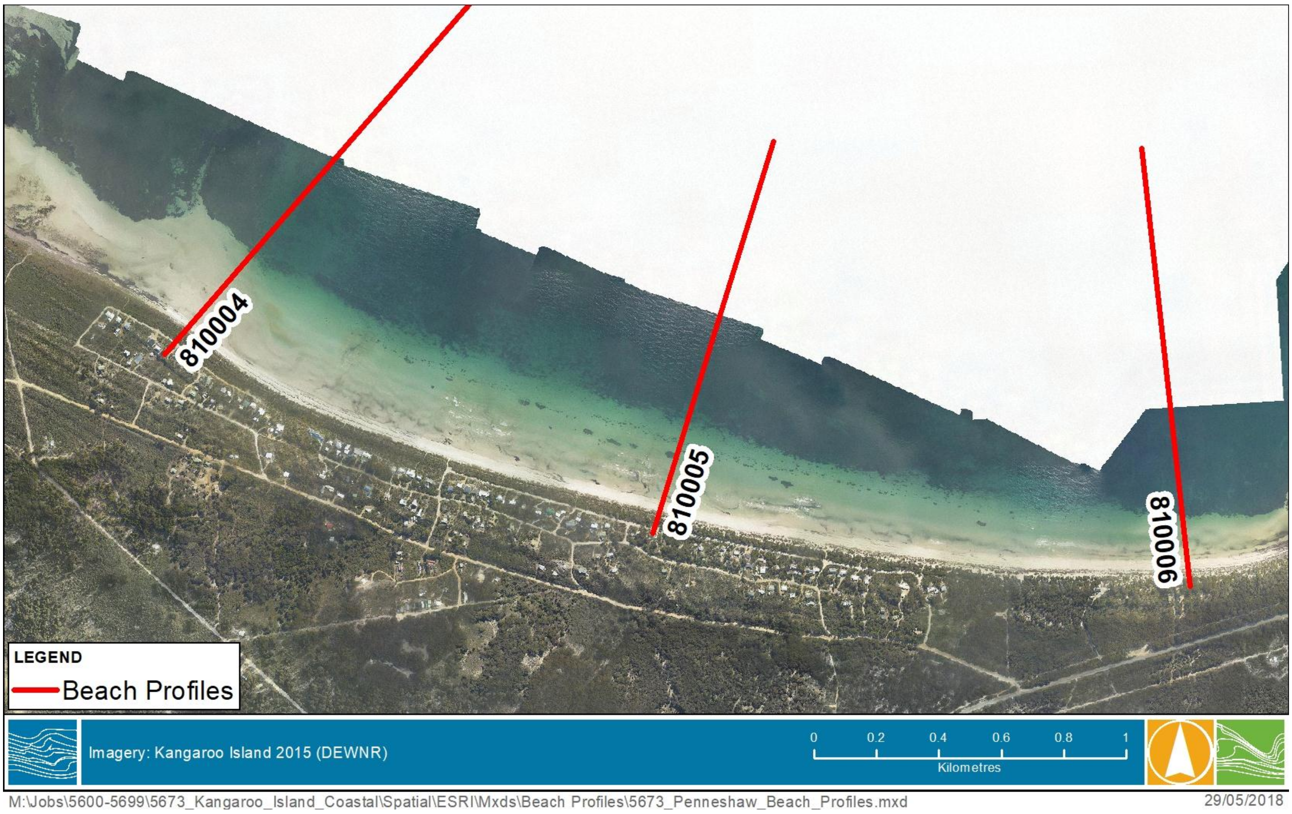

FIGURE 4-12 ISLAND BEACH CROSS SHORE PROFILES

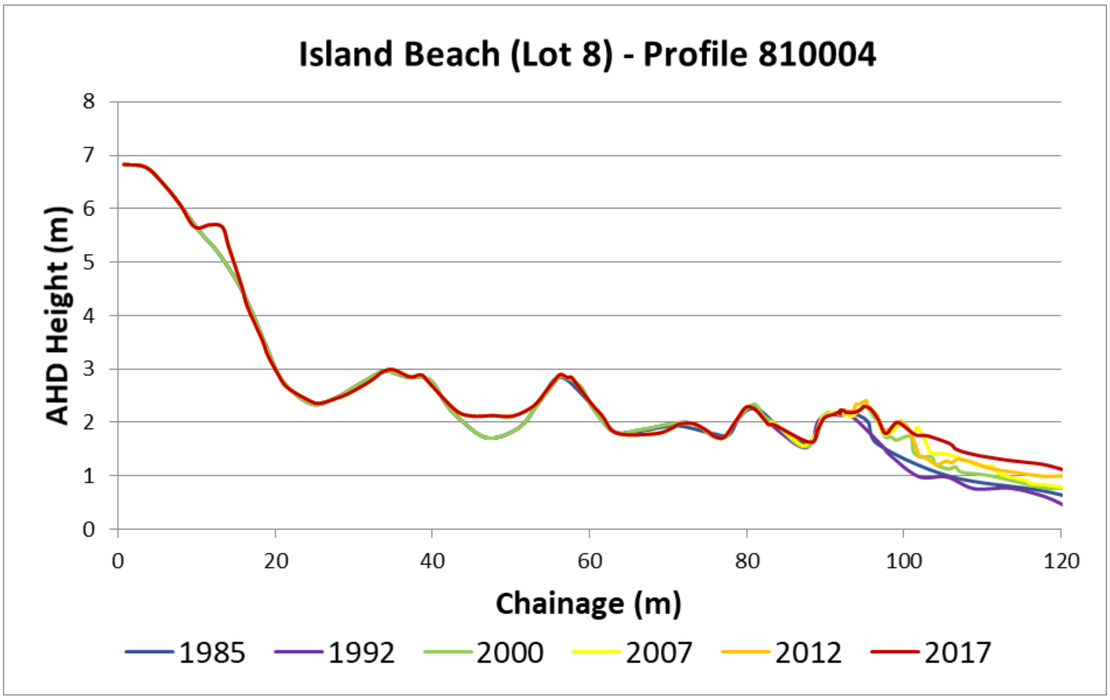

FIGURE 4-13 ISLAND BEACH CROSS SECTION - 810004

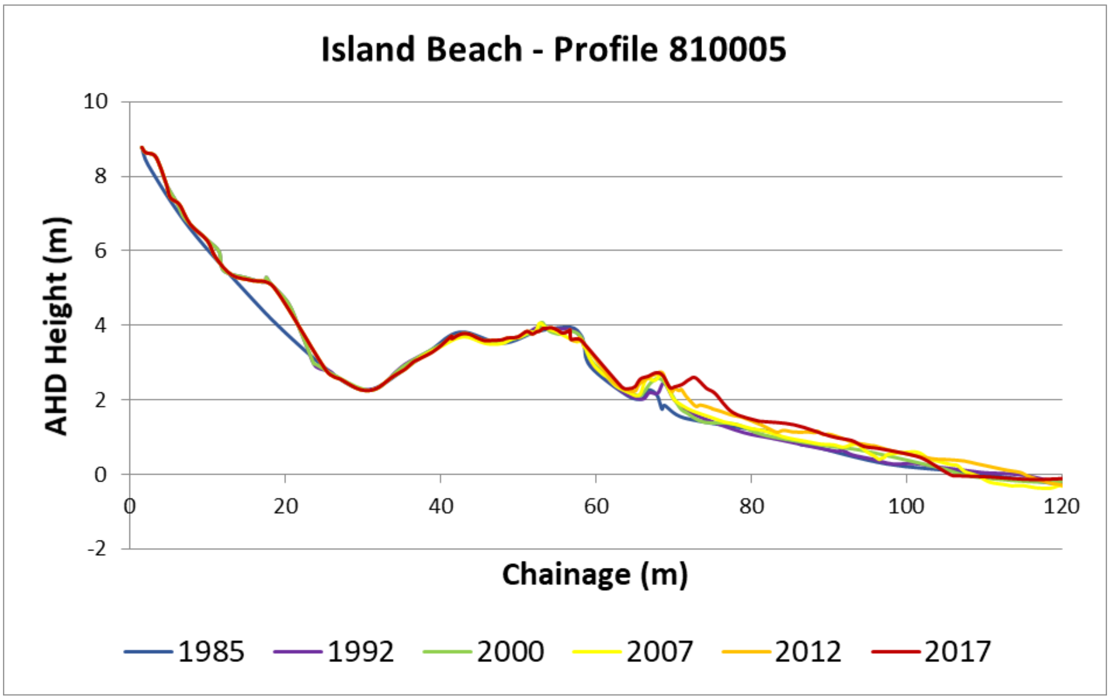

FIGURE 4-14 ISLAND BEACH CROSS SECTION - 810005

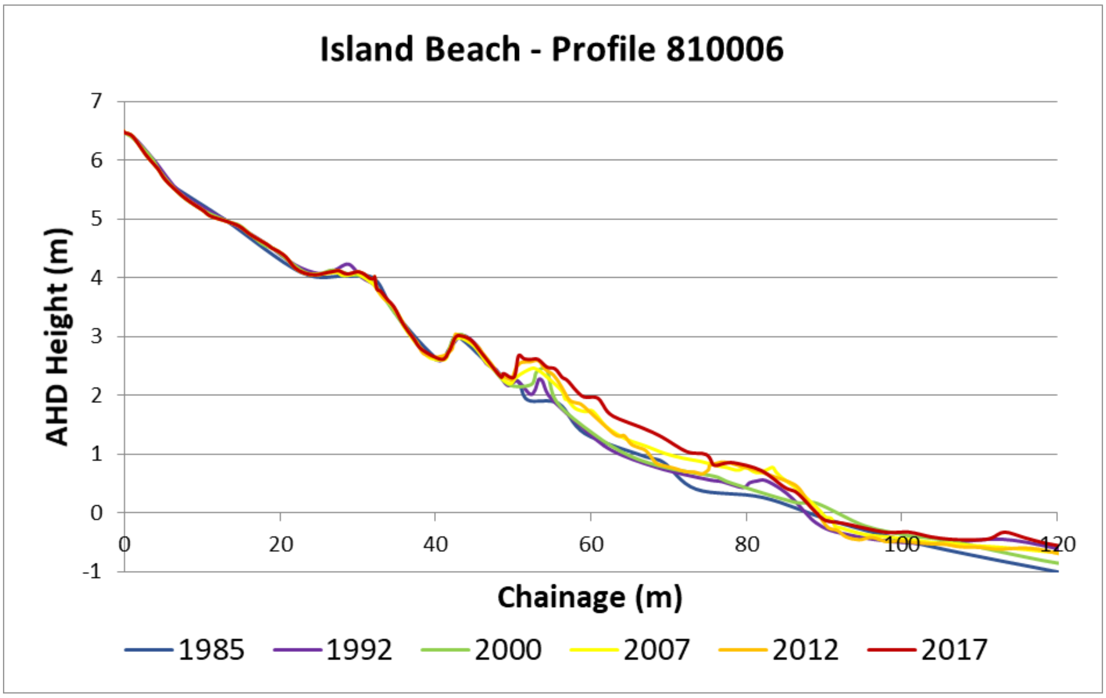

FIGURE 4-15 ISLAND BEACH CROSS SECTION - 810006

Penneshaw

Three beach profiles measurements are available for Penneshaw, the location of which is shown in Figure 4-16. In general, Profiles 810001 and 810002 show a trend of accretion over the survey period while the southern profile (81003) shows recession occurring.

Profile 810001 shows significant accretion (see Figure 4-17) with the development of a new dune formation between chainages 60 and 140 which is in the order of 2-3m high. The maximum accretion rate observed for this profile is 1.8 m/year which occurs at the 1m AHD contour and is in the order of a 50m seaward.

Profile 810002 is shown in Figure 4-18. The accretion is not occurring at the same rate as for 81001. This location has an average accretion rate across the profile of 0.5 m/year between the contours of 0m AHD and 2m AHD.

Profile 810003 located within the south eastern corner of the bay has receded between the 1m AHD and 3m AHD contours at a maximum rate of around 0.5 m/year (see Figure 4-19).

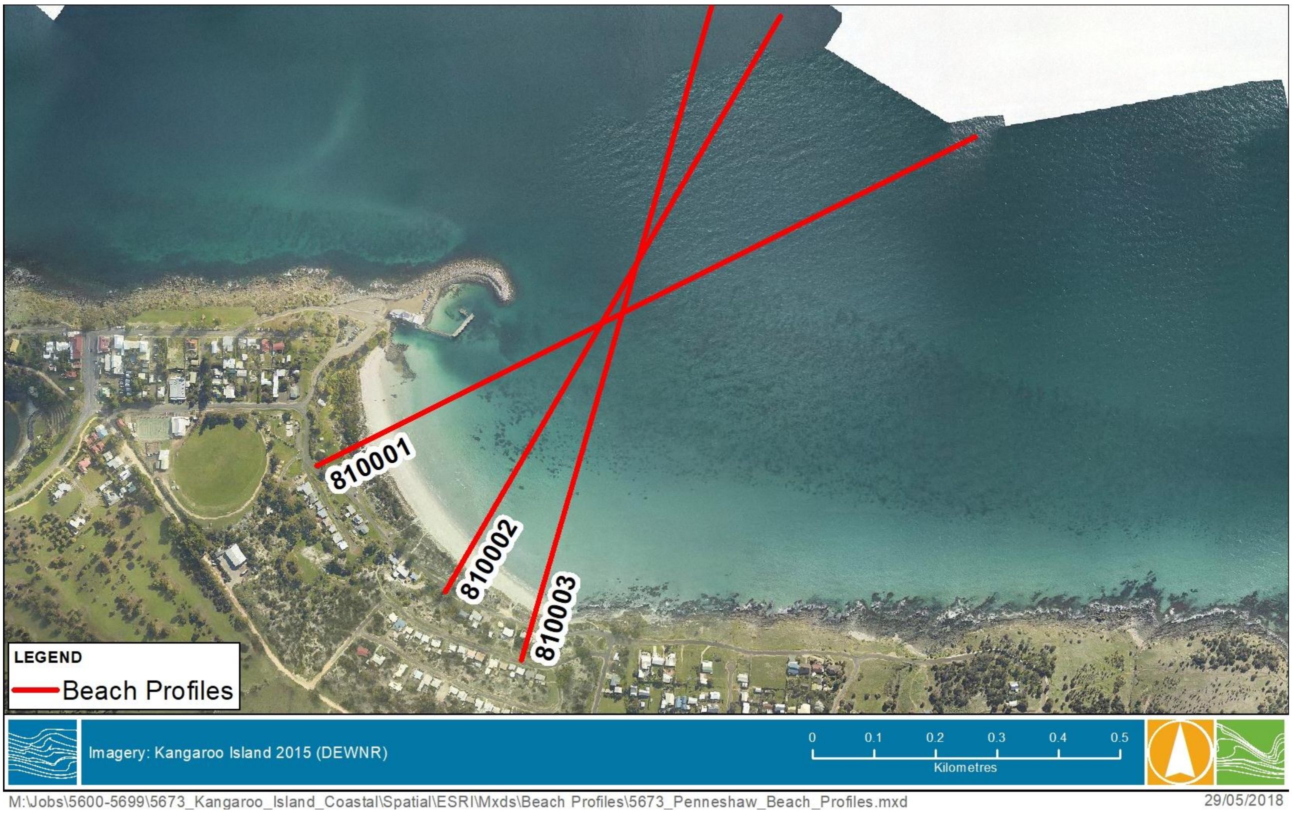

FIGURE 4-16 PENNESHAW CROSS SHORE PROFILES

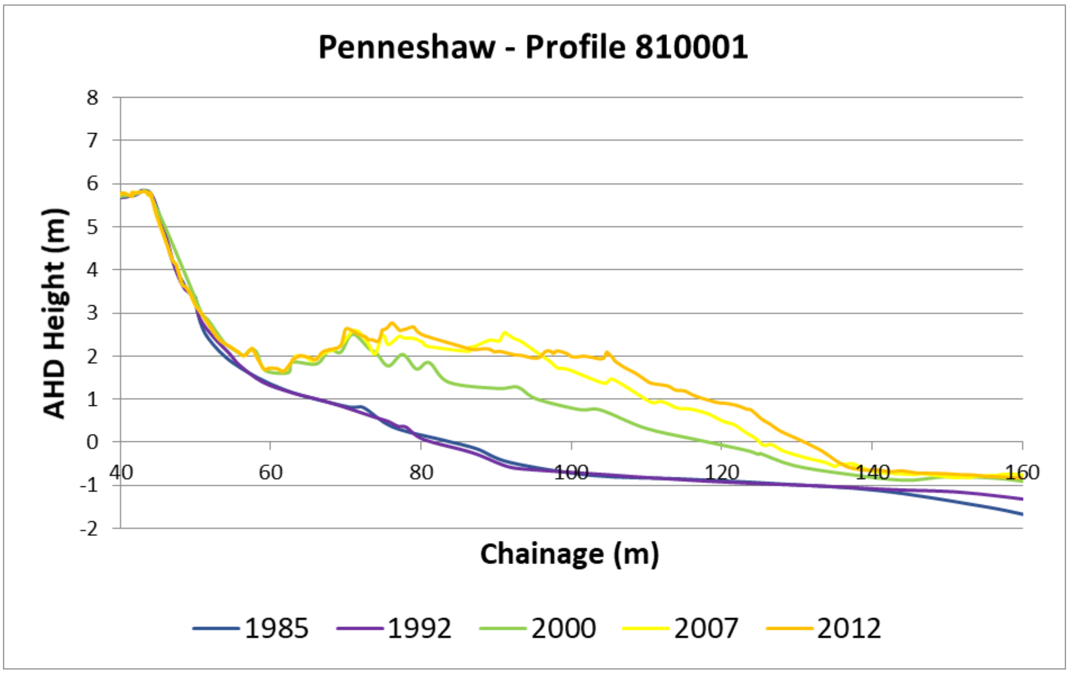

FIGURE 4-17 PENNESHAW BEACH CROSS SECTION - 810001

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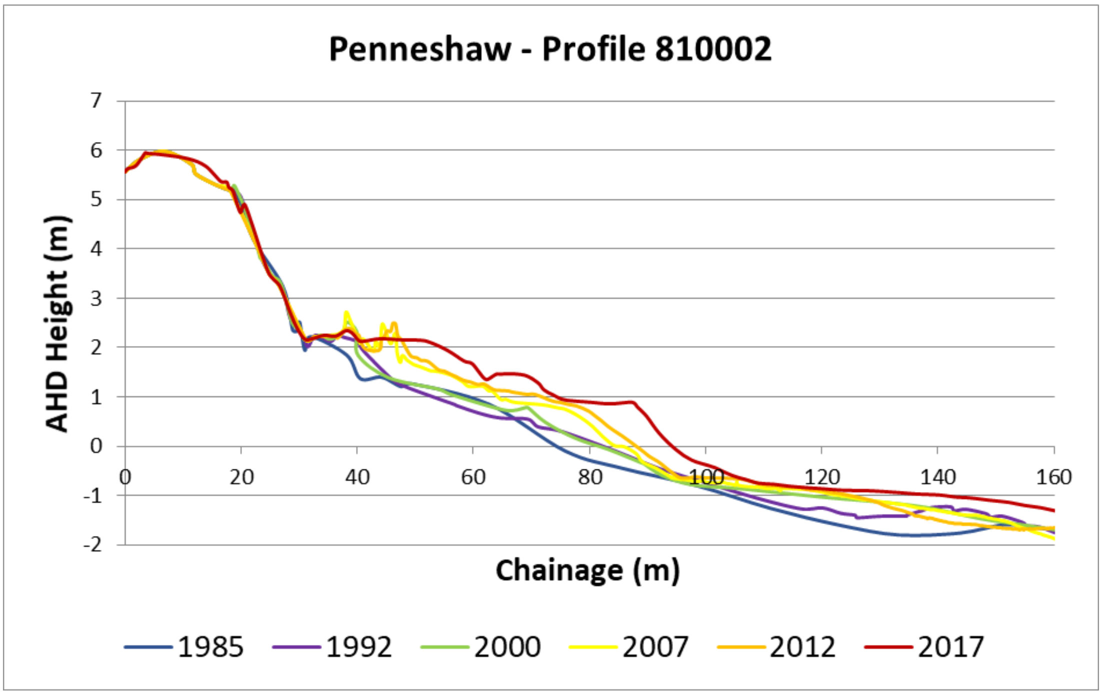

FIGURE 4-18 PENNESHAW BEACH CROSS SECTION - 810002

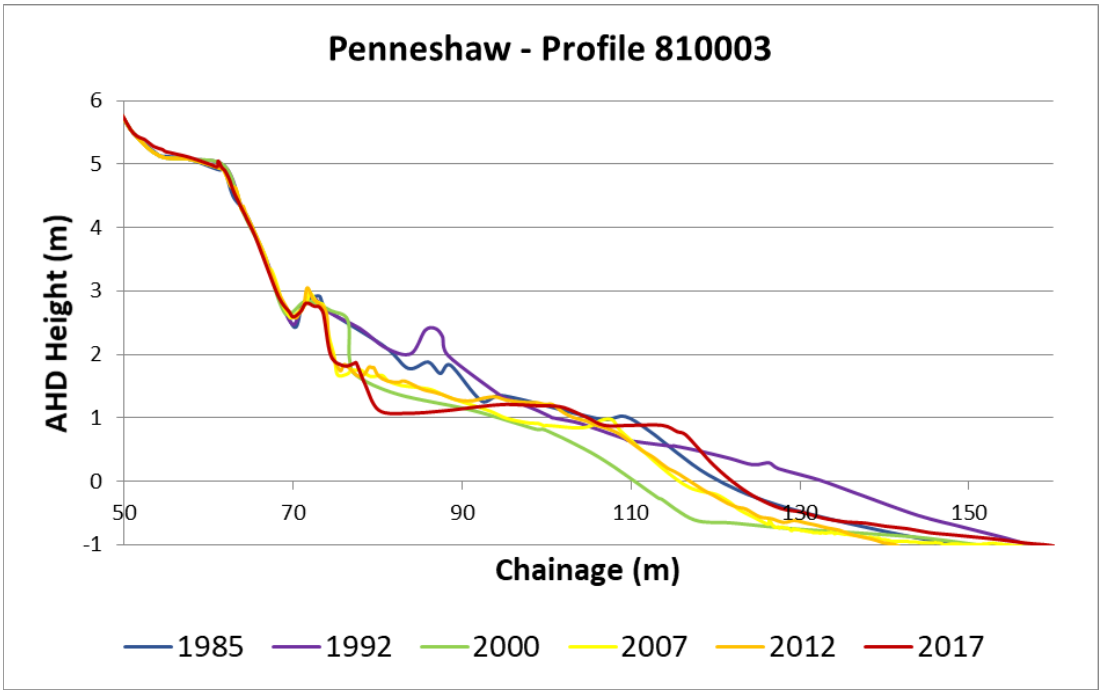

FIGURE 4-19 PENNESHAW BEACH CROSS SECTION - 810003

Antechamber Bay

The measurements available for Antechamber Bay beach profiles 810007 and 81008 (see Figure 4-20) only cover a period of five years from 2007 through to 2012. As such any trends identified may not accurately represent the long-term trends within the area.

The northern most profile (81007) is located near the mouth of the Chapman River and is potentially impacted by movement in the location of the mouth of the river as a result of riverine flows. The measured profiles are shown Figure 4-21 and show minor recession of around 10m at roughly the 2.5m AHD contour, equating to a recession rate of 2m a year. The sand removed from the upper profile appears to have been redistributed over the lower beach section which shows accretion of up to 5m up to the 1m AHD contour. This profile is not considered representative of the whole beach system due to the influence of the river mouth.

The southern profile presented in Figure 4-22 (81008) has a large foredune with a crest height of roughly 15m AHD. At the foot of the foredune there has been accretion of roughly 10m which has been supplied by retreat of around 1m within the foredune face between the 3m AHD and 7m AHD contour.

FIGURE 4-20 ANTECHAMBER BAY CROSS SHORE PROFILES

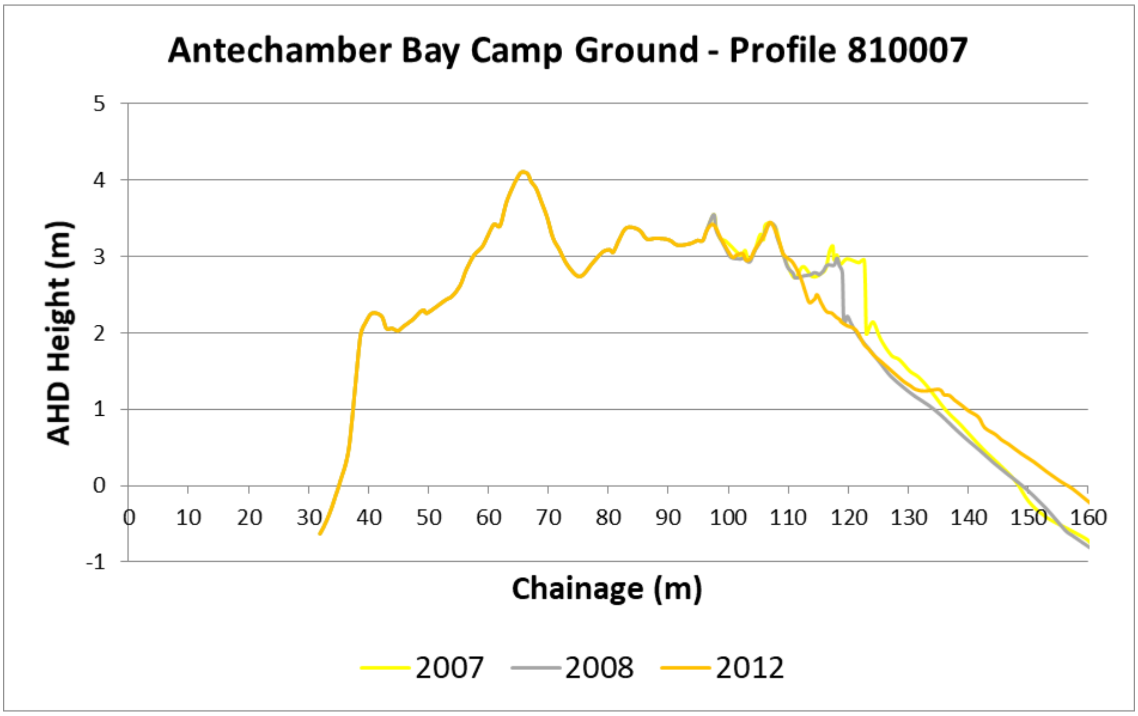

FIGURE 4-21 ANTECHAMBER BAY CROSS SECTION - 810007

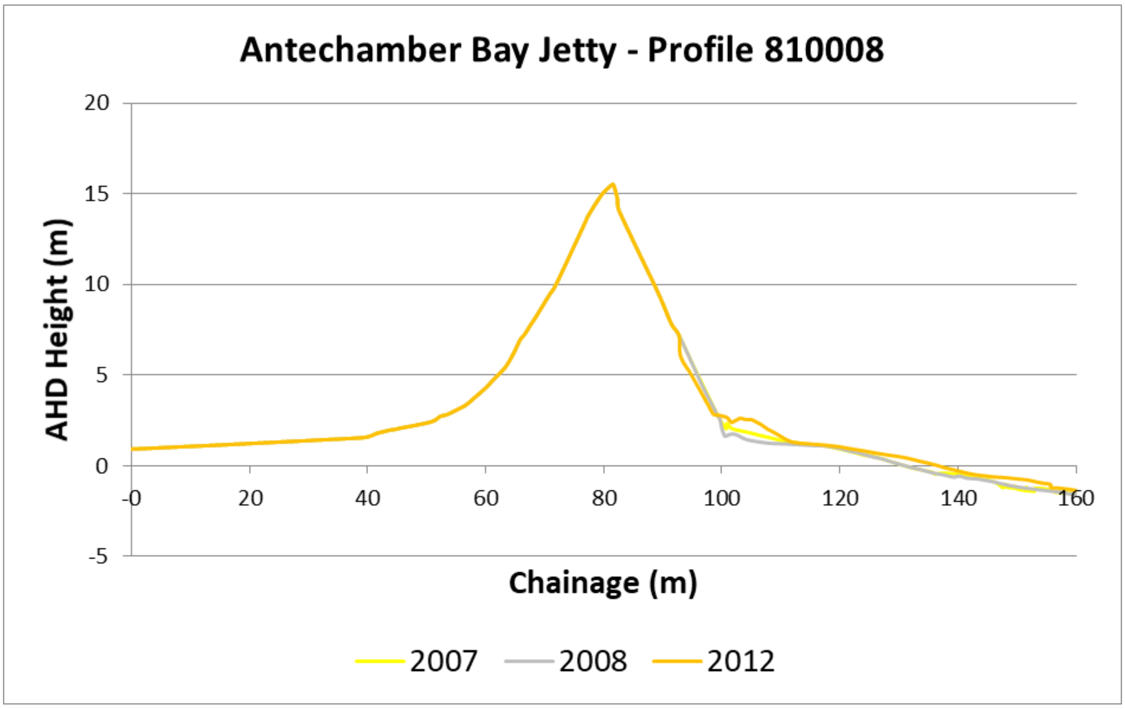

FIGURE 4-22 ANTECHAMBER BAY CROSS SECTION – 810008

4.3.2 Historic Aerial Imagery Analysis

To estimate an allowance for historical shoreline movement trends, available historic aerial imagery has been compared to the most recent aerial imagery captured 2015, by tracing the vegetation lines at the rear of the beaches, or cliff edge for rock shorelines.

Historic imagery was sourced from 1999, 1989, 1992, and 2001. A wider range of historic images is available for the study area however due to the cost of the data only 8 images were able to be selected to the analysis. The selection of the images therefore focussed on providing good spatial and temporal coverage over all the coastline.

An example of the imagery comparison at Baudin Beach is presented in Figure 4-23.

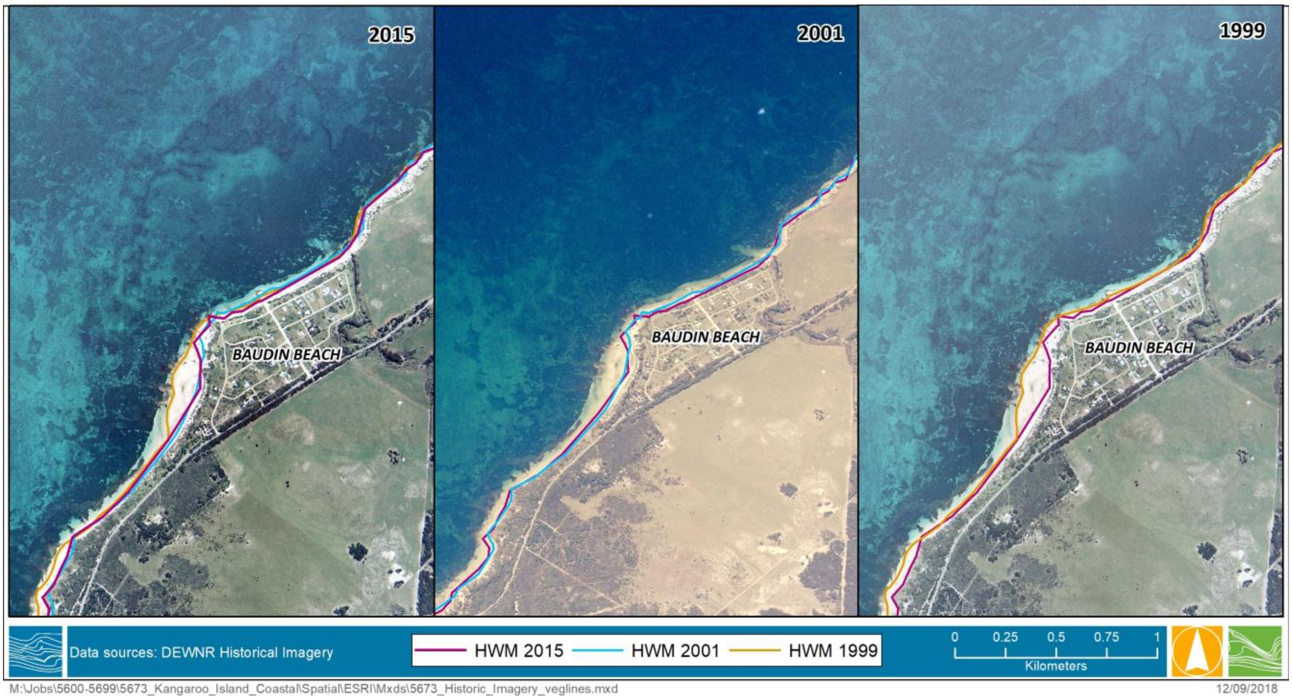

FIGURE 4-23 HISTORIC IMAGERY COMPARISON – BAUDIN BEACH

4.3.3 Slope Analysis

The SMARTLINE dataset does provide some information on the slope of the rock coastline areas. However, the resolution of the data was insufficient for use in this study. Instead, a slope analysis was undertaken on the available LiDAR imagery using the ArcGIS spatial analyst toolbox.

For the purposes of this first pass assessment, gentle to moderately sloping hard rock shorelines where defined as those shorelines where the slope was less than 45 degrees. The slope angle was determined from the LiDAR dataset. This assumption could be further refined based on a steep slope criterion of 15 to 30 degrees.

Where the slope angle was 45 degrees or greater, the hard rock erosion hazard zones were then estimated by mapping a potential slump hazard zone extending the same distance horizontally landwards of the cliff top as the height of the cliff above its base.

This creates a hazard zone landwards of the cliff by assuming a maximum slumping and instability angle of 45° rising landwards from the base of the cliff. An example of the analysis approach as applied to the shoreline at Kingscote is presented in Figure 4-24.

FIGURE 4-24 SLOPE ANALYSIS FOR KINGSCOTE

4.4 Short Term Erosion Hazards

The large waves, elevated water levels and strong winds generated by a storm can cause severe erosion on sandy foreshores. Wave characteristics and the storm surge can generally be estimated for a storm of any given intensity and size, however the storm tide level depends upon when the peak surge occurs in relation to the astronomical tide. A large surge with severe waves occurring at low tide might result in less erosion than a mild surge and moderate wave conditions occurring at high tide.

For the present study, no detailed wave or storm tide modelling has been undertaken. The storm tide levels provided by the Coast Protection Board for the 100 year ARI event has been adopted for the water level, while the 100 year ARI wave conditions as defined by Mariani (2012) for has been adopted for the wave conditions. This assumes a severe storm tide occurring is assumed to occur in association with a severe wave event.

As noted in Table 4-1, the numerical model SBEACH has been applied to model the cross-shore beach, berm, and dune erosion produced by the storm waves and elevated ocean water levels.

Results are presented for current and future sea level rise conditions. It should be noted that the future sea level storm erosion estimates are indicative only as they do not explicitly consider the landward and upward migration of the dune areas which is expected to occur as a result of sea level rise. For the purposes of estimating the storm erosion component of the overall erosion hazard extent, S2, the storm erosion magnitude under current sea level conditions is applied to both current and future scenarios. This is consistent with the approaches adopted for other coastal hazard studies.

4.4.1 Storm Induced Erosion Analysis

The cross-shore profiles for the storm induced erosion assessment were those provide by the Coast Protection Board, as described in Section 4.3.1 for Emu Bay, Brownlow, Island Beach, and Hog Bay. These profiles were used as they extend sufficient distance offshore to capture the nearshore and offshore bed slope. On the landward side, the profiles were extended where necessary using data extracted from the LiDAR Digital Elevation Model (DEM).

The resultant storm erosion profiles for each location are presented in the following figures, along with site specific comments.

- Emu Bay – under existing conditions erosion or scarping of the foredune during a storm tide event is likely to occur. Under the future conditions at 2100, additional scarping of the higher dune ridge towards the rear of the beach is predicted to occur. Overall, the magnitude of erosion under the 1% AEP storm tide and wave conditions is expected to be in the order of 10 to 15m.

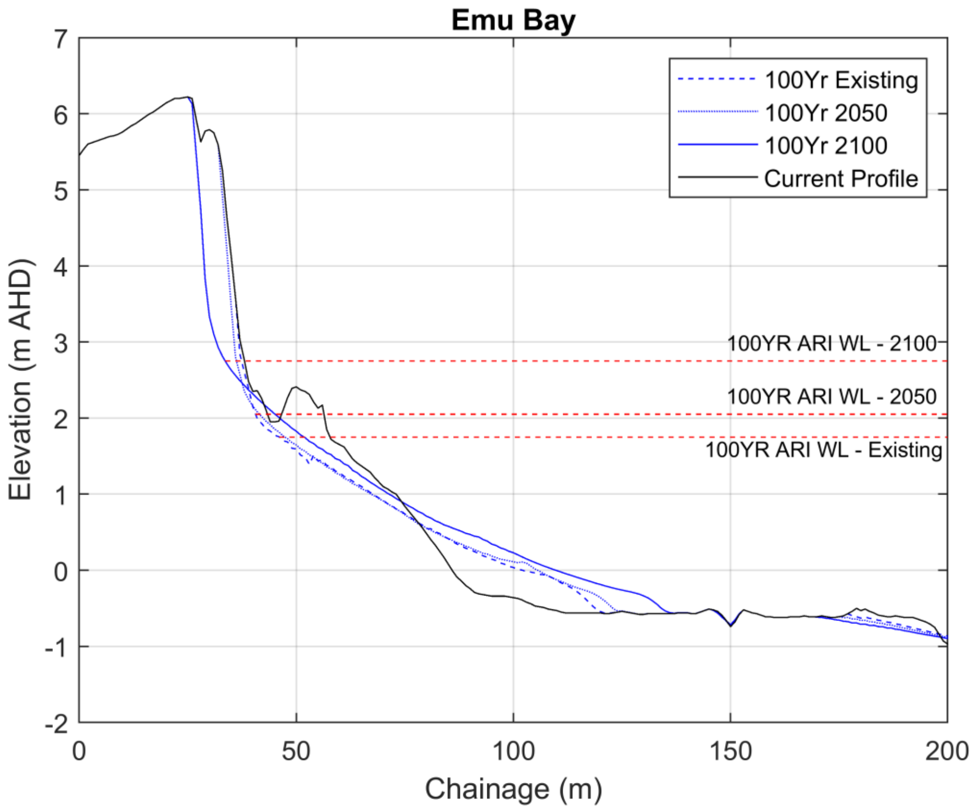

FIGURE 4-25 STORM INDUCED EROSION – EMU BAY

- Brownlow – this location is highly susceptible to storm induced erosion. The modelling results are indicative only, as the model predicts overtopping and inundation under existing and future conditions which could potentially result in the completed erosion of the small levee which runs along the foreshore. Once the levee is removed the erosion progress rapidly into the backshore area. The erosion model has limitations under these conditions as indicated by the variability in the profile results.

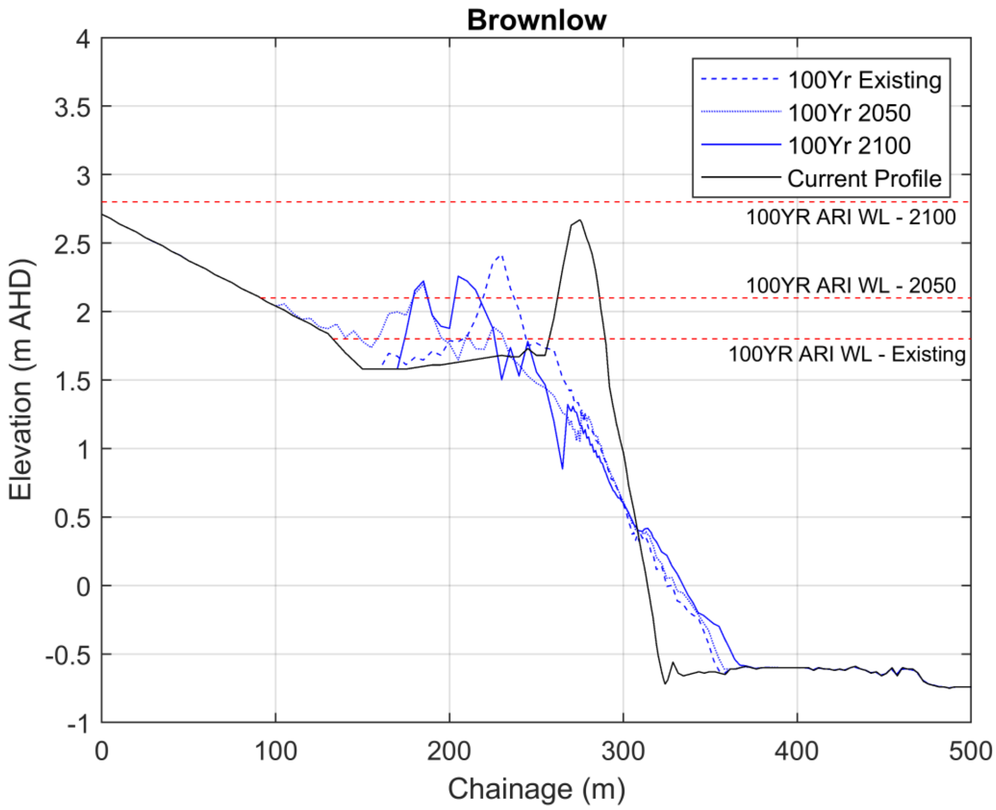

FIGURE 4-26 STORM INDUCED EROSION – BROWNLOW

- Island Beach – two profiles were analysed at Island Beach, the northern profile (810004, Figure 4-12) and the middle profile (810005). The results in each location shown that storm erosion is limited to the frontal dune areas until the 2100 scenario where the impacts are increased due to the high-water level relative to the dune height.

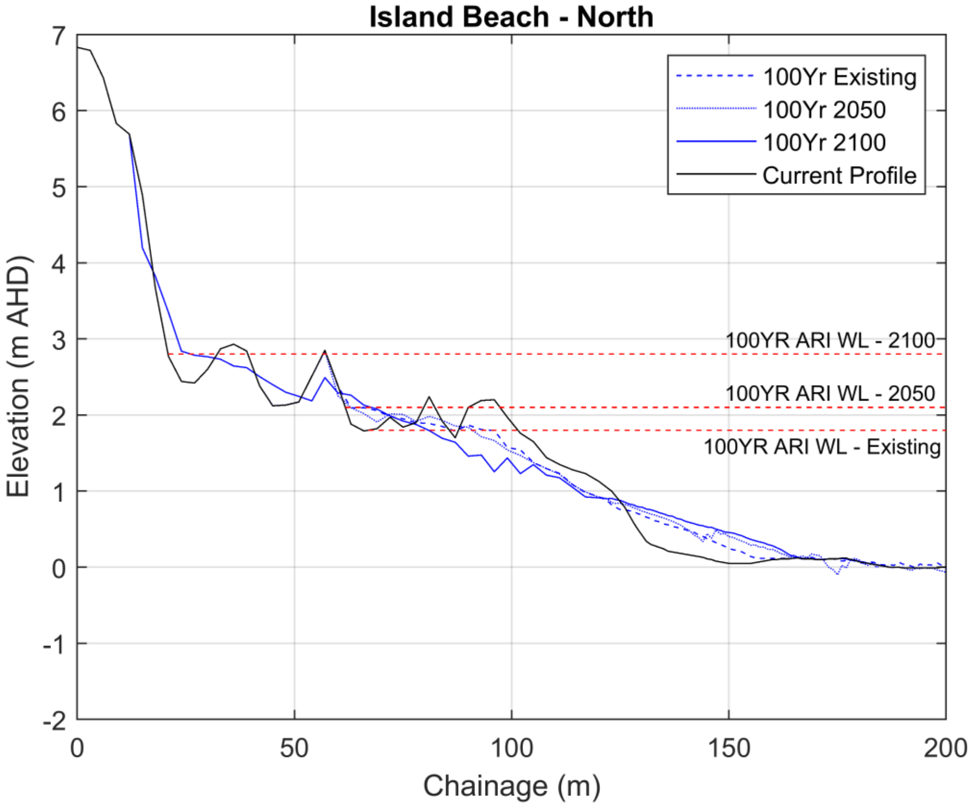

FIGURE 4-27 STORM INDUCED EROSION – ISLAND BEACH NORTHERN PROFILE

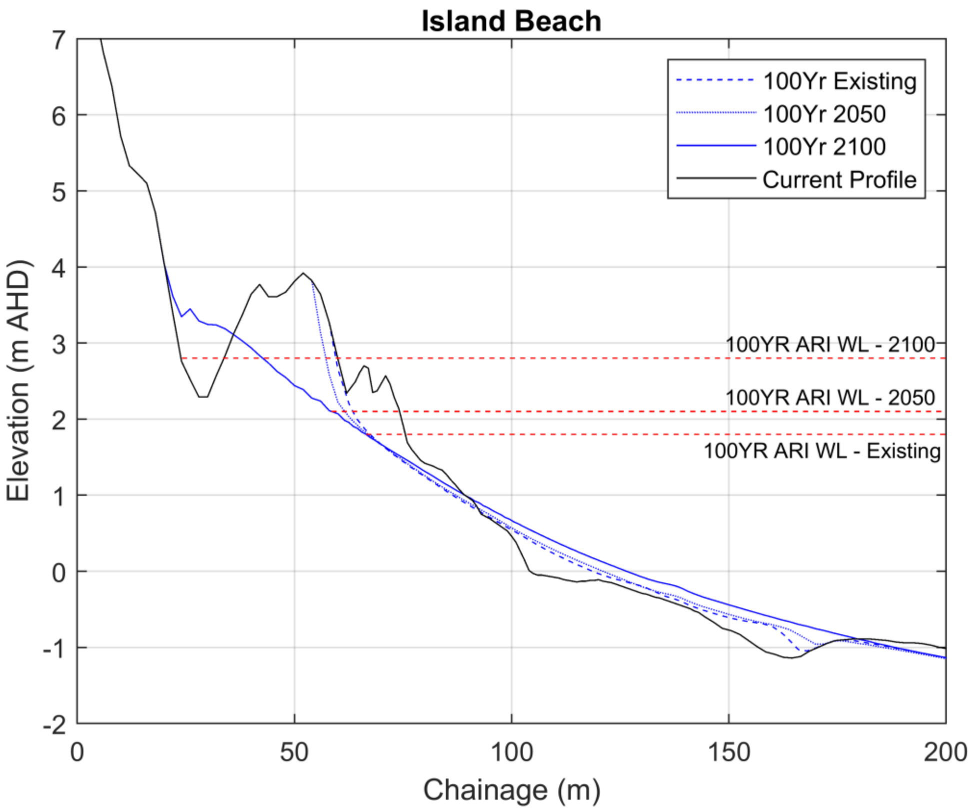

FIGURE 4-28 STORM INDUCED EROSION – ISLAND BEACH MIDDLE PROFILE

- Penneshaw (Hog Bay) – The modelled storm erosion results at Hog Bay show erosion of the beach profile which is limited in all cases by the backshore bluff at around 6m AHD. The backshore bluff also limits the shoreward migration of the dune areas as a result of sea level rise.

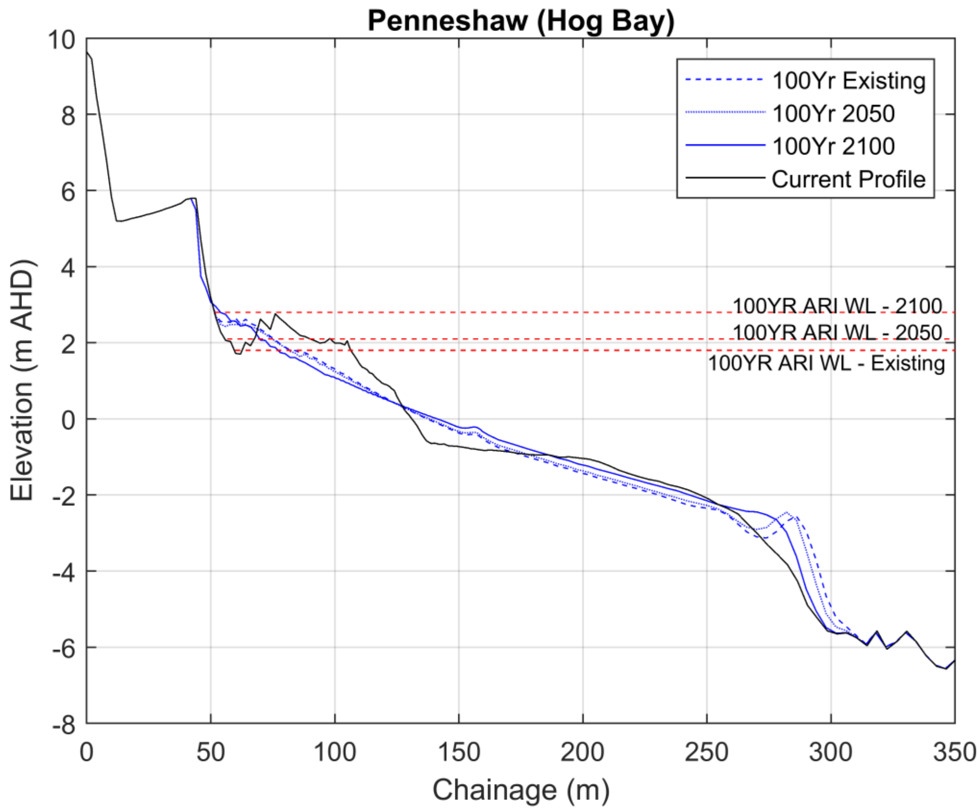

FIGURE 4-29 STORM INDUCED EROSION – ISLAND BEACH MIDDLE PROFILE

4.5 Shoreline Response to Sea Level Rise

4.5.1 Bruun Factor

Traditionally the Bruun Rule (Bruun 1962) has been used to estimate sandy coastlines response to sea level rise. However, as no wave statistics are available for the study area, a Brunn factor was applied to provide a first pass assessment for erosion due to sea level rise. On open coasts, the Brunn factor is typically in the range of 50 to 100 (Mariani et al, 2012). This means that the coastal recession will be 50 to 100 times the magnitude of sea level rise. This provides a conservative approach to identifying areas potentially at risk. Both Brunn Factor values have been included in the mapped erosion extents provided in the on-line mapping. Example maps are also provided in Appendix B.

TABLE 4-2 ESTIMATED SHORELINE RECESSION RATES IN RESPONSE TO SEA LEVEL RISE

SLR Scenario	Bruun Factor = 50	Bruun Factor = 100
2050 (0.3m)	15	30
2100 (1.0m)	50	100

4.5.2 Mean High Water Springs Change

Wide, low gradient sand and silty tidal flat occur in areas with reduced wave exposure. On Kangaroo Island these are restricted to the protected sandy shores in the Bay of Shoals, Western Cove sandflats and samphire flats, and the Eastern Cove's Pelican Lagoon.

As mentioned in Section 4.1.2, these shorelines will become increasingly exposed with sea level rise. A representative indicator of the location of future shorelines in these locations is the Mean High-Water Springs (MHWS) tidal plane. This is the level to which the existing fringing vegetation is likely to migrate to.

The erosion prone extent for these areas has therefore been mapped using the Mean High-Water Springs values presented in Table 3-2. This defines the upper limit of the intertidal zone. The intertidal zone includes areas regularly but not permanently inundated and washed by waves; i.e., areas extending from Mean Low Water Mark to the upper limit of wave-wash sufficiently frequent as to prevent establishment of terrestrial vegetation (due to wave run-up and storm activity, this limit generally lies a little above the astronomical high tide line or MHWM) (Sharples, et al, 2009).

4.5.3 Accelerated Erosion Rates

As noted in Table 4-1, soft rock shores tend to progressively erode and recede landwards at slow to moderate but fairly continuous rates under stable sea-levels. However, soft rock shoreline retreat rates are expected to increase with a rising sea-level, primarily because of reduced wave attenuation as water deepens over the near shore profile, allowing stronger wave attack (Trenhaile, 2011).

In order to allow for expected acceleration of shoreline retreat rates with sea-level rise, a conservative allowance of 2 x historical recession rates has been applied.

Both the future recession extents with and without accelerated erosion rates have been included in the online mapping.

4.6 Erosion Hazard Mapping

The potential coastal erosion hazard extents for different shoreline morphologies has been mapped across the study area. Hazard extents have been mapped where information was available and include the combination of long-term erosion, short term storm erosion and long-term recession due to sea level rise where applicable (S1 + S2 + S3). The exception to this is the case of gentle to moderately sloping rock shorelines where the rate of erosion is negligible and hence no mapping was required. An example of the resultant hazard extent mapping is provided in Figure 4-30 and Figure 4-31.

The total coastal erosion extent presented in the mapping is the total of the long-term recession, short term erosion and shoreline response to sea level rise or combination of these factors where applicable. The sandy, soft rock, hard rock and flats areas have been mapped based on their general locations as indicated by the SMARTLINE mapping, with amendments in specific areas to reflect site information.

General comments are provided in the following sections.

FIGURE 4-30 EXAMPLE OF EROSION HAZARD MAPPING – SAPPHIRETOWN / ISLAND BEACH (FOR BRUUN FACTOR 50)

FIGURE 4-31 EXAMPLE OF EROSION HAZARD MAPPING – SAPPHIRETOWN / ISLAND BEACH (FOR BRUUN FACTOR 100)

4.6.1 Sandy Shorelines

Sandy shorelines are the most susceptible to coastal erosion. For sandy shorelines, erosion zones are shown separately for a Bruun Factor of 50 and 100. Where no storm erosion information is available, the storm erosion component has been set to zero.

The following observations from the analysis are provided:

- Erosion at Emu Bay is limited by the more resistant calcarenite or bedrock at the back of the beach. Only limited infrastructure (BBQ shelter, playground and public toilet) is likely to be impacted for the Brunn Factor of 50 case. For a Brunn Factor of 100 these assets as well as a number of private properties are within the erosion hazard zone extent.
- The erosion extent shown at Brownlow is significant due to the low-lying nature of the area and the limited shoreline levee. There is only a limited volume of sand within the beach system to buffer erosion due to storm events. Under a 100 year ARI storm tide event this location could experience significant erosion and inundation (as discussed in Section 5.3).
- Within Nepean Bay, the erosion zone extends to the Nepean Esplanade under existing conditions and then into the adjacent properties under future scenarios. The location is also highly susceptible to inundation (as discussed in Section 5.3).
- The erosion zone at Sapphiretown and Island Beach is generally limited to areas forward of access ways which run along the foreshore. With a more conservative Brunn Factor of 100, the results indicate some of the adjacent properties may also become impacted. There is a step erosion zone both the Bruun Factor of 50 and 100 scenarios around the mouth of the river, to represent the greater erosional potential and dynamic nature of the spit.
- Erosion at Penneshaw is generally limited to areas seaward of Frenchman's Terrace, although the properties adjacent to the road may be impacted by the end of the century.
- Erosion extents at Antechamber Bay have limited impact on property or roads.

4.6.2 Estuaries, Lagoons and Tidal Flats

The erosion potential for estuary, lagoon and tidal flat areas relates to the increased permanent or more frequent inundation that occurs as a result of sea level rise. With more frequent higher inundation effectively a new 'shoreline' forms. The mean high water springs extent has been used to define this new shoreline.

The most significant impacts occur within Nepean Bay, immediately south of Brownlow, where the new shoreline could impact the sewage treatment plant by 2100.

Other areas impacted include the Chapman River and Lashmar Lagoon at Antechamber Bay. The extent of permanent water within these areas could be increased and increased connection between the lagoon and estuary with increasing sea level rise.

At Nepean Bay/Western Cove the future shoreline extends to Hog Bay Road by 2100, along with the North Coast Road in the Wisanger area.

The steep shoreline morphology around much of Pelican Lagoon means there is generally limited change in shoreline extent with sea level rise. The exceptions are the low-lying intertidal areas adjacent to Sapphiretown and to the south adjacent to Hog Bay Road. There may be erosion risks to Hog Bay road beyond 2070 due to the constantly higher water levels in this area of the lagoon.

4.6.3 Soft Rock

Soft Rock shorelines can be susceptible to coastal erosion. For these shorelines, erosion zones are shown based on current erosion rates and also for accelerated erosion rates as a result of increased wave energy on the shoreline. In general, this shoreline type is limited in extent and the predicted shoreline erosion extents are also limited.

4.6.4 Hard Rock

Hard rock shorelines are the least susceptible to erosion. Only steeply sloping (>45 degree) sections have been mapped for this shoreline type. The erosion extent represents the potential failure/erosion zone and few impacts have been noted.

5 INUNDATION HAZARD ASSESSMENT

5.1 Inundation Processes Overview

As discussed in Section 1.2, coastal inundation includes both long-term and short-term inundation conditions. Long-term inundation is likely to occur as a result of a change in the mean water level and tidal range as a result of sea level rise. Short-term inundation is associated with extreme water levels and waves, occurs under current mean sea level conditions, and will be increased as a result of sea level rise.

5.1.1 Long Term Inundation

In the case where the estuary, coastal lagoon or tidal flats are always or almost always connected to the ocean the change in tidal elevations and subsequent extents of inundation with sea level rise could be expected to expand into low lying swampy areas adjacent to existing tidal and estuarine channels. Low lying swampy areas that experience frequent tidal inundation due to sea level rise could be expected to evolve into muddy intertidal areas that may be fringed by proto shorelines of increasingly salt tolerant vegetation. The increased tidal extent will also affect the potential impacts associated with catchment derived flood events This is the condition most likely to effect estuary, coastal lagoon or tidal flats in the study area.

The exception is the Chapman River at Antechamber Bay, which is more exposed to waves and where a sandy berm at the mouth limits the size of the channel conveying flows between the ocean and the estuary. Behind the berm a water body forms and sand build-up on the berm can be periodically close the entrance channel. This results in an increase in water levels upstream increasing the extent of the water body until the berm can be overtopped and a new channel formed. Currently DEW is responsible for dredging the mouth of the Chapman River which generally occurs bi-annually.

As discussed in Section 4.5, on sandy shorelines an increase in sea level rise is expected to lead to general beach recession. In estuary or lagoon entrances, this would also be expected to be accompanied by landward and upward translation of the entrance berm (Figure 5-1). This could result in the following (adapted from Hanslow et. al., 2000 & Haines, 2016):

- An increase in low tide levels. This would reduce the gradient across the berm and result in more rapid closure following and opening. There could also be increased inundation of fringing vegetation and potentially elevated local groundwater levels.
- An increase in the typical water depth in the estuary. This may enhance sedimentation into the estuary from catchment inflows, as well as increasing sedimentation of the flood tide delta. Other potential impacts include reduced vertical wind mixing, and an increased tendency towards closure.
- Higher estuary water levels as a result of a higher berm height. This would be most noticeable in estuaries that are closed for extended periods.

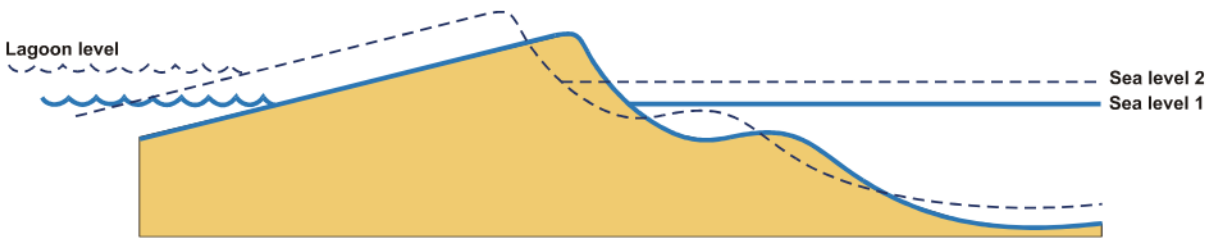

FIGURE 5-1 SANDY BERM RESPONSE TO INCREASING SEA LEVEL (FROM HANSLOW ET AL, 2000)

5.1.2 Short Term Inundation

Short-term coastal inundation results from elevated coastal water levels along area of low lying low terrain. Increases in local coastal water levels can be a result of tides, low pressure systems, and storms. These conditions can be exacerbated by catchment and stormwater runoff.

The term storm tide refers to coastal water levels produced by the combination of astronomical and meteorological sea level forcing, as described in Section 3.1.3.

The shoreline within estuaries and coastal lagoons can also be affected by short term storm tide inundation. Where an estuary entrance is open, the storm tide can propagate upstream resulting in increased inundation along the estuary floodplain. This can exacerbate catchment derived flooding if the peak flood level coincides with the elevated ocean water level.

5.2 Assessment and Mapping Approach

Coastal inundation has been assessed as follows:

- Long Term Inundation: Existing and future tidal levels (specifically the MHSW tidal plane, as detailed in Table 3-2) have been mapped as an indication of potential long-term inundation as a result of increasing tidal elevations will sea level rise.
- Short term Inundation: The Coastal Policy (Coast Protection Board, 2016) stipulates the 100-year Average Recurrence Interval (ARI) water level should be applied to assess the predicted coastal inundation. As detailed in Table 3-4, the Coast Protection Board has provided storm tide parameters for the 100-year Average Recurrence Interval (ARI) water level, wave setup and wave run-up. The maximum water level, including wave setup and runup, has been mapped to provide a conservative assessment of inundation extents. Wave setup and runup could be included as freeboard rather than explicitly included in the mapping.

Both the MHWS tidal plane and peak 100-year ARI water level has been mapped across the study area using a “static” or “bathtub” water level approach but accounting for local features such as levees or banks which may provide some protection in particularly areas to a low-lying backshore. There are limitations to the bathtub approach, however for the purpose of providing a first pass assessment of areas at risk from extreme coastal water levels, this is considered sufficient.

As for the erosion hazard mapping, the inundation hazard extents can be accessed via the following link: https://bit.ly/2NyJXdm

5.2.1 Long Term Inundation

Given that much of the coastline within the study area is steeply sloping there are only limited low lying locations, where direct long term tidal inundation as a result of sea level rise will occur.

Those areas most affected by long term inundation as Brownlow, Nepean Bay, Sapphiretown, American River and Antechamber Bay. Specific impacts include:

- Within the Bay of Shoals impacts are limited to potential inundation of access roads and the North Coast Road under future conditions.
- The golf course and land south of Brownlow are likely to experience regular inundation under future conditions. This may also impact those properties located at the southern end of The Parade and Links Road.

- Within Nepean Bay, the long-term inundation of the low-lying flats under future conditions could impact Hog Bay Road. No residential properties are affected, however access roads to Nepean Bay may be regularly inundated.
- At American River, long term inundation would impact a number of low lying foreshore areas, in particular the new playground on Tangara Drive, the CFS shed, CWMS pump stations (x2) and the tennis courts.
- Long term inundation at Sapphiretown is limited to the existing lagoon area located between the boat ramp and the coast. The boat ramp area may also be affected. By 2100, the rear sections of properties along Fourth Street will also be impacted.
- At Antechamber Bay, the long-term increase in mean sea level will likely result in an increase in the sandy berm at the Chapman River entrance and in turn higher water levels along the river and into Lashmar Lagoon.

5.2.2 Storm Tide Inundation

The storm tide mapping for the study area indicates the following:

- Within Emu Bay, the existing dunes limit storm tide inundation. However, erosion of these dune areas under future conditions may expose some properties to increased risk of inundation.
- Inundation of the low-lying land within the Bay of Shoals is shown under both existing and future conditions. This is likely to impact a number of road/access ways, including Bellmore Road, Dover Court and North Cape Road. The boat ramp and breakwater at Bay of Shoal will also be impacted, as well as a number of coastal properties.
- In the vicinity of Kingscote, the impacts are limited to Governor Wallen Drive between the boat ramp and Reeves Point is susceptible to inundation along with the BBQ shelters and public toilets at Reeves Point. Infrastructure including the seawalls around Kingscote Pier will also likely be impacted by storm tide inundation, as will the Kingscote tidal pool and surrounds.
- The low levee at Brownlow is sufficient to prevent extensive inundation under existing conditions, however not the 2050 or 2100 conditions. A significant number of properties as well as roads and access ways are likely to be affected under these future conditions.
- Nepean Bay is extensively inundated under existing and future conditions. Properties and roads including Hog Bay Road are likely to be impacted. Council has provided information that '*During the 2016 storm surge event, the north eastern section was inundated to some extent. Since then, Council has raised The Esplanade by approximately 0.5m in that area which <u>will not be reflected in the LiDAR data</u>.*' As the full extent of the road raising is not available, this has not been considered within the inundation mapping.
- At American River, the majority of properties east of Buick Drive are likely to be impacts under the 2100 future conditions. Under existing conditions, the flooding is generally restricted to properties along Tangara Drive, including the boat ramp, wharf, associated buildings, the campground and several private properties.
- At Sapphiretown, those properties located close to the boat ramp are impacted under future climate scenarios, as are those along Fourth Street.
- Inundation at Island Beach is generally restricted to the foreshore by the existing dune system. However, future erosion of these areas would potentially expose the backshore properties to storm tide inundation.
- Storm tide inundation within Pelican Lagoon has the potential to impact Hog Bay Road under existing and future conditions.

- At Antechamber Bay, the storm tide could propagate up the Chapman River and into Lashmar Lagoon resulting in a significant extent of inundation. However, this inundation extent will depend on the conditions at the Chapman River entrance and it is unlikely the full flood extent as mapped would be realised.
- Along D'Estrees Bay there are a number of low lying locations and properties impacted under existing and future conditions.

6 GROUNDWATER HAZARD ASSESSMENT

Although groundwater is generally not considered within the scope of a coastal hazard assessment, there are potential impacts to groundwater systems that may occur as a result of future changes in sea level. The following section provides an initial review of the groundwater systems within the study area and identifies what the potential impacts may be in the future. Insufficient information is currently available to map future groundwater hazards for the study area. However, preliminary locations have been identified where further investigations into groundwater hazards may be warranted in the future.

6.1 Overview

Coastal groundwater systems vary widely and are influenced by the host geology, groundwater recharge and flow processes and connectivity to the marine environment. Aquifer systems are primarily classified into sedimentary aquifer systems where groundwater is stored and moves through the pore spaces between grains of rock. The other type is the fracture rock or karstic aquifer systems where groundwater moves through fractures of solution features within a matrix that (usually) has low porosity. The sedimentary aquifer systems are more predicable in aquifer response to change and effects are felt more continuously across the landscape. Fractured rock and karstic aquifer systems are less predictable and only respond through the irregularly spaces cavities.

An analysis of the surface geology of Kangaroo Island (refer Figure 6-1) has indicated that there is an extensive distribution of Quaternary sediments adjacent the coastline. This Quaternary sequence consists of the Saint Kilda Formation and the Bridgewater Formation. The Bridgewater Formation is dominant and is typically a poorly consolidated yellow pinkish-brown fine to coarse fossiliferous calcareous sand or calcarenite, locally capped by calcrete. This formation commonly hosts shallow unconfined aquifers. Present also in the Island is a minor distribution of Permian Cape Jervis Formation, typically unconsolidated yellow-green siltstone, sandstone, sandy limestone and grit with rounded pebbles, boulders and residual erratics. There is limited drill hole information that describes the hydrogeological nature of Permian sequence.

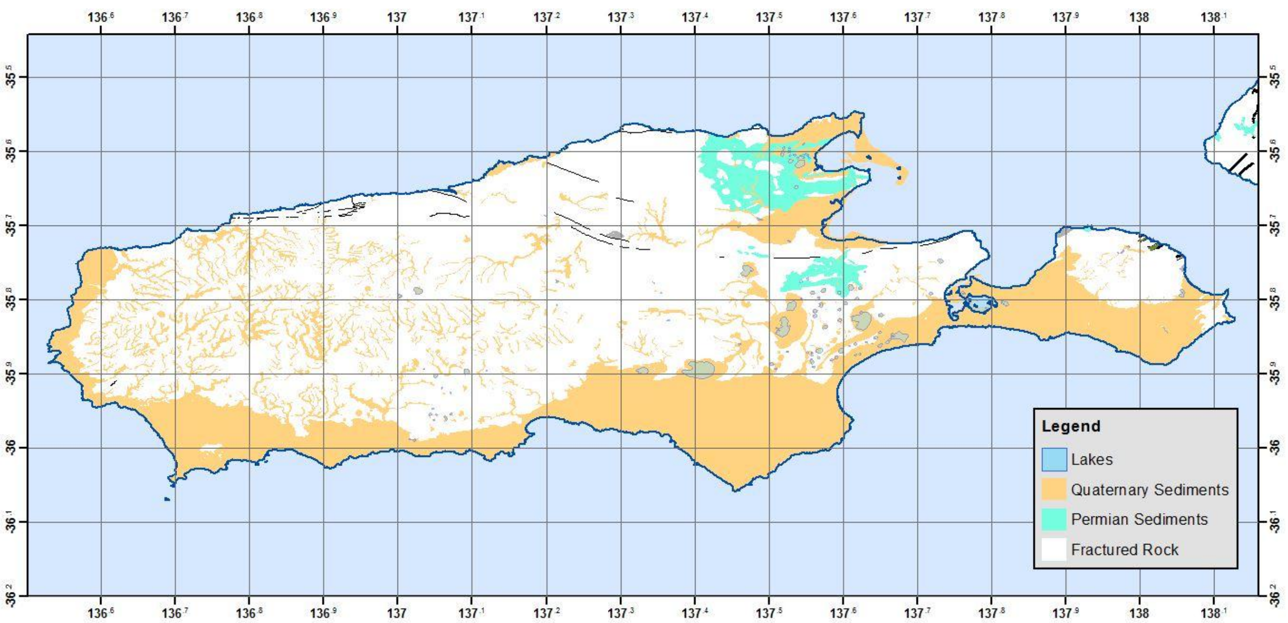

FIGURE 6-1 SURFACE GEOLOGY OF KANGAROO ISLAND

Land systems (and built infrastructure) most vulnerable to the predicted climate change impact of sea level rise are those of low topographic elevation (refer Figure 6-2). Sedimentary aquifer systems are commonly associated with low-lying coastal areas as the host geological material is often deposited in such environments and is relatively easily eroded (keeping topographic elevations low). Fractured rock and (sometimes) karstic aquifer systems are commonly hosted in geological materials resistant to erosion – often forming higher topographic relief coastal landscapes.

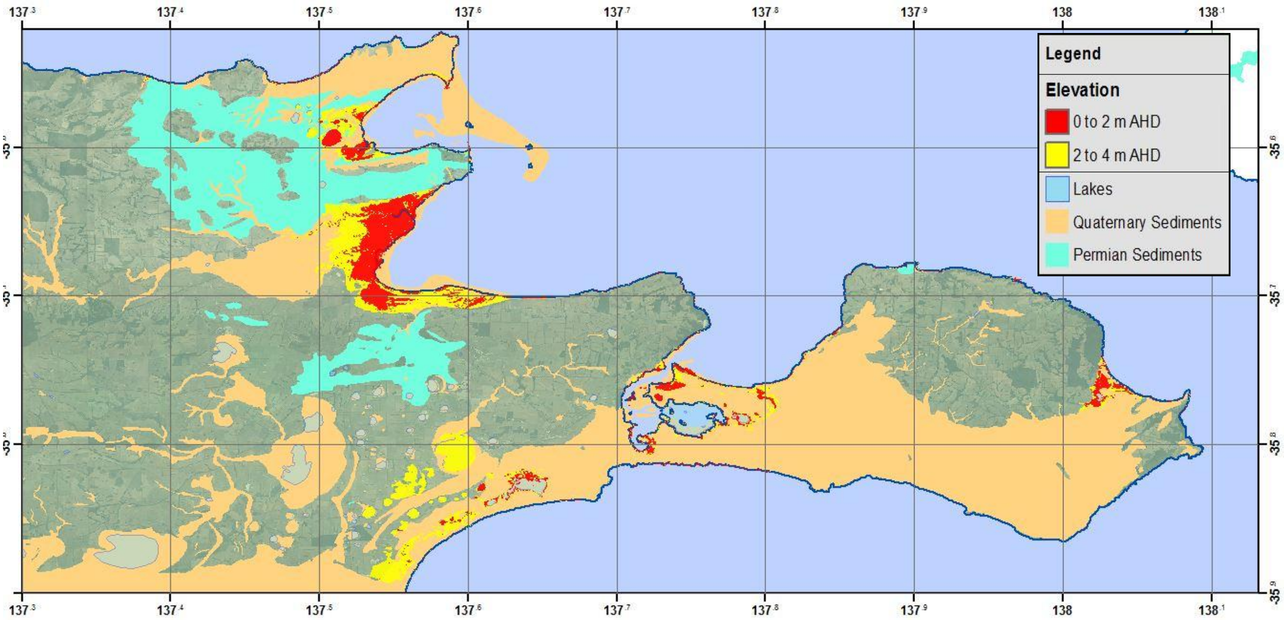

FIGURE 6-2 AREAS OF LOW TOPOGRAPHIC ELEVATION ASSOCIATED WITH COSTAL SEDIMENTARY AQUIFERS

Unconfined aquifer systems (i.e. have no overlying impervious material that would cause the aquifer to pressurise) that are connected (i.e. discharge directly) to the marine environment have their aquifer storage (the volume of groundwater held within the aquifer) effectively controlled by the sea level elevation and the ability for groundwater to move through the aquifer (the transmissivity). The combination of these two factors influence how full an aquifer is on average and the variability of recharge to the aquifer and groundwater extraction from the aquifer would influence seasonal fluctuations and long-term trends.

Typically, unconfined aquifer systems (sedimentary or fractured rock) don’t show significant response to tidal changes due to the response times of groundwater moving through the aquifer material within the coastal zone. The exception to this may be karstic systems with large cavities that would translate tide changes inland. The extent to which the tide changes in the receiving environment (the sea) influences the water table inland is often not investigated but anticipated to be only 10’s of metres in width (refer Figure 6-3). It would be influenced by geomorphological features such as beach sand depth, beach width, back-beach dune systems and tide height range.

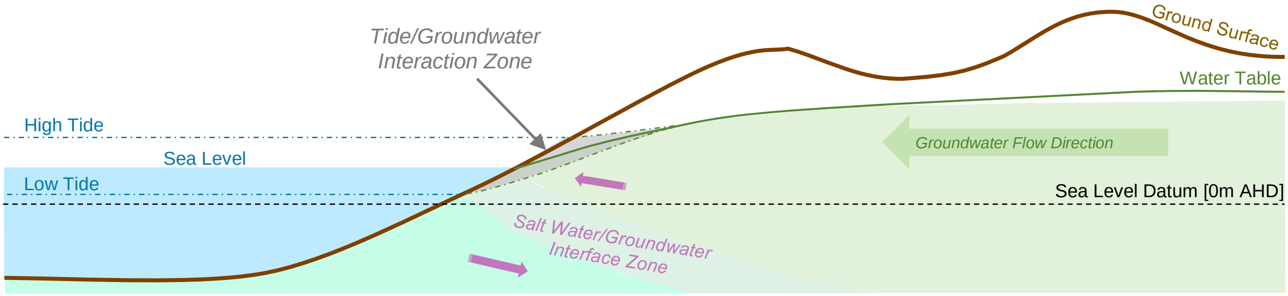

FIGURE 6-3 SCHEMATIC OF THE RELATIONSHIP BETWEEN WATER TABLE AND SEA LEVEL INTERCHANGE

Where groundwater discharges to the marine environment a 'Salt Water/Groundwater Interface Zone' is often present (refer Figure 6-3) where the denser sea water penetrates inland in deeper parts of the aquifer whilst the groundwater (being less dense) flows over this intrusion as it discharges to the marine environment. The extent of the intrusion and the profile of this interface zone is influenced by factors such as aquifer thickness, rate of discharging groundwater flow and density difference between the two waters. This interface zone is also dynamic in that it may vary spatially due to seasonal variation in groundwater flow due to varying recharge and extraction stress that may be placed on the aquifer system.

6.2 Climate Change Impacts

The impacts on coastal groundwater systems by the onset of predicted climate change elements include:

- **Reduced Winter Rainfall**: This would result in reduced winter recharge, effectively reducing groundwater storage within the aquifer (measured as lowered water table elevations) and reducing discharge to the marine environment;
- **Increased Summer Storms**: This may marginally increase summer-time recharge however greater evaporation rates and the inefficiencies of re-wetting the near surface soil profiles at each event will reduce the likely effective recharge volume from more frequent summer storm events.
- **Rising Sea Levels**: The marine environment acts as a dynamic boundary condition that influences groundwater discharge. If sea levels were to rise, this would effectively raise the height of the available 'window' of discharge, backing the groundwater levels up inland. This would be observed as rising water table levels in areas adjacent the groundwater discharge zones. The salt water/groundwater interface zone would also effectively ingress inland as the denser sea water pushes against the groundwater discharge head pressures.

The combined effects (refer Figure 6-4) of the predicted climate change elements described above, are likely to be observed as:

- Rising water tables adjacent the coastline which may
  - inundate buried infrastructure;
  - invoke increase land salinisation and prolonged land inundation due to reduced soil vadose zone in low-lying area;
- Increased the salinity of aquifer systems as the saltwater/groundwater interface zone migrates inland;
- Possible no observed change of inland groundwater levels as the reduced recharge (and thus aquifer storage) is countered by the backing-up of water table elevation due to the rising sea level.

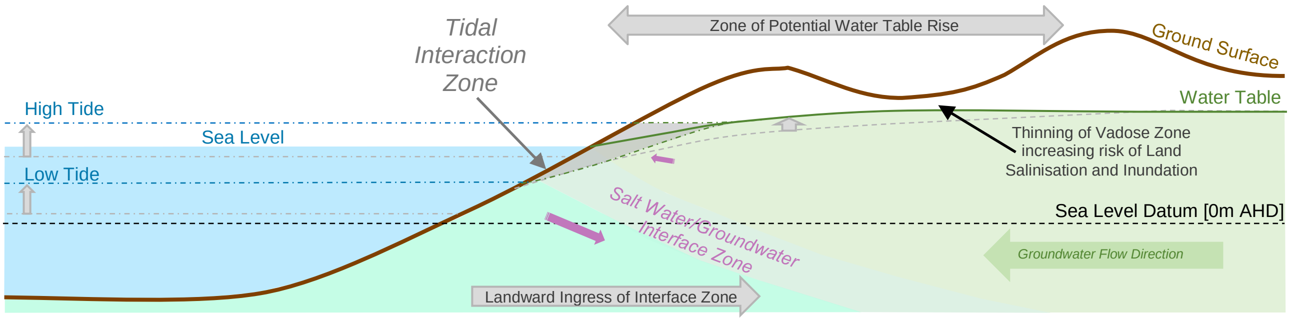

FIGURE 6-4 SCHEMATIC OF THE RELATIONSHIP BETWEEN WATER TABLE AND SEA LEVEL INTERCHANGE

6.3 Implications for the Study Area

In the event sea level rise is an outcome of how climate may change, areas of low topographic elevation are likely to experience rising water tables, and if reliant on local groundwater sources for water supply an increase in groundwater salinity. It is difficult to anticipate the magnitude of change in sea level and the corresponding re-adjustment of hydrological processes. It is reasonable to anticipate that areas currently lower than 2 m AHD topographic elevation would be the most susceptible to altered hydrogeological processes described in Section 6.2.

Figure 6-5 and Figure 6-6 below show the relationship between susceptible hydrogeology and topographic elevation for Pelican Lagoon and Eastern Cove. Other areas likely to be susceptible include Western Cove and Nepean Bay.

Potential impacts from increased saline intrusion and higher groundwater levels include footing/foundation requirements for saturated soils for structures as well as roadways, corrosion of concrete structures, operation and maintenance of septic/sewerage systems, operation of stormwater systems, and flooding of buried utilities.

For example, many of the existing Community Wastewater Management Schemes (CWMS) include pumping stations along the foreshore areas. There is the potential for groundwater to be contaminated through leakage of these systems and well as through leakage of domestic septic systems.

Hog Bay Road along the southern extent of Pelican Lagoon is also low lying and increases in groundwater levels may impact the road foundations, resulting in increased maintenance requirements.

Coastal inundation resulting from storm events can also result in an increased salinity within the fresh groundwater layer, which may never recover. There may also be impacts on vegetation due to higher saline groundwater levels.

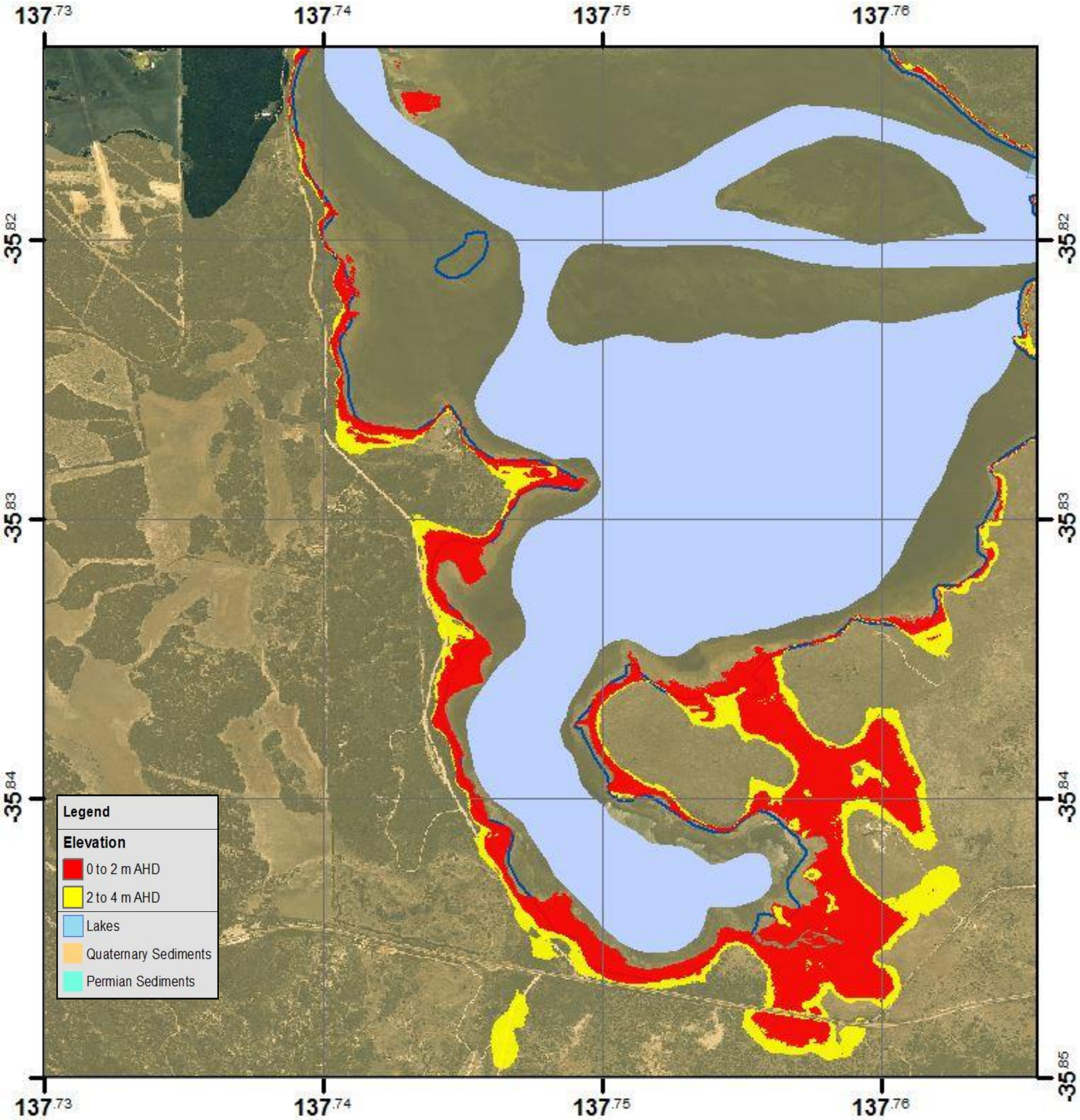

FIGURE 6-5 AREAS OF LOW TOPOGRAPHIC ELEVATION WHERE HOG BAY ROAD IS ADJACENT PELICAN LAGOON

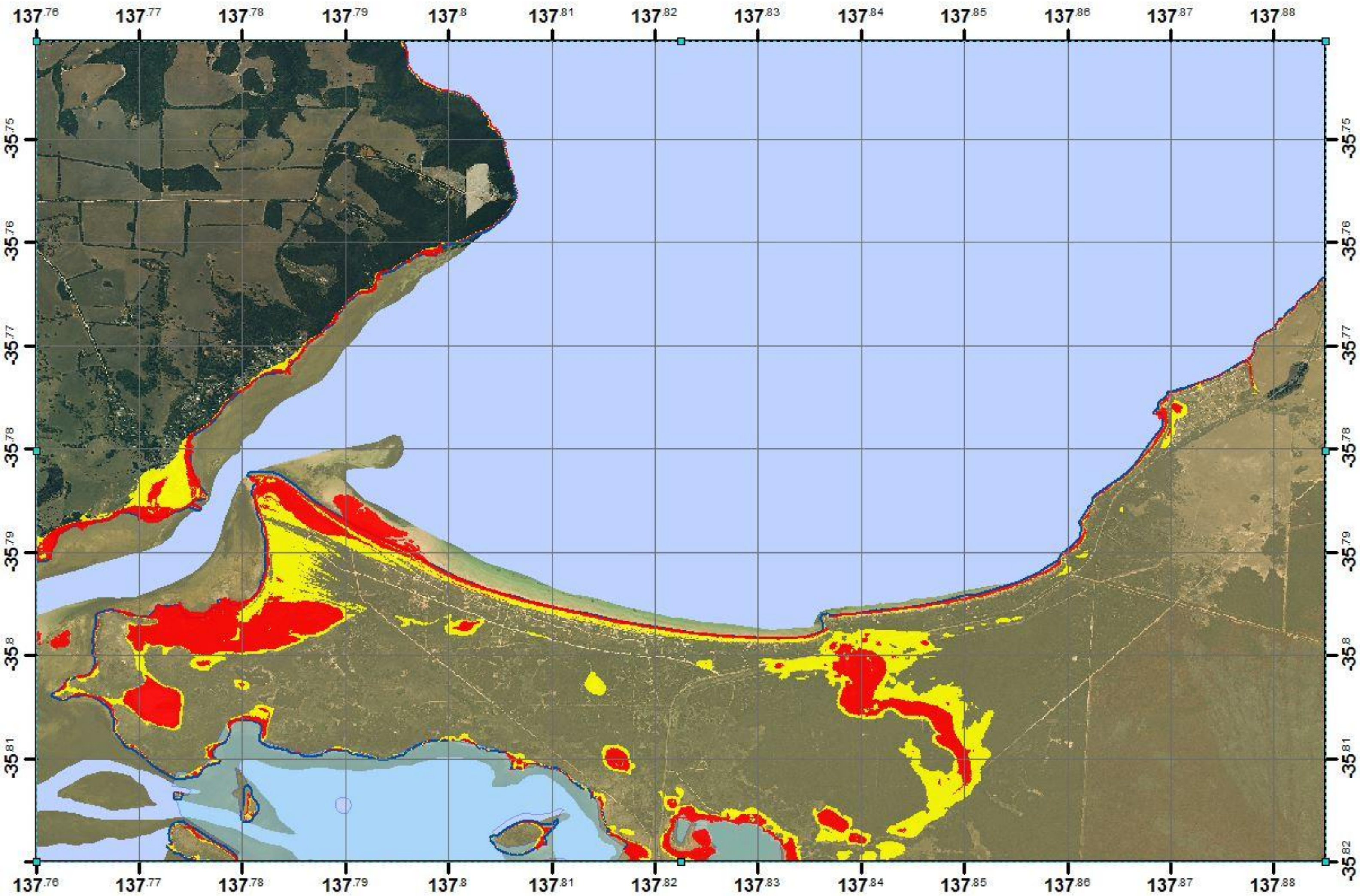

FIGURE 6-6 AREAS OF LOW TOPOGRAPHIC ELEVATION OF SETTLEMENT AREA ADJACENT EASTERN COVE

Legend

Elevation

0 to 2 m AHD

2 to 4 m AHD

Lakes

Quaternary Sediments

7 EXISTING PROTECTION STRUCTURES

7.1 Overview

The following overview of the existing coastal protection structures within the study area is based on information provided by Council, observations on site, and the results of the hazard assessment described in Section 5.

Emu Bay

- There appear to be several sections possibly informal coastal protection structures at Emu Bay, adjacent to the Pier and Boat Ramp. It comprises predominantly of dumped rock, although the structure is more formal around the end of the boat ramp. Visual inspection indicates there is some damage to areas of the rock work.
- Councils has indicated that '*the Boat ramp and Jetty are currently being upgraded'.* The upgrades will need to consider future inundation and erosion impacts to maintain usability and protection levels.

Kingscote

- Short and Fotheringham (1986) details the cliff subsidence that has occurred along a 10-40m high sections of cliff between Beare Point and Reeves Point in Kingscote, Figure 7-1. The subsidence is a result of infiltration from land above as well as wave action at the cliff toe. To address the wave processes, 300m of rock protection has been placed at the toe to stabilise the cliff.

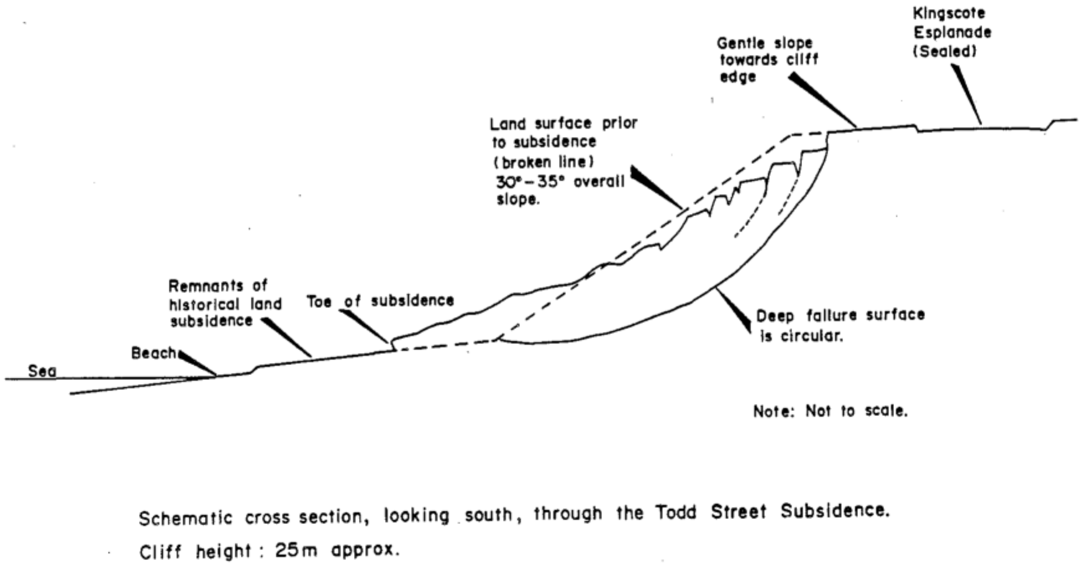

FIGURE 7-1 CLIFF SUBSIDENCE AT KINGSCOTE (FROM MORRIS 1983, AS DETAILED IN SHORT AND FOTHERINGHAM 1986)

- Marine infrastructure such as the piers and wharfs are supported by coastal structures such as rock seawalls.
- Coastal protection structures are incorporated into the existing public assets in Bay of Shoals/Kingscote, such as the breakwater in Figure 7-2.

FIGURE 7-2 EXISTING STRUCTURES IN BAY OF SHOALS AND KINGSCOTE

Brownlow Levee

- Originally constructed in the 1980s with an extension and upgrade in 2008/09, the levee at Brownlow runs along the foreshore from Lovers Lane to Links Road, then inland along Links Road.
- Council notes that there were a few breaches of the original levee during the May 2016 storm surge event however property and infrastructure inundation was avoided due to 2008/09 upgrades.
- The storm tide inundation mapping indicates that the levee provides protection from existing conditions, however will be overtopped under future sea level rise scenarios. The DEM data shows that the levee has a low point at the intersection of Burdon Drive and Links Road, where it can potentially be outflanked. This could provide a flow path for storm tide inundation under current conditions, as shown in Figure 7-3 for existing conditions. However, it is assumed for the existing condition mapping that the volume of water through the low point would be insufficient to flood the area behind the levee and this area has not been included in the risk analysis for existing conditions.

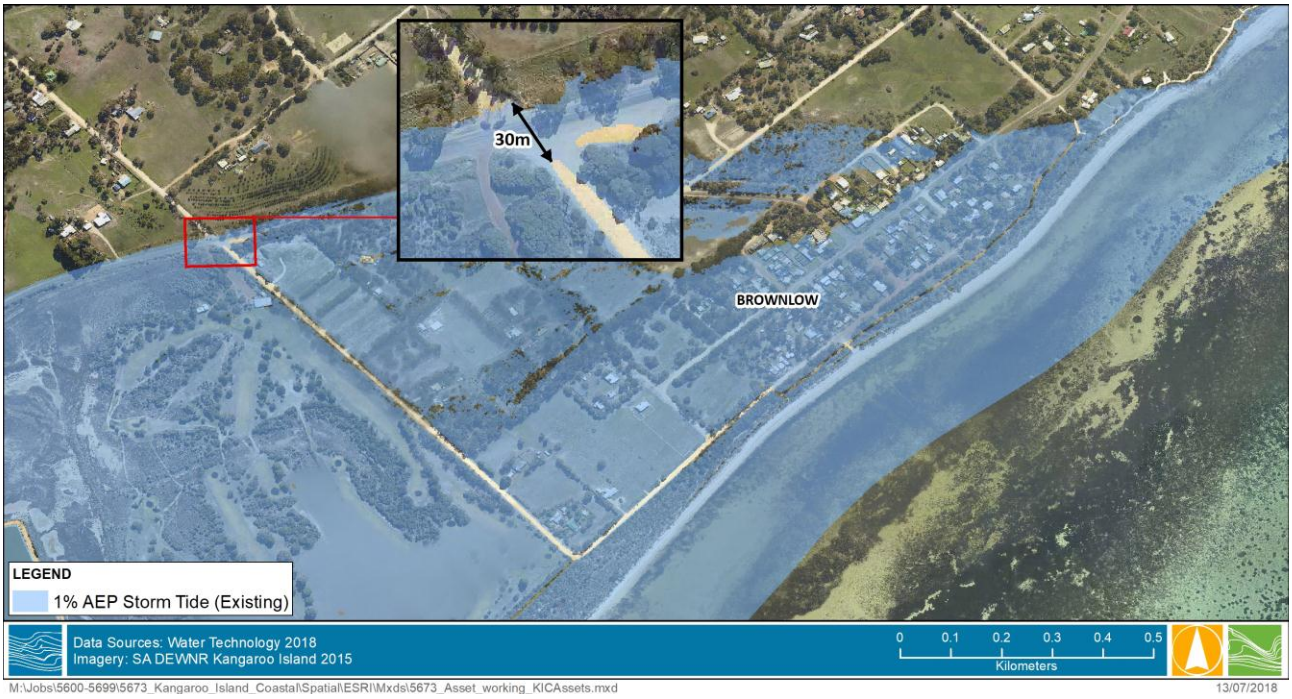

FIGURE 7-3 BROWNLOW ROAD LEVEE AND POTENTIAL LOCATION OF OUTFLANKING

Nepean Bay

- Nepean Bay does not have any formal coastal protection structures.
- Council has however raised the north eastern end of The Esplanade by approximately 0.5 m to provide some protection from storm tide inundation following inundation that occurred during the 2016 storm surge event. In this event there was inundation of properties at the north eastern extent of the area.
- The upgrade to the roadway was not included in the LiDAR DEM and therefore has not been included in the storm tide inundation mapping due to lack of detailed information on the extent of the works.

American River

- The existing coastal protection levee at American River is in poor condition and Council suggested it be raised following storms in 2011 which caused considerable damage to infrastructure. However, with little community support due to the potential visual impact of a new levee the application was withdrawn.
- The pier and boat ramp at American River (Figure 7-4) are well used, however the moorings are subject to inundation, such as in May 2016.

Baudin Beach

- The existing coastal protection structures around the jetty/ boat ramp at Baudin Beach were removed in 2016.

Penneshaw

- Coastal protection structures are incorporated into the existing public assets at Penneshaw, such as the breakwater seen in Figure 7-4.
- The wharf and jetty at Penneshaw are highly used facilities and important for the Island ferry link. The Council are undertaking plans for future development and infrastructure requirements.

- Christmas Cove Marina and boat ramp are ~5 years old and are designed with rock revetments and breakwaters at the entrance.

Existing structures in Emu Bay, American River and Penneshaw are shown in Figure 7-4 below.

FIGURE 7-4 EXISTING STRUCTURES IN EMU BAY, AMERICAN RIVER AND PENNESHAW

8 ASSETS AT RISK

The analysis detailed in this section has been carried out to identify the assets that may be at risk from coastal inundation or erosion (whether in public or private ownership). The risk profiles developed will subsequently be used to identify priority areas to inform the adaptation strategy.

8.1 Overview

Risk Management is the term applied to a logical and systematic method of establishing the context, identifying, analysing, evaluating, treating, monitoring and communicating the risks associated with any activity, function or process in a way that will enable organisations to minimise losses and maximise opportunities (Standards Australia, 2009). Risk is identified as the product of the likelihood and consequence of an event impacting on an asset or objective.

An asset and infrastructure database was developed by collating Council/Government GIS layers and assets identified from aerial imagery. The Council GIS layers included location information for pumping stations, drains/pipes, jetties and features of interest. Additional assets with social, cultural or economic significance were identified visually using aerial imagery.

The asset and infrastructure database is presented in the online map and is provided as a geodatabase with this report. The asset database was separated into privately owned and Council owned assets. Where ownership was unclear, they have been included under Council's assets as a conservative approach.

Risk profiles have been developed for all assets by assigning scores to the consequence of each relevant coastal hazard and the likelihood of this coastal hazard impacting the asset over the planning periods being considered within this study. This involved utilising GIS analysis tools to intersect the erosion and inundation hazard extents presented in Section 5 with the asset database.

The risk profile is determined by applying the likelihood and consequence ratings to a risk matrix such as the one shown in Table A-3, Appendix A. The risk profile assists with the identification and analysis of priority risks for subsequent decision making and planning.

Table A-1 within Appendix A displays a description and semi-quantitative score that has been assigned to the range of coastal hazard likelihoods. Table A-2 within Appendix A displays a description and semi-quantitative score that has been assigned to the range of coastal hazard consequences. Table A-3 within Appendix A display the resulting risk matrix.

The likelihood ratings in Table A-1 are interpreted as follows for assessing inundation risks to assets:

- Present day scenario: there is a 1% probability of a 100-year ARI event occurring within the year therefore an **Unlikely** likelihood descriptor was assigned.
- 2050 scenario: there is a 33% probability of a 100-year ARI event occurring within the next 32 years and therefore a **Possible** likelihood descriptor applies.
- 2100 scenario: there is an 82% probability of a 100-year ARI event occurring within the next 82 years and therefore a **Likely** likelihood descriptor applies.

This is similar to the approach recently adopted for the Southend Adaptation Strategy (Wattle Range Council, 2018).

The coastal hazard extents are derived from a combination of events or conditions rather than related to a specific event and also differ depending on the type of shoreline (i.e. sandy, soft rock, hard rock). However, for simplicity the same likelihood descriptors as for the inundation hazards have been applied. The assessment of consequences for both erosion and inundation was based on a “Do Nothing” scenario.

8.2 Public Asset Risk

The number of public assets at risk from coastal erosion or inundation hazards defined for each area are summarised in Table 8-1 to Table 8-7 with further information presented in Appendix B. Each table contains the number of each asset type in each area and is coloured coded according to the risk rating, described in Table A-4.

Key observations of the results of the public asset risk assessment include:

- The majority of wastewater pumping stations were not at risk of inundation or erosion hazards, however at American River and Brownlow Beach, there is a total of 8 and 6 stations at risk respectively. The number of at-risk pumping stations is represented as a percentage of the total number of pumping stations per area.
- The public assets at Penneshaw have a relatively low risk rating, however under the 2100 erosion scenario, there is a extreme risk to the pipe/drain network.
- For pipes and drains, the number of assets identified was calculated in relation to the length of infrastructure, represented by a percentage of the total length within each area. There were no impacted pipes and drains in Emu Bay or D’Estrees Bay.
- The number of ‘Other Assets’ represents the assets including tennis courts, heritage sites, camping grounds etc.

TABLE 8-1 EMU BAY ASSETS AND RISK RATING

Assets	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
Pumping Stations (%)	-	-	-	-	-	-
Pipes/Drains (%)	-	-	-	-	-	-
Jetties (No.)	-	-	-	1	1	1
Other Assets (No.)	-	-	1	5	6	7

In Emu Bay there were no impacted pumping stations, pipes or drains. There is no erosional impact to public assets before the 2100 scenario, with only one historic asset (Emu Bay Shack Site) being highly at risk in the 2100 erosion hazard. The Emu Bay jetty and boat ramp are at risk of inundation in all sea level rise scenarios, as well as the car park and an industrial outflow.

TABLE 8-2 KINGSCOTE ASSETS AND RISK RATING

Assets	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
Pumping Stations (%)	-	-	-	-	-	-
Pipes/Drains (%)	-	-	-	0.1	0.2	0.2
Jetties (Count)	-	-	-	4	4	4
Other Assets (Count)	-	-	1	7	8	9

**Asset to note: Culturally significant Reeves Point.*

The only public asset at risk from erosional hazard in Kingscote is the Reeves Point Historical Site with a high risk. A minimal distance of pipes/drains are impacted by the inundation scenarios. Four jetties are impacted by the inundation scenarios, currently at a low risk and developing to a medium risk with future sea level rise scenarios. A number of 'other assets' are at low to medium risk from future sea level rise scenarios, including several car parks, piers, boat ramps and Kingscote Tidal Pool.

TABLE 8-3 BROWNLOW BEACH ASSETS AND RISK RATING

Assets	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
Pumping Stations (%)	-	-	33.3	33.3	50	50
Pipes/Drains (%)	-	3.7	32.7	11	30.5	32.1
Jetties (Count)	-	-	-	-	-	-
Other Assets (Count)	-	1	6	1	6	6

The public asset risks in Brownlow are categorised as extreme by the 2100 erosion scenario, with 32.7% of all pipes and drains considered at a extreme risk in the 2100 scenario. Six assets are considered to be at extreme risk in the 2100 erosion scenario.

TABLE 8-4 NEPEAN BAY ASSETS AND RISK RATING

Assets	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
Pumping Stations (%)	-	-	-	-	-	-
Pipes/Drains (%)						
Jetties (Count)	-	-	-	-	-	-
Other Assets (Count)	2	2	8	16	18	20

By 2100, 8 public assets will be at extreme risk levels, including car parks, the Nepean Bay Conservation Park and Cygnet Estuary Conservation Park.

TABLE 8-5 AMERICAN RIVER ASSETS AND RISK RATING

Assets	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
Pumping Stations (%)	-	-	-	25	37.5	50
Pipes/Drains (%)	-	-	-	8.3	10.4	14.5
Jetties (Count)	-	-	-	1	1	1
Other Assets (Count)	-	-	2	11	12	16

American River is mostly protected from erosional risk, with just 2 assets at extreme risk levels in the 2100 erosion scenario. American River is most at risk from inundation, with low risk levels already present with existing conditions. Pumping stations are at extreme risk from the 2100 inundation scenario, and 16 other assets are at a high risk level, such as the tennis courts, car parks and American River CFS.

TABLE 8-6 PENNESHAW ASSETS AND RISK RATING

Assets	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
Pumping Stations (%)	-	-	-	-	-	-
Pipes/Drains (%)	-	-	4	0.1	0.1	0.3
Jetties (Count)	-	-	-	1	1	1
Other Assets (Count)	1	1	1	4	4	4

The public assets at Penneshaw are at a comparatively low risk, however with the 2100 erosion scenario, there is an extreme risk to the pipe/drain network.

TABLE 8-7 D'ESTREES BAY ASSETS AND RISK RATING

Assets	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
Pumping Stations (%)	-	-	-	-	-	-
Pipes/Drains (%)	-	-	-	-	-	-
Jetties (Count)	-	-	-	-	-	-
Other Assets (Count)	-	-	-	4	4	6

There is a low to medium risk to public assets in D'Estrees Bay, with 6 assets being affected by the 2100 Inundation scenario, such as car parks. There is no erosional risk to public assets.

8.3 Roads Risk

The percent of public roads at risk from coastal erosion or inundation hazards defined for each area are summarised in Table 8-8 to Table 8-11. Each table contains the percent of road at risk and is colour coded according to the risk rating described in Table A-3. Further mapping information is available in Appendix B.

The roads included in the risk/consequence analysis were roads with specific costing data provided by the council and does not include all roads in the area. These roads were intersected with the erosion and inundation extents to calculate the percent of road that would be at risk. This percentage was used as a guide to estimate the value of the risk, detailed in Section 9.2.

Key observations of the results of the public road risk assessment include:

- The majority of roads are at extreme risk levels in the 2100 erosion and inundation scenarios.
- The major roads in American River are not impacted by any erosion scenarios.
- Frenchmans Terrace in Penneshaw is not impacted by any inundation scenarios.
- The worst affected road is Nepean Esplanade in Nepean Bay, which is at a extreme risk level in the 2050 and 2100 erosion and inundation scenarios, and a moderate and high risk level in the existing erosion and inundation scenarios respectively.
- All roads, except Frenchmans Terrace in Penneshaw, are at moderate to extreme risk levels in the 2100 inundation scenario.

TABLE 8-8 CONSEQUENCE RATING FOR AFFECTED ROADS IN BAY OF SHOALS / KINGSCOTE / BROWNLOW

Percent of Road affected (%)	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
Third Street	0	0	100	0	89	92
First Street	0	13	100	0	93	100
North West Terrace	0	0	100	0	76	99
Samphire Road	0	9	92	0	100	100
High Street	0	7	100	0	68	100
Links Road	0	1	34	2	42	100
Governor Wallen Drive	8	11	29	11	35	70
The Parade	0	100	100	1	90	100

A few roads in the Bay of Shoals, Kingscote and Brownlow region are at a low to medium risk of inundation and erosion in the existing scenario. The Parade is at a extreme risk in the 2050 erosion scenario and Samphire Road is at extreme risk in the 2050 erosion and inundation scenarios. All the other roads in the 2050 inundation scenario are at medium to high risk. All of the roads are at risk in the 2100 erosion and inundation scenarios, with 6 being at extreme risk levels from erosion, and 7 from inundation.

TABLE 8-9 CONSEQUENCE RATING FOR AFFECTED ROADS IN NEPEAN BAY

Percent of Road affected (%)	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
Marina Crescent	0	0	100	5	100	100
Nepean Esplanade	20	100	100	81	100	100
Ocean View Drive	0	0	100	27	85	100
Western Cove Road	0	4	64	66	82	82

Most of the affected roads in Nepean Bay will be at a extreme risk from both erosion and Inundation in the 2100 scenario. Western Cover road will be at a high risk through all inundation scenarios and the 2100 erosion scenario. The roads are more at risk from inundation than erosion in existing scenarios.

TABLE 8-10 CONSEQUENCE RATING FOR AFFECTED ROADS IN AMERICAN RIVER

Percent of Road affected (%)	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
Bimberta Avenue	0	0	0	33	36	100
Moreanda Avenue	0	0	0	30	41	100
Tangara Drive	0	0	0	32	64	89
Trethewey Court	0	0	0	0	0	23

The roads in American River are not affected by erosion scenarios. They are at medium to high risk in the 2050 Inundation scenario and two roads are at a extreme risk in the 2100 inundation scenario.

TABLE 8-11 CONSEQUENCE RATING FOR AFFECTED ROADS IN PENNESHAW

Percent of Road affected (%)	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
Frenchmans Terrace	5	9	54	0	0	0

Frenchmans Terrace in Penneshaw is not at risk from Inundation but is at a low risk from the existing and 2050 erosion scenario. This jumps to a high risk in the 2100 erosion scenario.

8.4 Private Asset Risk

Private assets at risk have also been assessed. The cadastre information provided by Council has been used to intersect property parcels with the erosion and inundation extents for the existing, 2050 and 2100 sea level rise scenarios, including provision for storm tide impacts. For each private land parcel within a hazard extent, the percentage of the parcel affected by the hazard was then calculated.

Each property parcel was assigned a consequence rating on the criteria detailed in Table A-2, but also incorporating the % of property parcel affected, as shown in Table 8-12. Likelihood ratings are the same as for the pubic asset assessment. Each table is coloured coded according to the risk rating, described in Table A-4. The results of this analysis are presented in Table 8-8 to 8-21.

TABLE 8-12 CONSEQUENCE RATING FOR PROPERTY PARCELS

Consequence Rating	% of Property Parcel Affected
Insignificant	< 1
Minor	1 – 10
Medium	10 – 40
Major	40 – 100
Extreme	100

TABLE 8-13 AMERICAN RIVER PROPERTY PARCELS CONSEQUENCE RATING

% of Property Parcel Affected	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
< 1	1	1	0	2	1	1
1 – 10	0	0	1	7	7	3
10 – 40	0	1	0	5	12	8
40 – 100	0	0	1	12	18	42
100	0	0	0	5	12	38

In American River only 1 property is at high risk from future erosion scenarios, however there are 38 properties which are 100% inundated and at extreme risk in the 2100 inundation scenario.

TABLE 8-9 ANTECHAMBER BAY PROPERTY PARCELS CONSEQUENCE RATING

% of Property Parcel Affected	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
< 1	0	0	1	2	2	1
1 – 10	0	2	1	1	1	3
10 – 40	0	0	2	3	3	3
40 – 100	0	0	2	3	3	3
100	0	0	0	0	0	0

Antechamber Bay has two properties at a high-risk level in the 2100 Erosion scenario and 3 properties at high risk in the 2100 Inundation Scenario.

TABLE 8-10 BROWN BEACH PROPERTY PARCELS CONSEQUENCE RATING

% of Property Parcel Affected	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
< 1	0	0	0	0	0	0
1 – 10	2	1	0	3	3	2
10 – 40	0	2	1	0	0	1
40 – 100	0	0	6	0	0	0
100	0	0	0	0	0	0

Brown Beach has mostly low to moderate risk, but 6 properties are at a high risk in the 2100 Erosion scenario.

TABLE 8-11 BROWNLOW PROPERTY PARCELS CONSEQUENCE RATING

% of Property Parcel Affected	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
< 1	6	4	3	3	5	2
1 – 10	6	12	9	0	7	5
10 – 40	3	13	11	4	5	5
40 – 100	0	10	11	3	26	7
100	0	0	114	0	92	118

Private assets are significantly impacted in Brownlow, with 114 properties at a extreme risk level in the 2100 erosion scenario, and the 118 properties in the 2100 inundation scenario. There is low to moderate risk to private assets in the existing and 2050 inundation and erosion scenarios.

TABLE 8-12 D'ESTREES BAY PROPERTY PARCELS CONSEQUENCE RATING

% of Property Parcel Affected	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
< 1	0	0	0	0	0	1
1 – 10	0	0	0	0	0	2
10 – 40	0	0	0	1	0	0
40 – 100	0	0	0	3	4	4
100	0	0	0	0	0	0

There is no risk to private assets from any erosion scenario in D'Estrees Bay. There is a moderate to high risk to private property in the 2100 inundation scenario.

TABLE 8-13 EMU BAY PROPERTY PARCELS CONSEQUENCE RATING

% of Property Parcel Affected	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
< 1	0	0	1	3	3	2
1 – 10	1	0	0	4	4	3
10 – 40	0	1	3	2	2	3
40 – 100	0	0	2	0	0	1
100	0	0	4	1	1	1

The private assets in Emu Bay are at moderate to extreme risk in the 2100 Erosion and Inundation scenarios. There are also private properties with low to moderate risk in the existing erosion and inundation scenarios.

TABLE 8-14 ISLAND BEACH PROPERTY PARCELS CONSEQUENCE RATING

% of Property Parcel Affected	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
< 1	2	0	0	0	1	0
1 – 10	0	3	2	3	4	4
10 – 40	0	0	33	0	5	8
40 – 100	0	0	44	0	0	4
100	0	0	3	0	0	0

There is a moderate to extreme risk to private property in the 2100 erosion scenario in Island Beach, with 44 properties at high risk and 3 and extreme risk. In the 2100 inundation scenario, there are 4 properties at high risk.

TABLE 8-15 KINGSCOTE PROPERTY PARCELS CONSEQUENCE RATING

% of Property Parcel Affected	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
< 1	0	1	0	3	2	2
1 – 10	1	1	2	9	13	5
10 – 40	1	0	4	10	12	22
40 – 100	0	1	1	3	6	16
100	0	0	1	0	0	2

Kingscote has one property at a extreme risk and 2 properties at a high level risk in the 2100 erosion scenario. There are also 16 properties at high level risk and 2 properties at the extreme risk level in the 2100 inundation scenario.

TABLE 8-16 MUSTON PROPERTY PARCELS CONSEQUENCE RATING

% of Property Parcel Affected	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
< 1	1	1	0	0	1	0
1 – 10	0	0	1	1	1	2
10 – 40	0	0	1	1	1	0
40 – 100	0	0	0	0	0	1
100	0	0	0	0	0	0

There are low to moderate risk levels to private property from erosion and inundation, but there is one property that is at a high risk level in the inundation 2100 scenario in Muston.

TABLE 8-17 NEPEAN BAY PROPERTY PARCELS CONSEQUENCE RATING

% of Property Parcel Affected	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
< 1	1	0	0	3	1	0
1 – 10	0	0	3	5	8	2
10 – 40	0	2	9	13	16	0
40 – 100	0	23	2	41	49	31
100	0	0	94	5	30	77

The private assets in Nepean Bay are at a moderate to extreme risk in both the erosion and inundation 2100 scenario. 94 properties are at extreme risk of being 100% impacted by the 2100 erosion scenario, with 77 at extreme risk in the inundation 2100 scenario. The number of properties affected includes all those within the flood or erosion hazard extents and so rural areas outside the main township of Nepean Bay are also included in the count of properties at risk.

TABLE 8-18 PELICAN LAGOON PROPERTY PARCELS CONSEQUENCE RATING

% of Property Parcel Affected	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
< 1	3	4	1	1	0	0
1 – 10	0	1	4	3	4	2
10 – 40	1	1	1	3	3	2
40 – 100	0	0	1	1	1	2
100	0	0	0	0	0	0

The private assets in Pelican Lagoon are at moderate to high risk in both the erosion 2100 scenario and inundation 2100 scenario. There is 1 property in the erosion 2100 scenario at high risk and 2 in the inundation 2100 scenario.

TABLE 8-19 PENNESHAW PROPERTY PARCELS CONSEQUENCE RATING

% of Property Parcel Affected	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
< 1	1	1	5	0	0	0
1 – 10	0	2	9	1	1	0
10 – 40	2	3	4	4	4	3
40 – 100	0	0	10	1	1	3
100	0	0	17	1	1	1

Penneshaw has a significant extreme risk to private property, with 17 properties at risk in the 2100 erosion scenario and 1 in the 2100 inundation scenario. There is also one property that is at risk of 100% inundation in the existing inundation scenario.

TABLE 8-20 SAPPHIRE TOWN PROPERTY PARCELS CONSEQUENCE RATING

% of Property Parcel Affected	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
< 1	0	0	0	0	0	1
1 – 10	0	0	0	1	0	0
10 – 40	0	0	2	1	0	1
40 – 100	0	0	1	2	4	1
100	0	0	0	0	0	3

There are 3 properties at extreme risk of being 100% affected by the 2100 inundation scenario. There is also a moderate to high risk of private property being affected by the 2100 erosion scenario.

9 MONETARY VALUE OF ASSETS

The purpose of this section is to determine a financial value for the assets that have been identified as at risk to coastal erosion or inundation and for which the Council considers it has some responsibility or liability. Given there is generally conjecture of responsibility for some assets and private property these have also been included for consideration in the assessment. Where the value of the asset was unable to be obtained, these have been listed as data gaps for Council to include at a later date.

9.1 Public Asset Values

Public assets that are subject to erosion or inundation are represented within the 'Other Assets' category. Monetary values for these assets are estimated based on information provided by Council where available.

Pumping stations and pipes/drains were assigned a monetary value using a percentage of the total monetary value of these assets within each area.

Total monetary costs for assets within the erosion and inundation extents is summarised in Table 9-1 to Table 9-7. Within each table, "no data" represents where there was no cost information available for an asset category that was within the erosion or inundation extent. Additionally, in the asterisked values indicate where the cost data is incomplete.

It is important to note that there are some assets of historical and cultural significance that do not have a monetary value, but hold high significance to the community, such as Reeves Point in Kingscote. Additionally damage to some assets will not result in complete loss of value, but rather the need for repairs, such as Kingscote Tidal Pool, CWMS pump stations and roads. Wharfs and jetties in Penneshaw, Kingscote and Emu Bay are owned by DPTI and leased to Council for 99 years.

TABLE 9-1 AMERICAN RIVER MONETARY VALUE OF ASSETS AT RISK

	Erosion			Inundation		
Assets	Existing	2050	2100	Existing	2050	2100
Pumping Stations	-	-	-	$312,500	$468,750	$625,000
Pipes/Drains	-	-	-	$392,400	$490,000	$679,700
Boat ramps / Marinas/ Breakwaters	No Data	No Data	No Data	No Data	No Data	No Data
Other Assets	-	-	$685,000	$1,500,000	$1,530,000	$1,565,000

TABLE 9-2 BROWNLOW MONETARY VALUE OF ASSETS AT RISK

	Erosion			Inundation		
Assets	Existing	2050	2100	Existing	2050	2100
Pumping Stations	-	-	$250,000	$250,000	$375,000	$375,000
Pipes/Drains	-	$427,650	$3,823,800	$1,285,500	$3,569,300	$3,752,000
Boat ramps / Marinas/ Breakwaters	No Data	No Data	No Data	No Data	No Data	No Data
Other Assets	No Data	No Data	No Data	No Data	No Data	No Data

TABLE 9-3 NEPEAN BAY MONETARY VALUE OF ASSETS AT RISK

	Erosion			Inundation		
Assets	Existing	2050	2100	Existing	2050	2100
Pumping Stations	-	-	-	-	-	-
Pipes/Drains		No Data	No Data	No Data	No Data	No Data
Jetties	-	-	-	-	-	-
Other Assets	No Data	No Data	No Data	No Data	No Data	No Data

TABLE 9-4 PENNESHAW MONETARY VALUE OF ASSETS AT RISK

	Erosion			Inundation		
Assets	Existing	2050	2100	Existing	2050	2100
Pumping Stations	-	-	-	-	-	-
Pipes/Drains	-	-	$93,100	$3,000	$3,000	$6,300
Jetties	-	-	-	-	-	-
Other Assets	No Data	No Data	No Data	$1,105,000	$1,105,000	$1,105,000

TABLE 9-5 KINGSCOTE MONETARY VALUE OF ASSETS AT RISK

	Erosion			Inundation		
Assets	Existing	2050	2100	Existing	2050	2100
Pumping Stations	-	-	-	-	-	-
Pipes/Drains	-	-	-	$16,200	$20,000	$24,500
Jetties	No Data	No Data	No Data	No Data	No Data	No Data
Other Assets	-	-	No Data	$1,800,000	$1,800,000	$1,800,000

TABLE 9-6 EMU BAY MONETARY VALUE OF ASSETS AT RISK

	Erosion			Inundation		
Assets	Existing	2050	2100	Existing	2050	2100
Pumping Stations	-	-	-	-	-	-
Pipes/Drains	-	-	-	-	-	-
Boat ramps / Marinas/ Breakwaters	No Data	No Data	No Data	$110,000	$110,000	$110,000
Other Assets	-	-	-	$283,135	$283,135	$283,135

TABLE 9-7 D'ESTREES BAY MONETARY VALUE OF ASSETS AT RISK

	Erosion			Inundation		
Assets	Existing	2050	2100	Existing	2050	2100
Pumping Stations	-	-	-	-	-	-
Pipes/Drains	-	-	-	-	-	-
Jetties	No Data	No Data	No Data	No Data	No Data	No Data
Other Assets	-	-	-	No Data	No Data	No Data

9.2 Road Values

The monetary value of the public roads that are subject to coastal erosion or inundation are detailed in Table 9-8. These values are estimated based on information provided by Council where available. The value was calculated using the percentage of road at risk. This percentage was then taken from the overall road value provided by Council to calculate the cost of each erosion and inundation scenario.

TABLE 9-8 MONETARY VALUE FOR AFFECTED ROADS IN NEPEAN BAY

Road Damages	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
Marina Crescent	-	-	$9,034	$410	$9,034	$9,034
Nepean Esplanade	$7,615	$37,371	$37,371	$30,426	$37,371	$37,371
Ocean View Drive	-	-	$18,354	$5,072	$15,686	$18,534
Western Cove Road	-	$714	$12,914	$15,537	$16,508	$18,706

TABLE 9-9 MONETARY VALUE FOR AFFECTED ROADS IN AMERICAN RIVER

Road Damages	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
Bimberta Avenue	-	-	-	$1,173	$1,262	$3,531
Moreanda Avenue	-	-	-	$1,308	$1,802	$4,366
Tangara Drive	-	-	-	$172,172	$314,326	$434,924
Trethewey Court	-	-	-	-	-	$1,130

TABLE 9-10 MONETARY VALUE FOR AFFECTED ROADS IN PENNESHAW

Road Damages	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
Frenchmans Terrace	$20,419	$38,191	$228,083	-	-	-

TABLE 9-11 MONETARY VALUE FOR AFFECTED ROADS IN BAY OF SHOALS/KINGSCOTE/BROWNLOW

Road Damages	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
Third Street	-	-	$272,284	-	$243,636	$249,505
First Street	-	$365	$2,807	-	$2,603	$2,807
North West Terrace	-	-	$13,001	-	$9,940	$12,867
Samphire Road	-	$724	$7,596	-	$8,198	$8,215
High Street	-	$3,138	$45,051	-	$30,836	$45,051
Links Road	-	$158	$7,056	$456	$8,637	$20,725
Governor Wallen Drive	$3,522	$4,875	$13,052	$4,911	$15,625	$30,992
The Parade	-	$13,302	$13,302	$77	$11,960	$13,302

9.3 Private Asset Values

To estimate values associated with private property assets, the average house price for Kangaroo Island ($259,500 as of 18 July 2018, (Investment Property Kangaroo Island SA, 2018)) was adopted as the likely costs associated with private property parcels. The private asset data, consequence rating based on the percentage of the property parcel impacted, and resultant risk tables from Section 8.3 were used to estimate the potential costs associated with the relevant erosion or inundation hazards for each area.

Table 9-12 provides a summary separately for erosion and inundation for each area for each planning horizon.

TABLE 9-12 SUMMARY OF VALUE OF PRIVATE ASSETS AFFECTED BY COASTAL HAZARDS

Property Parcel Damages	Estimated Value of Assets Affected by Coastal Hazards					
	Erosion			Inundation		
	Existing	2050	2100	Existing	2050	2100
American River	$2,595	$67,470	$194,625	$3,897,690	$7,255,620	$18,050,820
Antechamber	$0	$25,950	$508,620	$757,740	$757,740	$781,095
Brown Beach	$25,950	$142,725	$1,154,775	$38,925	$38,925	$90,825
Brownlow	$288,045	$2,825,955	$32,419,335	$812,235	$29,025,075	$32,286,990
D'Estrees Bay	$0	$0	$0	$609,825	$726,600	$755,145
Emu Bay	$12,975	$64,875	$1,598,520	$448,935	$448,935	$679,890
Island Beach	$5,190	$38,925	$10,937,925	$38,925	$378,870	$1,297,500
Kingscote	$77,850	$197,220	$726,600	$1,318,260	$2,042,265	$4,922,715
Muston	$2,595	$2,595	$77,850	$77,850	$80,445	$207,600
Nepean Bay	$2,595	$4,307,700	$25,379,100	$9,661,185	$17,830,245	$25,638,600
Pelican Lagoon	$72,660	$88,230	$301,020	$417,795	$428,175	$519,000
Penneshaw	$132,345	$223,170	$6,617,250	$713,625	$713,625	$999,075
Sapphiretown	$0	$0	$311,400	$441,150	$726,600	$1,027,620

10 SUMMARY

10.1 Overview

The coastal assets, public land and infrastructure within the vicinity of the coastline are subject to increased risk, and to date limited consideration has been given to the likely long-term management requirements to address this risk.

The primary objective of the study is to understand and map the existing coastal hazards and the associated risk to coastal assets, public land and infrastructure and from this to develop coastal adaptation strategies across the affected communities for Council and other Stakeholders such as State Government and private landholders. This assessment has focussed on the eastern section of the Kangaroo Island coastline, from Smith Bay in the north to Point Tinline in the south.

10.2 Coastal Hazard Mapping

Erosion Hazard Assessment

The Coastal Policy (Coast Protection Board, 2016) indicates coastal erosion should be assessed for a 100-year timeframe. The policy recommends consideration of local long-term erosion or accretion trends, potential storm erosion, as well as likely recession due to sea level rise. The assessment approach for each of these components and their applicability to a section of coast depends on the local coastal morphology, with sandy coasts responding differently to oceanographic (wind, wave and current) forces compared to steeper or more resistant coastlines.

For this assessment the different coastal morphologies across the study area have been identified and then the most relevant approach to quantify the potential for coastal erosion under current and future conditions has been applied. The resultant coastal hazard zones have been presented in map form.

Inundation Hazard Assessment

Coastal inundation includes both long-term and short-term inundation conditions. Long-term inundation is likely to occur as a result of a change in the mean water level and tidal range as a result of sea level rise. Short-term inundation is associated with extreme water levels and waves, occurs under current mean sea level conditions, and will be increased as a result of sea level rise.

For this assessment both long-term and short-term and coastal inundation have been mapped across the study area to quantity the potential for coastal inundation under current and future conditions. As with the erosion hazards, inundation hazard zones have been presented in map form.

Groundwater Hazard Assessment

Although groundwater is generally not considered within the scope of a coastal hazard assessment, there are potential impacts to groundwater systems that may occur as a result of future changes in sea level. For this project an initial review of the groundwater systems within the study area has been undertaken to identify what the potential impacts may be in the future. Insufficient information is currently available to map future groundwater hazards. However, preliminary locations have been identified where further investigations into groundwater hazards may be warranted in the future.

10.3 Asset and Infrastructure Risks

An analysis has been carried out to identify the assets that may be at risk from coastal inundation or erosion (whether in public or private ownership). The risk profiles developed will subsequently be used to identify priority areas to inform the adaptation strategy.

Risk profiles have been developed for all assets by assigning scores to the consequence of each relevant coastal hazard and the likelihood of this coastal hazard impacting the asset over the planning periods being considered within this study. The risk profile is determined by applying the likelihood and consequence ratings to a risk matrix.

Key observations of the results of the public asset risk assessment include:

- The majority of wastewater pumping stations were not at risk of inundation or erosion hazards, however at American River and Brownlow Beach, there is a total of 8 and 6 stations at risk respectively. The number of at-risk pumping stations is represented as a percentage of the total number of pumping stations per area.
- The public assets at Penneshaw have a relatively low risk rating, however under the 2100 erosion scenario there is a extreme risk to the pipe/drain network.
- For pipes and drains, the number of assets identified was calculated in relation to the length of infrastructure, represented by a percentage of the total length within each area. There were no impacted pipes and drains in Emu Bay or D'Estrees Bay.

The percent of public roads at risk from coastal erosion or inundation hazards for each community were analysed. This percentage was used as a guide to estimate the value of the risk.

Key observations of the results of the public road risk assessment include:

- The majority of roads assessed are at extreme risk levels in the 2100 erosion and inundation scenarios.
- The major roads in American River are not impacted by any erosion scenarios.
- Frenchmans Terrace in Penneshaw is not impacted by any inundation scenarios.
- The worst affected road is Nepean Esplanade in Nepean Bay, which is at a extreme risk level in the 2050 and 2100 erosion and inundation scenarios, and a moderate and high-risk level in the existing erosion and inundation scenarios respectively.
- All roads analysed, except Frenchmans Terrace in Penneshaw, are at moderate to extreme risk levels in the 2100 inundation scenario.

Potential impacts and risks to private assets were also assessed. The property parcel information provided by Council was compared to the erosion and inundation mapping for the existing, 2050 and 2100 sea level rise scenarios. For each private land parcel within a hazard extent, the percentage of the parcel affected by the hazard was then calculated.

From this information a financial value for the assets that have been identified as at risk to coastal erosion or inundation has been estimated. Where the value of the asset was unable to be obtained, these have been listed as data gaps. This information can be used to prioritise future adaptation strategies or responses and support applications for funding to undertake future assessments and projects.

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APPENDIX A
RISK ASSESSMENT DEFINITIONS

TABLE A-1 LIKELIHOOD RANKING

Likelihood Level	Description	Annual Exceedance Probability
1 – Rare	Recurrent events are unlikely to occur more than once per century. Single events are not expected to occurred but are possible.	< 1%
2 – Unlikely	Recurrent events are expected to occur only 1-2 times per century. Single events are unlikely.	1-10%
3 – Possible	Recurrent events are expected to occur every decade or so. Single events are less likely than not.	10 – 50%
4 – Likely	Recurrent events are expected several times each decade. Single event more likely to occur than not	50 - 90%
5 – Almost Certain	Recurrent events expected to happen several times per year. Single event highly likely.	> 90% probability

TABLE A-2 CONSEQUENCE RANKING

Consequence Level	Social	Economic	Environment
5 – Catastrophic	Loss of life and serious injury. Large long-term or permanent loss of services, employment wellbeing, finances or culture (e.g. > 75% of community affected), no suitable alternative sites exist.	Permanent loss or damage to property, plant and equipment	Permanent loss of flora or fauna (no chance of recovery) with national impact.
4 – Major	Serious injury. Medium-term disruption to services, employment wellbeing, finances or culture (e.g. < 50% of community affected), very limited suitable alternative sites exist.	Permanent loss or damage to property, plant and equipment	Long term loss of flora and fauna (limited change of recovery) with regional impact.
3 – Moderate	Minor injury. Major short-term or minor long-term disruption to services, employment wellbeing, finances or culture (e.g. < 25% of community affected), limited suitable alternative sites exist.	Significant loss or damage to property, plant and equipment	Medium term loss of flora and fauna (recovery likely) with regional impact.
2 – Minor	Small to medium disruption to services, employment wellbeing, finances or culture (e.g. < 10% of community affected), many suitable alternative sites exist.	Loss or damage to property, plant and equipment	Short term loss of flora and fauna (strong recovery) with local impact.
1 – Insignificant	Minimal short-term inconveniences to services, employment wellbeing, finances or culture (e.g. < 5% of community affected), many alternative sites exist.	Minor loss or damage to property, plant and equipment	Negligible to no loss of flora and fauna (strong recovery) with local impact.

TABLE A-3 RISK ASSESSMENT MATRIX

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

TABLE A-4 RISK PROFILE DEFINITION

Risk Profile	Definition
Low	Tolerable risk. A level of risk that is low and manageable without intervention.
Medium	A level to frisk that may require intervention to mitigate.
High	A level of risk requiring significant intervention to mitigate.
Extreme	Immediate action required.

APPENDIX B
ASSET MAPPING


EMU BAY
Erosion
Existing
2050
2100
Marine Infrastructure
Car Park
Educational Facility
Marine Infrastructure
Drain/Pipe
Cadastre
Affected Cadastre (Erosion 2100)
Data Sources: Water Technology 2018
Imagery: SA DEWNR Kangaroo Island 2015
0
0.25
0.5
0.75
1
Kilometers
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20/07/2018


EMU BAY
Inundation
Existing
2050
2100
Marine Infrastructure
Car Park
Educational Facility
Marine Infrastructure
Drain/Pipe
Cadastre
Affected Cadastre (Inundation 2100)
Data Sources: Water Technology 2018
Imagery: SA DEWNR Kangaroo Island 2015
0
0.25
0.5
0.75
1
Kilometers
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20/07/2018


KINGSCOTE
Erosion
Existing
2050
2100
Marine Infrastructure
Car Park
Playground; Pool
Public BBQ
Community Buildings
Conservation Park; Park; Plain
Marine Infrastructure
Historic Sites
Hospital
Public Service Buildings
Educational Facility
Quarry
Telephone Exchange
Pumping Station
Drain/Pipe
Cadastre
Affected Cadastre (Erosion 2100)
Data Sources: Water Technology 2018
Imagery: SA DEWNR Kangaroo Island 2015
0
0.5
1
1.5
2
Kilometers
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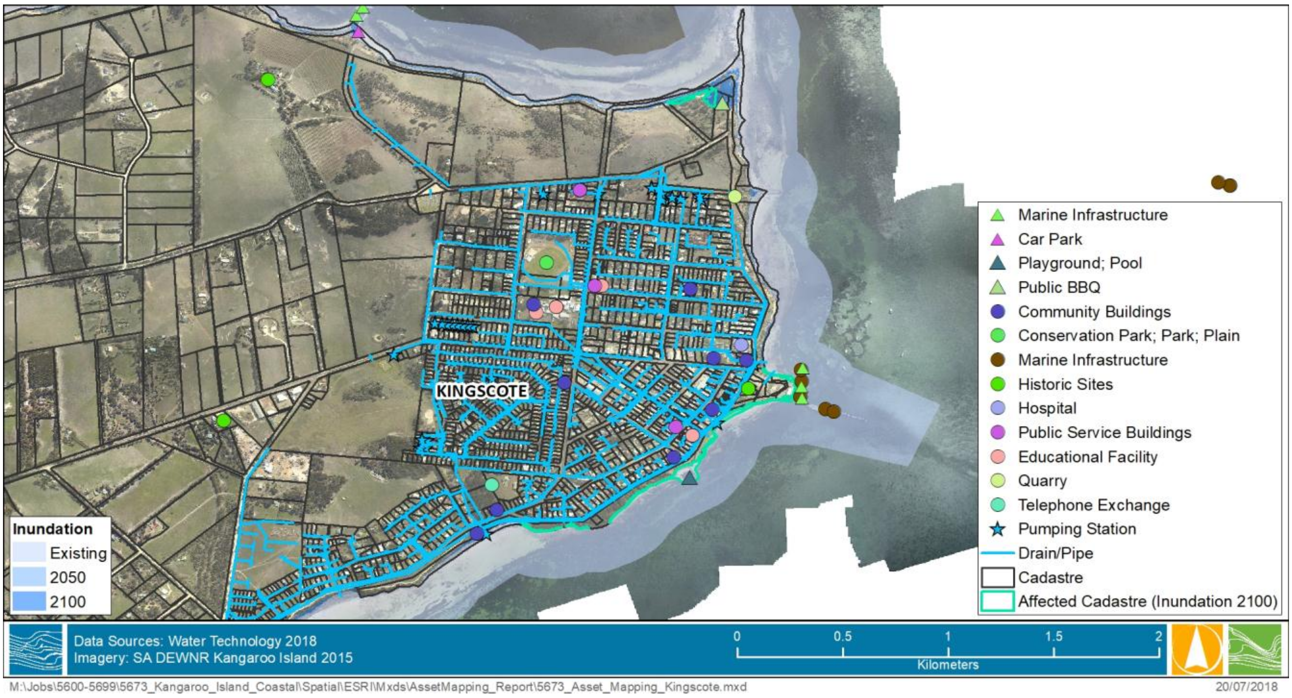
KINGSCOTE
Inundation
Existing
2050
2100
Marine Infrastructure
Car Park
Playground; Pool
Public BBQ
Community Buildings
Conservation Park; Park; Plain
Marine Infrastructure
Historic Sites
Hospital
Public Service Buildings
Educational Facility
Quarry
Telephone Exchange
Pumping Station
Drain/Pipe
Cadastre
Affected Cadastre (Inundation 2100)
Data Sources: Water Technology 2018
Imagery: SA DEWNR Kangaroo Island 2015
0
0.5
1
1.5
2
Kilometers
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20/07/2018


BROWNLOW
Erosion
Existing
2050
2100
Community Buildings
Caravan/Camp Ground
Conservation Park; Park; Plain
Golf Course
Historic Sites
Pumping Station
Drain/Pipe
Drain/Pipe
Cadastre
Affected Cadastre (Erosion 2100)
Data Sources: Water Technology 2018
Imagery: SA DEWNR Kangaroo Island 2015
0 0.5 1 1.5 2
Kilometers
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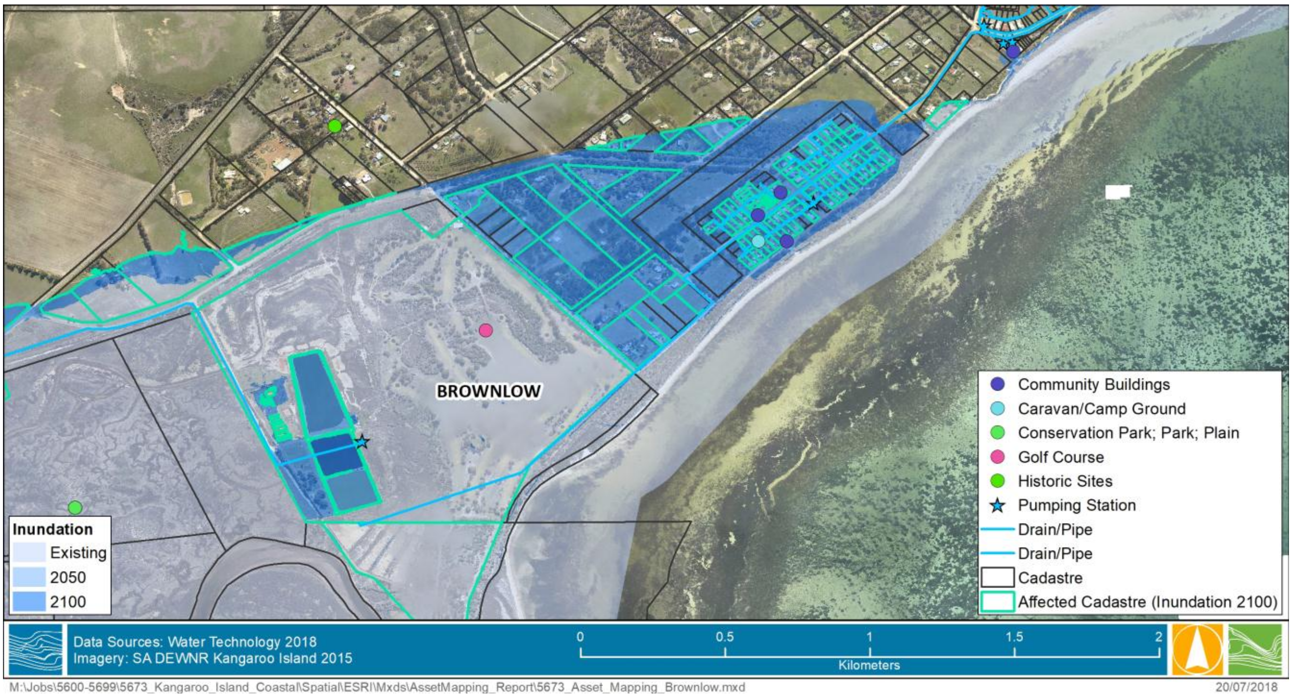
BROWNLOW
Inundation
Existing
2050
2100
Community Buildings
Caravan/Camp Ground
Conservation Park; Park; Plain
Golf Course
Historic Sites
Pumping Station
Drain/Pipe
Drain/Pipe
Cadastre
Affected Cadastre (Inundation 2100)
Data Sources: Water Technology 2018
Imagery: SA DEWNR Kangaroo Island 2015
0 0.5 1 1.5 2
Kilometers
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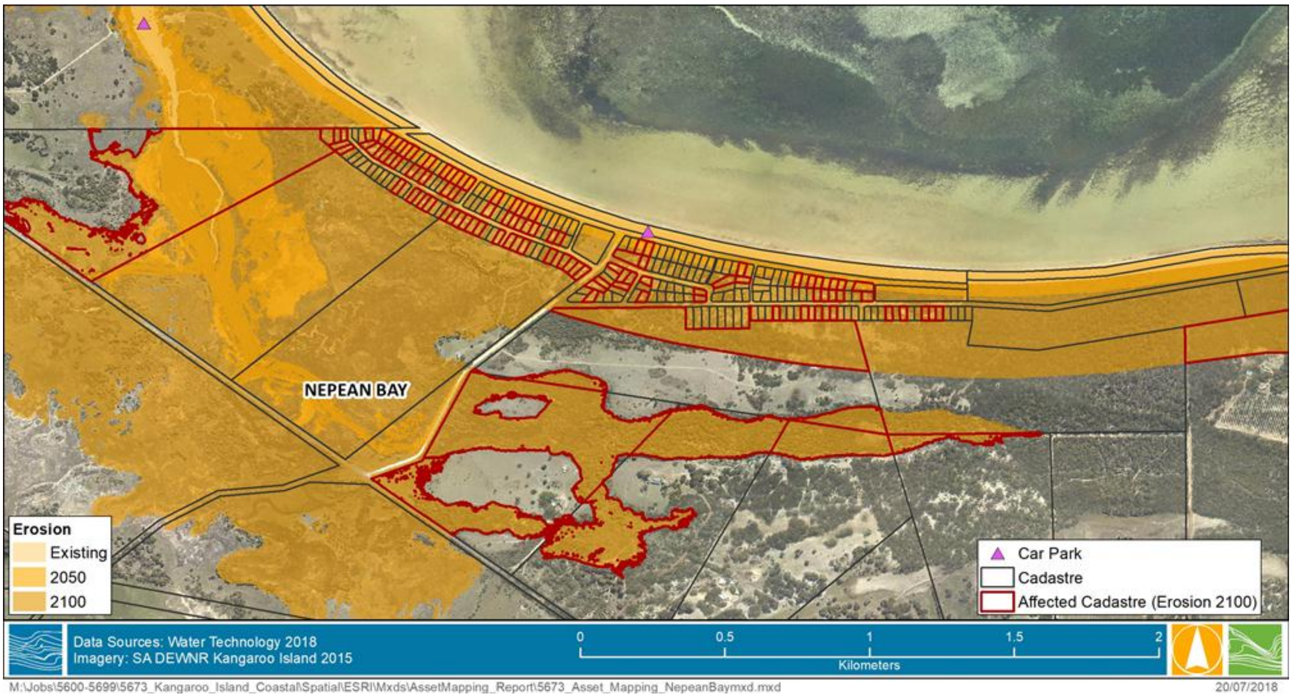
NEPEAN BAY
Erosion
Existing
2050
2100
Car Park
Cadastre
Affected Cadastre (Erosion 2100)
Data Sources: Water Technology 2018
Imagery: SA DEWNR Kangaroo Island 2015
0
0.5
1
1.5
2
Kilometers
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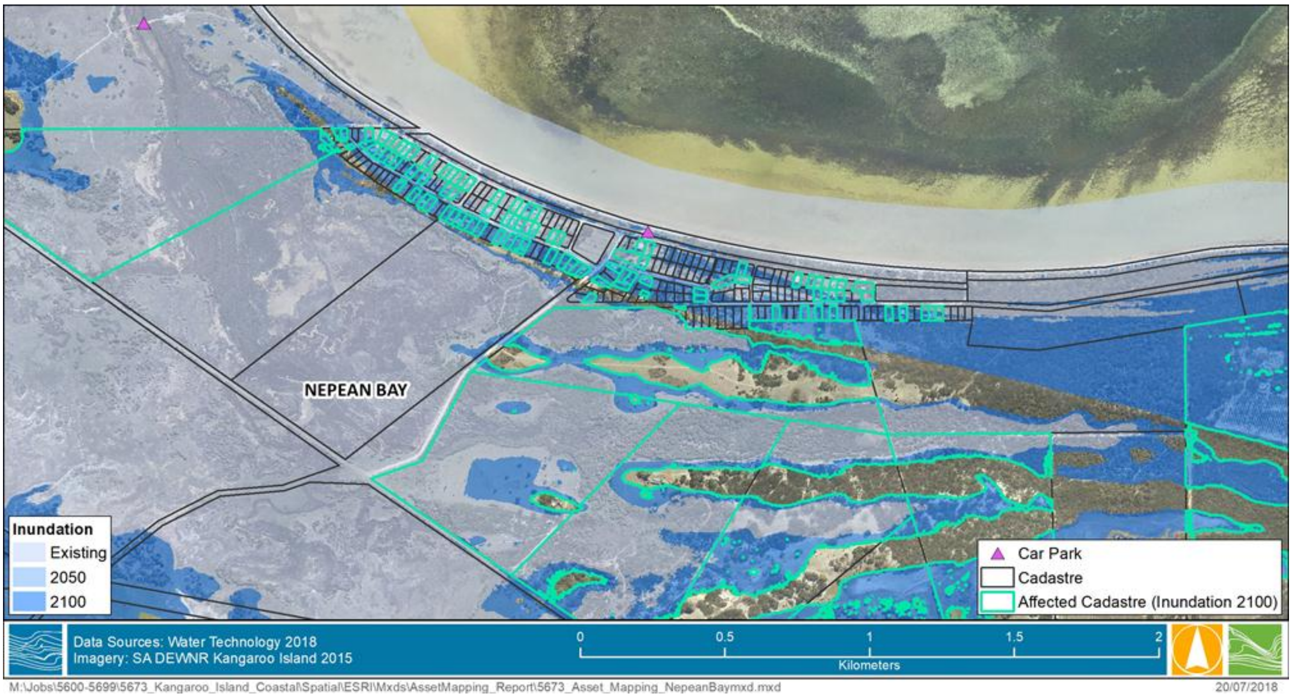
NEPEAN BAY
Inundation
Existing
2050
2100
Car Park
Cadastre
Affected Cadastre (Inundation 2100)
Data Sources: Water Technology 2018
Imagery: SA DEWNR Kangaroo Island 2015
0
0.5
1
1.5
2
Kilometers
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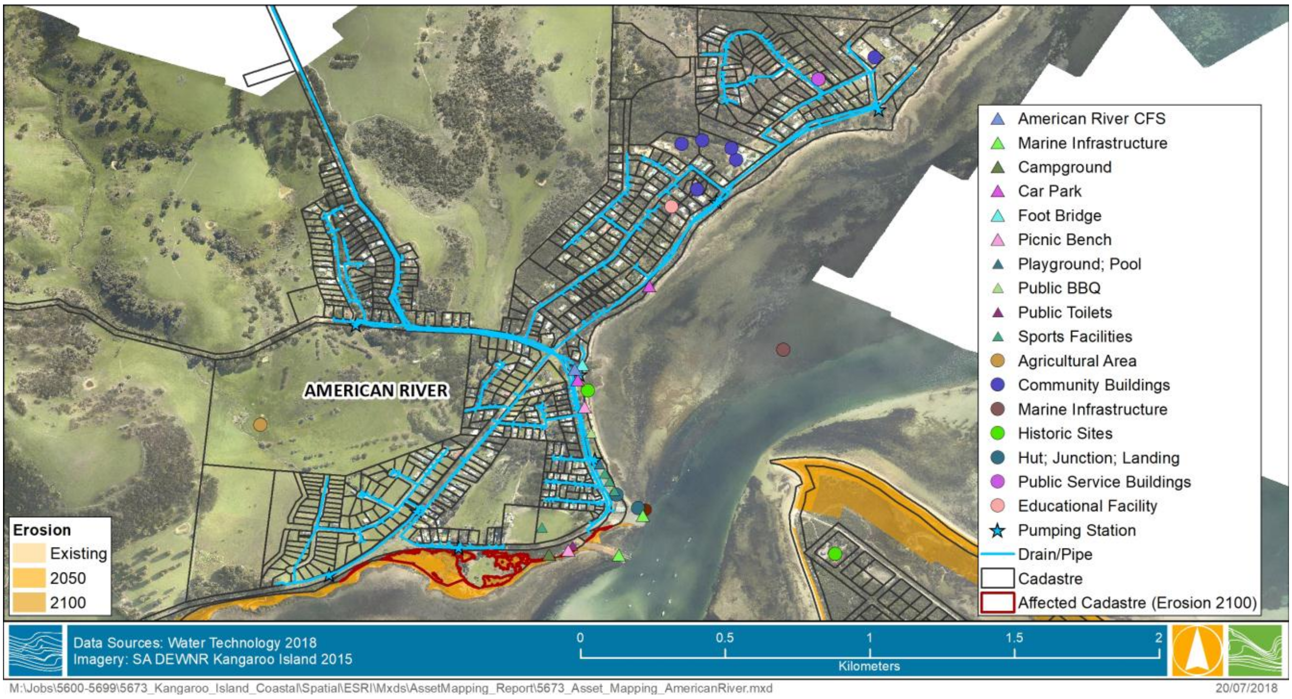
AMERICAN RIVER
Erosion
Existing
2050
2100
American River CFS
Marine Infrastructure
Campground
Car Park
Foot Bridge
Picnic Bench
Playground; Pool
Public BBQ
Public Toilets
Sports Facilities
Agricultural Area
Community Buildings
Marine Infrastructure
Historic Sites
Hut; Junction; Landing
Public Service Buildings
Educational Facility
Pumping Station
Drain/Pipe
Cadastre
Affected Cadastre (Erosion 2100)
Data Sources: Water Technology 2018
Imagery: SA DEWNR Kangaroo Island 2015
0
0.5
1
1.5
2
Kilometers
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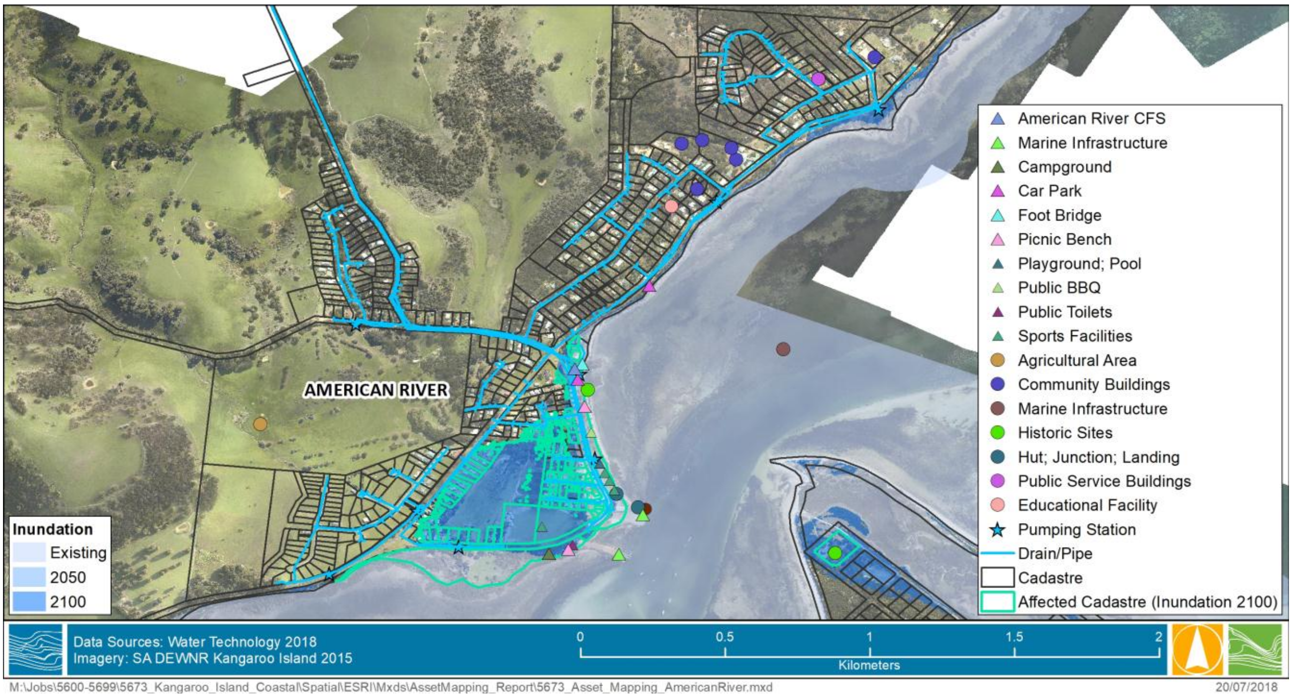
AMERICAN RIVER
Inundation
Existing
2050
2100
American River CFS
Marine Infrastructure
Campground
Car Park
Foot Bridge
Picnic Bench
Playground; Pool
Public BBQ
Public Toilets
Sports Facilities
Agricultural Area
Community Buildings
Marine Infrastructure
Historic Sites
Hut; Junction; Landing
Public Service Buildings
Educational Facility
Pumping Station
Drain/Pipe
Cadastre
Affected Cadastre (Inundation 2100)
Data Sources: Water Technology 2018
Imagery: SA DEWNR Kangaroo Island 2015
0
0.5
1
1.5
2
Kilometers
M:\Jobs\5600-5699\5673_Kangaroo_Island_Coastal\Spatial\ESRI\Mxds\AssetMapping_Report\5673_Asset_Mapping_AmericanRiver.mxd
20/07/2018


SAPPHIRETOWN
Erosion
Existing
2050
2100
Historic Sites
Cadastre
Affected Cadastre (Erosion 2100)
Data Sources: Water Technology 2018
Imagery: SA DEWNR Kangaroo Island 2015
0
0.25
0.5
0.75
1
Kilometers
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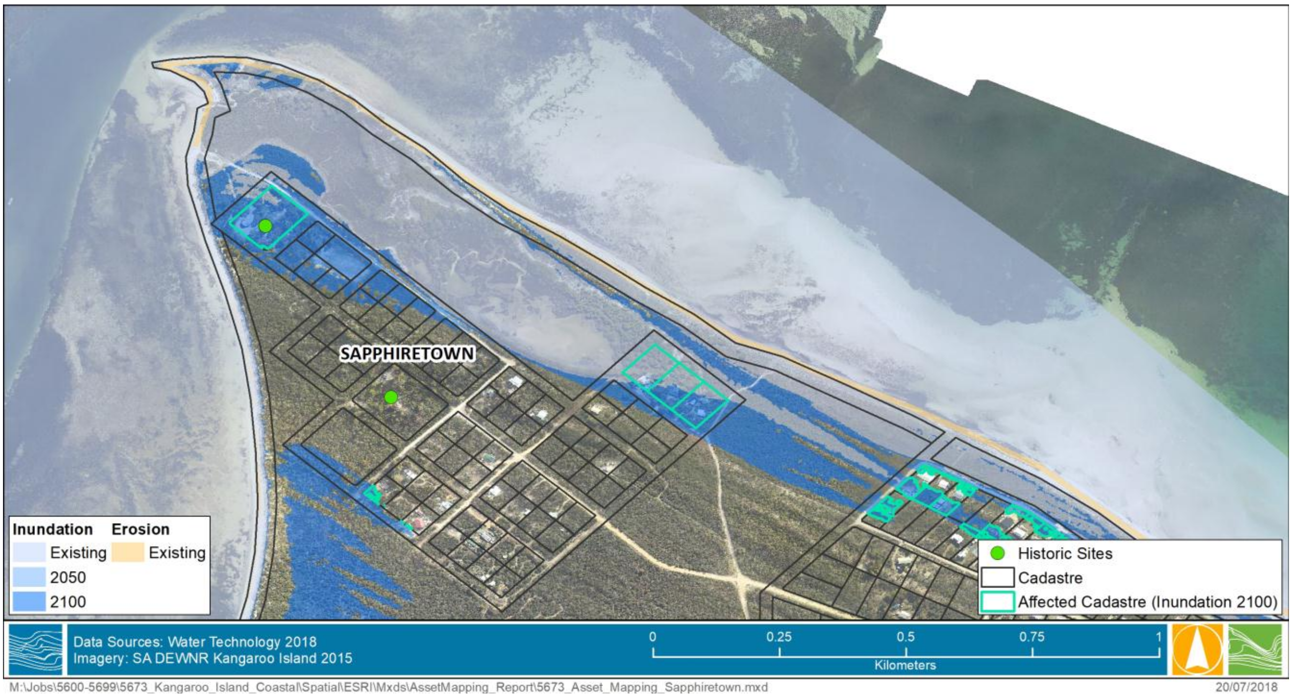
SAPPHIRETOWN
Inundation
Existing
2050
2100
Erosion
Existing
Historic Sites
Cadastre
Affected Cadastre (Inundation 2100)
Data Sources: Water Technology 2018
Imagery: SA DEWNR Kangaroo Island 2015
0
0.25
0.5
0.75
1
Kilometers
M:\Jobs\5600-5699\5673_Kangaroo_Island_Coastal\Spatial\ESRI\Mxds\AssetMapping_Report\5673_Asset_Mapping_Sapphiretown.mxd
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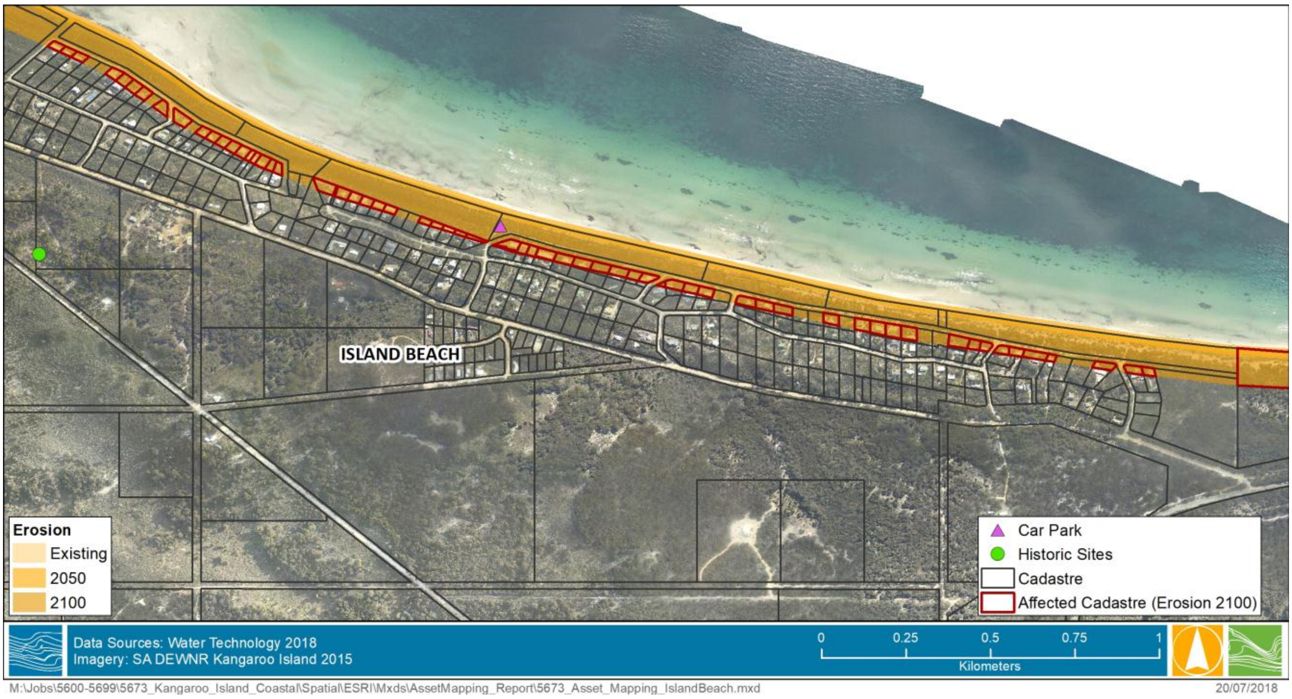
ISLAND BEACH
Erosion
Existing
2050
2100
Car Park
Historic Sites
Cadastre
Affected Cadastre (Erosion 2100)
Data Sources: Water Technology 2018
Imagery: SA DEWNR Kangaroo Island 2015
0
0.25
0.5
0.75
1
Kilometers
M:\Jobs\5600-5699\5673_Kangaroo_Island_Coastal\Spatial\ESRI\Mxds\AssetMapping_Report\5673_Asset_Mapping_IslandBeach.mxd
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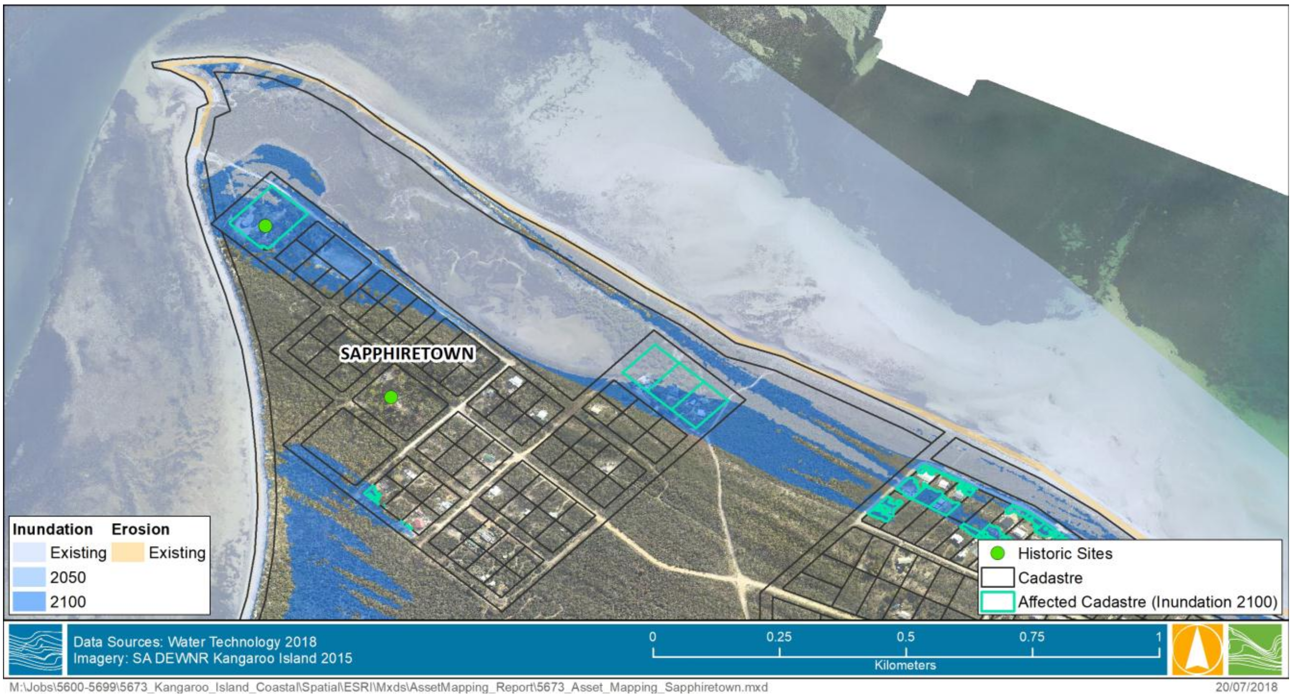
SAPPHIRETOWN
Inundation
Existing
2050
2100
Erosion
Existing
Historic Sites
Cadastre
Affected Cadastre (Inundation 2100)
Data Sources: Water Technology 2018
Imagery: SA DEWNR Kangaroo Island 2015
0
0.25
0.5
0.75
1
Kilometers
M:\Jobs\5600-5699\5673_Kangaroo_Island_Coastal\Spatial\ESRI\Mxds\AssetMapping_Report\5673_Asset_Mapping_Sapphiretown.mxd
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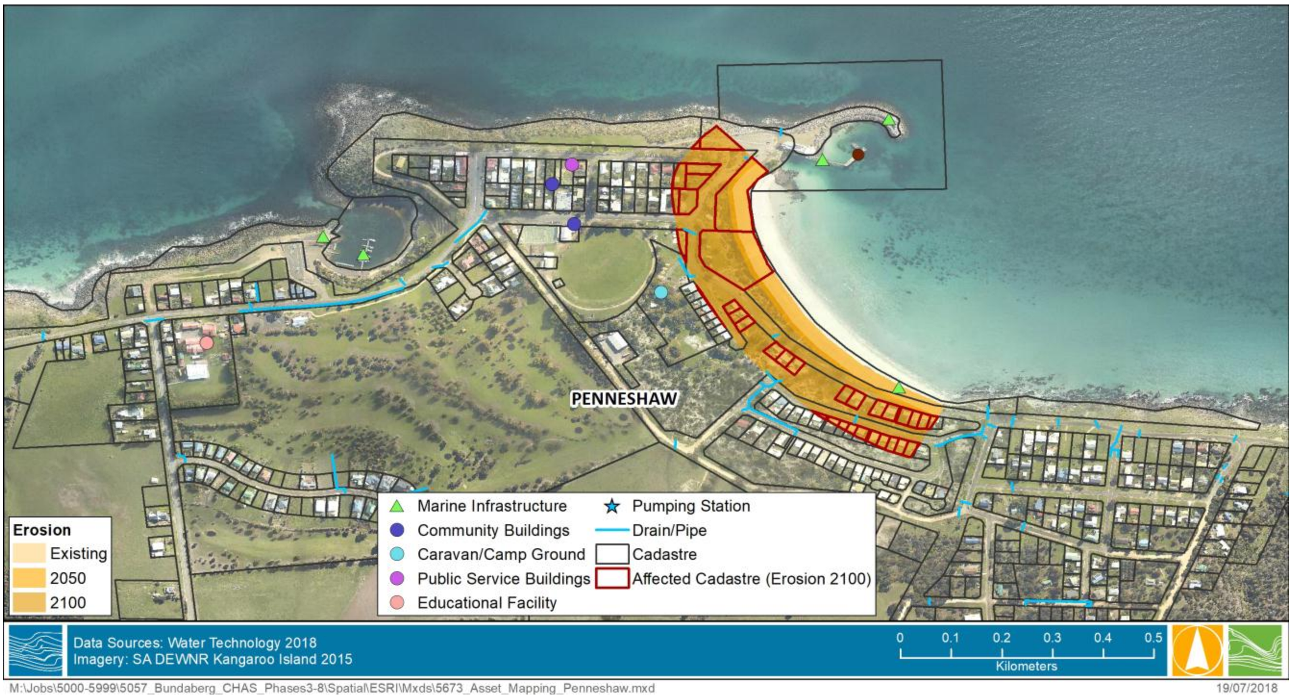

PENNESHAW
Erosion
Existing
2050
2100
Marine Infrastructure
Community Buildings
Caravan/Camp Ground
Public Service Buildings
Educational Facility
Pumping Station
Drain/Pipe
Cadastre
Affected Cadastre (Erosion 2100)
Data Sources: Water Technology 2018
Imagery: SA DEWNR Kangaroo Island 2015
0 0.1 0.2 0.3 0.4 0.5
Kilometers
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19/07/2018

PENNESHAW
Inundation
Existing
2050
2100
Marine Infrastructure
Community Buildings
Caravan/Camp Ground
Public Service Buildings
Educational Facility
Pumping Station
Drain/Pipe
Cadastre
Affected Cadastre (Inundation 2100)
Data Sources: Water Technology 2018
Imagery: SA DEWNR Kangaroo Island 2015
0 0.1 0.2 0.3 0.4 0.5
Kilometers
M:\Jobs\5600-5699\5673_Kangaroo_Island_Coastal\Spatial\ESRI\Mxds\AssetMapping_Report\5673_Asset_Mapping_Penneshaw.mxd
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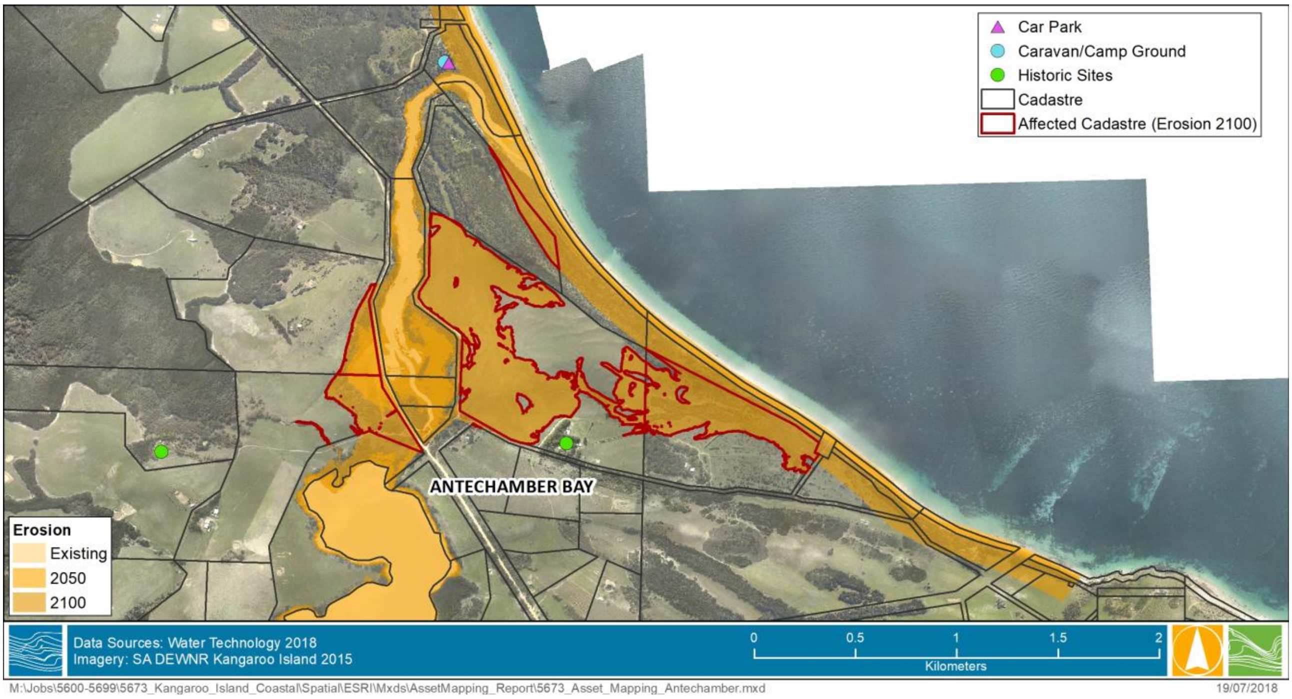
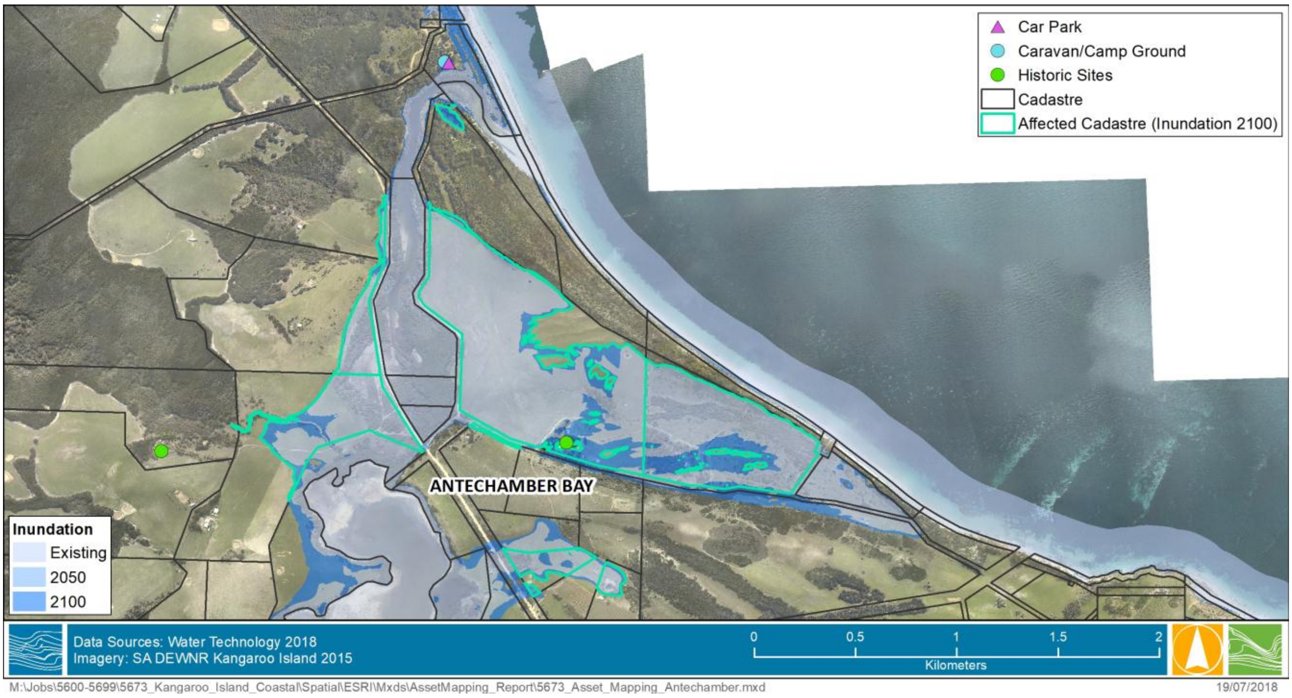

Car Park
Caravan/Camp Ground
Historic Sites
Cadastre
Affected Cadastre (Erosion 2100)
ANTECHAMBER BAY
Erosion
Existing
2050
2100
Data Sources: Water Technology 2018
Imagery: SA DEWNR Kangaroo Island 2015
0
0.5
1
1.5
2
Kilometers
M:\Jobs\5600-5699\5673_Kangaroo_Island_Coastal\Spatial\ESRI\Mxds\AssetMapping_Report\5673_Asset_Mapping_Antechamber.mxd
19/07/2018


Car Park
Caravan/Camp Ground
Historic Sites
Cadastre
Affected Cadastre (Inundation 2100)
ANTECHAMBER BAY
Inundation
Existing
2050
2100
Data Sources: Water Technology 2018
Imagery: SA DEWNR Kangaroo Island 2015
0
0.5
1
1.5
2
Kilometers
M:\Jobs\5600-5699\5673_Kangaroo_Island_Coastal\Spatial\ESRI\Mxds\AssetMapping_Report\5673_Asset_Mapping_Antechamber.mxd
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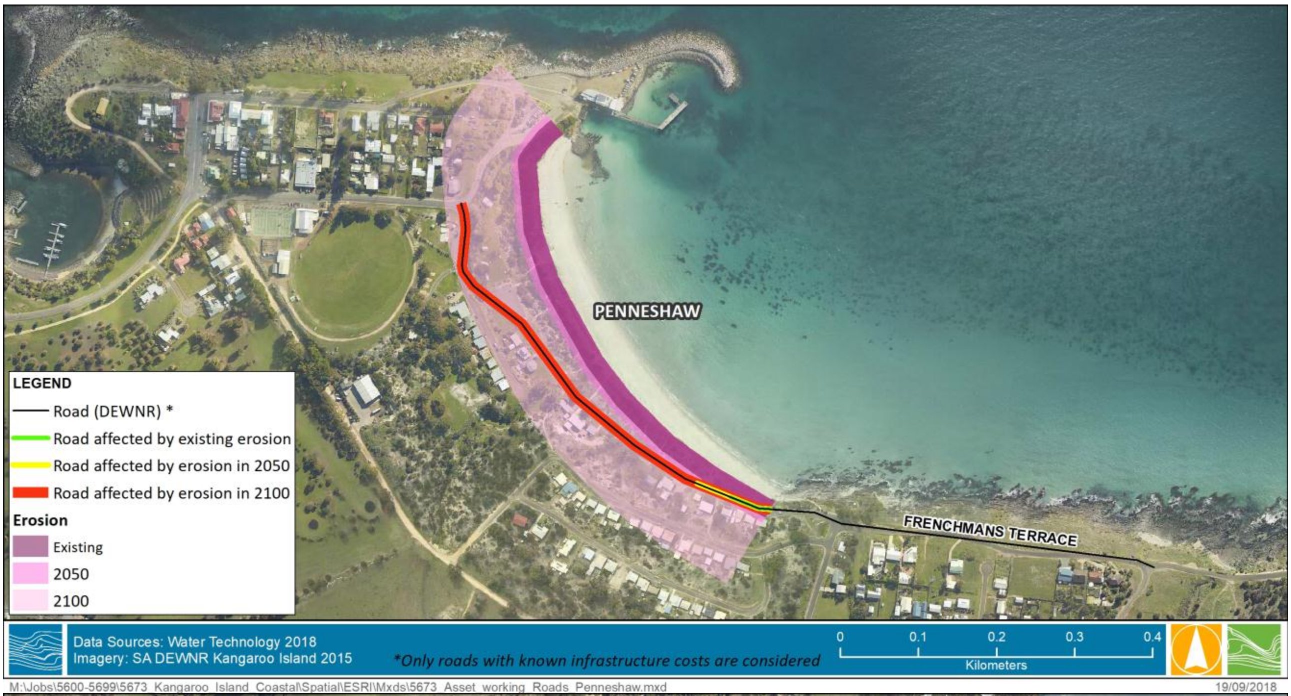
PENNESHAW
FRENCHMANS TERRACE
LEGEND
Road (DEWNR) *
Road affected by existing erosion
Road affected by erosion in 2050
Road affected by erosion in 2100
Erosion
Existing
2050
2100
Data Sources: Water Technology 2018
Imagery: SA DEWNR Kangaroo Island 2015
*Only roads with known infrastructure costs are considered
0 0.1 0.2 0.3 0.4
Kilometers
M:\Jobs\5600-5699\5673_Kangaroo_Island_Coastal\Spatial\ESRI\Mxds\5673_Asset_working_Roads_Penneshaw.mxd
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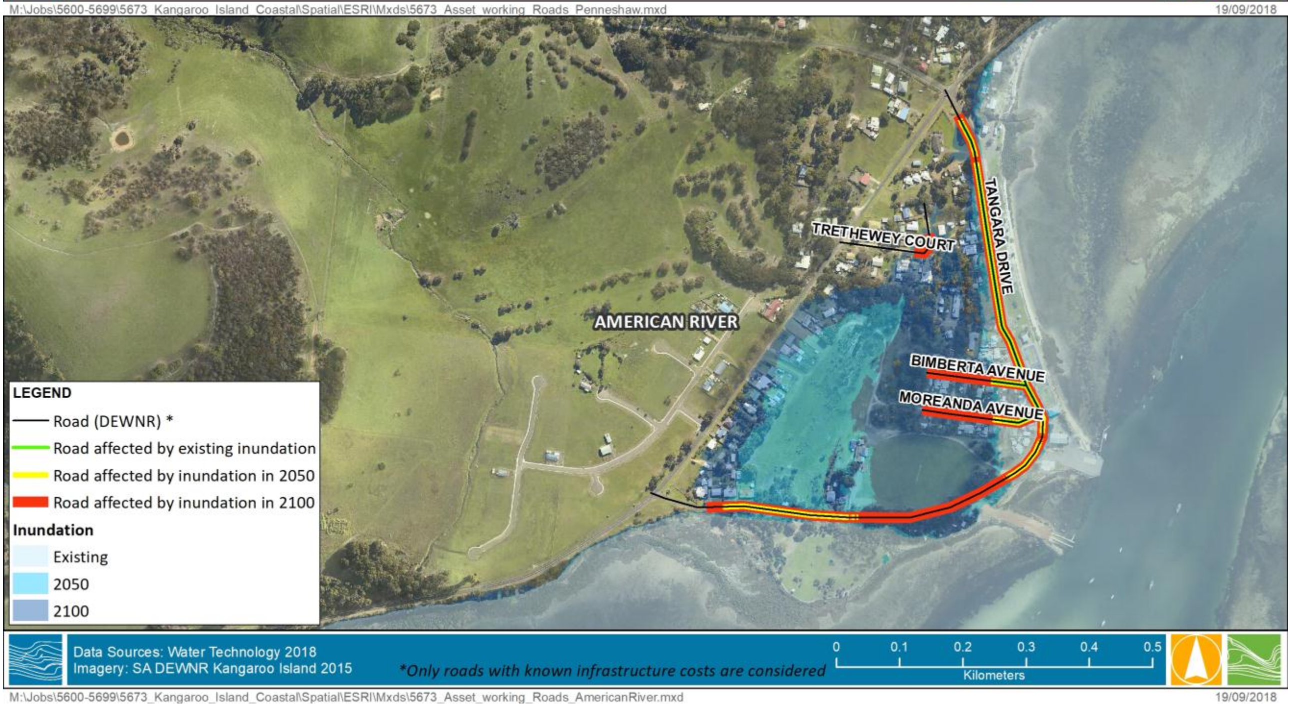
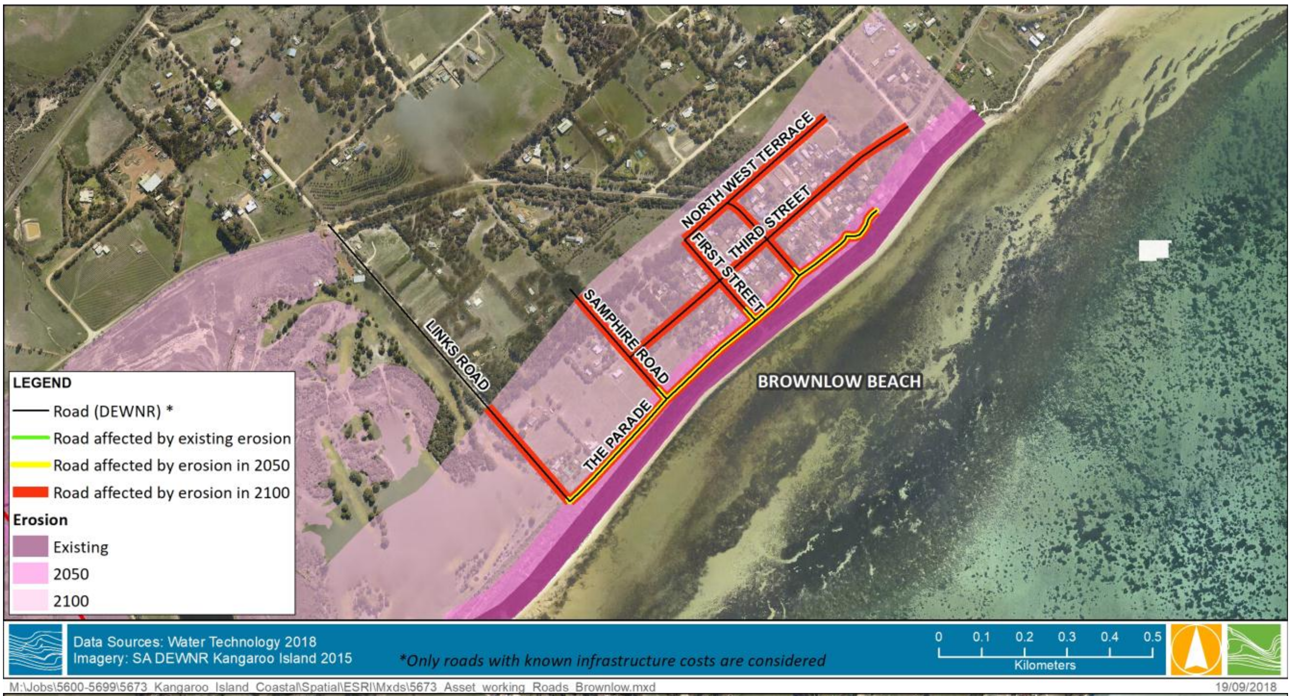
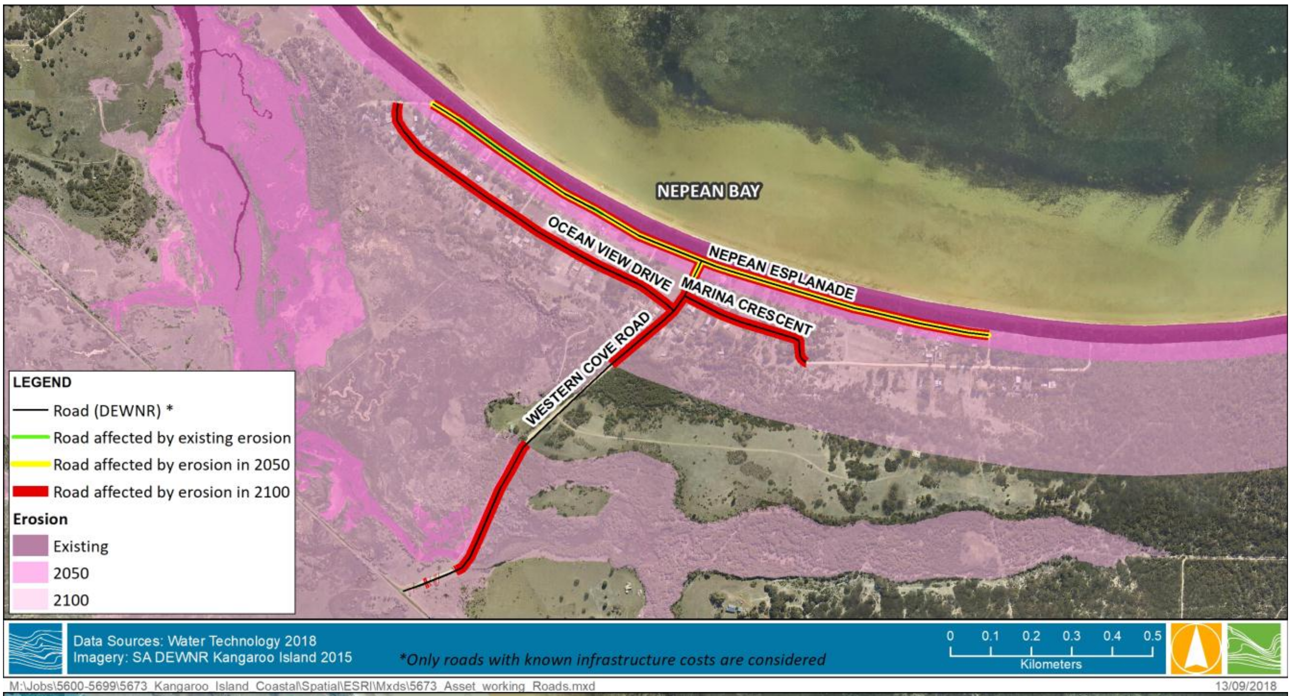

TRETHEWEY COURT
TANGARA DRIVE
AMERICAN RIVER
BIMBERTA AVENUE
MOREANDA AVENUE
LEGEND
Road (DEWNR) *
Road affected by existing inundation
Road affected by inundation in 2050
Road affected by inundation in 2100
Inundation
Existing
2050
2100
Data Sources: Water Technology 2018
Imagery: SA DEWNR Kangaroo Island 2015
*Only roads with known infrastructure costs are considered
0 0.1 0.2 0.3 0.4 0.5
Kilometers
M:\Jobs\5600-5699\5673_Kangaroo_Island_Coastal\Spatial\ESRI\Mxds\5673_Asset_working_Roads_AmericanRiver.mxd
19/09/2018

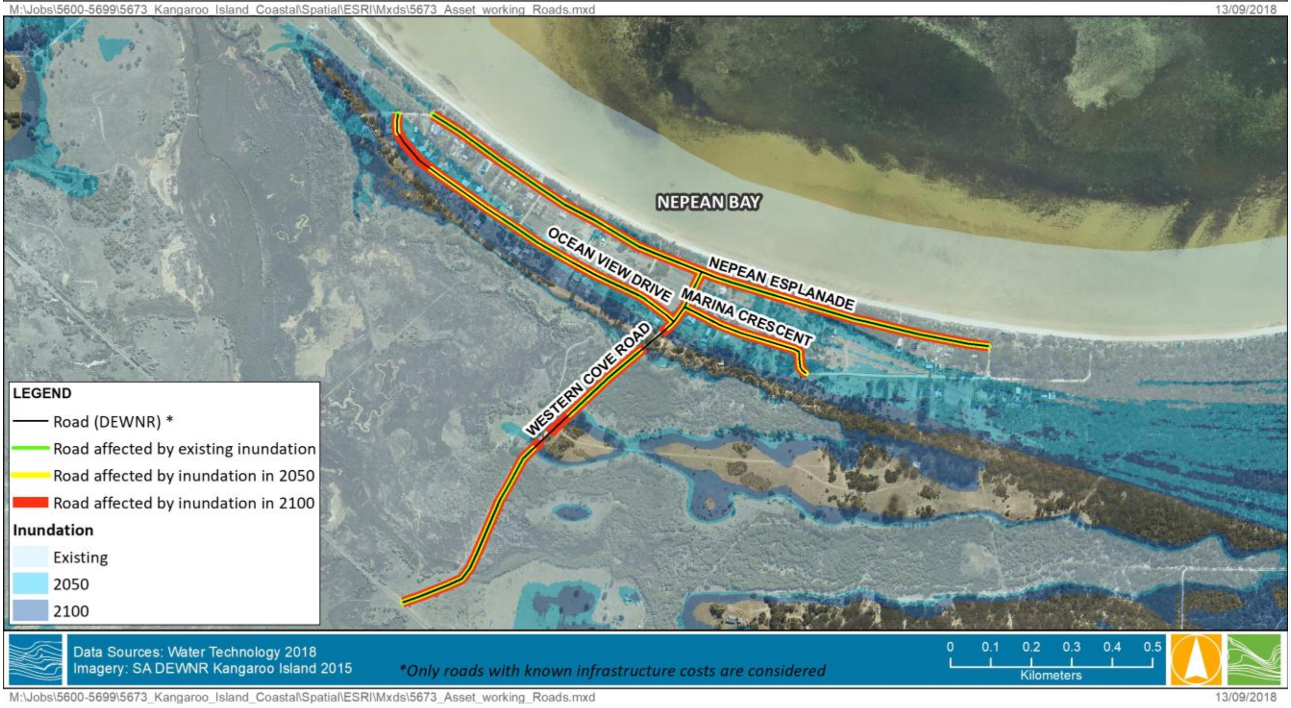

NORTH WEST TERRACE
THIRD STREET
FIRST STREET
SAMPHIRE ROAD
LINKS ROAD
THE PARADE
BROWNLOW BEACH
LEGEND
Road (DEWNR) *
Road affected by existing erosion
Road affected by erosion in 2050
Road affected by erosion in 2100
Erosion
Existing
2050
2100
Data Sources: Water Technology 2018
Imagery: SA DEWNR Kangaroo Island 2015
*Only roads with known infrastructure costs are considered
0 0.1 0.2 0.3 0.4 0.5
Kilometers
M:\Jobs\5600-5699\5673_Kangaroo_Island_Coastal\Spatial\ESRI\Mxds\5673_Asset_working_Roads_Brownlow.mxd
19/09/2018


NORTH WEST TERRACE
THIRD STREET
FIRST STREET
SAMPHIRE ROAD
LINKS ROAD
THE PARADE
BROWNLOW BEACH
LEGEND
Road (DEWNR) *
Road affected by existing inundation
Road affected by inundation in 2050
Road affected by inundation in 2100
Inundation
Existing
2050
2100
Data Sources: Water Technology 2018
Imagery: SA DEWNR Kangaroo Island 2015
*Only roads with known infrastructure costs are considered
0 0.1 0.2 0.3 0.4 0.5
Kilometers
M:\Jobs\5600-5699\5673_Kangaroo_Island_Coastal\Spatial\ESRI\Mxds\5673_Asset_working_Roads_Brownlow.mxd
19/09/2018


GOVERNOR WALLEN DRIVE
KINGSCOTE
LEGEND
Road (DEWNR) *
Road affected by existing erosion
Road affected by erosion in 2050
Road affected by erosion in 2100
Erosion
Existing
2050
2100
Data Sources: Water Technology 2018
Imagery: SA DEWNR Kangaroo Island 2015
*Only roads with known infrastructure costs are considered
0 0.1 0.2 0.3 0.4 0.5
Kilometers
M:\Jobs\5600-5699\5673_Kangaroo_Island_Coastal\Spatial\ESRI\Mxds\5673_Asset_working_Roads_Kingscote.mxd
19/09/2018


GOVERNOR WALLEN DRIVE
KINGSCOTE
LEGEND
Road (DEWNR) *
Road affected by existing inundation
Road affected by inundation in 2050
Road affected by inundation in 2100
Inundation
Existing
2050
2100
Data Sources: Water Technology 2018
Imagery: SA DEWNR Kangaroo Island 2015
*Only roads with known infrastructure costs are considered
0 0.1 0.2 0.3 0.4 0.5
Kilometers
M:\Jobs\5600-5699\5673_Kangaroo_Island_Coastal\Spatial\ESRI\Mxds\5673_Asset_working_Roads_Kingscote.mxd
19/09/2018


NEPEAN BAY
NEPEAN ESPLANADE
OCEAN VIEW DRIVE
MARINA CRESCENT
WESTERN COVE ROAD
LEGEND
Road (DEWNR) *
Road affected by existing erosion
Road affected by erosion in 2050
Road affected by erosion in 2100
Erosion
Existing
2050
2100
Data Sources: Water Technology 2018
Imagery: SA DEWNR Kangaroo Island 2015
*Only roads with known infrastructure costs are considered
0 0.1 0.2 0.3 0.4 0.5
Kilometers
M:\Jobs\5600-5699\5673_Kangaroo_Island_Coastal\Spatial\ESRI\Mxds\5673_Asset_working_Roads.mxd
13/09/2018


NEPEAN BAY
NEPEAN ESPLANADE
OCEAN VIEW DRIVE
MARINA CRESCENT
WESTERN COVE ROAD
LEGEND
Road (DEWNR) *
Road affected by existing inundation
Road affected by inundation in 2050
Road affected by inundation in 2100
Inundation
Existing
2050
2100
Data Sources: Water Technology 2018
Imagery: SA DEWNR Kangaroo Island 2015
*Only roads with known infrastructure costs are considered
0 0.1 0.2 0.3 0.4 0.5
Kilometers
M:\Jobs\5600-5699\5673_Kangaroo_Island_Coastal\Spatial\ESRI\Mxds\5673_Asset_working_Roads.mxd
13/09/2018

Melbourne

15 Business Park Drive
Notting Hill VIC 3168
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Level 3, 43 Peel Street
South Brisbane QLD 4101
Telephone (07) 3105 1460
Fax (07) 3846 5144

Adelaide

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Fax (08) 8357 8988

Perth

Ground Floor
430 Roberts Road
Subiaco WA 6008
Telephone 0438 347 968

Geelong

PO Box 436
Geelong VIC 3220
Telephone 0458 015 664

Gippsland

154 Macleod Street
Bairnsdale VIC 3875
Telephone (03) 5152 5833

Wangaratta

First Floor, 40 Rowan Street
Wangaratta VIC 3677
Telephone (03) 5721 2650

Wimmera

PO Box 584
Stawell VIC 3380
Telephone 0438 510 240

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info@watertech.com.au

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