Kiama Coastline Coastal Management Program Stage 2 - Final report

October 2021

KIAMA MUNICIPAL COUNCIL

Document Control Sheet

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	Client Reference:	N21130
Synopsis:	**This report presents Stage 2 of Kiama Councils Coastal Management Program completed by BMT for Kiama Municipal Council.**	

REVISION/CHECKING HISTORY

Revision Number	Date	Checked by		Issued by	
00	23.12.2020	PEH		TD	
01	02.06.2021	MPB			
02	10.09.2021				
03	15.10.2021	PEH		MT	

DISTRIBUTION

Destination	Revision										
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Executive Summary

Kiama Municipal Council with the assistance of the NSW Department of Planning, Industry and Environment (DPIE) resolved to prepare a Coastal Management Program (CMP) for the Kiama Coastline, in accordance with the provisions of the NSW *Coastal Management Act 2016* (CM Act). The CMP shall define the long-term strategy for the coordinated and sustainable management of the coastal zone. The NSW Coastal Management Manual (the manual) specifies five stages of preparing a CMP. This report fulfils Stage 2, building on the Stage 1 Scoping Study report (Kiama Municipal Council, 2020).

Stage 2 of the CMP process "involves undertaking detailed studies that help councils to identify, analyse and evaluate risks, vulnerabilities and opportunities". The scope for this Stage 2 report covers:

- An assessment of physical coastal processes, and the development of sediment transport conceptual model/s;
- A probabilistic assessment of beach erosion and shoreline recession (inc. both underlying and sea level rise (SLR) induced recession);
- An assessment of tidal and coastal inundation for the study area, and at the timeframes required by the manual (i.e. current, 20, 50 and 100 years);
- A first-pass assessment of cliff and slope instability; and
- A detailed risk assessment, bringing together the results of the coastal hazard mapping and conceptual models from previous sections, and identifying key "areas of interest (AoI)" for each risk in the study area that should be targeted for management.

Key coastal hazards and associated risks to land and assets (built and natural) within the Kiama coastal environment (the study area) have been identified within this report, and are summarised in Figure 1 and Figure 2, as well as below. Key coastal hazards included within this study were:

(a) **Coastal erosion**, which is loss of sand from a beach system via a combination of coastal processes.

(b) **Coastal inundation** occurs when a combination of marine and atmospheric processes raises the water level at the coast above normal elevations, causing land that is usually 'dry' to become inundated by sea water.

(c) **Tidal inundation** is the flooding of land by tidal action under average meteorological conditions and the incursion of sea water onto low lying land that is not normally inundated, during a high sea level event such as a king tide or due to longer-term SLR.

(d) **Cliff and slope instability**, which refers to the variety of potential hazards and risks associated with both natural and trained cliff faces (steep face of rock), and was assessed via a high-level walk over by a trained geomorphologist.

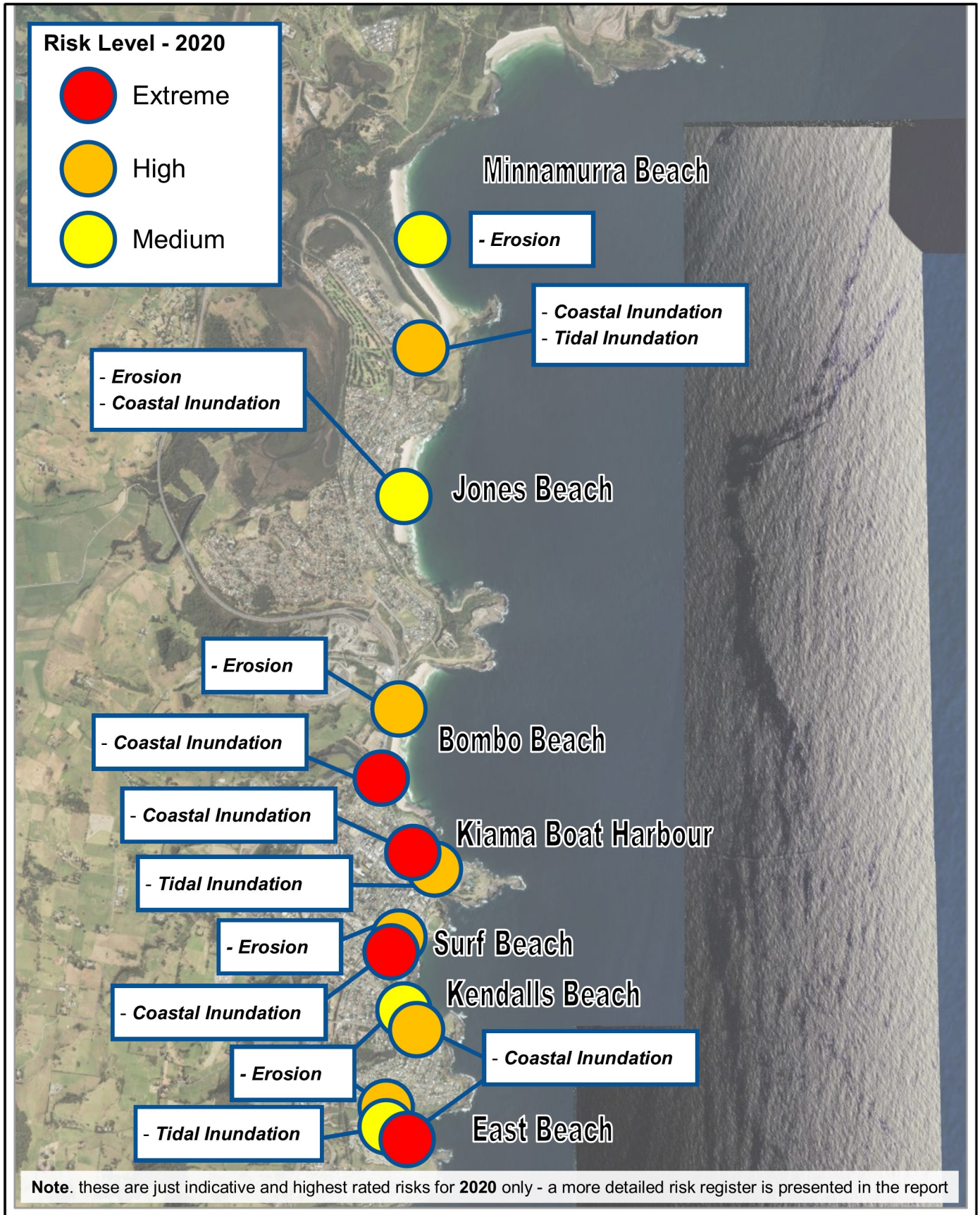
Risk Assessment summary (current risk only):

- **Minnamurra** – Minnamurra Beach has a medium risk for coastal erosion, and a medium to high risk for coastal and tidal inundation (of some assets along the foreshore).

- **Jones Beach** – Jones Beach has a medium risk for coastal erosion and coastal inundation in the present day increasing to high risk over time.
- **Bombo Beach** – Bombo Beach, sand dunes, and foreshore assets are being impacted by coastal erosion and coastal inundation. Coastal erosion has been rated as a high risk to several assets, while coastal inundation ranges from medium to extreme, depending on the asset being impacted.
- **Kiama Boat Harbour** – The boat harbour is impacted by both coastal and tidal inundation. Coastal inundation was found to result in medium to extreme risk, depending on the asset being impacted, whereas tidal inundation was found to result in medium to high risk.
- **Surf and Kendalls Beaches** – both these beaches are impacted by coastal erosion and coastal inundation. For Surf Beach, erosion has been rated as a high risk to several assets, while coastal inundation ranges from medium to extreme, depending on the asset being impacted. Kendalls Beach on the other hand, has erosion rated as a medium risk, and coastal inundation ranging from medium to high risk, depending on the asset being impacted.
- **Easts Beach** – has been predicted to be impacted by all three of the coastal hazards. Erosion has been rated as a high risk to several assets, tidal inundation was rated as a medium risk, while coastal inundation ranged from a high to extreme risk, depending on the asset being impacted.
- **Werri Beach** – Werri Beach, sand dunes, and foreshore assets are being impacted by coastal erosion and coastal inundation. Coastal erosion has been rated as a low to high risk, while coastal inundation ranges from medium to extreme, depending on the asset being impacted.
- **Walkers Beach** – has been predicted to have a medium risk to coastal inundation.
- **Gerroa / Seven Mile Beach** – several areas around the entrance to the Crooked River have been predicted to be impacted by coastal and tidal inundation hazards. Coastal inundation has been found to provide a medium to high risk to several assets within the area, while tidal inundation was found to pose only a medium risk currently.

Please note that many of these risks increase with time, as the consequence and / or likelihood of the coastal hazard increases. See the more detailed risk assessment / register presented within the report and Appendix E for more site-specific information.

The next stage of preparation of the CMP is the Stage 3 Options Assessment, during which options for managing the high/extreme risks from coastal hazards and other issues affecting the Kiama coastline will be investigated.



Note. these are just indicative and highest rated risks for **2020** only - a more detailed risk register is presented in the report

Title:

Kiama North - Key Risk Summary

Figure: **EX-1**

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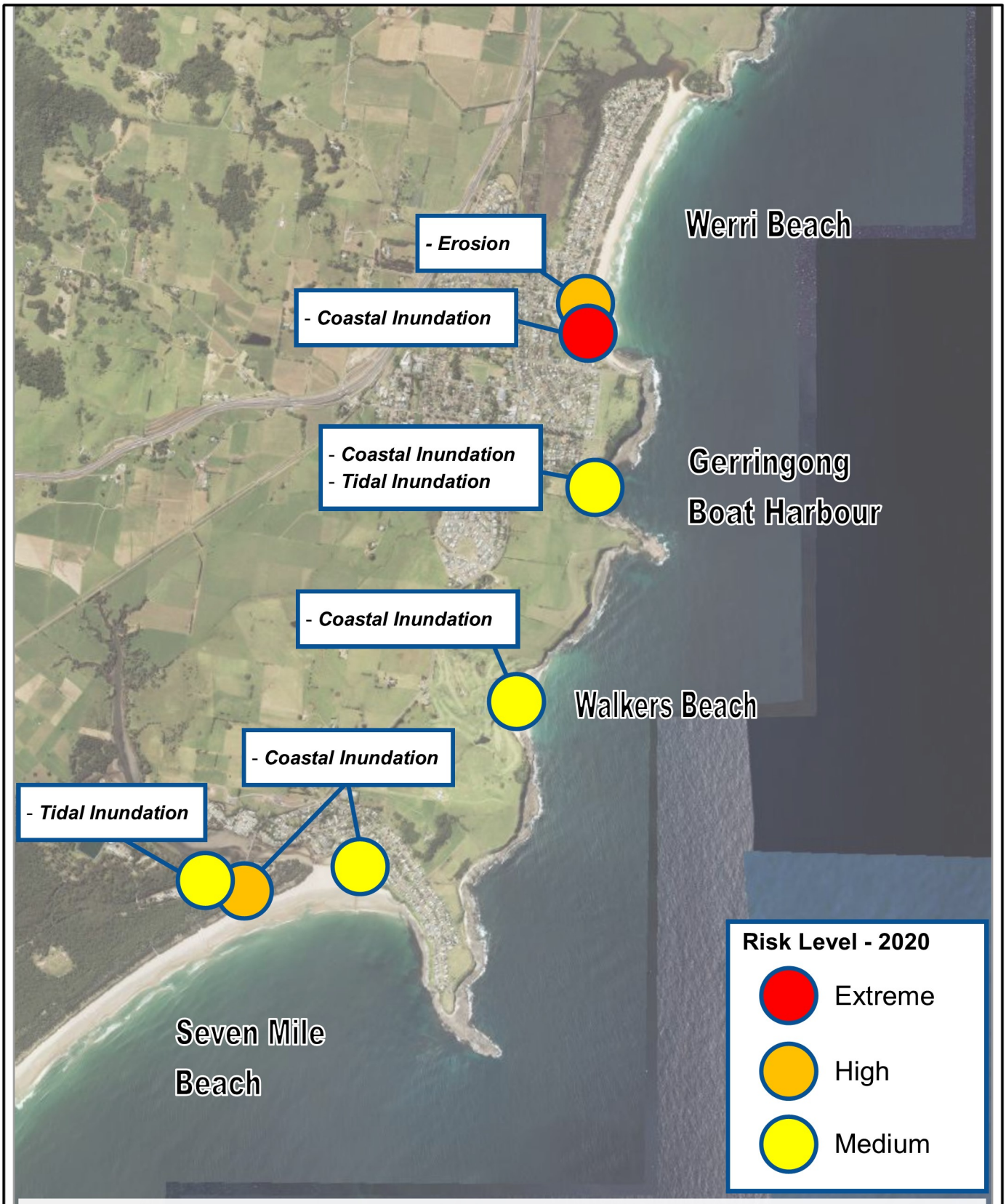

Note. these are just indicative and highest rated risks for **2020** only - a more detailed risk register is presented in the report

Title:

Kiama South - Key Risk Summary

Figure: **EX-2**

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Glossary and Abbreviations

Accommodation Space – an area that allows sediment to deposit into it and to accumulate without being readily available to erode again. Such areas serve to 'capture' sediments moving through them.

Accretion – the build-up of sediments, either to form shoals or increase in bed level, or to extend a beach or dune seaward.

Aleatory (uncertainty) – refers to uncertainty that is inherent to the process and can be defined by probabilistic distributions or quantities. For example, rolling a die has an aleatory uncertainty in that no single result is guaranteed, however the expected likelihood of results can be well-quantified.

Alongshore (Longshore) – parallel to the shoreline.

Beach Profile – A cross-section taken across the beach from the dune into the ocean in the nearshore zone.

Bedrock – a general term for rock underlying soil or sand.

Berm – A protruding horizontal sandform on the beach caused by wave action depositing sand.

Breaker zone – the nearshore area in which waves begin breaking.

Bruun Rule – A methodology for estimating coastal recession due to changes in sea level.

Closure depth – a depth beyond which changes in the seabed are not thought to occur.

Coastal Hazard – potential threats to assets defined under the Coastal Management Act (NSW, 2016) that encompasses: (1) beach erosion, (2) shoreline recession, (3) watercourse entrance instability, (4) coastal inundation, (5) cliff instability, (6) tidal inundation and (7) hazards due to the interaction of coastal processes and catchment floodwaters.

Coastal Management Plan (CMP) – as detailed in the Coastal Management Act (NSW, 2016) a strategy for managing land and assets within the coastal zone.

Cross-shore – normal to the shoreline.

Dune – shore-parallel sandforms that typically lie at the back of beaches. Formed by beach sand being blown landward and interact with the sand on the beach.

Epistemic (uncertainty) – refers to uncertainty due to a lack of understanding or potential error in the inputs to a process. For example, in a coastal management context, SLR in 2100 will be a fixed number, however as it relies on many assumptions about ongoing oceanic/atmospheric processes and potential emissions, it cannot be accurately predicted. Therefore, a range of potential scenarios and outcomes is used to attempt to quantify its epistemic uncertainty.

Foredune – Larger and more established vegetated dune systems that are often eroded under heavy storm activity (forming a dune scarp). Foredune sediments interact with the beach under erosion/recession processes.

Intermittently closed and open lakes and lagoons (ICOLL) – Coastal lakes and lagoons that are open to the sea from time to time, but also experience closure when sediments infill their entrances.

Littoral – pertaining to the shore. i.e. littoral sediment transport is sediment transport occurring in or adjacent to intertidal areas.

Overwash – the effect of waves overtopping a beach berm and flowing into areas behind it. Typically, overwash might occur over a coastal barrier into the estuary behind it.

Probabilistic model – a mathematical tool for assessing a range of variables and outcomes based on their predicted probability of occurring.

Percentile – in the context of this report, percentile describes the probability of occurrence. For example, 95th percentile means that there is only a 5% chance of exceedance of this value.

Progradation – a movement (of a dune for example) towards the sea.

Recession – a movement (of the shoreline for example) landward. Typically used to refer to ongoing landward movement of the shoreline under a rising sea level or due to a net sediment deficit in the sediment sub-compartment.

Sediment Compartment – a section of the coast defined by similar sediment transport features. Often broken down into primary, secondary, and tertiary sediment compartments, that relate to increasingly specific and local sediment transport processes. Usually constrained at each end by significant landforms such as headlands, islands, etc.

Shoreface – the area of underwater land extending offshore from the beach. Usually partitioned into an ‘upper shoreface’ that experiences active sediment transport and wave breaking, and the lower shoreface which is generally stable over geologically small timescales (years to decades).

Table 1 Table of Abbreviations

AEP	Annual Exceedance Probability
AHD	Australian Height Datum
AOI	Area of Interest
ARI	Average Recurrence Interval
BMT	BMT Commercial Australia Pty Ltd
BOM	Bureau of Meteorology
CI	Confidence Interval
CMP	Coastal Management Program
DEM	Digital Elevation Model
DPIE	Department of Planning, Industry and the Environment
ECL	East Coast Low
ENSO	El Niño Southern Oscillation
EVA	Extreme Value Analysis
GE	Google Earth
HAT	Highest Astronomical Tide
HHWSS	Higher High-Water Solstice Spring
IPCC	Intergovernmental Panel on Climate Change
KMC	Kiama Municipal Council
LAT	Lowest Astronomical Tide
LGA	Local Government Area
MCA	Multi criteria analysis
MHW	Mean High Water
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
NPWS	National Parks and Wildlife
PoT	Peak-over-Threshold
RCPs	Representative Concentration Pathways
SLR	Sea Level Rise
SROC	IPCC Special Report on the Oceans and Cryosphere

1 Introduction and Background

1.1 Acknowledging Country

While this report focusses on the present-day uses and values of the Kiama Coastline and its surrounds, BMT and Kiama Municipal Council acknowledges the traditional custodians of the land, the Dharawal (Wodi Wodi) people, who have cared for this land since time immemorial. We pay our respects to their elders, past, present and emerging, and commit ourselves to a future with reconciliation and renewal at its heart.

1.2 A Coastal Management Program for the Kiama Coastline

Kiama Municipal Council (Council) with the assistance of the NSW Department of Planning, Industry and Environment (DPIE) has resolved to prepare a Coastal Management Program (CMP) for the Kiama Coastline. The CMP shall define the long-term strategy for the coordinated and sustainable management of the coastal zone, with the aim of achieving the objects of the *Coastal Management Act 2016* (the CM Act). The key focus for this CMP is to manage the Kiama coastal environment in an ecologically sustainable way, for the social, cultural and economic well-being of the Kiama people.

This CMP is being prepared to meet the mandatory requirements for CMPs set by the CM Act and the accompanying NSW Coastal Management Manual (OEH, 2018) (the Manual). The Manual specifies 5 stages of preparation of a CMP, as shown in Figure 1-1. This report fulfils Stage 2 of the CMP preparation process.

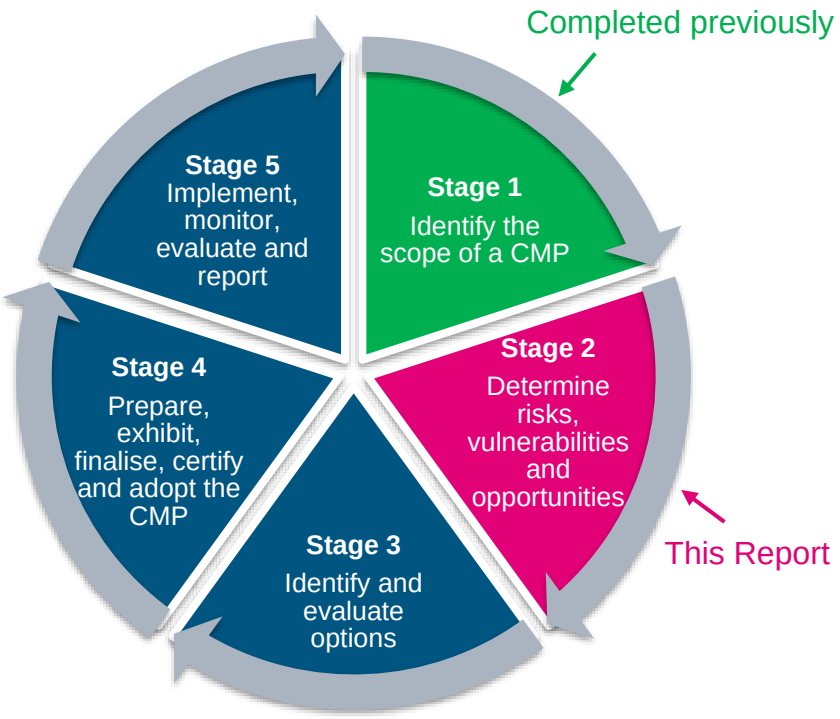


Figure 1-1 The 5 Stage Process for Preparing a CMP

1.3 Purpose and scope of this CMP Stage 2 Report

Currently, Council has completed Stage 1 of the CMP process (Scoping Study), which established the context for management, identified key risks and outlined the forward program for subsequent CMP stages and associated studies/tasks, as well as develop a community engagement strategy to communicate the values and issues of the CMP. This report presents Stage 2 of the program, which addresses and fills knowledge gaps (previously identified in the Scoping Study) (Kiama Municipal Council, 2020). As per the Manual, Stage 2 of the CMP preparation process "*involves undertaking detailed studies that help councils to identify, analyse and evaluate risks, vulnerabilities and opportunities*".

The scope for this Stage 2 report is detailed below, based upon the requirements identified in the Stage 1 Scoping Study for the Kiama coastal environment:

- An assessment of governing physical coastal processes, and the development of sediment transport conceptual models for each key secondary sediment compartment contained within the study area.
- A probabilistic assessment of beach erosion and shoreline recession (inc. both underlying recession, and Sea Level Rise (SLR) induced recession) using Monte Carlo simulations, and based upon agreed model input parameters, as well as the NSW Sediment Compartment Framework. Outputs for beach erosion and shoreline recession have been used to develop maps of relevant probable erosion extents (e.g. 10th percentile, 50th percentile, 90th percentile, etc)[1]. This hazard mapping approach has also incorporated the presence of bedrock and other such features that provide a limit to erosion extents.
- An assessment of tidal and coastal inundation for the study area, which incorporates various components of elevated oceanic water level (i.e. astronomical tide, wind set up, wave set up, barometric set up, wave run up, and future SLR and wave climate change), and has been combined for relevant return periods and storm durations, at the timeframes of interest for Council, as well as what is recommended within the Manual (i.e. current, 20-, 50-, and 100-years). Considering the potential location of the shoreline in the future with shoreline recession, the elevated ocean levels have been mapped to illustrate potential areas of inundation from wave overtopping.
- A high-level, first-pass assessment of cliff and slope instability, which was based on a review of literature, LiDAR and geomorphic site inspections relating to the geology, coastal cliff/slopes types and failure mechanisms, and assets. The assessment is a first pass screening for cliff and slope stability, and will be used to develop recommendations for areas requiring a detailed geotechnical assessment; and interim planning controls.
- A detailed risk assessment, which has brought together the results of the coastal hazard mapping and conceptual models from previous sections, and through the course of the Risk Assessment Workshop and data review, it has identified key "hotspots" for each risk in the study area that

[1] 10th percentile = 90% exceedance; 50th percentile = 50% exceedance; 90th percentile = 10% exceedance.

should be targeted for management (hence defining the scope for Stage 3 of the CMP), and to reduce high risks.

1.4 Area covered by the CMP

The coastal zone is defined under the CM Act as comprising four coastal management areas being, in order of priority, 1) the coastal wetlands and littoral rainforest area, 2) coastal vulnerability area, 3) coastal environment area, and 4) coastal use area.

It should be noted that the Coastal vulnerability areas have not yet been mapped for the Kiama study area, and this process will occur once this CMP has been completed and certified (through a planning proposal, and in accordance with the EPA Act via the Gateway process).

The area covered by the CMP and of interest in this Stage 2 Report will primarily focus on beaches and bays within the Kiama LGA that are in close proximity to settlements, infrastructure and assets (as shown in Figure 1-2). These include Minnamurra Beach, Jones / Boyds Beach, Bombo Beach, Black's Beach / Kiama Harbour, Surf Beach, Kendall's Beach, Easts Beach, Werri Beach, Gerringong Boat Harbour, Seven Mile Beach (approximately 2km of the northern-most section).

1.5 The Kiama coastline

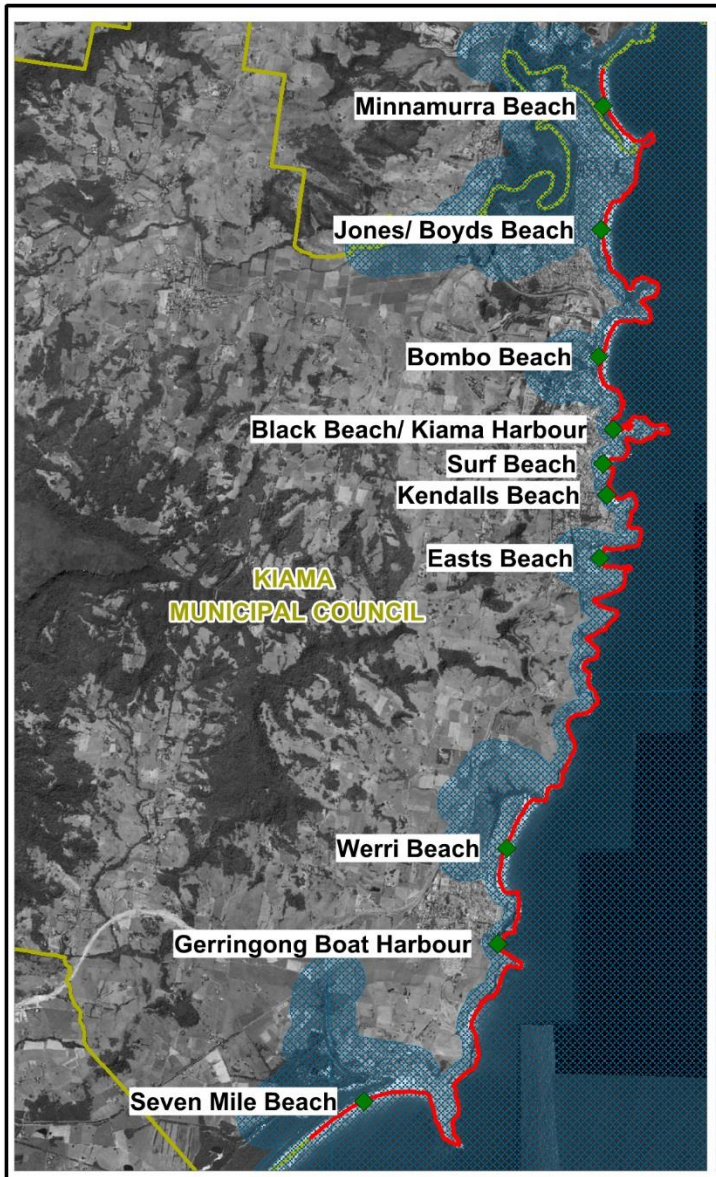
The Kiama local government area (LGA) is located on the south coast of New South Wales, about 130 km south of Sydney. The coastline extends for approximately 34 km from the Minnamurra River at the north (where it meets the Shellharbour LGA) to 2km south of Black Head (where it meets the Shoalhaven LGA). The regions coastal zone experiences the ongoing effects of coastal hazards, which form from natural coastal processes. These hazards influence and impact the amenity of this popular area, and has, and will continue to threaten natural and built assets into the future.

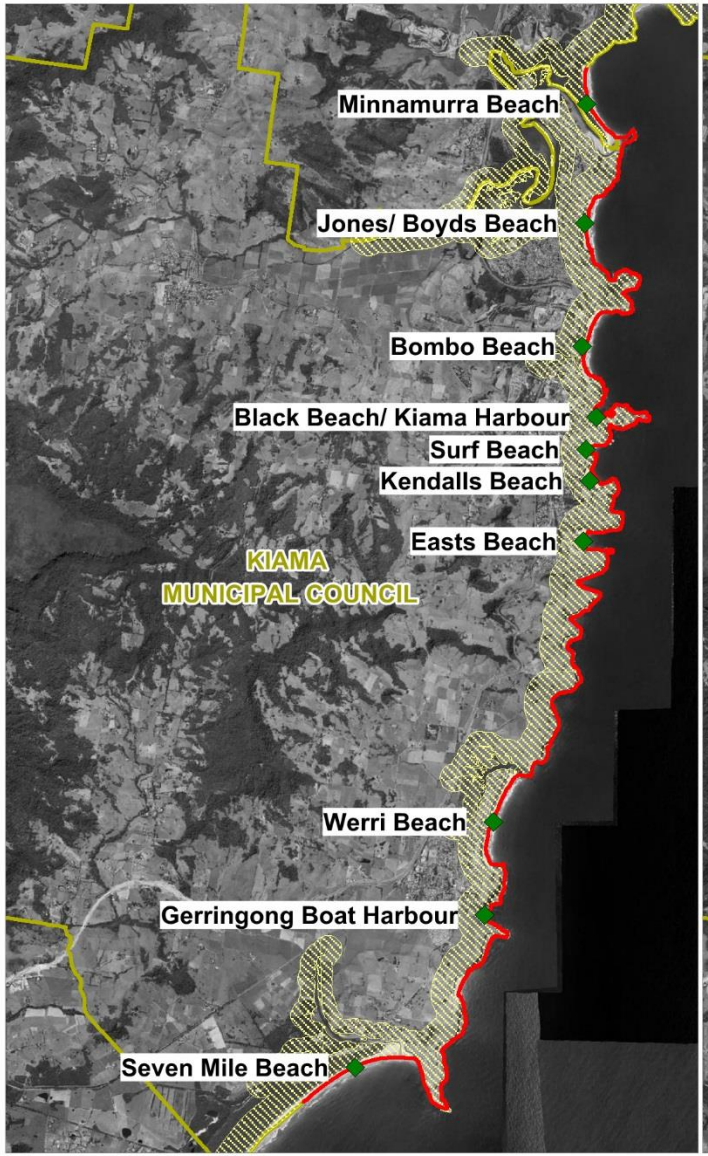
The Kiama coast is characterised by embayed and pocket beaches (with the exception of Seven Mile Beach), interspersed with prominent rocky headlands and cliffs formed of Permian age sedimentary and volcanic rocks. At a regional scale, the coastline faces southeast, experiences a high energy wave climate, and spans both the Kiama Coast and Shoalhaven River coastal sediment compartments (shared with Shellharbour and Shoalhaven LGA's respectively; see Figure 1-3). Locally, Kiama's beaches are very compartmentalised, with steep shoreface slopes meaning that little sediment transfer is likely between adjacent beach systems. Tall cliffs and wide rocky shore platforms are a typical feature of Kiama's rocky sections of coast.

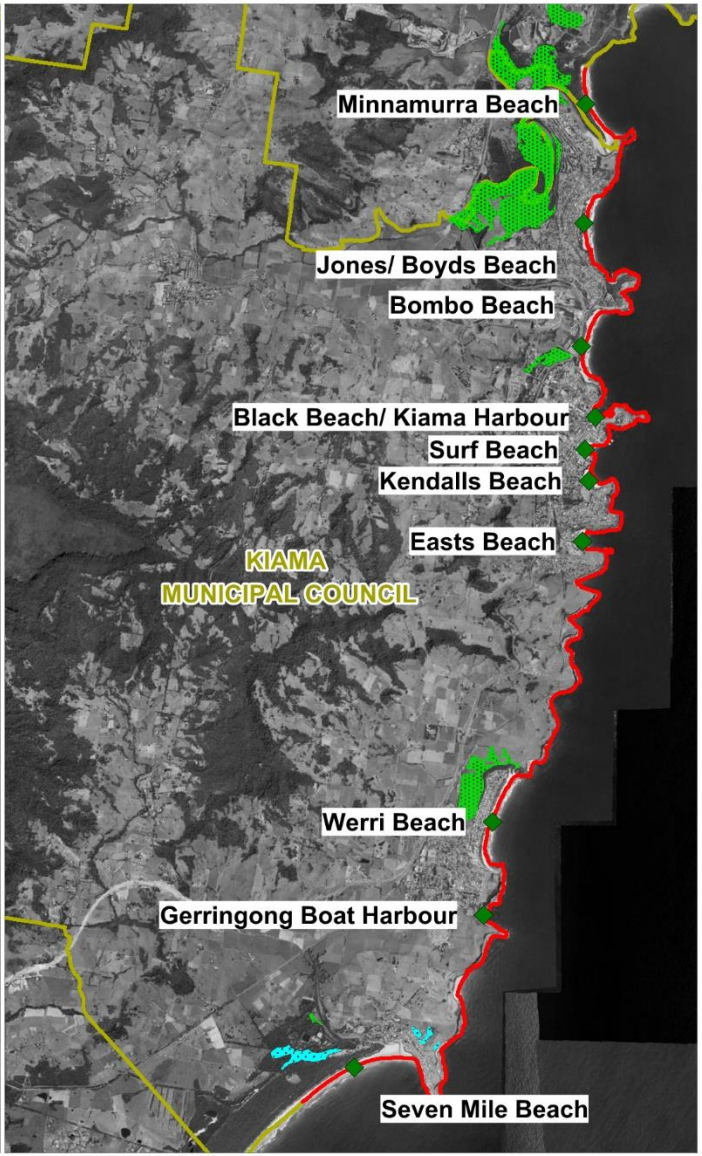
1.6 Timeframes relevant to CMP planning

The CMP will be prepared to extend for a 10-year period from 2022 to 2032. The following timeframes are considered by the CMP (as recommended within the CM Act and the manual), including the analysis undertaken and presented in this Stage 2 Report:

- 2020 / Present Day;
- 2040 (i.e. 20 years time);
- 2070 (i.e. 50 years time); and
- 2120 (i.e. 100 years time).







LEGEND

◆ Focus Beach/Bay

— Study Area - Coastline

▭ LGA Boundary

▨ Coastal Environment Area

▨ Coastal Use Area

▨ Littoral Rainforest

▨ Coastal Wetlands

Title:

SEPP Coastal Management Areas Kiama Municipal Council

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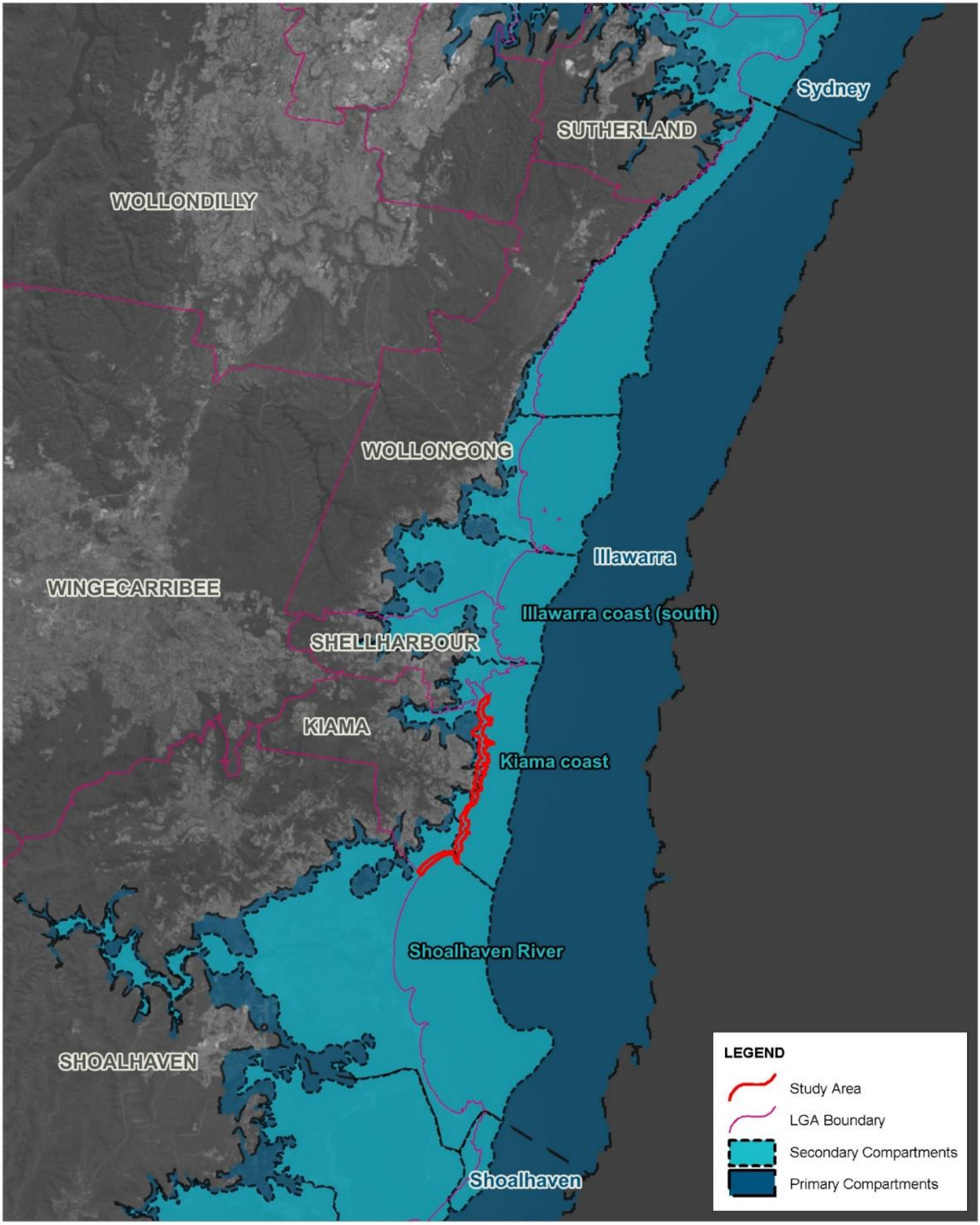

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Coastal Sediment Compartments

Figure: **1-3**

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1.7 Consultation undertaken for Stage 2

Consultation was undertaken throughout the preparation of this Stage 2 report with Council staff and Department of Planning, Industry and Environment (DPIE) – Environment, Energy, and Science (EES), as well as several other key agency representatives. An Expert Panel Workshop as well as a Risk Assessment Workshop were conducted with several agencies, Council staff, independent research institutions (i.e. UOW) and other relevant stakeholders. Invitees to the workshops included various representatives from the organisations listed in Table 1-1 and Table 1-2.

Table 1-1 Expert Workshop Invitees

Organisation	Representative(s)
Kiama Municipal Council (Council)	Byron Robinson Mitchell Golding
Department of Planning, Industry and Environment (DPIE – Environment, Energy, and Science)	Andrew Williams Dr. Phil Watson Dr. Michael Kinsela
University of Wollongong (UOW)	Professor Colin Woodroffe
BMT	Verity Rollason Dr. Tom Doyle Toby Devlin Madelaine Broadfoot

Table 1-2 Risk Assessment Workshop Invitees

Organisation	Representative(s)
Kiama Municipal Council (Council)	Byron Robinson Mitchell Golding Megan Hutchison Tim McLeod Ed Patterson Darren Brady Renee Winston Marianne Hazell
DPIE - EES	Andrew Williams
DPIE Crown Lands	Tui Williams
Transport for New South Wales (TfNSW)	Kym Warner Deon Voyer Hamid Eqbal
Sydney Water	Nathan Harrison
Christopher Royal	Sydney Trains

Organisation	Representative(s)
BMT	Verity Rollason Dr. Tom Doyle Toby Devlin

1.8 Structure of this Report

This report presents the results of the technical investigations, separated into several key categories, which addressed the project purpose and scope as described in Section 1.3 This document is therefore organised as follows:

- Section 1 – Introduction and background to the Kiama coastal environment
- Section 2 – A review of the coastal geomorphology and processes (inc. conceptual models)
- Section 3 – Presentation of coastal erosion and recession modelling and mapping
- Section 4 – Presentation of coastal and tidal inundation results and mapping
- Section 5 – Recognition of uncertainty involved within this study
- Section 6 – Presentation of cliff and slope instability assessment and mapping
- Section 7 – Kiama coast risk assessment
- Section 8 – Study conclusions, and way forward.

Additionally, there are a series of Appendices that provide detailed explanation of the hazard analysis methodologies, as well as the full compendium of hazard maps.

2 Coastal Geomorphology and Processes

2.1 Introduction

A thorough understanding of the coastal hazards and processes in the study area and broader region is fundamental to the development of this coastal hazard risks, vulnerabilities and opportunities study (CMP Stage 2). This chapter details an understanding of the coastal geomorphology and physical processes within the study area, including regional sediment transport conceptual models.

2.2 Sediment Compartments

The Coastal Management Manual (OEH, 2018) recommends the use of sediment compartments as a framework for considering coastal processes to analyse coastal hazards. Sediment compartments are defined as an area of coast that behaves in a broadly homogenous way with respect to sediment transport processes, sources and sinks (Thom, *et al.*, 2018).

The open coast of the study area, extending from Minnamurra River to the Council boundary along Seven Mile Beach, sits within the primary sediment compartment of the Illawarra, which extends from Port Hacking (southern Sydney) in the north to Beecroft Head in the south (CoastAdapt, 2018). This area experiences primarily northward sediment transport in line with the predominant south-easterly wave direction, however, for the most part the beach systems tend to be part of closed sediment boundaries. This means little if any sediment sharing or transport occurs between the secondary compartments (Short, 2020). The primary compartment is exposed to storms, including east coast lows (extra-tropical cyclones) as well as climate variations due to the El Niño Southern Oscillation (ENSO).

The study area is also encompassed within two secondary sediment compartments, which include (from the north):

(2) The **Kiama Coast**, is a 34 km long basaltic section of the NSW coast that extends from Bass Point in the north, to Black Head in the south; and

(3) The **Shoalhaven River**, is a 25 km long section of coast, bordered by Black and Beecroft Heads.

These secondary compartments are separated by major rocky headlands, which also contain substantial submerged rocky reef / outcrops. These points control the movement of sediments, and subsequent sections of this report will discuss the process driving this sediment transport within and around these compartments (CoastAdapt, 2018). The coastal sediments are largely composed of sands (terrigenous quartz), with some rocky outcrops offshore and in minor headlands.

There are numerous key tertiary compartments within the study area. These are coastline sections on the scale of individual beach systems, each one affected by coastal processes in different ways. The tertiary sub-compartments for this project, separated by secondary compartment, are illustrated in Figure 2-1.

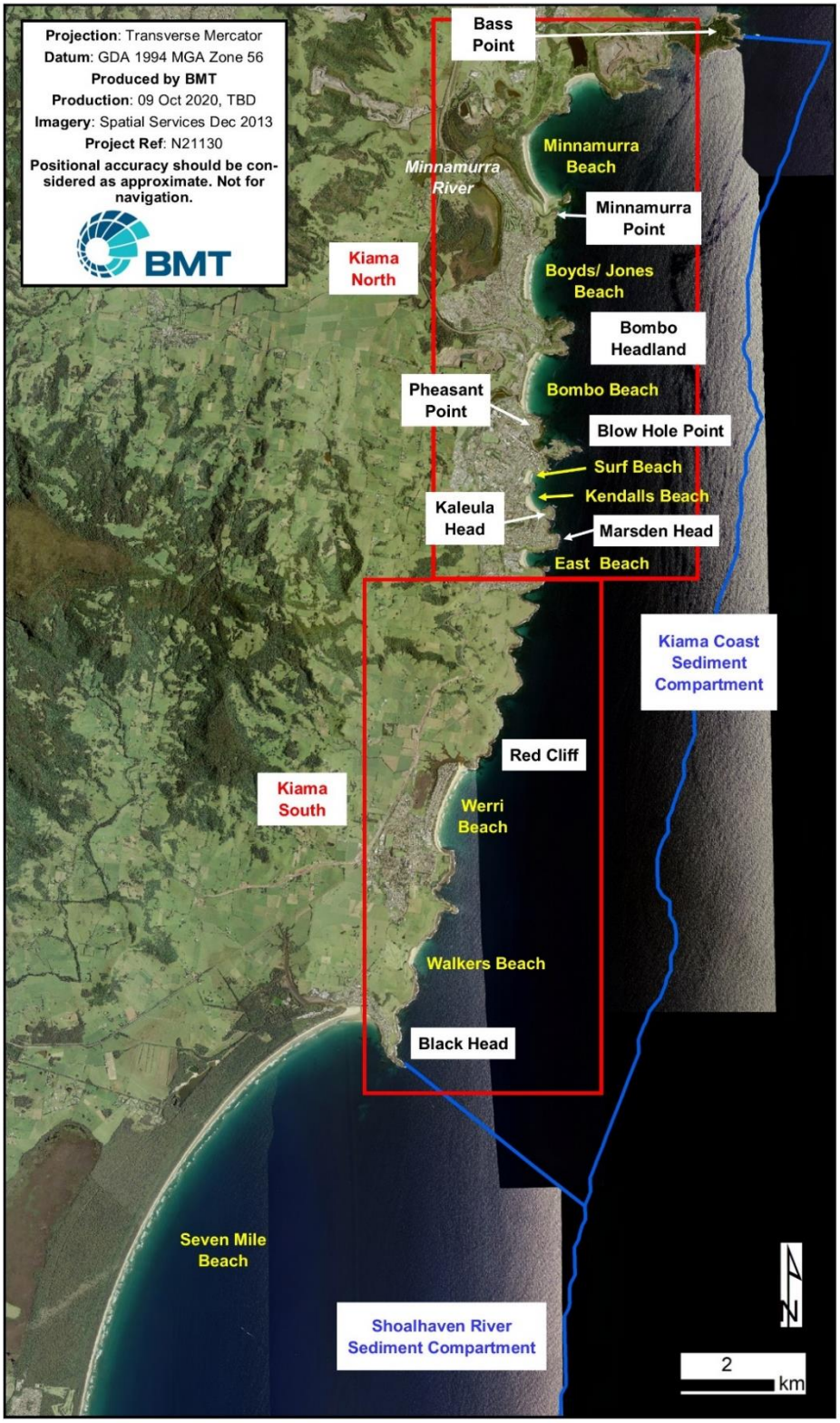


Figure 2-1 Aerial image of the Kiama and Shoalhaven shorelines, delineating key geological and coastal features. Note. Red outline shows the sub-compartments used to investigate the coastal hazards and processes for this region (Imagery: LPI, 2013).

2.3 Wind and Waves

Seasonal windroses for the Bombo Headland Station (BoM, station 068242 at 15 mAHD) are shown in Figure 2-2. Red dots (on outside rim of the rose) show the top 10 events in each rose, and blue dots show the top 0.1% of conditions. These show that there are strong seasonal differences, but that the majority of the extreme winds come from the south.

Wave roses are shown for the Port Kembla wave data in Figure 2-3. These show far less variation in wave conditions (compared to wind), with the majority of waves coming from the south–east sector. A small percentage of the waves come from the east-northeast, but these are generally low energy. The strongest waves typically occur during winter and come from the south-east, but significant easterly events can occur in the summer.

It is important to understand wind and wave processes, as they are key drivers influencing sediment transport mechanisms on the coast, and hence needs to be considered when investigating coastal hazards. For example, while storm waves often produce devastating instantaneous damage and beach-dune erosion, the normal / calmer (or 'ambient') wave climate that continues post-storm is what is responsible for the beach and dune recovery, longer-term sediment delivery and shoreline orientation (i.e. swell waves bring sand back to the beach) (Ranasinghe *et al.* 2004; Harley *et al.* 2011; Mortlock and Goodwin 2015). The interaction of wind, waves and sediment transport is further explored in Section 2.5 and Appendix B.2, while the relationship or influence these processes have in regard to coastal hazards (and hazard modelling inputs) is further developed in Section 3 (esp. Section 3.2), and Section 4 (esp. Section 4.2).

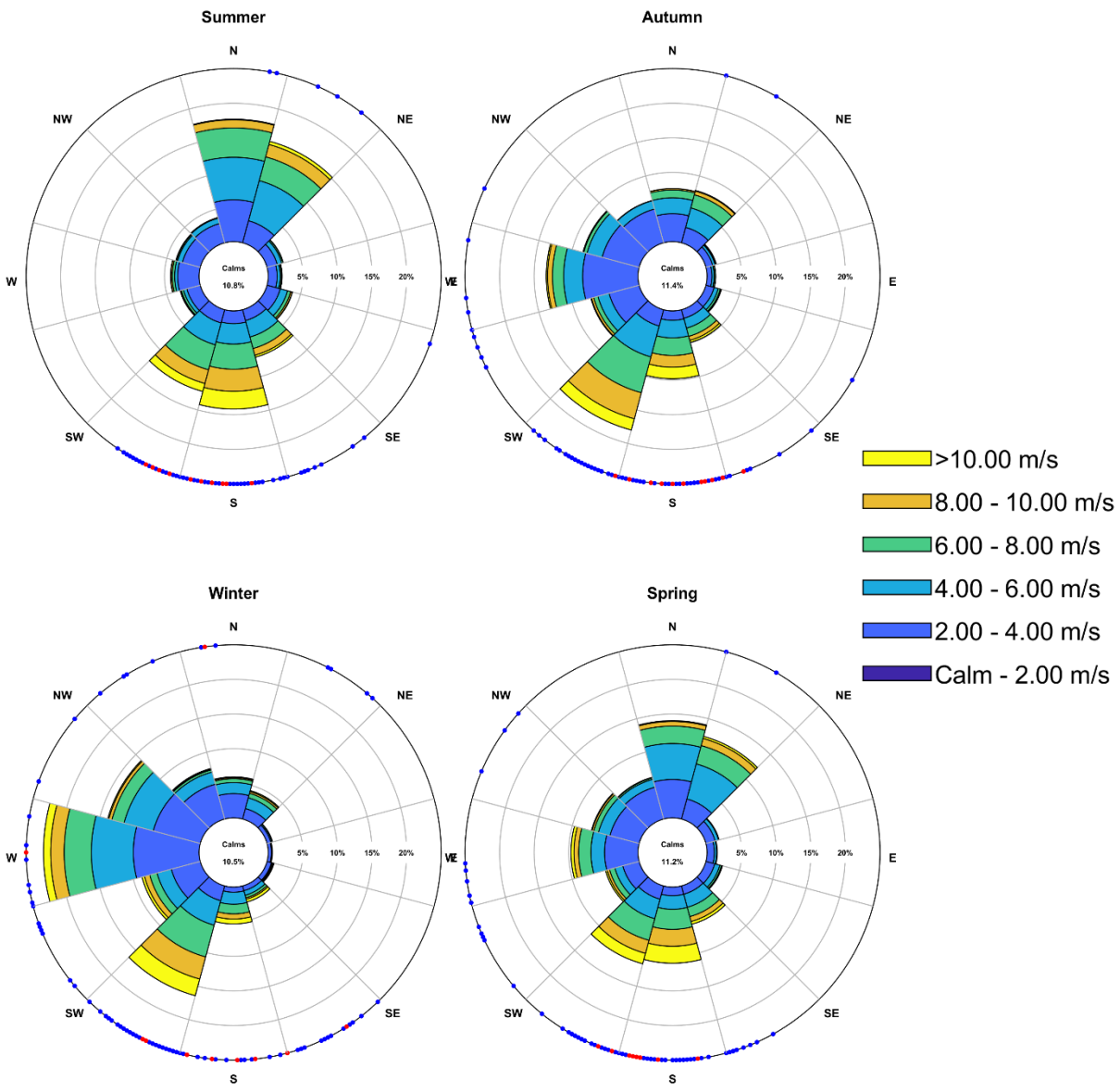


Figure 2-2 Windrose at Bombo Headland (station 068242, 2001-2020)

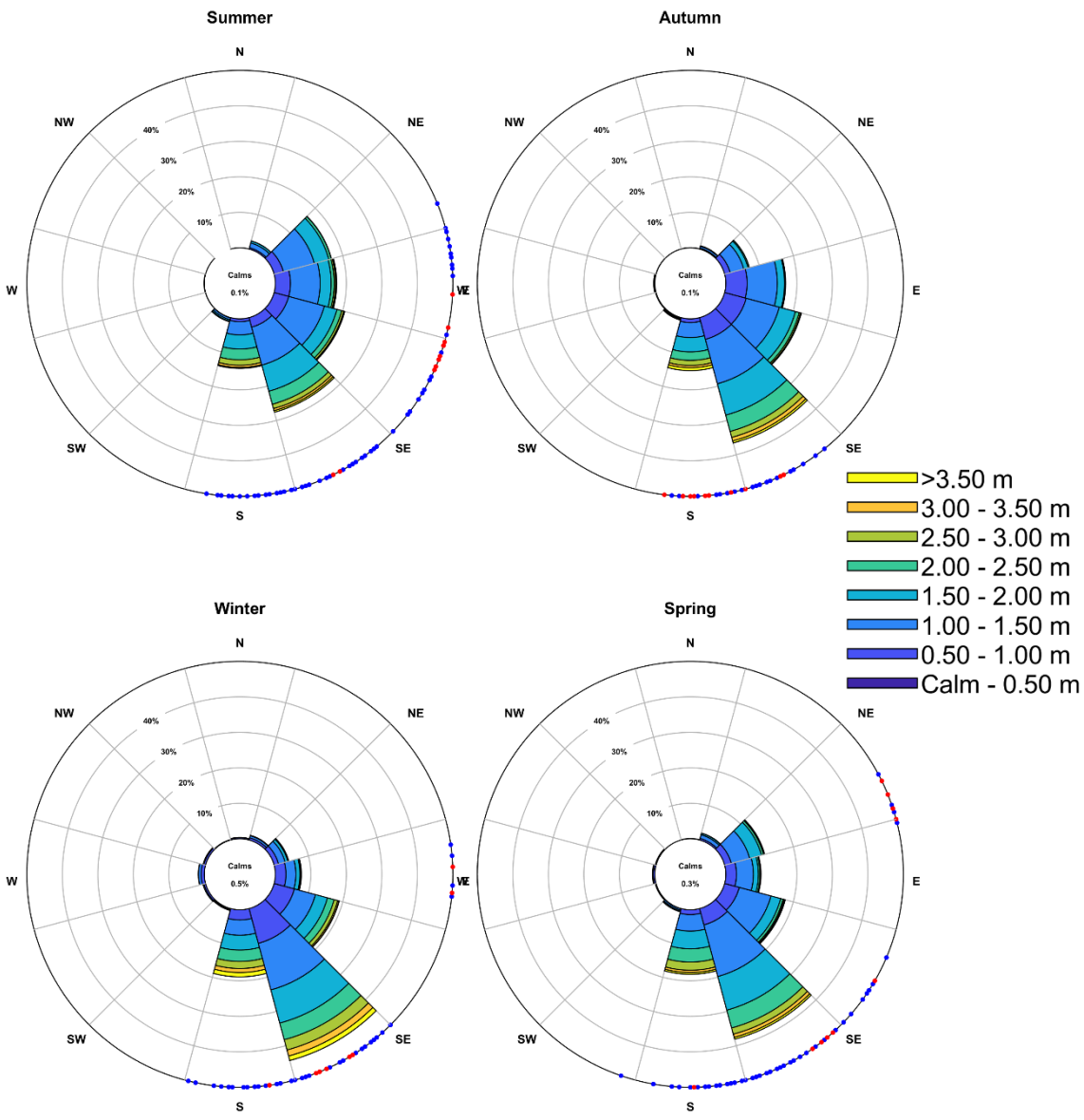


Figure 2-3 Waverose at Port Kembla wave buoy (2012-2020)

2.4 Tides, Water Level and Storms

Tides at Kiama follow a macro-tidal (tidal range >1m), semi-diurnal (two high/low tides per day) pattern. The nearest long-term tide gauge is at Fort Denison (Sydney), which shows that the present highest astronomical tide is 1.15 mAHD (approx. 1.23m with SLR), which is similar to the 1-year storm-tide level. The additional 0.08m added to the HAT (1.15m) is derived from the IPCC RCP 8.5 SLR projections for 2020, and is explained further in Section 2.4.1 below (and Table 2-3). Storms elevate these tidal levels, but do no exceed 1.5 mAHD. The extreme water levels (or storm water levels) were derived from the Fort Denison tide records, using extreme value analysis (EVA) and peak-over-threshold (PoT) methods to extract extreme / storm events (classed by water level peaks above 1 mAHD). The results are shown in Table 2-2 and have been extracted / presented to match the selected planning timeframes set for this study (see Section 1.6). Further details of the tidal analysis, EVA and tidal planes analysis can be found in the Appendix B.

Table 2-1 Tidal Planes (at Fort Denison)

Name	Description	Level (m AHD)
HAT	Highest Astronomical Tide. The potential combination of all astronomic components. i.e. the highest astronomic high-tide possible (inc. SLR).	1.23
MHWS	Mean High Water Springs. The average high tide during spring tides.	0.63
MHW	Mean High Water. The average of all high tides.	0.54
MHWN	Mean High Water Neaps. The average high tide during neap tides.	0.45

Table 2-2 Extreme Water Levels (at Fort Denison)

Frequency (ARI)	Water Level Best Fit (m) (5-95% CI)
1-year	1.21 (1.19 – 1.22)
10-year	1.35 (1.32 – 1.37)
20-year	1.38 (1.35 – 1.41)
50-year	1.41 (1.38 – 1.44)
100-year	1.43 (1.39 – 1.47)

Similar to wind and waves processes, it is important to understand tides and storms, as they are key drivers influencing sediment transport mechanisms and inundation on the coast, and hence needs to be considered when investigating coastal hazards. The relationship or influence these processes have regarding coastal hazards (and hazard modelling inputs) is further investigated in Section 3 (esp. Section 3.2), Section 4 (esp. Section 4.2), and Appendix B.2.

2.4.1 Sea Level Rise (SLR)

A relative shift in all ocean water levels can occur for several reasons. The first is a change in the ground level due to geological effects. These effects are usually small, but localised areas may experience significant changes due to effects from the prevailing geology. The second is observed SLR due to ongoing climate change.

The Intergovernmental Panel on Climate Change (IPCC) is the most widely recognised body that disseminates objective science on climate change and its associated impacts. The IPCC has released several broad documents that detail the state of the current science and prediction, the latest of which is the Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC) (IPCC, 2019). The SROCC details the following conclusions:

- Mean sea level has risen globally throughout that 20th century and has accelerated in recent decades.
- Total mean SLR from 1902 to 2015 is 0.16 m (likely range of 0.12-0.21 m).
- The rate of SLR over 2006-2015 is 3.6 mm/year (very likely range of 3.1-4.1 mm/year).
- The Greenland and Antarctic ice sheets are predicted to lose mass at an increasing rate throughout the 21st century.
- Strong reductions in greenhouse gas emissions in the coming decades are required in order to reduce further changes after 2050.

These projected changes (last two points) are based on a range of different global climate models that simulate several potential future scenarios of carbon emissions. These different scenarios are known as *Representative Concentration Pathways* (RCPs). While it is currently difficult to predict the pathway that the global society will 'adopt' over the longer-term, these different RCPs provide suitable pathways to quantify potential impacts that would result for each one.

For the purpose of coastal management planning in east coast Australia, it is suitable at this stage to adopt the most conservative RCP8.5. This represents a 'business as usual' pathway where limited success is achieved in reducing global carbon emissions. In the context of erosion risk, this represents SLR constantly accelerating throughout the 21st century and continuing to accelerate beyond 2100.

Offshore from Kiama, the projected sea level curves are summarised in Figure 2-4, of particular interest is the dark blue curve, as it represented the adopted RCP scenario for this study; RCP8.5. Table 2-3 outlines the projected sea levels (RCP8.5) at key planning timeframes (present-day, 20-years, 50-years and 100-years) relative to the 1986–2005 averages, for the Kiama study area.

Table 2-3 RCP 8.5 Projections (Offshore of Kiama)

Year	Mean Projection (m *)	Lower CI (5%) (m *)	Upper CI (95%) (m *)	Standard Deviation
2020	0.08	0.05	0.12	0.02
2040	0.23	0.16	0.31	0.05
2070	0.50	0.36	0.67	0.10
2120	1.32 ^	0.98 ^	1.67 ^	0.21 ^

** m above the 1986 – 2005 average sea level*

^ extrapolated

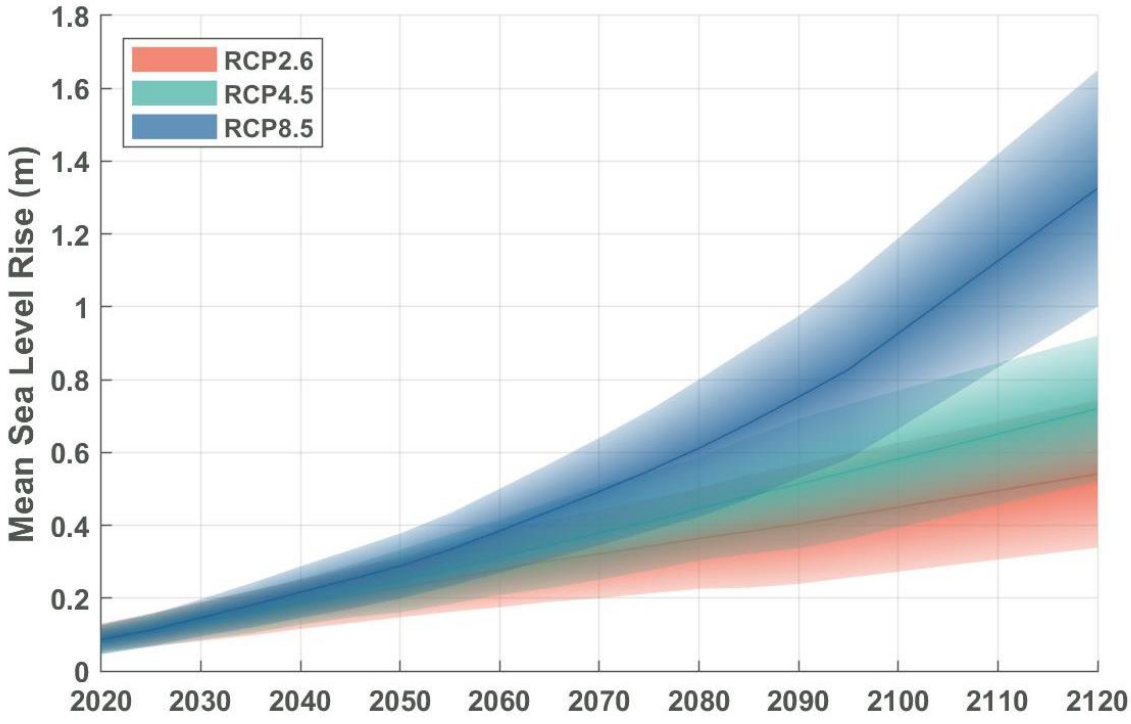


Figure 2-4 Different RCP Sea Level Projections offshore of Kiama (IPCC, 2019)

Please note. for SLR timeframes considered in this CMP that go beyond the timeframes detailed in the latest IPCC publications (e.g. 2120), trend extrapolation of the IPCC data was used (IPCC, 2019; CSIRO, 2020). Essentially, the trend extrapolation uses the last 5 years of the modelled IPCC dataset (i.e. 2095 – 2100), and keeps the same rate that is observed over that 5 year period to our desired timeframe (i.e. 2120).

2.5 Sediment Transport

The Illawarra Primary sediment compartment extends from Point Hacking in the north, to Beecroft Head in the south (Figure 1-3). It is a reasonably exposed compartment, that is south-trending, and is dominated by its geology (Short, 2020). The study area is comprised within the southernmost two secondary compartments: the Kiama Coast, and the Shoalhaven River. The Kiama Coast compartment is composed of Permian basalt, which makes up the dominant rocky headlands and platforms found here, as well as the prevalent small, embayed beaches. The Shoalhaven River compartment is different as it contains one of the longest beaches in the area, Seven Mile Beach, along with the sediment delivering Shoalhaven River and Delta (one of the few fluvial sources on the NSW coast). The barriers, both within this primary and selected secondary compartments, are small in number and size, with only the Perkins-Windang (Illawarra South) and in particular the Seven Mile-Comerong system (Shoalhaven River) accumulating larger volumes of sand, some of the latter probably sourced from the Shoalhaven River.

Sediment transport is mobilised through either longshore, or cross shore processes (driven primarily by wind or wave energy). Cross shore transport generally occurs during storm events, and is the movement of sand perpendicular to the shoreline, which occurs as a result of a change in the equilibrium conditions (e.g. storm surges, SLR and/ or wave forcing) (Cardno, 2020). High wave events erode the subaerial beach and move sand to the subtidal part of the beach profile where it forms sand bars typically 50 to 100 m from the shoreline and can happen over very short time periods (<24hrs). Part of the sand in these bars is subsequently worked back on shore during periods of lower wave energy and hence is not generally lost entirely from the beach system. In addition to waves, wind energy also contributes to cross shore processes. In this area, onshore winds play a large role in transporting sand from the beach face into the foredunes, such as those at Seven Mile Beach, or the larger transgressive dunes (now stabilised) found at Perkins-Windang Beach (Illawarra South compartment).

Longshore sediment transport typically occurs over longer periods of time (e.g. seasonally or years) with oblique wave action moving sediment along the shoreline. The two secondary compartments within the study area are considered to be closed, with very limited longshore sediment transport along these compartments and no leakage from one compartment to the next (Short, 2020). The following sections describe the likely sediment transport trends for the three secondary sediment compartments within the study area.

Based on the review of available literature and an aerial photography (photogrammetric) analysis, a conceptual model of sediment transport was developed for each secondary compartment within the study area. These conceptual models inform the assessment of the behaviour of the coastal environment, as well as possible erosion and recession trends. The conceptual models are illustrated in Figure 2-5 to Figure 2-7. Arrows represent sediment transport pathways, as well as highlighting key sediment sinks, possible sources and exchanges of sand.

2.5.1 Kiama Coast – North

The tertiary sediment compartments (beaches) contained within the Kiama Coast (North) area (i.e. top red boundary in Figure 2-1), are all generally small embayed beaches that appear to be closed, and have limited to no connection to the adjoining tertiary or secondary compartments. Key sandy beaches (from the north) found within this region include: Minnamurra, Jones, Bombo, Surf, Kendalls, and East (Figure 2-1).This sub-compartment is exposed to storm events, which initiates the cross-shore sand exchange depicted in Figure 2-5. Storm waves move sand to the nearshore (and form sand bars), which then slowly works its way back to the beach and shoreline during calmer conditions (Figure 2-5). Due to the embayed and rocky nature of these beaches, there seems to be no prominent longshore processes. Some sand might be exchanged between the township beaches during strong northerly wave events, however cross shore processes dominate. These beach systems still maintain a positive sediment budget, and this is most probably due to small amounts of sand still being supplied to the system from the inner shelf (observed within the photogrammetric analysis, and in Doyle *et al*., 2019), limited fluvial sources (i.e. the mature Minnamurra River), or localised in situ carbonate production of sediment (i.e. Bombo Beach).

2.5.2 Kiama Coast – South

Werri Beach is the key sandy feature found within the Kiama Coast (South) area (i.e. the bottom red boundary in Figure 2-1). Werri Beach occupies the first embayment south of the Kiama township. The beach trends to the south for roughly 2 km (facing eastward), curving round to face northeast in the southern corner. It is backed by now developed relict dune ridges (Short, 2007), has an active foredune system backing the beach, and has Werri Lagoon break out across the northern end of the system. Like those tertiary compartments found in the northern region of the LGA, Werri Beach is exposed to storm events, which initiates the cross-shore sand exchange depicted in Figure 2-6. Due to the embayed and rocky nature of the Kiama Coast (South), there seems to be no prominent longshore processes occurring along Werri Beach. Despite the limited longshore sands, Werri Beach still maintains a positive sediment budget (approx.. + 0.7 m^2 m^{-1} yr^{-1}), and this is most probably due to small amounts of sand still being supplied to the system from the inner shelf (observed within the photogrammetric analysis, and Goodwin *et al*., 2015), or localised in situ carbonate production of sediment (i.e. generally there is a higher carbonate concentration in the beach sands). Having a high carbonate concentration of the beach sands may indicate there is biogenic *in situ* production of carbonate (which is contributing to the beach sand volumes) by carbonate-secreting organisms within nearby rocky reefs (Carvalho, 2018).

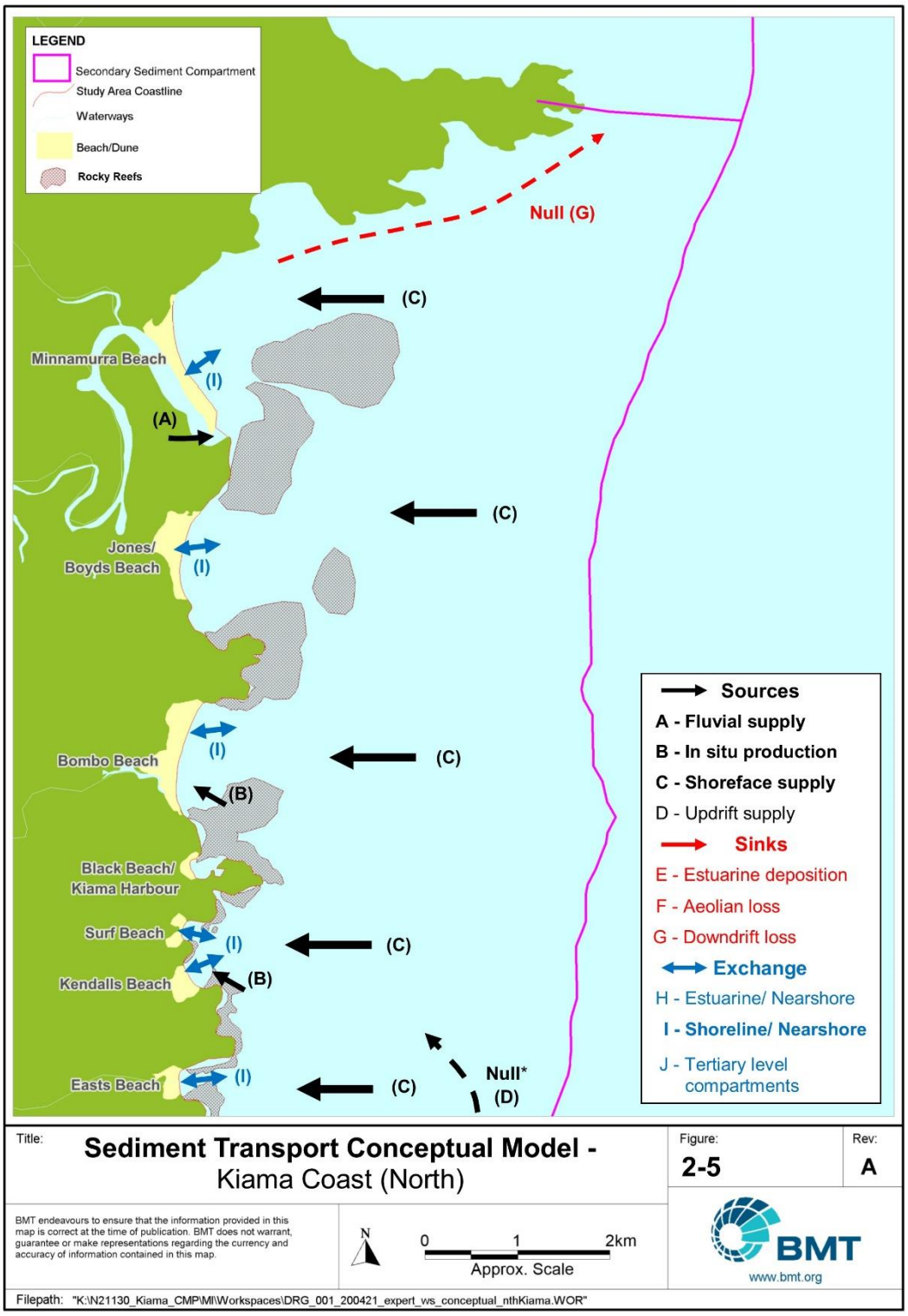


Figure 2-5 Sediment transport conceptual model for the northern region of the Kiama Coast secondary sediment compartment.

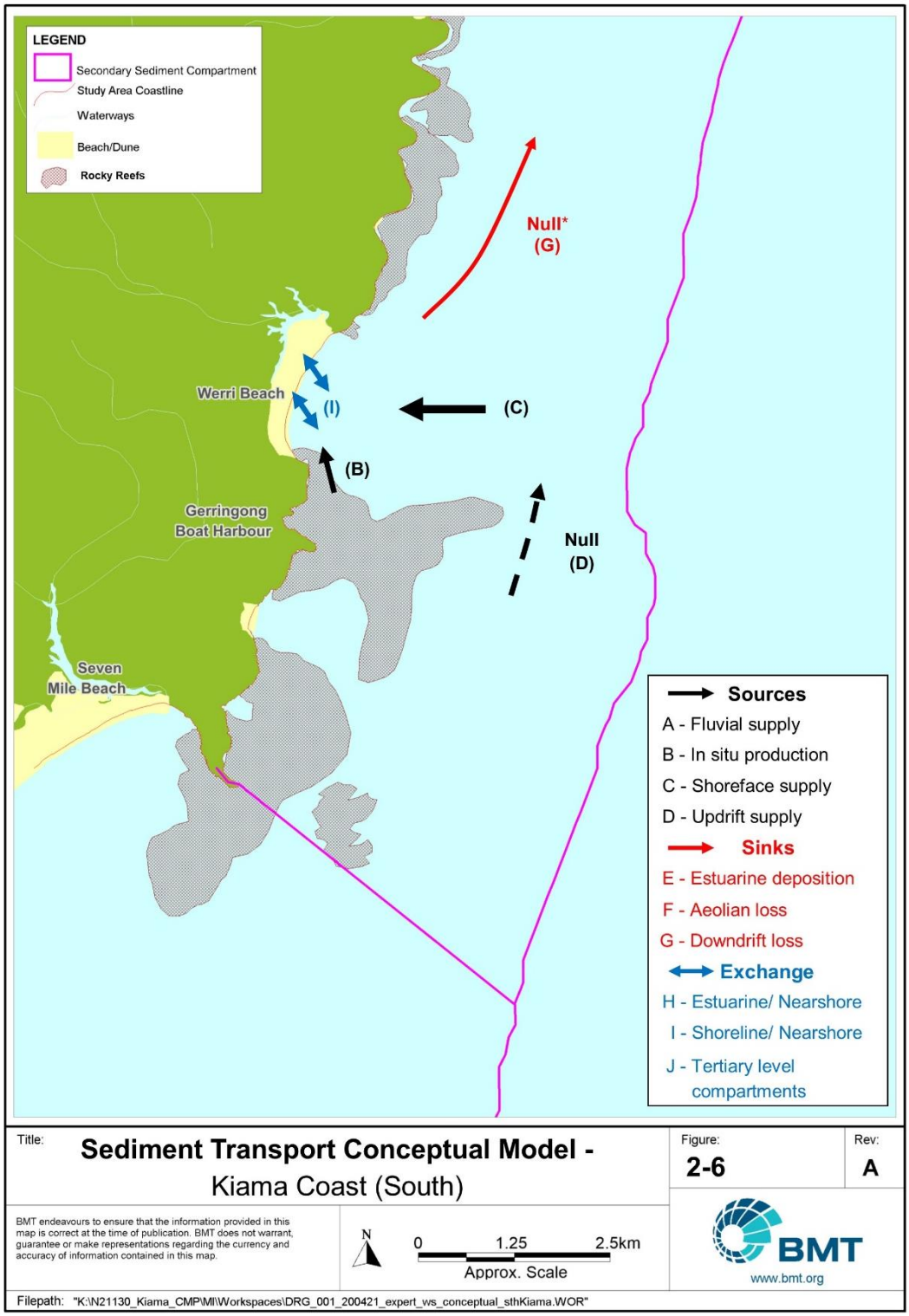


Figure 2-6 Sediment transport conceptual model for the southern region of the Kiama Coast secondary sediment compartment.

2.5.3 Seven Mile Beach (part of Shoalhaven River compartment)

The southern boundary of the study area is only part the way down Seven Mile Beach, however the key coastal processes are defined for the first complete tertiary compartment; Seven Mile Beach - Comerong Island. Seven Mile Beach is one of the longest beaches on the south coast of NSW, with a length of 12.5 km, and forming part of the Shoalhaven River delta. Unlike many other systems in NSW, the large, mature river found here has been supplying fine sand to Seven Mile Beach. This has helped build the beach and foredunes seaward, forming the present 1.5 km wide sandy barrier. In addition to the fluvial supply of sand, offshore supplies of sand may also be entering the Shoalhaven River compartment. Seven Mile Beach has a modern (1820 - 2010) net sand supply rate of 2.5 $m^3m^{-1}yr^{-1}$ (Goodwin *et al*., 2015).

Like the other tertiary systems within the Kiama Coast compartment, cross shore processes and exchanges of sand dominate the Shoalhaven compartment (Figure 2-7). Storm waves initiate the nearshore (sand bar) - shoreline sand exchange, and aeolian wind energy keeps the active foredune ridges supplied of sand. Despite sand moving into the incipient dunes from the beach, the system still maintains a positive sediment budget, and this is most probably due to small amounts of sand still being supplied to the system from the inner shelf and the Shoalhaven River (Goodwin *et al*., 2015) (Figure 2-7). There are also cross shore sand exchanges between the estuary inlet (river mouth) and the nearshore. For example, during periods of low fluvial flow, tidal currents transport marine sands into the estuary (thus no sediments are discharged to the coast) and constrain the entrances towards closure. When freshwater flows increase, it is likely some sand is discharged to the nearshore through the Crookhaven Heads entrance even if the Shoalhaven Heads entrance remains unbreached). During very large catchment flows, the Shoalhaven heads entrance becomes breached and sediments are brought to the coast from the Shoalhaven River catchment, as well as from erosion of riverbanks (Carvalho, 2018).

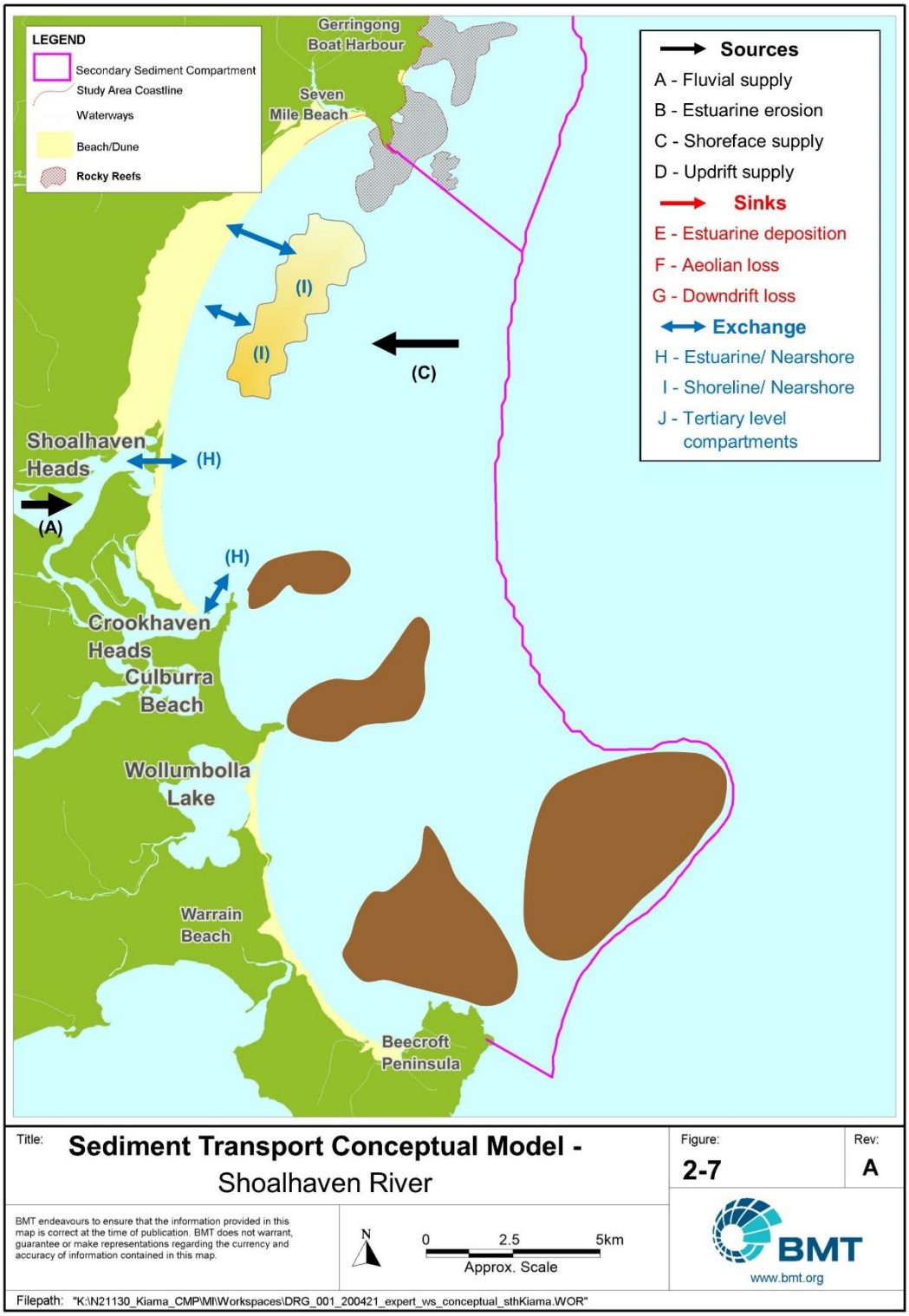


Figure 2-7 Sediment transport conceptual model for the Shoalhaven River secondary sediment compartment.

3 Coastal Erosion and Shoreline Recession Assessment

3.1 Erosion Hazard Modelling Methodology

The extents of potential coastal erosion have been calculated using a probabilistic model developed by BMT. This model considers the key sediment transport processes (storm demand, net sediment movements and SLR impacts) and combines them for future years to estimate a future erosion hazard area.

In line with the recommendations of the NSW Coastal Management Manual, the modelling has been conducted in a probabilistic way. Instead of using a single set of inputs for the sediment transport processes, the probabilistic methodology uses assumed ranges of inputs with associated probabilities. The result is a range of potential future erosion conditions that can be quantified as having a certain probability of occurring (based on the underlying science and known assumptions).

Probabilistic modelling of erosion provides an additional benefit for coastal managers in incorporating the sporadic and uncertain nature of coastal processes, and to assess the sensitivity of different areas of the coastline to these.

The distributions of input values and the method of incorporation are expanded on in the preceding section and Appendix A. In short, suitable ranges of the erosion volume associated with each of the key processes (listed below) have been randomly sampled over 1,000,000 iterations to produce a range of possible total erosion volumes. These volumes have then been converted to an associated setback by analysing the geometry of the beach/dune system in the 2018 Marine LiDAR. Finally, the erosion setbacks were ‘clipped’ where they intersected areas of likely bedrock to produce the final erosion extent.

3.1.1 Key Input Variables

For this study, the set of input parameters and distributions was developed based on the literature review underpinning the development of conceptual models of the study area (see Section 2.2) and refined in a modelling expert workshop.

The key input variables for the erosion hazard modelling include:

- Storm demand / bite (or “Fluctuating Erosion” – Appendix A.2.2)
- Net sediment supply / deficit (or “Cumulative Erosion” – Appendix A.2.3)
- SLR and the recession in response to that rise (or “SLR Recession and Accommodation Space” – Appendix A2.1)
- Geological influences on erosion (see Appendix A.2.4).

The input parameters selected for use in the erosion hazard assessment for the Kiama coastline are briefly described in the following section, and more thoroughly described in Appendices A and B.

3.1.2 Input distributions

The modelling approach requires that every input parameter be described as a probability distribution that captures the variability and uncertainty of the parameter. The distribution types (Figure 3-1)

represent the collective understanding about a parameter's likely range of values, with an appropriate degree of complexity. Naturally variable but well understood inputs are represented by 'complex' statistical distributions (such as normal distributions or gaussian curves) based on a detailed research. Less well understood parameters use simplistic distributions (such as the triangular distribution) that are suitable for representing an approximate range of probable values (upper and lower bounds), centred around a 'best guess' modal value. The bounds of these simplistic distributions are designed to capture a range of observed or potential values with an appropriate level of conservativism.

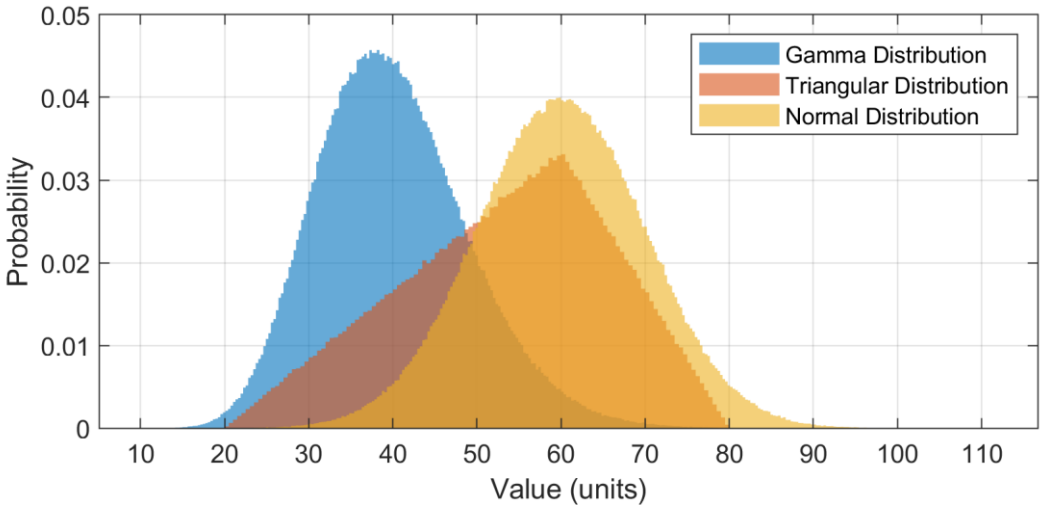


Figure 3-1 Example distribution types

3.1.3 Model Timeframe Scenarios

As per the requirements and recommendations of Council, and the Coastal Management Manual (OEH, 2018), the probabilistic modelling and hazard mapping has been conducted for the following timeframes:

- Present day (2020)
- 2040
- 2070
- 2120.

3.2 Erosion Hazard Processes and Probabilistic Input Parameters

3.2.1 Storm Demand (Fluctuating Erosion)

The most recognised form of beach erosion on sandy beaches is that due to storm activity. 'Storm demand' is the volume of sand that is 'lost' from the beach, causing the shoreline to retreat, and often creating a near-vertical 'scarp' effect in the foredune. In beaches without significant net sediment supply or deficit, the lost sediment often forms a sand bar, which is slowly transported back onto the beach in the weeks and months after the storm. This process is known as beach 'recovery'.

Storm demand is usually considered a temporary process, but may trigger or exacerbate other more permanent processes. Regardless, a suitable 'buffer' of land needs to be established to account for intermittent storm erosion events, or a series of sequential events, without losing the whole dune before the beach recovery process can take effect.

The fluctuating (storm demand) erosion component used in the current modelling follows Kinsela et. al (2017), which used a gamma function derived based on earlier work by Gordon (2015) to define the storm demand for exposed open-coast beaches in NSW. This parameterisation was validated as fit-for-purpose by Kinsela and others (2017) by comparing the predictions to observations of historical maximum erosion escarpments at exposed beaches. Figure 3-2 illustrates the gamma distributions used, and the relationship to percent exceedance (i.e. 1% chance probability of the storm occurring) used for this parameter. Which follows the recommendations of Woodroffe *et al* (2012), whereby a probabilistic framework is being applied to beach erosion hazard modelling.

As not all beaches within the study area are equally exposed to wave energy and the associated erosion hazard, scaling factors for the 'exposure' have been applied. These scaling factors have been based on the amount of wave energy that is able to make it to the nearshore areas rather than being dissipated or lost around headlands and shoals. Scaling factors on the fluctuating erosion component have been based on ratio of significant wave height squared between the offshore and nearshore areas for a series of points along the coastline. This is a simplified approximation of wave energy, but is likely to provide an appropriate scaling factor for more sheltered beaches. Adopted fluctuating erosion scaling factors are presented in Figure A-8 (Appendix A.2.2).

Further description of the quantification of storm demand potential for the Kiama beaches is presented in Appendix A (A.2.2 Fluctuating Erosion Parameterisation).

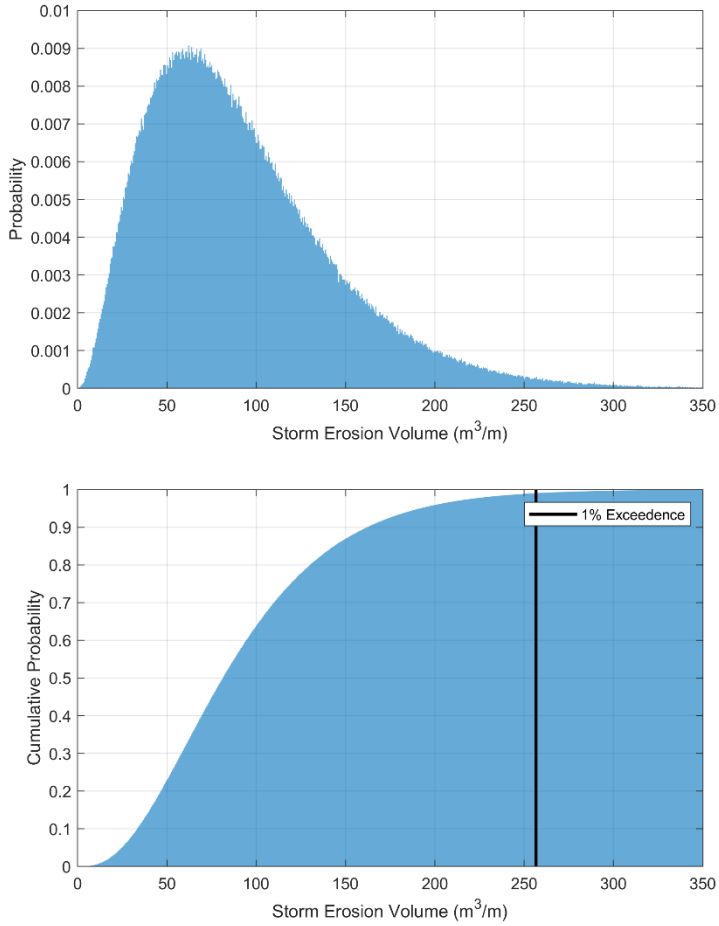


Figure 3-2 Storm Demand Gamma Distribution

3.2.2 Net Sediment Supply/Deficit (Cumulative Erosion)

Where beaches are gaining sediment faster (/ slower) than they are losing it, there will be a net sediment supply (/ deficit). The reason for this can be a short-term interruption in the 'normal' sediment transport processes (such as a new rock groyne blocking sediment from leaving a beach).

Quite often though, the causes of net sediment effects are long-term in nature and difficult to study. Many of these relate to changes in wind, wave and sea level conditions that may be cyclical over decades to millennia.

Kiama is part of the Illawarra primary sediment compartment, which experiences a general tendency for sand to move progressively north. The beaches in Kiama, however, appear largely stable, with rocky headlands restricting the exchange of sand between beaches. It is possible that there is a net sediment supply from the shoreface. BMT investigated for any sediment supply/ deficit using available photogrammetry data for the period 1949 to 2018, using the method outlined in Doyle *et al* (2019; Doyle, 2019), and data obtained from the NSW Beach Profile Database (DPIE, 2020). Photogrammetric analysis of the beach foredune profiles shows that many of the dunes had smaller volumes of sand prior to 1980, but have remained stable since. In general, the main conclusion to be drawn from the photogrammetric analysis is that there is no evidence of a net-erosive effect for these beaches. Some beaches appear to have an ongoing accretionary process of up to 40-

50cm/year (foredunes have a slightly higher rate – see Table A-1 for more information), though it is unknown whether this is a long-term storm recovery, or ongoing. Regardless, it is conservative to assume that over the modelled timeframe of 100 years, that there is a net zero long-term sediment transport (i.e. the beaches are meta-stable).

Further description of the methodology used to analyse net sediment effects for the Kiama beaches is presented in Appendix A (A.2.3 – Cumulative Erosion Parameterisation). Appendix A.2.3 also presents the output results of the photogrammetric analysis conducted by BMT (see Figure A-10 to Figure A-14).

3.2.3 Sea Level Rise and associated shoreline recession (SLR Recession)

Future SLR will result in the underwater sandy areas to be deeper than they are currently. This change may allow some of the sediments eroded by storm effects to remain in the deeper nearshore zone and not fully recover to the upper beachface. This process continues until the seabed profile has risen in-line with the sea levels. As storm demand only draws sediments a certain distance offshore, this process does not extend into deep waters, so the area that can trap sand (the accommodation space), and therefore the total volume 'demand', can be calculated easily. This volume represents a volume that has come from the beach and foredune, and will therefore result in beach recession.

The response of the shoreface to SLR for the Kiama study area has been modelled using the Bruun Rule (Bruun, 1962). The Bruun rule assumes that the shoreface profile rises in line with the sea levels and will retreat until the volume of set-back is equal to the accommodation volume. This model assumes that all other net inflows of sediment are negligible, and that the sediment must come from the beach and dune part of the active profile. It also effectively assumes that the shoreface is well-approximated by a concave Dean-type profile (Dean, 1991).

This study has adopted updated SLR projections, based on the recent SROCC report by the IPCC, and the RCP 8.5 scenario for all modelled coastal hazards. Further detail about the adopted RCP scenario (RCP8.5) and projected localised SLR curves are shown in Section 2.4.1. For shoreline recession modelling, the SLR component is represented as a normally distributed input of values from the SROCC report summarised in Table 3-1 and shown in Figure 3-3 (and further described in Appendix B).

Table 3-1 Sea Level Rise Distribution Parameters

Year	RCP8.5 Mean (meters above the 1986-2005 average sea level)	RCP8.5 Standard Deviation
2020	0.08	0.02
2040	0.23	0.05
2070	0.50	0.10
2120	1.32 (*extrapolated*)	0.21 (*extrapolated*)

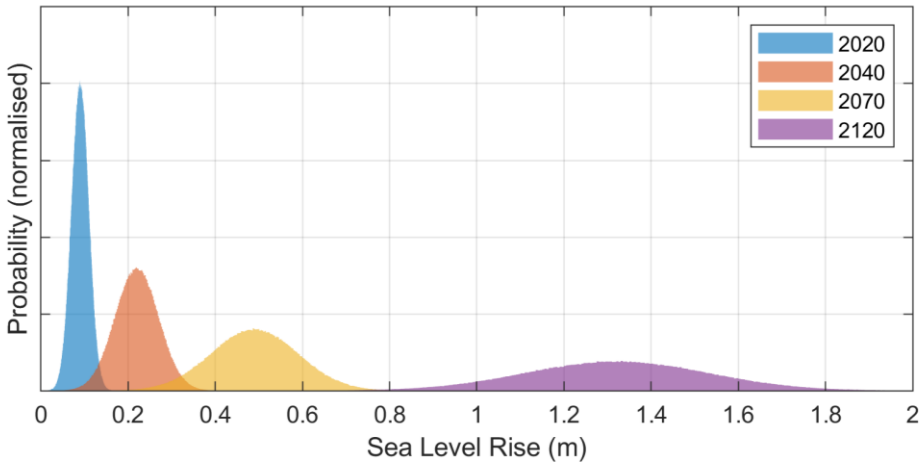


Figure 3-3 Adopted Sea Level Rise Distributions

The beach slopes have been taken from the shoreface profiles, which were extracted from the 2018 Marine LiDAR (DPIE, 2018), and then 'calibrated' as Dean profiles (Dean, 1991). These cross-shore profiles were taken at several locations through each of the key beaches and are shown (along with the calibrated profiles) in Appendix A.2.1.

The depth of closure has been applied as a triangular distribution (Figure 3-4) with bounds spanning from the Hallermeier littoral zone limit to the outer shoal depths (Hallermeier, 1981) based on the wave record at Port Kembla (to 2020). This results in depths of closure from ~10m to ~30m respectively (for beach sand). These values have been truncated by applying a minimum depth of closure where analysis of the cross-shore profiles demonstrates existing natural controls on the sediment exchange.

The methodology for calculating the erosion effect of SLR is presented in Appendix A (A.2.1 – SLR Recession and Accommodation Space Parameterisation).

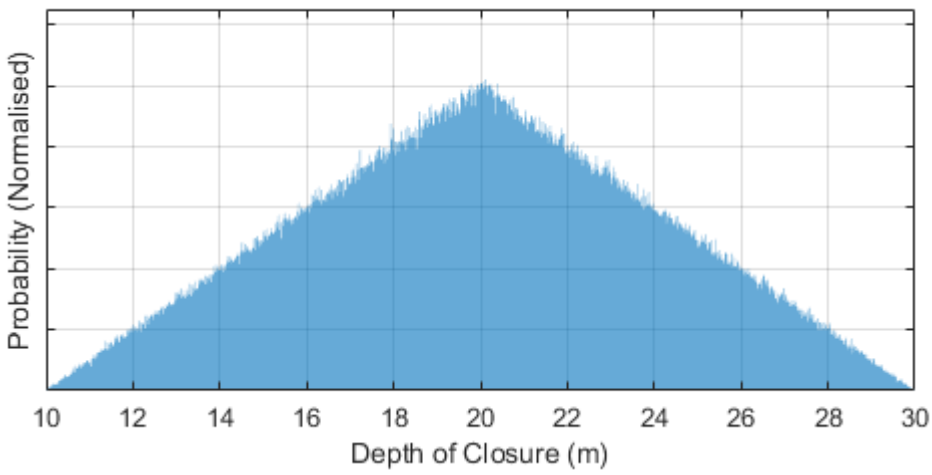


Figure 3-4 Sampled Depth of Closure Distribution

3.2.4 Geological Influence on Erosion Hazard

A key driver of uncertainty in erosion hazard analysis is the underlying geological influences. The study area is a complex mix of erodible sands, alluvial deposits, as well as high-level bedrock substrate and exposed rock cliffs. The methodology of the probabilistic erosion hazard model assumes that all topography is readily erodible and generally represents erodible sands. As such, a treatment has been applied to limit the erosion hazard extent where known bedrock deposits will limit the erosion hazard. To do this, a 'likely bedrock' extent has been developed and used to clip the extent of the erosion hazard so as to not extent into this area.

This likely bedrock extent has been developed based expert judgement drawing on quaternary geological information (Roy, 1980), the Marine LiDAR from 2018 (DPIE, 2018) and recent aerial imagery taken from Nearmap.

More detailed information about the geological influences on the Erosion Hazard modelling is presented in Appendix A (A.2.4 – Geological Influence on Erosion Hazard).

3.3 Erosion / Recession Hazard Results

Considering the requirement of a set of outputs that convey the variability and magnitude of potential erosion recession hazards, several hazard exceedances have been presented:

- **Possible:** Corresponding to a setback distance that is the **most likely** to be reached (50% of 1 million simulations predicted shoreline setback **greater or equal** to this distance).
- **Unlikely:** Corresponding to conditions that are only exceeded with combinations of high sea-level rise and extreme storm erosion (only 10% of 1 million simulations predicted shoreline setback **greater or equal** to this distance).
- **Extreme / Rare:** An upper bound setback extent (only 1% of 1 million simulations predicted shoreline setback **greater or equal** to this distance).

These exceedances can be interpreted as a probability of being exceeded. For example, when examining the 'Extreme' exceedance hazard extent, there is less than a 1% chance that this will be exceeded over the timeframe of the projection. Such conditions provide Council with an improved decision-making tool where different 'risk appetites' can be adopted for different applications as required.

It should be noted, however, that this probabilistic interpretation depends on the input distributions that have been applied and should be updated if further research or data becomes available on appropriate ranges of these.

Example probabilistic modelling outputs for a central location at Kendalls Beach are provided in Figure 3-5. The histograms illustrate the density of modelling results and the relative contribution of the storm and SLR erosion components to the total coastal recession for each planning horizon. As expected, the contribution of SLR to the total coastal recession increases with time.

Example exceedance probability curves for central Kendalls Beach are also shown in Figure 3-5. These outputs (and the equivalent outputs for other locations) provide the basis for erosion hazard mapping, such as that shown in Figure 3-6 for the coastline between Easts Beach and Kiama

Harbour. The full set of probabilistic modelling outputs and erosion hazard maps can be found in Appendix F, and the key model outputs can be found in Appendix A (A.2.5).

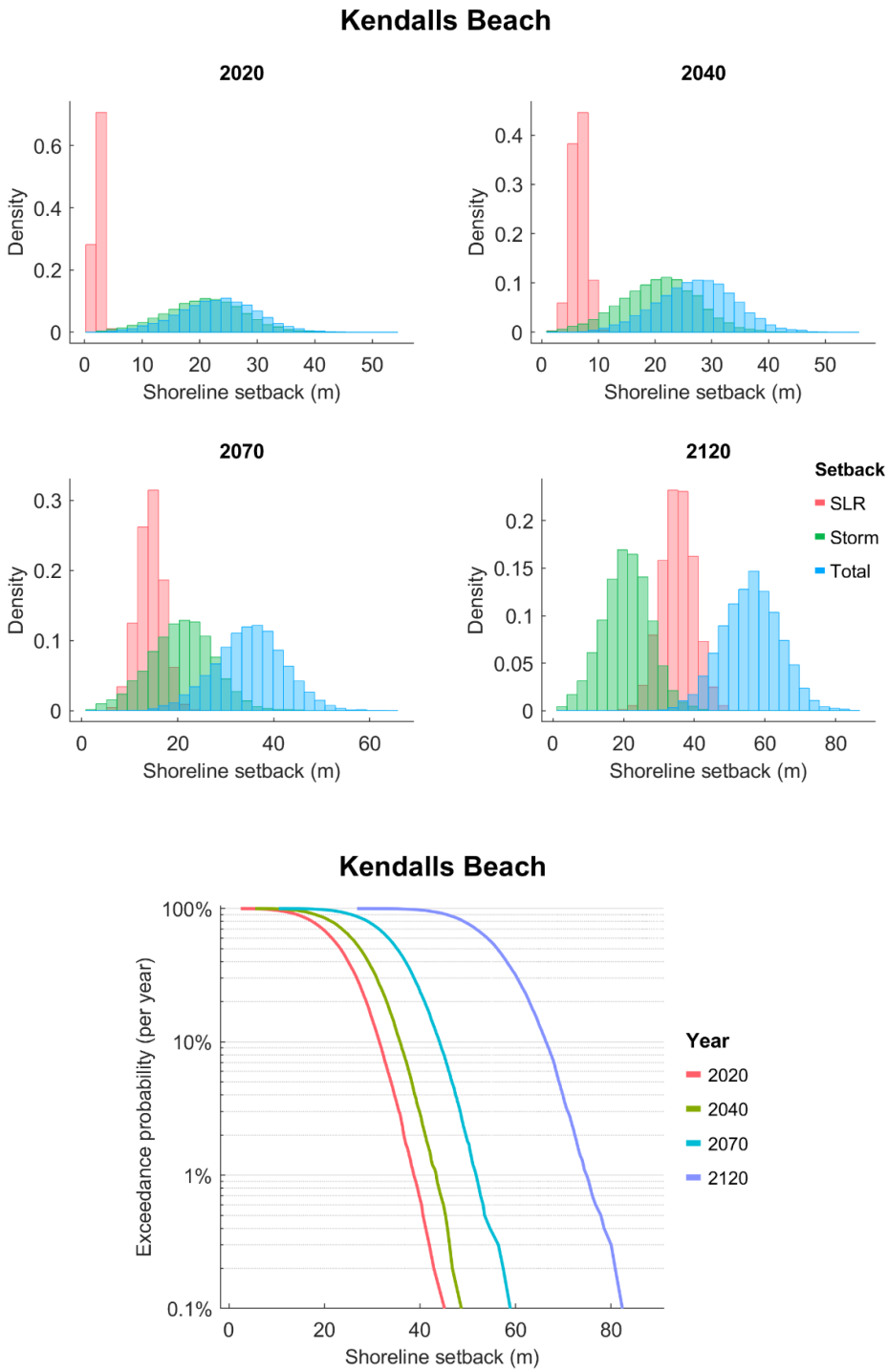


Figure 3-5 Example Erosion Hazard Probabilistic Modelling Results at Kendalls Beach: Histograms Illustrating the Shoreline Setback Contributions and Results Density (top); Exceedance Probability Curves (bottom)

Figure 3-6 Example 2120 Erosion Hazard Map

4 Coastal / Tidal Inundation Hazard Assessment

4.1 Inundation Hazard Modelling Methodology

Like the erosion hazard modelling (Section 3.1), the inundation modelling has been assessed probabilistically. The components of storm-tide and SLR are both defined by statistical distributions of the most likely results. Most of the time, the average values of these distributions are reported as the most likely, with a 5-95% range often reported as the 'error bounds', or 'confidence interval'.

For this study, the full distributions were statistically combined (integral convolution) and then any additional wave effects were added as required. The result was the following different levels:

- **Almost Certain**: A 95% exceedance level, representing a lower-bound confidence interval, with a 95% chance that inundation will be greater than this
- **Possible**: A 50% exceedance level, representing the most likely (highest probability) inundation level, with higher and lower levels being progressively less likely.
- **Unlikely**: A 5% exceedance level representing an upper-bound confidence interval, with only a 5% chance of inundation higher than this.

Each of these different inundation extents were calculated and mapped for a Tidal Inundation HAT condition, as well as two Coastal Inundation conditions: a 20-year ARI; and a 100-year ARI.

4.1.1 Key Input Variables

For this study, the set of input parameters and distributions were developed based on a modelling expert workshop.

The key input variables for the **tidal inundation** hazard modelling include:

- Highest Astronomic Tide (constant value, calculated using Fort Denison tide gauge record)
- Probabilistic future SLR (RCP 8.5 values from SROC).

The key input variables for the **coastal inundation** hazard modelling includes:

- Storm Tides and Tide Anomalies (or Open Coast Extreme Sea Levels)
- Waves (constant value, Wave Setup / Runup)
- Probabilistic future SLR (RCP 8.5 values from SROC).

4.1.2 Model Timeframe Scenarios

As per the recommendations of the Coastal Management Manual (OEH, 2018), the probabilistic modelling and hazard mapping for inundation has also been conducted for the following timeframes:

- Present day (2020)
- 2040
- 2070
- 2120.

4.2 Tidal Inundation Processes and Probabilistic Input Parameters

4.2.1 Tidal Inundation (or Astronomic Tide)

Tides occur as a response to astronomic gravitational forces (largely the effects of the sun and the moon). In Kiama, the tides vary in a semi-diurnal pattern (two high, and two low tides per 24-hours) and a moderate spring/neap variation (larger tides during full and new moons). Other longer-term variations also occur that mean certain high tides are larger than others.

The theoretical highest high tide that can be caused by astronomic forces alone is known as the 'Highest Astronomic Tide' (HAT) (see Section 2.4).

Tidal inundation areas are those lands that are within the inter-tidal range (up to HAT). Most often, these areas do not contain any development, and are composed of beaches, estuary banks, marshes and mangrove areas, which are largely tolerant of regular inundation.

Rare high tides (e.g. HAT) may further inundate adjacent low-lying areas that are less tolerant of inundation. Rising sea levels may increase the frequency at which many areas are inundated by tidal conditions in the future, and may extend tidal inundation further landward than at present.

Astronomical tide effects can be used for tide prediction by calculating the relative amplitude and timing (phase) of each of these forcing components (constituents) using astronomic tidal analysis. This analysis is conducted by analysing tidal water level gauges and attempting to remove any non-astronomic effects. Relatively high-quality predictions can be derived from long-term tide gauges and key levels (tidal planes) can be reported. For this project, astronomic tidal analysis was conducted on Fort Denison tide gauge data to predict the HAT for the Kiama study area. Table 4-1 (below) outlines the results of this tidal analysis.

Table 4-1 Tidal Planes at Fort Denison

Name	Description	Level (m MSL)	Source
HAT	Highest Astronomical Tide. The potential combination of all astronomic components. i.e. the highest astronomic high-tide possible.	1.15	MHL (2017)
MHWS	Mean High Water Springs. The average high tide during spring tides.	0.64	MHL (2018)
MHW	Mean High Water. The average of all high tides.	0.51	
MHWN	Mean High Water Neaps. The average high tide during neap tides.	0.39	

Further information on the methodology for analysing Astronomic Tide for the Kiama coastline is presented in Appendix B (B.2 – Astronomic Tide).

4.2.2 Sea Level Rise

SLR will increase the overall risk of tidal inundation. The increase in 'base' water level under a future climate scenario will increase the frequency at which certain elevations will be impacted by inundation from the coast. For example, some areas that are only inundated by the HAT under present-day conditions will have the potential to be inundated by normal high tides by 2100 or beyond.

Assessment of risk due to SLR has been based on the latest projections of SLR by the IPCC (and SROCC) (see Section 2.4.1). The tidal inundation probabilistic assessment adopts the SLR distributions presented in Section 3.2.3 (Table 3-1).

For SLR timeframes considered in this CMP that go beyond the timeframes detailed in the latest IPCC publications (e.g. 2120), trend extrapolation of the IPCC data was used.

4.3 Coastal Inundation Processes and Probabilistic Input Parameters

4.3.1 Storm-Tide and Tidal Anomaly (or Extreme Sea Levels)

Many other disturbances to the ocean can cause changes to the coastal water levels. These can be due to atmospheric effects of wind and air pressure pushing on the ocean from the top, or from geological effects such as landslides, or earthquakes causing tsunamis disrupting the water at depth. In either case, what might be small variations in the deep ocean, can often be amplified towards the shoreline.

As these processes alter the normal tidal signal but can occur at any part of the tide (high tide and low tide), they are known as the 'tidal anomaly'. When driven by storm effects, the resulting combination of the regular high tide and barometric storm surge is known as the 'storm tide'. Figure 4-1 shows an example of a tidal cycle in NSW, as well as several tidal anomalies for that period (from MHL, 2019).

In Kiama, storm-tide predominantly drives extreme tidal water levels. Different storm tide heights have been extracted from an Extreme Value Analysis of water levels at the Sydney Fort Denison Tide Gauge for different event frequencies (Annual Recurrence Intervals) of the 100-year ARI and 20-year ARI. These represent conditions that have a 1% chance and 5% chance of occurring in any year respectively (see Section 2.4). Observed extreme tidal water levels at the Fort Denison tide records have been analysed from 1965 to 2019. A peak-over-threshold (PoT) methodology was used to extract extreme events classed as water level peaks above 1 mAHD separated by a minimum 6-day period. These extremes have been fitted to a generalised pareto distribution for extrapolation. For each given ARI, the uncertainty bounds represent the 5-95 percentile[2] range from a normal distribution around the mean. The results of this analysis are shown in Figure 4-2 (below). The analysis focused on the observed total water level statistics only, however we note that tidal anomalies within 0.3-0.6m are typical for this section of coastline (MHL 2018).

Further information on the methodology for analysing extreme water levels for the Kiama coastline is presented in Appendix B (B.5 – Open Coast Extreme Sea Levels).

[2] 5th percentile = 95% exceedance; 95th percentile = 5% exceedance

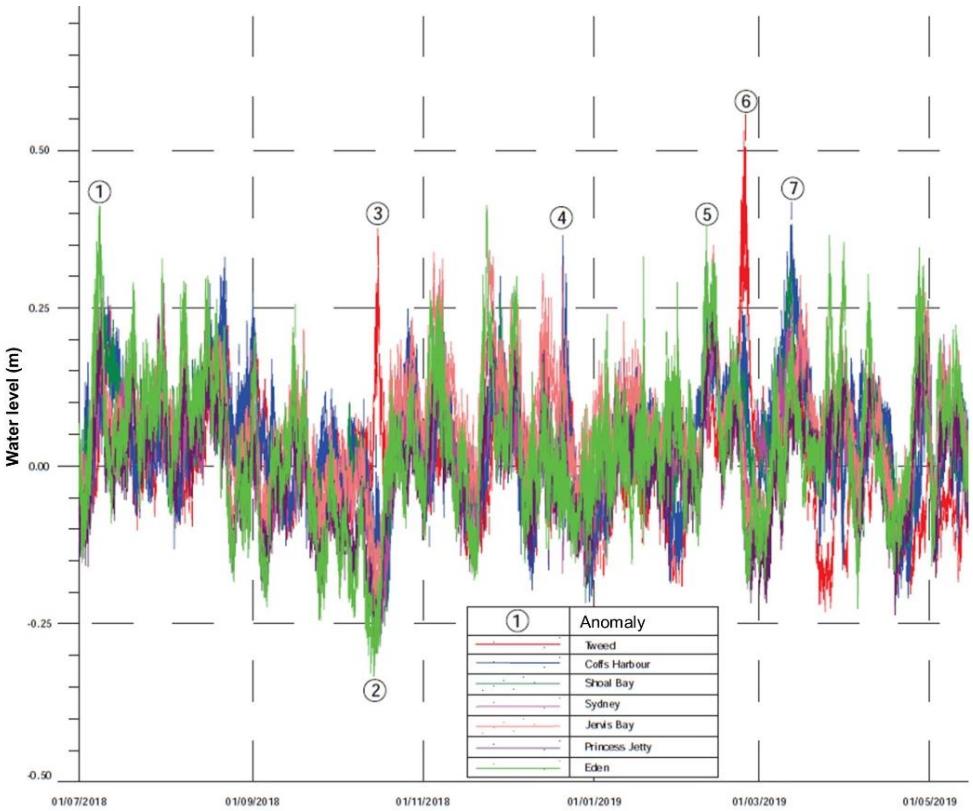


Figure 4-1 Typical tidal anomalies along the NSW coast (from MHL 2019)

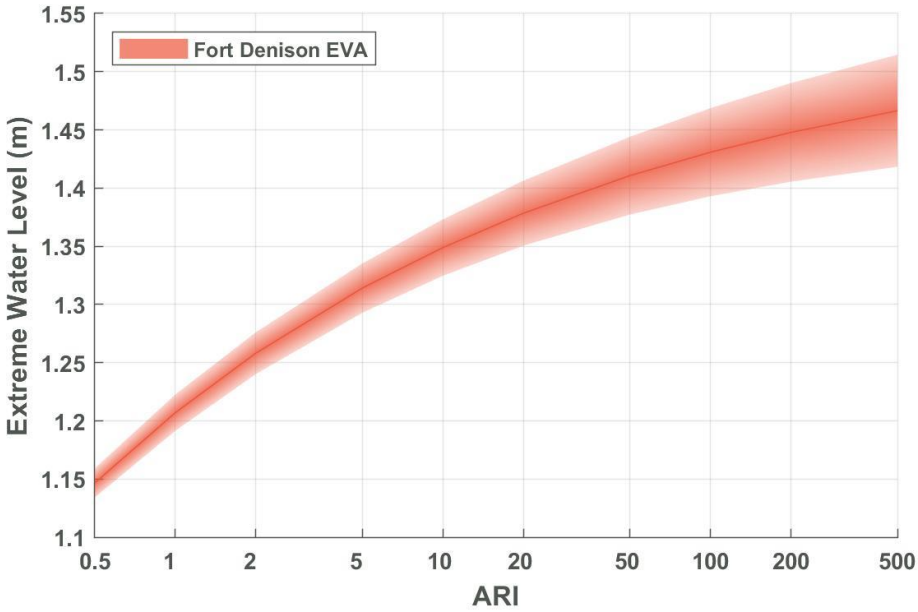


Figure 4-2 Extreme Value Analysis at Fort Denison (5-95% CI shown)

4.3.2 Waves (inc. Wave Setup / Runup)

As waves approach the shoreline, they become affected by the shallowing sea bed, which causes them to slow and steepen (i.e. 'shoal up'). This effect can cause waves to break, releasing the wave energy in a bore that pushes water further towards the shore. This has two key effects on the water level:

(1) The persistent landward force of waves 'holds' water nearer to the shoreline, causing the average water level at the shoreline to be slightly higher than in the deeper waters. This process is known as wave setup.

(2) As the waves reach the shoreline, the landward momentum of the water allows the wave to surge up the sloped beach face temporarily until gravitation forces return the water downslope. This process is known as wave runup and is commonly seen in the swash zone at the beach under normal conditions.

During extreme wave conditions, these processes can increase the extent of the inundation hazard by pushing seawater into areas beyond the regular swash zone for short periods of time. While the area exposed to this component of the hazard is not fully 'inundated', the temporary wave effects can damage property and cause a safety risk. Even temporary salt water inundation can impact vegetation, and damage infrastructure.

In assessing wave setup/runup effects for Kiama, the model of Stockdon and others has been applied (Stockdon *et al*., 2006). This relates an extreme significant wave height and wavelength with the relevant beach slope to calculate components of both the wave setup and runup. Based on analysis of the 2018 Marine LiDAR, many of the beaches within the Kiama coastline have a beach slope in this region less than 0.1. As such, $\tan\beta=0.1$ (1:10) has been taken as a suitable approximation for beach slope.

For coastal inundation hazard assessments, the waves that are most likely to coincide with high-tide conditions are likely to be of greatest interest. As such the 6-hourly wave conditions have been used at the same recurrence interval (ARI) as the storm tide (i.e. 100-year storm-tide combined with a 100-year wave height to calculate the wave runup level). The 100-year wave condition is not likely to be perfectly correlated with a 100-year storm-tide, however it is a conservative assumption and one that is commonly made. The wave runup conditions that have been applied over the Kiama coastline are shown in Table B-3 (Appendix B.5)

The analysis of suitable maximum wave setup/runup effects is detailed in Appendix B (B.6 – Wave Setup / Runup).

4.3.3 Sea Level Rise

SLR will increase the overall risk of coastal inundation. The increase in 'base' water level under a future climate scenario will increase the frequency at which certain elevations will be impacted by inundation from the coast. For example, some areas that are only inundated by the largest storms under present-day conditions will have the potential to be inundated by normal surf conditions by 2100 or beyond. Assessment of risk due to SLR has been based on the latest projections of SLR by

the IPCC (and SROCC) as detailed in Section 2.4.1. The coastal inundation probabilistic assessment adopts the SLR distributions presented in Section 3.2.3 (Table 3-1).

For SLR timeframes considered in this CMP that go beyond the timeframes detailed in the latest IPCC publications (e.g. 2120), trend extrapolation of the IPCC data was used.

4.3.4 Future Inundation Modelling

In order to calculate appropriate inundation levels to assess for future planning timeframes, the various components of potential future inundation need to be combined. As each component is uncertain, a probabilistic approach has been used to incorporate the statistical distributions and derive a range of outputs based on certain likelihoods.

Future Tidal Inundation extents and mapping has been developed using the constant HAT value (presented in Table 4-1), plus a probabilistic future SLR component (which is represented as a normally distributed input of the RCP8.5 values published in the SROCC report) (Appendix B.4).

Future event based conditions for the Coastal Inundation hazard has been developed and mapped using two probabilistic components (Extreme Sea Levels and Sea Level Rise – convoluted into a single normal distribution) and a single constant (Wave Set/ Runup).

For more information on how both Tidal and Coastal Inundation have been modelled now and into the future, see Appendix B (esp. Appendix B.7).

4.4 Tidal Inundation Hazard Results

The assessment of tidal inundation hazard has adopted the Highest Astronomic Tide (HAT) as the defining inundation condition. HAT represents the highest water level that can be achieved by astronomic tidal forces alone. These conditions are likely to be exceeded by storm-tide conditions at least yearly, but are a good representation of areas that can be considered ‘inter-tidal’.

The adopted mapping methodology extrapolates the HAT conditions for different years (i.e. including SLR) landward based on a suitable Digital Elevation Model (DEM). The DEM adopted has been developed based on the 2018 Marine LiDAR survey data of the onshore areas at 5 m resolution.

Smoothing and processing of the resulting inundation datasets was undertaken in GIS to fill small ‘holes’ in the inundation layers. The expected inundation extent (50th percentile), as well as the upper (95th percentile) and lower (5th percentile)[3] confidence extents have been included in the mapping.

An example map for the 2120 HAT Tidal Inundation hazard is shown in Figure 4-3 for Mid-Kiama. A complete set of inundation hazard maps can be found in Appendix G.

Tidal inundation levels (HAT with SLR added) are presented for the Kiama region in Table 4-2.

[3] 5th percentile = 95% exceedance; 95th percentile – 5% exceedance

Table 4-2 Tidal Inundation Levels for Kiama (brackets represent 95% and 5% exceedance)

Planning Year	HAT (mAHD)
2020	1.23 (1.20 – 1.27)
2040	1.38 (1.31 – 1.46)
2070	1.65 (1.51 – 1.82)
2120	2.47 (2.13 – 2.82)

Figure 4-3 Example 2120 HAT Inundation Hazard Map (Tidal Inundation)

4.5 Coastal Inundation Hazard Results

The assessment of coastal inundation hazard has adopted the 100-year ARI and 20-year ARI for assessment. The 20-year ARI represents conditions that have a 5% probability of being met or exceeded within a given year. Similarly, the 100-year conditions have a 1% chance of occurring each year.

The 100-year conditions are typically used for planning and design purposes and are likely to be close to the highest recorded conditions in Australia. The 20-year conditions represent extreme events that are likely to have been experienced by most residents of an area at some stage.

Combined still water level and wave runup inundation conditions were mapped for this study using a GIS wave runup tool. This tool requires a simple definition of a 'wave runup zone' within which the wave runup levels are applied to define the peak inundation depth. For this study, the wave runup zone was defined as being within a 100m buffer of the shoreline. The influence of wave setup and runup processes beyond this zone (such as areas set back inland from the shoreline and up small creeks) is assumed to be minimal and therefore only the still water levels are applied there. This adopted approach produces a minor discontinuity at the 100m landward buffer location where there is a transition from the higher water level that includes wave influences to the lower water level that considers tide and surge only.

The adopted mapping methodology within the GIS tool takes the analysed wave runup and still water level output along the coast and extrapolates them overland based on a suitable DEM (as per HAT extrapolation). The DEM has been developed based on the 2018 Marine LiDAR survey data of the onshore areas at 5 m resolution.

Smoothing and processing of the resulting inundation datasets was undertaken in GIS to fill small 'holes' in the inundation layers. The expected inundation extent (50th percentile), as well as the upper (95th percentile) and lower (5th percentile) confidence extents have been included in the mapping.

An example map for the 2120 100-year ARI Coastal Inundation hazard is shown in Figure 4-4 for Mid-Kiama. A complete set of inundation hazard maps can be found in Appendix G.

Specific still-water inundation levels and maximum wave runup levels are presented in Table 4-3. Note that as per the mapping, wave runup conditions are only likely to impact areas immediately adjacent to the shoreline.

Table 4-3 Coastal Inundation Still-Water and Wave Runup Levels (brackets show 5% and 95% exceedance)

Planning Year	20-Year ARI (mAHD)		100-Year ARI (mAHD)	
	Still Water Level *	Wave Runup Level	Still Water Level *	Wave Runup Level
2020	1.46 (1.42 – 1.51)	5.25 (5.21 – 5.30)	1.52 (1.46 – 1.57)	5.58 (5.52 – 5.63)
2040	1.60 (1.52 – 1.67)	5.39 (5.31 – 5.46)	1.65 (1.57 – 1.73)	5.71 (5.63 – 5.79)
2070	1.87 (1.72 – 2.02)	5.66 (5.51 – 5.81)	1.92 (1.77 – 2.08)	5.98 (5.83 – 6.14)
2120	2.70 (2.38 – 3.03)	6.49 (6.17 – 6.82)	2.76 (2.43 – 3.08)	6.82 (6.49 – 7.14)

** Including SLR component*

Figure 4-4 Example 2120 100-Year ARI Inundation Hazard Map (Coastal Inundation)

5 Uncertainty involved in Hazard Assessments

5.1 Future Climate

Globally, local decision makers found within the coastal zone are confronted with uncertainties about future climate, SLR and associated impacts. It is therefore important to recognise that when predicting / modelling the future impacts of climate change, future projections are deeply uncertain and thus cannot be predicted with great certainty. Uncertainty about future climate projections come from several key sources, the first (which has the greatest unknown) is the future emissions of greenhouse gases and aerosols (AdaptNSW, 2020). This variable is impossible to quantify mathematically, so as described in Section 2.4.1, the IPCC have presented a series of emission pathways/ projections, known as *Representative Concentration Pathways* (RCPs). BMT have used the "global greenhouse gas emissions continue to rise" scenario, RCP8.5 to study the impact of a changing climate for Kiama. This is to ensure that management options and plans that come out of the CMP are apt to deal with severe impacts, but by taking an adaptive approach / strategy (through the NSW CMP process) they can also be scaled to a lower RCP, in response to a measured reduction in global greenhouse gas emissions. The IPCC is currently in its sixth assessment cycle with the final Synthesis Report due for release in 2022. At this time, future climate projections adopted for the CMP projects should be reviewed and considered in the context of the future climate coastal hazard and risk assessment outcomes. The second and third sources of uncertainty relate to the response of physical systems (i.e. coastal environment) to the increase in greenhouse gases and aerosols. Specifically, the second source is how large-scale systems (e.g. the whole ocean) will respond to climate change, whereas the third source relates to local system responses (e.g. NSW coastal system), given the large scale changes (AdaptNSW, 2020).

The key climate impacts this study have investigated include SLR, storm events / impacts and changes to wave climate (and associated geomorphologic processes, i.e. sediment transport, storm bite etc.). Due to the many uncertainties involved in producing future coastal projections of these impacts, BMT have conducted the modelling in a probabilistic way, so rather than using a single set of deterministically selected inputs for modelled processes, the probabilistic methodology uses assumed ranges of inputs with associated probabilities. The result is a range of potential future conditions that can be quantified as having a certain probability of occurring (based on the underlying science and known assumptions).

5.2 Coastal Hazard Parameters

5.2.1 Storm Erosion and Sediment Budget

The model that BMT have created and used is limited by the small amount of knowledge known for each process. Where possible, any likely error in the historical observations of different processes (for example, storm demand, or net sediment budget) has been accounted for with conservativism in the input distributions. However, there is a high degree of uncertainty as to whether these processes and distributions are valid for future climate scenarios. Chiefly, it is possible that climate change could alter the natural regional scale processes and/or the intensity and frequency of storms, both of which the model is highly sensitive to.

A key driver of uncertainty in erosion hazard analysis (and storm impacts) is the underlying geological influences. The study area is a complex mix of erodible sands, alluvial deposits, as well as high-level bedrock substrate and exposed rock cliffs. The methodology of the probabilistic erosion hazard model assumes that all topography is readily erodible and generally represents erodible sands. As such, a treatment has been applied to limit the erosion hazard extent where known bedrock deposits will limit the erosion hazard. To do this, a 'likely bedrock' extent has been developed and used to clip the extent of the erosion hazard so as to not extent into this area, please see Appendix A.2.4 for further details.

5.2.2 Photogrammetry

This analysis incorporates the available photogrammetric information for key beach settings contained within the Kiama LGA. This carries several limitations and considerations as follows:

- The number of data points available for each area differ, and therefore some beaches have less certainty about the long-term variability than others;
- Data points recorded after significant storm events may incorporate fluctuating erosion components that skew the analysis;
- Other 'one-off' changes, such as beach nourishment or dredging, may influence the observations;
- Historical data is not necessarily representative of sediment budget changes under long-term conditions due to long-period (multi-decadal) variations in sediment transport behaviour and due to climate change related effects.
- For pre-1960 imagery, errors are considered to be generally higher and can range from ±1 to 1.5 m in the horizontal and ±0.5 m in the vertical (due to lack of camera calibration). More specific details of the photogrammetric methods are given in Hanslow *et al.* (1997), or Hanslow (2007).

5.2.3 Bruun Rule

There are also inherent uncertainties and limitations in the applied 'multi-line' 1-dimensional modelling approach used to address recession / decrease in accommodation space due to SLR (see Appendix A.2.1). It is not guaranteed that the shoreface will accrete at the same rate as the mean sea level, and overall changes to the sediment transport regimes and the natural beach slope may therefore occur. It is also unclear that there is a critical depth beyond which no sediment exchange (negative and positive) can occur (the so called 'depth of closure'). However, it is likely that excepting for the other limitations detailed in this section, these assumptions are likely to be the best available tools and the assumption of an equal increase in the shoreface relative to sea level will result in a conservative estimation of the associated setback of the beach.

The Bruun rule was the underlying equation used to model long-term recession, and despite being questioned within the scientific literature (i.e. Ranasinghe et al., 2007), it is still considered an acceptable approach to use within the coastal industry.

The depth of closure (extent of which sand is mobilised by wave processes) is a key input to the Bruun rule. Within the modelling done by BMT, the depth of closure used for each coastal section was given a maximum where analysis of the cross-shore profiles demonstrates existing natural

controls on the sediment exchange. These appear as convex features in the shoreface profile and often coincide with the bounds of rocky substrate that restricts further sediment transport. Examples of such features are shown in Appendix A.2.4.

These adjustments reflect a potential inappropriateness of the Bruun model for such constrained sub-compartments. In reality, a 'perched' shoreface profile, or concave shoreface feature may have a surplus of sediment in the shoreface that can tolerate SLR without an associated shoreline recession (i.e. the 'accommodation space' is already at a stable capacity). However, given that the Kiama open coast is at a relatively low risk of erosion (due to steep topography, and prevalence of offshore rock features and underlying bedrock, it is considered fit-for-purpose to assume a Bruun-type recession effect for planning purposes, without introducing inappropriately high conservativism. For site-specific impact assessments where higher levels of precision are required (or can be achieved as new data may become available in future), this approach should be revisited.

5.2.4 Dune Slope Instability

The storm erosion volumes calculated as part of the probabilistic erosion hazard assessment have been converted into appropriate setbacks by applying the storm demand (in m^3/m) to beach-normal profiles at 5m spacings along the shoreline as taken from the DEM above 0mAHD. This approach has not included an assessment of the sand dune slope instability zone. Nielsen et al. (1992) provide a conceptual model for dune instability that has been adopted in many previous coastal erosion assessments in NSW. The method includes a +50% 'factor of safety' in the angle of repose of sand. The method is highly dependent on dune elevation and local sand characteristics (WRL 2012) which vary throughout the study area.

Site-based consideration of the dune instability slope may be appropriate in some locations as part of adaptation option planning and design. This is likely to focus on at risk areas with existing and/or planned development. The method of Nielsen et al. (1992) may provide a useful first pass screening for dune slope instability in certain areas where it is identified as applicable (may be considered as part of the subsequent Stage 3 of the CMP). However, a detailed geotechnical assessment would be needed to support detailed planning and design activities.

5.2.5 General

This study assumes that there will be no intervention of erosion processes for the modelled periods. It is possible however, that significant erosion events may result in emergency measures to protect property and amenities, such as by creating seawalls or conducting beach nourishment. Such measures can disrupt the natural sediment transport processes and result in altered likelihoods of setback in different areas than has been identified. If such measures or events take place, updates to the assessments presented in this report may be warranted.

The following general limitations of the assessment approach and modelling apply to this study:

- Significant uncertainty arises from fitting and extrapolating statistical distributions to very limited historical datasets. It is not possible to estimate the resulting bias associated with this approach.
- The ability to predict wave runup over and beyond the sloping beach profile (into the residential and populated areas) is limited and has been approximated using an empirical relationship.

Quantifying the risks to the community and/or existing assets from inundation and wave action are limited by the availability of nearshore and seabed elevation data and the assumption of a static coastal barrier. Site-based assessments of inundation and overtopping potential, building on the work described in this report, should be completed in support of detailed planning and design projects.

It is difficult to estimate the order of magnitude of the combination of these uncertainties due to the highly dynamic nature of storm tide events and the infinite variation in the physical parameters involved. It should be noted that statistical analysis and probabilistic modelling approaches, where thousands of events are used to provide long term estimates, tend to average out the variables and provide better accuracy in the result than that predicted for a single deterministic event.

6 Cliff and Slope Instability Hazard Assessment

6.1 Overview

The Kiama coastline includes lengths of rocky coast which are subject to coastal and geotechnical processes. To date, no LGA wide assessment of the cliff and slope instability has been completed for the Kiama coast. In light of this, a first pass geological 'walk over' assessment was undertaken for the purpose of characterising Kiama's rocky coast and screening any potential cliff and slope instability risks to built assets or public safety which may warrant further detailed geotechnical investigation, conducted by a qualified geotechnical engineer, and following an industry recognised methodology like that outlined by the Australian Geomechanics Society (AGS, 2007).

6.2 Study Area

The study area is characterised by a scenic rocky coastline with pocket beaches (with the exception of Seven Mile Beach) interspersed with prominent rocky headlands. The Kiama coast is made up of several different rock types, as detailed in geological mapping by Bowman and Stewart (1972) and Carr and Jones (2001), including (from north to south):

- Basalt
- Kiama Sandstone Member
- Blow Hole Latite Member, which include the following:
  - Columnar-jointed facies
  - Rifle Range Sandstone Member
  - Tube and breccia facies
  - Sheet and lobe facies
- Westley Park Sandstone.

The geological materials that make up the coast substrates influence the physical form on the varying rocky geomorphology that is exhibited within the study region.

6.3 Aims and Objectives

A high-level geomorphic assessment of cliff stability was conducted, based upon a review of literature, LiDAR and site inspections relating to the geology, coastal cliff/slopes types and failure mechanisms, and assets. The assessment provides a first pass screening for cliff and slope instability, and will be used to develop recommendations for areas requiring a more detailed geotechnical assessment (by a geotechnical engineer) and possible interim planning controls as part of the subsequent Stage 3 of the CMP.

This report focuses on detailed assessments to quantify (wherever possible) the likelihood and consequence of coastal hazards, as well as other identified risks to coastal habitats (e.g. as within coastal wetlands, littoral rainforests, and environment areas), and to community uses and values.

This CMP aims to provide a technically rigorous, scientifically accepted, high-level and defensible assessment of cliff and slope instability.

6.4 Assessment Approach

Herein is presented the results of a first pass field assessment of asset exposure to cliff and slope instability hazards. Safety risks / risk to life are also indicated (e.g., rock fall impacts, rock fishing risks, irresponsible community use of hazards areas – Kiama blowhole). The assessment included a three-day on-site survey and a review of available information, geomorphic descriptions of coastline, photos etc.

6.5 Summary of Exposure and Recommendations

The preliminary exposure assessment and recommendations for the Kiama coast are summarised below and presented in Figure 6-1.

6.5.1 Black Head at Gerroa

Land fronting the sewage pump station on the western side of Black Head appears disturbed. It is recommended that the slope stability be monitored. The sewage pump station on the eastern side of Black Head is situated on a weathered bedrock slope, that is fronted by a (potentially depositional) wide grassy terrace, some 5 metres above the sea. It is recommended that the slope and erosion stability be monitored.

Properties on Stafford St near Black head reserve are close to the cliff edge, where bedrock is highly fractured and localised cliff regression rates look to be higher than elsewhere (Figure 6-1). New development or extensions proposed for this area should require geotechnical assessment, especially where allotment boundaries are in close proximity to cliff line. Additionally, residents should monitor dwellings for signs of movement (e.g. formation of crack in brick work).

Burke Pde and some properties on this road are positioned on a low-lying terrace formed of alluvial/colluvial sediments, in front of bedrock cliffs. The land is possibly exposed to undercutting and slumping by wave action. Erosion of adjacent shorelines should be monitored, and formalised toe protection works may be warranted after a more detailed geotechnical investigation is conducted.

6.5.2 Gerroa to Gerringong farmland

No significant assets observed to be exposed to cliff and slope instability during the site visit.

6.5.3 Gerringong Harbour

No significant assets observed to be exposed to cliff and slope instability during the site visit.

6.5.4 Werri Beach and surrounds

The southern Werri Beach car park appears to be built on colluvium and exposed to wave, undercutting and slumping due to storm wave action (see Section 3). The adjacent shoreline to the car park should be monitored for erosion. If shoreline erosion occurs and threatens the car park asset, a more detailed geotechnical assessment may be warranted to determine the erosion

susceptibility of the car park. Additionally, a formalised toe protection works of the car park fronting the rocky slopes, may be warranted.

Geering St foreshores houses are located on a bedrock bluff slope. Under a future climate scenario, the toe of this slope may become exposed to wave action. If this occurs, some slope adjustment may occur in the event that highly weathered rock material and/or colluvial deposits become impacted by wave action. The geotechnical profile of this bedrock bluff slope is unknown at this stage. It is recommended that a geotechnical assessment be required for new development or extensions proposed where allotment boundaries adjoining the bluff slopes are located adjacent coastal hazard zones. Additionally, residents should monitor dwellings for signs of movement (e.g. formation of crack in brick work).

The road, foot path and car park on Pacific Ave is potentially built on the same colluvium sediments as the southern Werri Beach car park and possibly exposed to wave, undercutting and slumping due to storm wave action. This area may be possibly partially supported by bedrock, but will require further geotechnical investigation to confirm this risk. This area has been identified in the erosion mapping see Section 3.

6.5.5 Red Cliff to Loves Bay

This section of coast is backed by farmland and Kiama Coastal Walk, with no fringing assets observed to be at risk slope/cliff instability during the site visit.

6.5.6 East Beach and surrounds

No exposure to assets, with stable sloping profile with private assets set back from the coast. The Big4 Caravan Park, identified to have a potential exposure, appears to be built on bedrock.

6.5.7 Marsden Head to Kaleula Head

Residential properties on Boanyo Ave are located landward of a volcanic lava tube. The geological material underlying allotments adjacent to the exposed volcanic lava tube on the rocky shoreline is unknown. The underlying material may be unconsolidated sediments, consistent with exposures seaward of the property boundaries. If located on sediments/colluvium, these residential lots may be potentially exposed to hillslope process and associated geotechnical instability. Rock rubble fill placed seaward of properties suggest some instability has occurred in the past. A geotechnical assessment should be required for new development or extensions proposed within this area, particularly where allotment boundaries are in close proximity to cliff line. Additionally, residents should monitor dwellings for signs of movement (e.g. formation of crack in brick work).

Some residential properties along Boanyo Ave are in close proximity to an undercut cliff and cave profile, with the cliff face showing erosion from weathering and fracturing (see Figure 6-1). Future erosion of the cliff face profile will potentially threaten the properties built above the cave. A geotechnical assessment should be required for new development or extensions proposed along Boanyo Ave, where allotment boundaries are in close proximity to the cliff line. Additionally, residents can monitor dwellings for signs of movement (e.g. formation of crack in brick work).

A large block fall was observed down slope of a cliff side house on Gwinganna Ave, on the southern side of Kaleula Head. Additionally, a stormwater pipe discharging from the property down slope of the house was observed. A geotechnical assessment should be required for new development or extensions proposed at this property and the landowner may consider redirecting stormwater outflows away from the vertical cliff face (Figure 6-1). Additionally, residents can monitor dwellings for signs of movement (e.g. formation of crack in brick work).

6.5.8 Kendalls Point to Church Point

Some localised rockfall and undercutting was observed at Kendalls Point. The steep slope may adjust in the future which could potentially expose the footpath and campground pool. It is recommended that the cliff top pathway be monitored for evidence of slope movement (e.g. cracking), and a site specific geotechnical assessment is warranted, if this occurs (Figure 6-1).

At the showground and shared footpath on Church Point, evidence of slope movement exposing fill in places was observed, particularly where slope stabilisation works were absent. Recreational assets are at risk if slope movement continues in areas with over steepened slope profile (e.g. northern side of Church Point). Slope adjustment may expose sections of shared footpath and edges of the showground to geotechnical instability. Additionally, cracking of the shared footpath was observed on the southern side of Church point indicates slope movement. It is recommended that the cliff top pathway be further monitored for evidence of slope movement (e.g. cracking), and a site specific geotechnical assessment is warranted, if this occurs.

6.5.9 Blowhole Point to Kiama Harbour

On the north-west side of the Blowhole, approx.120 m of the Blowhole Point Rd, located immediately upslope of Stobo Rd, is situated on a highly weathered bedrock material. Evidence of minor rock falls was observed. The weathered vertical bedrock profile and proximity to wave action increases the roads exposure to slope instability. It is recommended that the cliff face be monitored for potential rock falls and slope movement and a site-specific geotechnical assessment is warranted, if this occurs.

Undercutting of the Harbour seawall towards the south-east was observed. It is recommended that a structural condition assessment be undertaken.

6.5.10 Pheasant Point

Properties located on and adjacent to the cliff face are exposed to cliff instability hazards (Figure 6-1). The thinly bedded sandstone exposed in the cliff face is relatively active, compared to the other sections of the Kiama coast. Houses cantilevered over the top of the actively eroding cliff face are highly exposed to geotechnical instability and increased exposure to undercutting where wave run up can reach the active cliff face. A geotechnical assessment should be required for new development or extensions proposed at this location, especially where allotment boundaries are in close proximity and/or extend over the active cliff line. The residents should monitor dwellings for signs of movement (e.g. formation of crack in brick work). Additionally, Council should monitor cliff stability downslope of cliff side residential properties.

Pheasant Point Dr footpath located adjacent to the cliff face, spanning Black Beach Reserve toilet block to the Continental Pool ocean baths footpath, is set above an actively eroding cliff face. In some sections a safety fence has been set up at the bottom of the cliff due to public safety risk of rock falls.

6.5.11 Bombo Headland to Cathedral Rocks

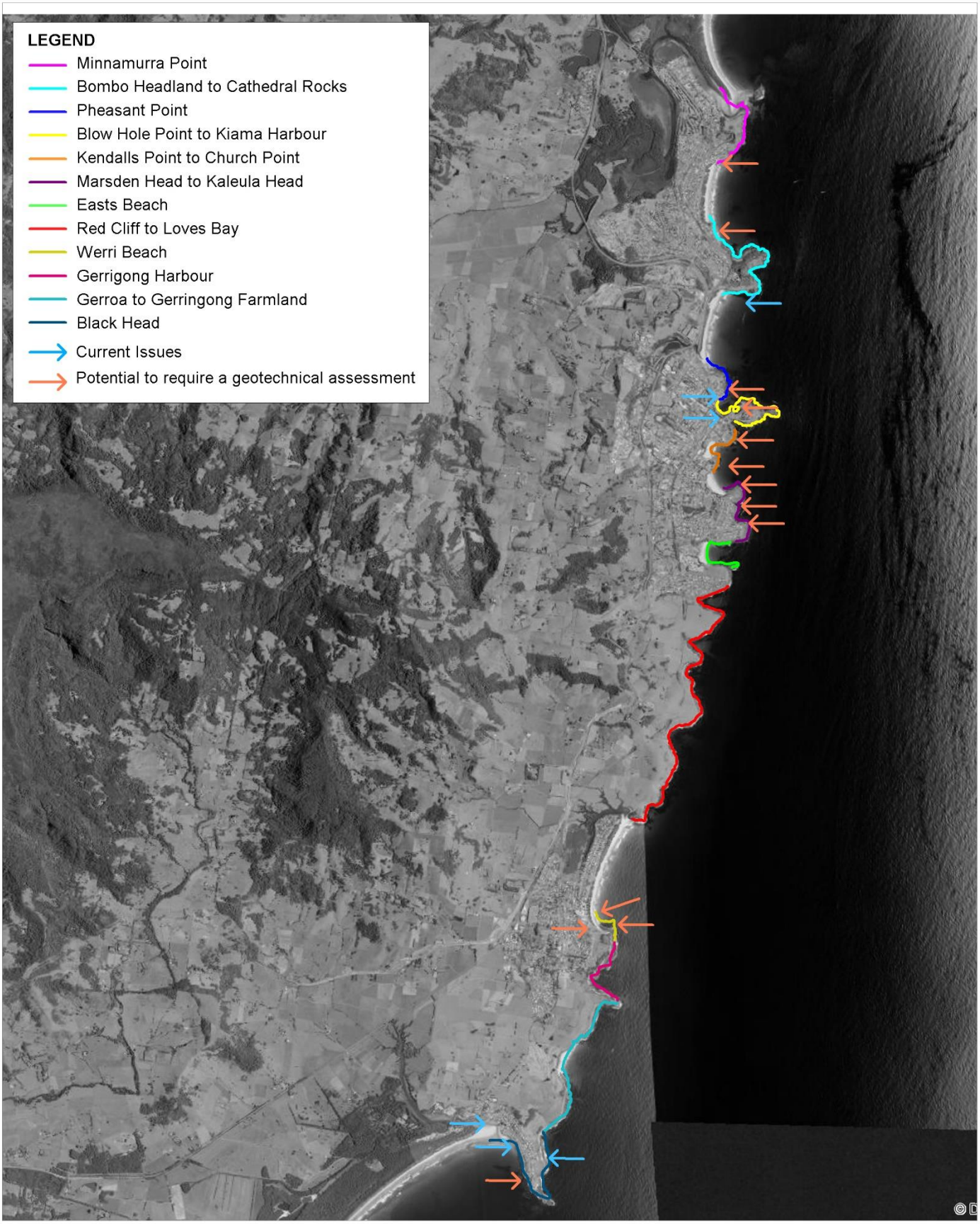
The southern side of Bombo Headland has an actively eroding cliff face. While no assets are in proximity to the eroding cliff face, there is a potential safety risk, however, drainage upgrades and safety fencing have reduced this risk.

The cliff top of Cathedral Rocks is developed with residential properties. The cliff face on the south side of Cathedral Rocks is vertical and highly jointed, with residential properties set back from the cliff face by some ~10 metres in this location. The rocky coast on the northern side of Cathedral Rocks is steeply sloping. The north facing slopes may have instability as the cliff face adjusts towards a more stable slope that is consistent with the jointing. Residents should monitor dwellings for signs of movement (e.g. formation of crack in brick work) and a geotechnical assessment should be required for new development or extensions proposed along Cliff Dr, where allotment boundaries are adjacent to the cliff line.

6.5.12 Minnamurra Point

Residential properties on Johnson St, southern side of Minnamurra Point are on low but steeply sloping cliff profiles. Evidence of slope instability was noted, including tree trunk adjustments and defects within built infrastructure. Additionally, observed fracturing of brick and concrete fencing indicates movement of the slope profile. A geotechnical assessment should be required for new development or extensions proposed at this location, particularly where allotment boundaries are adjacent to the cliff line. Additionally, residents can monitor dwellings for signs of movement (e.g. formation of crack in brick work).

The results and site details are discussed further, and photos are provided in Appendix D.



Title:

Cliff and Slope Instability Walkover

Figure: **6-1**

Rev: **A**

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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0 1.25 2.5km

Approx. Scale

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7 Kiama Risk Assessment

7.1 Risk Management Principles

A risk management approach is a powerful methodology for dealing with uncertainty in processes and information.

The Australian Standard process for analysing risks AS ISO 31000:2018 Risk management – Guidelines has been applied in this study. Risk is usually expressed in terms of risk sources, potential events, their consequences, and their likelihood. That is:

Risk	**=**	**Likelihood**	**✖**	**Consequence**
The effect of uncertainty on objectives		The chance of a risk event occurring		The outcome of an event affecting objectives

Therefore, both the 'likelihood' and 'consequence' of coastal hazards and other issues need to be analysed. Likelihood and consequence are combined to give the level of risk from coastal hazards to various locations, assets and values (community, ecological and economic) along Kiama's coast. Council will be using the outcomes of the risk assessment to help prioritise works and actions to address the implications of coastal hazards in the future.

Scales for likelihood, consequence and risk are discussed and analysed for the study area in the following sections.

For this Stage 2 report, Council has agreed that the risk assessment would focus on coastal hazards only because:

- this report provides the first LGA-wide assessment of the probability of exceedance of the coastal hazards at present out to 2120. This information was not available during the Scoping Study Stage 1 risk assessment; and
- the risk assessment for other coastal issues analysed for the Kiama coastline during the Stage 1 Scoping Study was considered current and the available data, knowledge and management actions are largely the same. Therefore, the outcomes of this assessment can be directly progressed to the Stage 3 management options assessment.

7.2 Risk Likelihood

The definition of coastal hazards inherently involves uncertainty relating to present-day coastal processes, plus climate change into the future. Assessing these processes using limited data and model assumptions necessarily requires consideration of the potential bounds of uncertainty in hazards assessment. In addition, there are uncertainties surrounding climate change projections, the timeframes over which this change may occur, and how climate change may modify coastal processes and the coastal environment.

Describing coastal hazards in terms of their likelihood or probability gives a clear signal that hazard lines are not absolute. Due to the uncertainties, limitations and assumptions used to assess hazards, there are a range of potential outcomes, across a range of probabilities of occurrence.

As documented in prior sections of this report, coastal hazards have been modelled and mapped in terms of their probability of exceedance. This provides a quantitative assessment of the "likelihood" of coastal hazards in the CMP area. The quantitative probabilities and equivalent qualitative likelihood descriptors that have been applied are provided in Table 7-1 below.

Table 7-1 Likelihood Scale Used to Assess Coastal Hazards

Likelihood	Description	Probability of Exceedance		
		Erosion Hazard ^	Coastal Inundation	Tidal Inundation
Almost Certain	There is a high possibility the event will occur as there is a history of periodic occurrence		95%	95%
Likely *	It is likely the event will occur as there is a history of casual occurrence			
Possible	There is an approximate 50/50 chance that the event will occur	50%	50%	50%
Unlikely	There is a low possibility that the event will occur, however, there is a history of infrequent / isolated occurrence	10%	5%	5%
Rare	It is highly unlikely that the event will occur, except in extreme circumstances	1%		

** Not used for this risk assessment, based on modelling methods*

^ In reference to the modelled erosion / recession hazard (Section 3)

7.3 Risk Consequence

The consequence of coastal hazards relates to the type of coastal hazard impact and the assets and values of coastal land affected. For example, the consequence of beach erosion at one beach may involve the loss of one or many houses, but at another beach it may be the loss of national park lands or foreshore reserves. The resulting 'risk' is different based on the value or asset exposed to the hazards (i.e. 'consequence'), even if the likelihood of the erosion event is the same.

The consequence scale used for Kiama is provided in Table 7-2. This scale considers the permanency and resilience of assets and land affected, as explained below. A social, environmental and economic consequence of the hazard impact is assigned, then the highest of these is used to determine the level of risk from the hazard.

Assigning a risk consequence inherently requires consideration of the resilience or adaptive capacity of the land or assets affected. National parks and other reserves remain usable and functional even if reduced in size by erosion. Beaches and dunes are naturally adapted to recover after erosion events, with dunes forming a naturally regenerating barrier to erosion and overwash for land behind.

By comparison, erosion and undermining of a building or house compromises the safety and continued use of the entire building. Such assets have a lower adaptive capacity and therefore a greater consequence of hazard impact. Similarly, where linear assets such as sewerage networks or train lines, are affected by erosion or inundation in one section, the entire network is compromised once one section of the linear asset is out of service. As this then affects a much greater population, and may be costly to rectify, the consequence of the impact is higher.

The other important factor considered when assigning the consequence of impact from the different coastal hazards is the permanency of the hazard impact itself. Erosion impacts are largely "permanent" because, even though the beach may recover (and sand returns), the land use or asset may no longer be tenable on that land. That is, once a house is undermined by erosion, it cannot be maintained in that location and the land use is permanently changed. Even for a park or reserve, the land is henceforth at risk from erosion, and this must be considered when designing facilities, rehabilitation etc on that land within the reserve or park.

Tidal inundation where the daily tidal level increases over time due to SLR is also largely considered to be a "permanent" impact, because the land is inundated so frequently that it is considered part of the waterway.

By comparison, coastal inundation during a storm may result in a high water level that lasts effectively for the few hours at the peak of the storm. The impact is lower, as it is periodic, allowing land use to remain much the same between storm events. Nonetheless, land use would still need to be resilient to the periodic impacts.

7.4 Level of Risk

The level of risk is determined through a risk matrix that combines the different scales of likelihood and consequence, such as shown in Table 7-3. In each risk assessment, the manner in which likelihood and consequence are combined to determine risk should be determined based on the context of that risk assessment. That is, there is no universal "risk matrix" but rather, this needs to be developed for each individual risk assessment.

For a coastal hazards risk assessment, there are a few factors that need to be considered in developing the risk matrix, including:

- The emotive nature of natural hazards, even if the risk consequence is considered insignificant or minor. Natural hazards such as coastal erosion are particularly emotive issues within communities, and history has shown that even small issues can command a high level of attention and community concern, with commensurate pressure for Council (or agencies) to take action.
- The combination of low probability events that have a catastrophic or major impact must be considered for management. For example, if a major road or transport network is affected by erosion, or the water supply system is compromised by coastal inundation, the impacts are far reaching and so planning needs to be in place for such events, even if that event is rare.
- The long timeframes over which coastal hazards may occur, with commensurate uncertainty in the hazard timing and degree of impact (see Section 5 for more information).

The resultant risk matrix ensures that Council and other agencies and land managers can prepare for risks over long planning timeframes, up to 100 years.

Table 7-2 Consequence Scale Used to Assess Impact of Coastal Hazards

Consequence	Society / Community	Environment	Economy
Catastrophic	Widespread permanent impact to community's services, wellbeing, or culture (e.g. > 25 % of community affected), or state loss, or no suitable alternative sites exist	Widespread, devastating / permanent impact (e.g. entire habitat destruction), or loss of all local representation of regionally important species (e.g. endangered species). Recovery unlikely, or requires substantial intervention.	Damage to property, infrastructure, or local economy ≥ $1M, or ongoing costs of $250,000 per year
Major	Major permanent or widespread medium term (somewhat reversible) disruption to community's services, wellbeing, or culture (e.g. up to 25 % of community affected), or regional loss, or only a few suitable alternative sites exist	Widespread semi-permanent impact, or widespread pest / weed species proliferation, or semi-permanent loss of entire regionally important habitat. Recovery may take ≥ 5 years.	Damage to property, infrastructure, or local economy of $350,000 - $1M, or ongoing costs of $100,000 per year
Moderate	Moderate short term / minor medium term (mostly reversible) disruption to services, wellbeing, or culture of the community (e.g. up to 10% of community affected), or sub-regional loss, or some suitable alternative sites exist	Significant environmental changes isolated to a small, localised area. Recovery may take 1- 5 years.	Damage to property, infrastructure, or local economy of $100,000 - $350,000, or ongoing costs of $50,000 per year
Minor	Small / short term (reversible) disruption to services, wellbeing, finances, or culture of the community (e.g. up to 5 % of community affected), or local loss, or many alternative sites exist	Environmental damage of a magnitude consistent with seasonal variability. Recovery may take up to 1 year.	Damage to property, infrastructure, or local economy of $10,000 - $100,000, or ongoing costs of $10,000 to $20,000 per year
Insignificant	Very small, short term disruption to services, wellbeing, or culture of the community (e.g. up to 1 % of community affected), or neighbourhood loss, or numerous alternative sites exist	Minimal short term impact, recovery may take up to 6 months, or habitat affected has many alternative sites available.	Damage to property, infrastructure, or local economy <$20,000 or less than $10,000 ongoing costs per year

Table 7-3 Risk Matrix Combining Probability and Consequence

		Consequence				
		Insignificant	Minor	Moderate	Major	Catastrophic
Likelihood Probability of Exceedance	Almost Certain 95%	Medium	Medium	High	Extreme	Extreme
	Possible 50%	Medium	Medium	High	High	Extreme
	Unlikely 5-10%	Low	Medium	Medium	High	High
	Rare 1%	Low	Low	Medium	High	High

7.5 Risk Assessment Inputs and Outcomes

7.5.1 Risk Workshops

The level of consequence was assigned to assets and land potentially affected by coastal erosion, coastal inundation and tidal inundation using inputs derived from a series of workshops with Council officers and state agency staff, as follows:

- A Council workshop involving representatives from various departments of Council including planning, engineering and asset management (including stormwater, roads and buildings), tourism facilities managers (e.g. for the Council-managed holiday parks), parks and recreation, and natural resources, plus DPIE representatives (from Biodiversity and Conservation Division) and Crown Lands.
- A workshop bringing together the various land and assets managers for Kiama Boat Harbour, including various departments within TfNSW (e.g. MIDO, major projects), Crown Lands, and Council, particularly those involved in the Harbour masterplan that is currently being prepared.
- A workshop with a representative from TfNSW managing climate change risks to trains within the Sydney Trains network, along with Council and DPIE representatives for the CMP project.
- A workshop with a representative from Sydney Water who assists with CMP preparation with regards to Sydney Water's water and sewerage networks.

Given the number of assets affected across the LGA, the approach taken was to:

- Consider key assets affected, at specific locations of interest, for example, the potential impact to train assets behind Bombo beach by 2120.
- Agree (or otherwise) on the applicability of that consequence rating to other similar assets in the LGA.
- Consider the integrated and interrelated nature of some assets to form a locality or area in its own right. The key example here is Kiama Boat Harbour where the various assets combine to form an

area of very high value to the community and associated commercial operations that is larger than the individual assets on their own.

7.5.2 Risk Tolerance

Present day extreme and high risks will need management action as a priority, therefore, a risk tolerance scale is used to determine which risks/locations/assets must be addressed as a priority, such as shown in Table 7-4. For future extreme and high risks, while there is a need to investigate and signal the future management intent in the present timeframe, implementation of these actions can be delayed until impacts are more imminent (or within the next CMP cycle).

The outputs from the coastal hazards assessment provided in this report cover the present day (2020), 20 year (2040), 50 year (2070) and 100 year (2120) timeframes. Risk levels have been assigned to each of these timeframes. However, active management responses realistically only need to be targeted towards current to 20 year risks.

Determining which risks to treat as part of the CMP is based upon Council's (and the community's) tolerance to risk. In most cases it would be expected that low risks can simply be monitored, rather than demanding valuable management resources, while extreme or high risks require more immediate management attention.

The risk tolerance scale for this project is given in Table 7-4. This scale was determined to be appropriate for use in discussion with Council during the Risk Assessment Workshop. The risk tolerance scale outlines the action required for different levels of risk, and so determines those assets / areas that require management treatment as a priority.

For future management actions, a trigger is vital to identify when impacts are imminent but with sufficient time to collate funding, gain approvals and undertake the detailed design for the strategy. This approach to managing coastal risks at present and over future long timeframes is explained in Table 7-5.

Table 7-4 Risk Tolerance Scale

Risk Level	Action required	Tolerance
Extreme / High	Eliminate or Reduce the risk or Accept the risk provided residual risk level is understood	**Intolerable**
Medium	Reduce the risk or Accept the risk provided residual risk level is understood	**Tolerable**
Low	Accept the risk	**Acceptable**

Table 7-5 Prioritisation for Risk Treatment Based upon Estimated Timeframes

Timeframe for Extreme / High Risks	Treatment Approach
Present Day / 2020	• Implement no regrets actions • Implement site specific management actions as required
2040	• Implement no regrets actions • Identify potential management option(s) • Identify trigger for implementation, should the option(s) be required. • Asset management protocol/ procedures • Planning for future development
2070	• Implement no regrets actions • Confirm preferred actions for managing future risks / assets • Confirm preferred triggers for action implementation (e.g. a depth or frequency of inundation as measured by existing or new water level monitoring gauges or points) • At trigger 1, commence planning, approvals, funding etc to implement preferred action • Asset management protocol/ procedures • Planning for future development
2120	

7.5.3 Outcomes of the Risk Assessment

For each of the relevant hazards (i.e., coastal erosion, coastal inundation, and tidal inundation), a register of affected assets and level of risk from the hazard has been generated based upon the workshop inputs, and is provided in Appendix E.

The assets listed are those deemed “at risk” of coastal hazards and are not a complete list of assets within the Kiama LGA/ study area. The risk register only identifies if the asset is affected - it does not indicate the percentage of land affected. The highest risk level encountered is listed in the register. The risk register is a direct output from the risk maps. The scale at which the risk maps are presented is of sufficiently high level that where small sections of land are affected, they will still be listed in the register.

A summary of the key areas impacted by the three hazards assessed (i.e., coastal erosion, coastal inundation, and tidal inundation) is provided below:

- **Jones Beach** – Jones Beach has a medium risk rating for coastal inundation. The shrubland behind the beach, some stormwater pits/ outlets and the Kiama Downs SLSC have a high risk of being impacted by coastal inundation at 2120.
- **Bombo Beach** – Bombo Beach and dunes are predicted to be impacted by all three hazards. Coastal erosion and inundation have been rated as having the greatest impacts though (extreme risks for several sections for all timeframes). The beach and dunes are very important features as they provide a protective buffer to the trainline and station, major highway, and several key assets including sewer and water for the Kiama area that are located behind the beach area. In the southern area of Bombo Beach, the South Coast Rail Bridge (over Spring Creek), and several

sewer mains and stormwater pits have also been given an extreme to high risk rating for coastal inundation impacts, for all timeframes, and will be a focus for the next stage of this CMP (i.e. Stage 3 – management options).

- **Kiama Boat Harbour** – The boat harbour is impacted by only coastal and tidal inundation, however both hazards have been found to result in a high - extreme risk to several assets within the area (for all timeframes), including the helipad, infrastructure and services within the Robertson Basin, Kiama boat ramp, Shoalhaven Street, Blowhole Point Access Roads, several stormwater pits / pipes, sewer mains / pipes and the Fisherman's markets.
- **Surf and Kendalls Beaches** – both these beaches are impacted by all three of the hazards, and each have been found to provide a high - extreme risk to several assets within the areas (for differing hazards, but at all timeframes), including the beaches themselves, Kiama SLSC, Saint Peter and Paul Catholic Church / parts of the Primary School lands, Coronation Park, Kendalls on the Beach Holiday Park, several sewer mains / pipes, and several stormwater pipes.
- **Easts Beach** – Easts Beach is predicted to be impacted by all three of the hazards, and each have been found to provide a high - extreme risk to several assets within the area (for differing hazards, but at all timeframes), including the beach environment itself (including the seawall under beach), Easts Beach Holiday Park, and several sewer / water mains.
- **Werri Beach** – Werri Beach is predicted to be impacted by all three of the hazards, and each have been found to provide a high - extreme risk to several assets within the area (for differing hazards, but at all timeframes), including the beach and dune environment itself, the shrubland behind the beach, and Pacific Avenue (south of Werri Beach Holiday Park).
- **Gerroa** – several areas around the entrance to the Crooked River have been predicted to be impacted by coastal and tidal inundation hazards, and each have been found to provide a high - extreme risk to several assets within the area (for differing hazards, and most timeframes), including the Seven Mile Beach and dune environment itself, several residences along Burke Parade, Seven Mile Holiday Park, and several key biodiverse habitats (inc. Eucalypt Forests, Native Grasslands, Shrubland / Heathland, Floodplain Forest).

The full register of affected assets and level of risk from the hazard is presented in Appendix E.

8 Where to from here?

This report has detailed the coastal hazards (i.e., coastal erosion / recession, coastal inundation, and tidal inundation) and associated risks to land and assets (built and natural) on the Kiama coastline. The next stage of preparation of the CMP is the Stage 3 Options Assessment, during which options for managing the high/extreme risks from coastal hazards and other issues affecting the Kiama coastline will be investigated. The risk assessment outcomes, as well as hazard mapping provided in this report will form key inputs to Stage 3 of the CMP preparation process. Stage 3 will assess these measures against multiple criteria to provide a short-list of preferred actions for implementation (and will be fully documented in a Stage 4 report).

The *Coastal Management Act 2016* defines the coastal zone as land comprised of the following coastal management areas:

- Coastal wetlands and littoral rainforest area
- Coastal vulnerability area
- Coastal environment area
- Coastal use area.

Currently there are no mapped coastal vulnerability areas (CVA) in the Kiama LGA. As councils develop CMPs which identify land subject to coastal hazards, this land can then be mapped as part of the CVA under the State Environmental Planning Policy (Coastal Management), 2018 (CM SEPP). Council plans to progress the process to map the CVA for the Kiama coastal zone, by amending the Coastal CM SEPP map through a planning proposal. This process will occur following the adoption and certification of the CMP.

Until there is a defined CVA, Clause 15 of the CM SEPP applies to all land within the coastal zone and requires that:

'*Development consent must not be granted to development on land within the coastal zone unless the consent authority is satisfied that the proposed development is not likely to cause increased risk of coastal hazards on that land or other land.*'

The NSW Planning Circular 'Planning for coastal hazards (PS 19-006) explains and provides guidance for councils and other consent authorities on how to disclose and assess coastal hazards under the CM SEPP. This planning circular also provides information to property owners on how, when and what details may be included on a planning certificate and how specialists studies should be used by Councils to consider coastal hazards in the planning process.

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