Eurobodalla Open Coast Coastal Management Program

Stage 2: Vulnerability Assessments

Eurobodalla Shire Council | Stage 2 | December 2022

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Acknowledgements

Acknowledgement of Traditional Owners

Eurobodalla Shire Council recognises Aboriginal people as the original inhabitants and custodians of all land and water in the Eurobodalla and respects their enduring cultural and spiritual connection to it.

Acknowledgment of Financial Assistance

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Executive Summary

Eurobodalla Shire Council with the assistance of the NSW Government is preparing a Coastal Management Program (CMP) for the Eurobodalla Coastline, in accordance with the provisions of the NSW Coastal Management Act 2016 (CM Act).

The NSW Coastal Management Manual (the manual) specifies five stages of preparing a CMP (**Figure E-1**).

Eurobodalla Shire Council has recently completed Stage 1 of the CMP process (Scoping Study) (Rhelm, 2021), 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 developed 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 identified in Stage 1, and in doing so builds upon on the coastal vulnerability information for the Eurobodalla coastline.

The Stage 2 additional studies completed and presented in this document are:

- Erosion assessments at key risk locations identified in Stage 1 (**Section 4**)
- Geotechnical assessments at key locations identified in Stage 1 (**Section 4.1**)
- Coastal inundation assessments at key risk locations identified in Stage 1 (**Section 5**)
- Conceptual sediment transport analysis of Batemans Bay (**Section 6**).

In addition, a series of community working groups were undertaken (24th – 25th August) to present the draft findings of the Stage 2 assessments.

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

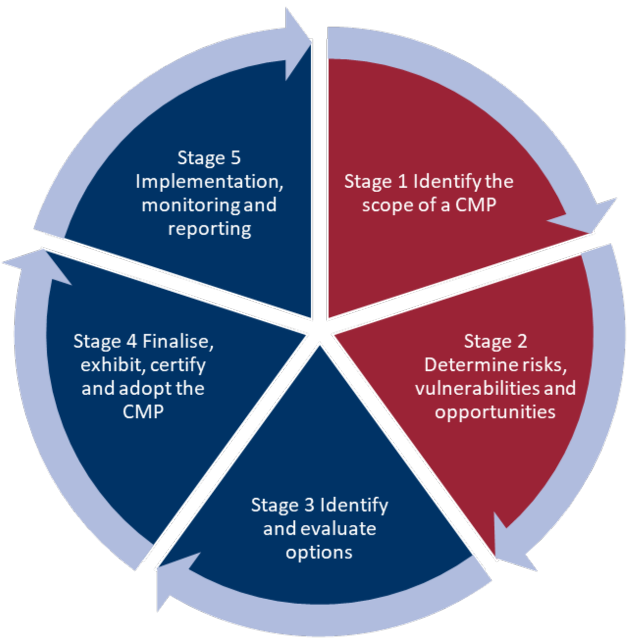

Figure E-1-1 The Five Stages of a CMP (Adapted from OEH, 2018a)

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Acronyms and Abbreviations

AHD	Australian Height Datum
CM Act	NSW *Coastal Management Act 2016*
CMP	Coastal Management Program
CZMP	Coastal Zone Management Plan
DPIE	NSW Department of Planning, Industry and Environment
ESC	Eurobodalla Shire Council
km^2	Square kilometres
m^2	Square metres
m^3	Cubic metres
m/s	Metres per second
m^3/s	Cubic metres per second
MSL	Mean Sea Level
NSW	New South Wales
OEH	Former NSW Office of Environment and Heritage
PoM	Plan of Management
WRL	Water Research Laboratory

Glossary*

Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average recurrence interval (ARI)	The average time between which a threshold is reached or exceeded (e.g. large wave height or high water level) of a given value. Also known as Return Period.
Catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
Climate change	A process that occurs naturally in response to long-term variables, but often used to describe a change of climate that is directly attributable to human activity that alters the global atmosphere, increasing change beyond natural variability and trends.
Coast	A strip of land of variable width that extends from the shoreline inland to the first significant landform that is not influenced by coastal processes (such as waves, tides and associated currents).
Coastal hazard	Coastal hazards, as defined by the CM Act, include beach erosion, shoreline recession, coastal lake or watercourse entrance instability, coastal inundation, coastal cliff or slope instability, tidal inundation, and erosion and inundation of foreshores caused by tidal waters and the action of waves, including the interaction of those waters with catchment floodwaters.
Coastal inundation	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. Alternatively, the elevated water level may result in wave run-up and overtopping of natural or built shoreline structures (e.g. dunes, seawalls). In the case of an estuary, coastal inundation may be caused by a combination of processes including high tides, storm surge and wave run-up onto the foreshore.
Coastal processes	Coastal processes are the set of mechanisms that operate at the land-water interface. These processes incorporate sediment transport and are governed by factors such as tide, wave and wind energy.
Coastal Zone	The coastal zone, as defined by the CM Act, means the area of land comprised of the following coastal management areas: (a) the coastal wetlands and littoral rainforests area, (b) the coastal vulnerability area, (c) the coastal environment area, (d) the coastal use area.
Design storm event	A significant event to be considered in the planning process.

Development	As defined in the *Environmental Planning and Assessment Act 1979*. New development refers to development of a completely different nature to that associated with the former land use, e.g. the urban subdivision of an area previously used for rural purposes. New developments involve re-zoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. Infill development refers to the development of vacant blocks of land that are generally surrounded by already developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. Redevelopment refers to rebuilding in an area, e.g., as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either re-zoning or major extensions to urban services.
Estuary	The CM Act defines an estuary as any part of a river, lake, lagoon, or coastal creek whose level is periodically or intermittently affected by coastal tides, up to the highest astronomical tide.
Extreme Ocean Water Level	The highest elevation reached by the sea/ocean as recorded by a tide gauge during a given period (after MHL, 2018).
Extreme Storm Event	Storm for which characteristics (wave height, period, water level etc.) were derived by statistical 'extreme value' analysis. Typically, these are storms with average recurrence intervals (ARI) ranging from one to 100 years.
Foreshore	The part of the shore, lying between the crest of the seaward berm (or upper limit of wave wash at high tide) and the ordinary low water mark, that is ordinarily traversed by the uprush and backrush of the waves as the tides rise and fall; or the beach face, the portion of the shore extending from the low water line up to the limit of wave uprush at high tide. The CM Act defines the foreshore as 'the area of land between highest astronomical tide and the lowest astronomical tide'.
Flood	A general and temporary condition of partial or complete inundation of normally dry land areas, including inundation as a result of sea/ocean storms and other coastal processes or catchment flows.

Flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk is divided into three types, existing, future and continuing risks as described below: • Existing flood risk is the risk a community is exposed to as a result of its location on the floodplain. • Future flood risk is the risk a community may be exposed to as a result of new development on the floodplain. • Residual flood risk is the risk a community is exposed to after floodplain risk management measures have been implemented.
Geographical information system (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
High Tide	The maximum height reached by a rising tide. The high water is due to the periodic tidal forces and the effects of meteorological, hydrologic, and/or oceanographic conditions.
Mean Sea Level (MSL)	MSL is a measure of the average height of the sea or ocean's surface such as the halfway point between the mean high tide and the mean low tide. At present, mean sea level is approximately equivalent to 0 mAHD (reported as 0.03 mAHD in MHL, 2019).
Probability	A statistical measure of the expected frequency or occurrence of flooding.
Risk	The chance of something happening that will have an impact on objectives, usually measured in terms of a combination of the consequences of an event and likelihood of occurrence.
Sea level rise	A rise in the level of the sea surface that has occurred or is projected to occur in the future, as measured from a point in time. The rise can be reported as a global mean or as measured at a specific point or estimated for a specific part of the sea or ocean.
Shoreline	The intersection between the sea and the land. The line delineating the shoreline is often approximated as the Mean High Water Mark, however, the definition can vary depending on the application.
Storm surge	The increase in coastal water level caused by the effects of storms. Storm surge consists of two components – the increase in water level caused by the reduction in barometric pressure and the increase in water level caused by the action of wind blowing over the sea surface (wind set-up).
Storm tide	An abnormally high water level that occurs when a storm surge combines with a high astronomical tide. The storm tide must be accurately predicted to determine the extent of coastal inundation.

Tidal inundation	The inundation 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 sea level rise. For planning controls, it is defined as the land that is inundated up to the level of Highest Astronomical Tide (HAT).
Wave run-up	The vertical distance above mean water level reached by the uprush of water from waves across a beach or up a structure.
Wave set-up	The rise in the water level above the still water level when a wave reaches the coast. It can be very important during storm events as it results in further increases in water level above the tide and surge levels.
Wind waves	Waves resulting from the action of the wind on the surface of the water.

*Many of the glossary terms here are derived or adapted from the *Coastal Management Glossary* (OEH, 2018d).

1 Introduction

The NSW Coastal Management Manual (the manual) specifies five stages of preparing a CMP (**Figure E-1**).

Eurobodalla Shire Council has recently completed Stage 1 of the CMP process (Scoping Study) (Rhelm, 2021), 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 identified in Stage 1, and in doing so builds upon on the coastal vulnerability information for the Eurobodalla coastline.

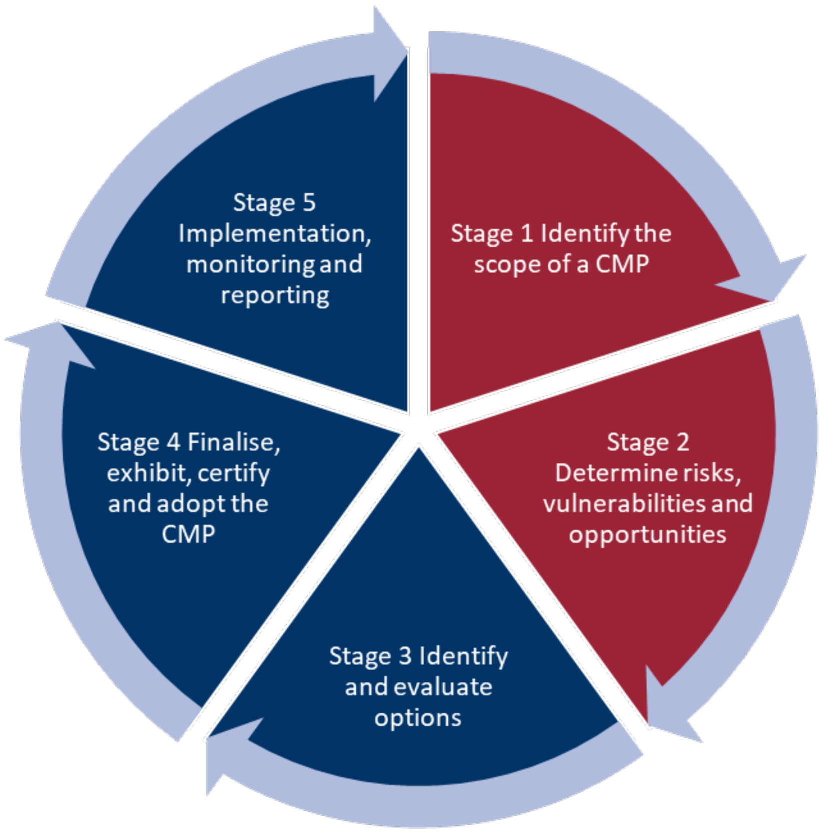

Figure 1-1 The Five Stages of a CMP (Adapted from OEH, 2018a)

The primary outcomes of this Stage 2 report, is to identify, analyse and evaluate risks and opportunities to support decision-making in Stage 3 and 4 of the CMP. As a result the Stage 2 additional studies were designed to reflect the scale and complexity of the management responses required in each coastal management area.

The outcomes of the Stage 2 report will be used in the CMP to:

- refine the mapping of coastal hazards
- provide context and data to support the identification and evaluation of management options in Stage 3
- quantify the nature and extent of exposure to coastal hazards and threats to public and private assets (both natural and built)

- understand the factors that contribute to coastal vulnerability and to current and future risks for the coastline
- understand the range of potential future scenarios.

The Stage 2 additional studies completed and presented in this document are:

- Erosion assessments at key risk locations identified in Stage 1 (**Section 4**)
- Geotechnical assessments at key locations identified in Stage 1 (**Section 4.1**)
- Coastal inundation assessments at key risk locations identified in Stage 1 (**Section 5**)
- Conceptual sediment transport analysis of Batemans Bay (**Section 6**).

In addition, a series of community working groups were undertaken (24th – 25th August) to present the draft findings of the Stage 2 assessments, with feedback examined and incorporated.

2 Community and Stakeholder Engagement

Community engagement in Stage 2 occurred primarily through community working groups. These working groups were established through registration of interest. Council sought registrations of interest through:

- Invitations issued to all relevant registered community groups, clubs and associations
- Invitations issues to all community members who had previously registered their interest in the CMP via Council's webpage
- Media release issued 16th July 2021
- Social media update on Council's Facebook Page 21st July 2021.

There were 52 registrations of interest for the working groups, resulting in five working groups with locality focus.

Due to COVID restrictions, the working groups were undertaken virtually using a combination of Microsoft Teams for voice and camera interactions, and an interactive online whiteboard (Miro) for presentation of project information and collaboration by participants.

The workshops were run over the 24th and 25th August 2021.

The working group session format was structured around:

- Presenting coastal hazard risks identified in the Stage 2 vulnerability assessments and getting feedback from participants on experiences with and concerns regarding these risks
- Input from participants on key coastal management issues, both local and regional
- Input from participants on coastal management actions they would like Council to consider in the CMP.

Council's CEMAC were also presented with an abridged version of the coastal hazard risks and opportunities across the LGA and given an overview of the sediment transport model.

The outcomes of the working groups have been used to inform:

- This Stage 2 report
- The identification of options for managing identified risks from coastal hazards and other issues affecting the Eurobodalla coastline (to be investigated in Stage 3 of the CMP).

A summary of the key outcome themes is provided in **Figure 2-1**.

Tourism opportunities such as coastal walks.

Property protection to be included in the CMP Vision Statement

ICOLL entrance management to be reviewed. Durras raised as priority review.

Protection of trees in urban and bushland areas

Dune management: protection of vegetation, recovery following erosion events, unrestricted pedestrian access. Revegetation attempts of dune at Long Beach has had mixed response from community.

How will **equitable distribution of funding and resources** be achieved?

Water quality issues in creeks and drains discharging to beaches and coast. Sewer impacts on swimming beaches (e.g. Broulee Head)

Weed management

Protection of intertidal species under sea level rise

Potential additional data and issues to be considered in sediment transport assessment.

All abilities access to beaches and foreshore

The CMP needs to provide **localised values, risks and recommendations**

Erosion protection priority location identified by community at Surfside (west and east of Pinnacle Point) and Cullendulla. Management options suggested included groynes, nourishment (on and off shore), offshore reefs, break walls, reclaimed land.

Increased tourism: impacts on facilities (e.g. parking, bike tracks, boat ramps), need for education to reduce environmental impacts (e.g. litter, trampling of dune vegetation)

CMP recommendations should include **adaptation pathways** with triggers not just single solutions.

Figure 2-1 Community Working Group Outcome Themes

3 Outcomes of Stage 1

3.1 First Pass Risk Assessment

The Scoping Study (Rhelm, 2021) considered threats to the coastal zone across a range of planning timeframes and pathways. A first-pass risk assessment process was applied to better understand the severity of known threats in the study area, at present and in the future.

A key input to the first pass risk assessment was an understanding of the exposure of the entire Eurobodalla coastline against the coastal hazard threats relevant to the open coast. To achieve this, the coastline was separated into smaller coastal compartments, a total of 46 each with similar foreshore character, and the exposure of each coastal compartment was then estimated based on available coastal hazard information (such as beach erosion, shoreline recession and coastal inundation mapping from within WRL, 2017 and SMEC, 2010; coastal cliff and slope instability from ACT Geotechnical 2012; coastal processes and contextual information from over 40 years of existing studies). Where no existing data or study was available, a screening level estimate of the erosion, recession and inundation exposure was developed to identify potential coastal risks that would warrant further investigation. This screening level hazard exposure was interpreted with observations made by the study team during the site visits (16th – 18th March 2021) to provide a first pass assessment of the risk profile against the 10 coastal hazard threats.

The first pass risk assessment of coastal hazards provided guidance for each location as to whether:

- Additional data or analysis is required in Stage 2 of the CMP to better define the risk prior to undertaking Stage 3- identification and evaluation of management options.
- No additional hazard analysis is required in Stage 2 as data is sufficient. There are however identified management issues relating to coastal hazards that will require addressing through the assessment of management options in Stage 3.
- The coastal hazard risk is sufficiently low that no further assessment of risk or risk management is required at that location.

The Scoping Study (Rhelm, 2021) presents the forward plan for Stages 2 to 5 of the CMP, this included the Stage 2 Assessments summarised in **Table 3-1** and presented in this document.

Table 3-1 Stage 2 Assessments from First Pass Risk Assessment

Location	Coastal Hazard	Stage 2 Assessment
Maloneys Beach	Erosion	Deterministic erosion hazard lines for 2100.
Long Beach	Erosion	Deterministic erosion hazard lines for 2100. 2021 geotechnical analysis to be considered.
	Coastal Inundation (Beaches)	Map wave runup and bore propagation extents for the beaches. Refine mapping of inundation using recent LIDAR and consideration of hydraulic connectivity.
	Inundation (Creek Entrances)	Hydraulic modelling of lake connection to the beach for 100 Year ARI (Present Day and 2100).
Cullendulla Beach	Inundation (Creek Entrances)	Hydraulic modelling of Cullendulla Creek for 1 Year ARI, 20 Year ARI, 100 Year ARI (Present Day, 2050, 2065 and 2100).
Surfside	Erosion	Deterministic erosion hazard lines for 2100. 2021 geotechnical analysis to be considered.
	Coastal Inundation (Beaches)	Map wave runup and bore propagation extents for the beaches. Refine mapping of inundation using recent LIDAR and consideration of hydraulic connectivity.
	Inundation (Creek Entrances)	Hydraulic modelling of Surfside Creek for HHWS, 1 Year ARI, 20 Year ARI, 100 Year ARI (Present Day, 2050, 2065 and 2100). Coincidence design flood events for 20 Year ARI Rainfall / 100 Year ARI Coastal (Present Day, 2050, 2065 and 2100).
Wharf Road	Erosion	No additional assessment required – BMT WBM (2017) lines reproduced in the map set for completeness (Map Series RH-04-01)
	Coastal Inundation (Beaches)	Map wave runup and bore propagation extents for the beaches. Refine mapping of inundation using recent LIDAR and consideration of hydraulic connectivity.
Batemans Bay CBD	Coastal Inundation (Beaches)	Map wave runup and bore propagation extents for the beaches. Refine mapping of inundation using recent LIDAR and consideration of hydraulic connectivity.
	Inundation (Creek Entrances)	Hydraulic modelling of Water Gardens for HHWS, 1 Year ARI, 20 Year ARI, 100 Year ARI (Present Day, 2050, 2065 and 2100). Coincidence design flood events for 20 Year ARI Rainfall / 100 Year ARI Coastal (Present Day, 2050, 2065 and 2100).
Boat Harbour	Coastal Inundation (Beaches)	Map wave runup and bore propagation extents for the beaches. Refine mapping of inundation using recent LIDAR and consideration of hydraulic connectivity.
	Inundation (Creek Entrances)	Hydraulic modelling of Hanging Rock Creek for HHWS, 1 Year ARI, 20 Year ARI, 100 Year ARI (Present Day, 2050, 2065 and 2100). Coincidence design flood events for 20 Year ARI Rainfall / 100 Year ARI Coastal (Present Day, 2050, 2065 and 2100).

Location	Coastal Hazard	Stage 2 Assessment
Corrigans Beach	Coastal Inundation (Beaches)	Map wave runup and bore propagation extents for the beaches. Refine mapping of inundation using recent LIDAR and consideration of hydraulic connectivity.
	Inundation (Creek Entrances)	Hydraulic modelling of Joes Creek for HHWS, 1 Year ARI, 20 Year ARI, 100 Year ARI (Present Day, 2050, 2065 and 2100). Coincidence design flood events for 20 Year ARI Rainfall / 100 Year ARI Coastal (Present Day, 2050, 2065 and 2100).
Caseys Beach	Erosion	No additional assessment required – WRL (2017) lines reproduced in the map set for completeness (Map Series RH-04-01)
	Coastal Inundation (Beaches)	Map wave runup and bore propagation extents for the beaches. Refine mapping of inundation using recent LIDAR and consideration of hydraulic connectivity.
	Inundation (Creek Entrances)	Hydraulic modelling of Shortbeach Creek for HHWS, 1 Year ARI, 20 Year ARI, 100 Year ARI (Present Day, 2050, 2065 and 2100). Coincidence design flood events for 20 Year ARI Rainfall / 100 Year ARI Coastal (Present Day, 2050, 2065 and 2100).
Malua Bay	Erosion	Deterministic erosion hazard lines for 2100.
	Coastal Inundation (Beaches)	Map wave runup and bore propagation extents for the beaches. Refine mapping of inundation using recent LIDAR and consideration of hydraulic connectivity.
	Inundation (Creek Entrances)	Hydraulic modelling of Reedy Creek for HHWS, 1 Year ARI, 20 Year ARI, 100 Year ARI (Present Day, 2050, 2065 and 2100). Coincidence design flood events for 20 Year ARI Rainfall / 100 Year ARI Coastal (Present Day, 2050, 2065 and 2100).
Barlings Beach	Erosion	No additional assessment required – WRL (2017) lines reproduced in the map set for completeness (Map Series RH-04-01)
Tomakin Cove	Erosion	Deterministic erosion hazard lines for 2100. 2021 geotechnical analysis to be considered.
	Coastal Inundation (Beaches)	Map wave runup and bore propagation extents for the beaches. Refine mapping of inundation using recent LIDAR and consideration of hydraulic connectivity.
Broulee	Erosion	No additional assessment required – WRL (2017) lines reproduced in the map set for completeness (Map Series RH-04-01)
	Inundation (Creek Entrances)	Hydraulic modelling of Candlagen Creek for HHWS, 1 Year ARI, 20 Year ARI, 100 Year ARI (Present Day, 2050, 2065 and 2100). Coincidence design flood events for 20 Year ARI Rainfall / 100 Year ARI Coastal (Present Day, 2050, 2065 and 2100).

3.2 Outcomes from Existing Studies

The *Eurobodalla Coastal Hazard Assessment* (WRL, 2017) and *Eurobodalla Shire Coastal Hazards Scoping Study* (SMEC 2010) were the primary contemporary studies utilised. The Eurobodalla Coastal Hazard Assessment (WRL, 2017) undertook a hazard assessment for current and future beach erosion, shoreline recession, first-pass coastal inundation, and geotechnical hazards at 17 high priority beaches (WRL 2017). Maximum wave runup levels were calculated for an additional 16 beaches in the *Eurobodalla Shire Coastal Hazards Scoping Study* (SMEC 2010).

'Bathtub analysis' for coastal inundation hazards was mapped at the 17 high priority beaches (WRL, 2017).

Future tidal inundation scenarios and TUFLOW model establishment has been undertaken for:

- Broulee Beach (Candlagen Creek) as part of the Tomakin, Mossy Point, Broulee Flood Study (WMA Water 2017)
- Long Beach Lagoon, Surfside Creek, Water Gardens, Hanging Rock Creek, Joes Creek, Shortbeach Creek as part of the Batemans Bay Urban Creeks Flood Study (Rhelm, 2021).

This Stage 2 report provides updated hazard information for high risk locations or to fill data gaps not previously included in prior studies.

The first pass risk assessment and forward plan undertaken in Stage 1 of the CMP (Rhelm, 2021) identified studies to be completed in Stage 2.

For the purposes of preparing a CMP consistent with the Manual that extends from 2022 to 2032 the timeframes undertaken in the Eurobodalla Coastal Hazard Assessment (WRL, 2017), consistent with Councils adopted Interim Coastal Hazard Adaptation Code have been utilised. These values (adjusted to present day sea level) are:

- Present Day
- 2050 (i.e. 22cm increase in sea level)
- 2065 (i.e. 33cm increase in sea level)
- 2100 (i.e. 71cm increase in sea level).

These values as documented in the Stage 1 (scoping study) report (Rhelm, 2021) are deemed adequate and appropriate for the preparation of the CMP. This includes both the fast-tracked Stage 2 components and those undertaken in this study.

3.3 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).

Eurobodalla Shire is identified within two primary coastal sediment compartments and six secondary sediment compartments (Geoscience Australia 2015), listed below and shown **in Appendix 1.** https://d28rz98at9flks.cloudfront.net/76502/76502_2.pdf : (Geoscience Australia 2015 and mapped 2016)

- Beecroft Head to Wasp Head (south Durras) (NSW 08/23)

  - Lake Tabourie coast – Warden Head to Wasp Head (NSW8.06/102), (Durras Beach is at the far southern end of this secondary compartment)
- Wasp Head to Cape Howe (NSW 09/24)
  - Murramarang - Wasp Head to Three Islet Point (NSW 9.01/103)
  - Batemans Bay – Three Islet Point to South Head (Mosquito Bay) (NSW9.02/104)
  - Moruya River – South head (Mosquito Bay) to Bingie Bingie Point (NSW 9.03/105)
  - Eurobodalla coast - Bingie Bingie Point to Cape Dromedary (NSW 9.04/106)
  - Mount Dromedary Coast – Cape Dromedary to Goalen Head (NSW9.05/107). Most of this compartment is in Bega Valley Shire LGA.

This area experiences some 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).

4 Beach Erosion and Shoreline Recession Assessment

Beach erosion and shoreline recession at several key ESC beaches were defined within the Eurobodalla Coastal Hazard Assessment (WRL, 2017) and Eurobodalla Shire Coastal Hazards Scoping Study (SMEC 2010). The Coastal Hazard Assessment (WRL, 2017) provides detailed calculation of erosion and recession using both deterministic and probabilistic methods. For the purposes of identifying coastal areas most at risk, the probabilistic approach within WRL (2017) was considered conservative and a consistent description of vulnerability was required across all beaches. As a result, deterministic hazard lines were recalculated at five beaches where probabilistic lines were previously defined. Further, consideration of recently acquired geotechnical data was incorporated into the hazard line redefinition.

The deterministic method applies a single value with a defined probability of occurrence for each parameter; namely annual shoreline recession/accretion, sea level rise and storm demand; where the single value represents the best estimation based on available data. In comparison, the probabilistic method utilises a range of possible values defined by a probability density function (PDF) that allows all variables to randomly vary over the pre-defined range and repeatedly combine these randomly sampled values, known as a Monte-Carlo simulation. The result is a range of possible shoreline responses, each with a defined likelihood. The adopted shoreline response is then selected based on the target risk profile (e.g. the 1% encounter probability).

Adopting the alternate approaches across the study area has the potential to bias any management options (Stage 3 of the CMP) to beaches where erosion vulnerability is defined by the probabilistic approach. Further, for the purposes of identifying management responses, the 100-year ARI is considered appropriate for the planning periods under consideration. As a result, deterministic hazard lines were redefined at the following beaches:

- Long Beach
- Surfside
- Malua Bay
- Tomakin Cove
- Broulee Beach

Hazard lines at all other locations (Maloneys Beach, Wharf Road, Caseys Bay, and Barlings Beach) were adopted from either WRL (2017), SMEC (2010) or BMT WBM (2009).

4.1 Geotechnical Assessment to refine beach erosion and shoreline recession

Many locations along the Eurobodalla coastline are characterised by rock headlands and nearshore rock outcrops. The presence of rock has the potential to limit the amount of coastal erosion along a particular shoreline if located at elevations that would be subject to erosive processes during coastal storm conditions and also has the potential to cause shoreline realignment when exposed in storms or as it emerges on a receding beach or as sea levels rise. Geotechnical investigations were commissioned to identify the presence and vertical elevation of competent rock at three locations, where the observable presence of rock has the potential to limit the currently defined erosion hazard exposure. These sites included Long Beach, Surfside and Tomakin Cove as recommended in the Eurobodalla Coastal Hazard Assessment (WRL, 2017) and via community consultation.

The scope of the commissioned geotechnical investigations involved:

- Stage 1 – Desk study

- Stage 2 – Non-intrusive field investigation
  - Engineering geological field mapping
  - Geophysical investigations
- Stage 3 – Compilation of a simplified geotechnical model.

The full description of geotechnical investigations and the findings are presented in **Appendix A**.

The primary purpose of undertaking the geotechnical investigations was to better understand the geological properties of key foreshore areas and update the assumptions made in the coastal hazard modelling and calculations such as scour potential (depth and distance landward).

The scour level of coastal erosion is generally adopted as -1mAHD, which aligns with observed eroded beach profiles following historic severe erosion events along the NSW coast, and is the value adopted in the Eurobodalla Coastal Hazard Assessment (WRL, 2017) for the calculation and mapping of coastal erosion extents. While the presence of rock was identified through all areas where geotechnical investigations were completed, the level of competent bed rock that underlies developed areas is below the adopted coastal erosion scour level of -1mAHD within WRL (2017) and hence will not have an influence on the erosion extents developed in WRL (2017).

At Long Beach, there exists a low crested sea wall that extends from the culvert structure at the end of Fauna Ave. Given the identified level of competent rock and the observed profile of the sea wall, the wall is unlikely to be founded on bed rock

4.2 Shoreline Recession Assessment

Location specific shoreline recession estimates at several key ESC beaches were assessed by WRL (2017). The detailed calculation of shoreline recession was based on long-term shoreline position trends and recession due to sea level rise (SLR).

The underlying shoreline movement was calculated based on analysis of photogrammetry data at each beach compartment, as summarised in Appendix C of WRL (2017). Recession due to SLR was estimated using the Bruun Rule, that requires an estimate of the active beach profile out to the closure depth and SLR. The Bruun Rule is a widely used method to estimate the magnitude of shoreline recession of a sandy beach in response to changes in sea level.

To produce deterministic vulnerability areas, the upper estimates long-term recession were adopted from WRL (2017, Table 6-1) for coastal planning purposes along with the mode value of the Bruun factor. The adopted values and the resulting deterministic estimates of shoreline recession are summarised in **Table 4-1**.

This approach adopts a conservative position in relation to future shoreline recession as a result of sea level rise, considered appropriate for coastal planning in the context of uncertainties present. Such uncertainties include the use of the Bruun Rule, which assumes a long, sandy beach with no effect from headlands and no exposed rock or erosion resistant substrate and the potential for the wider presence of bed rock to cause realignment as it emerges on a receding beach or as sea levels rise. These future impacts are extremely difficult to predict and must be based on assumptions of the beach behaviour. Where known or obvious, the presence of underlying bedrock was taken into account in the Bruun factor estimates within WRL (2017) and the subsequent work completed in this Stage 2 assessment. Future information showing emergence of rock or presence of near surface rock, beyond what has been identified within the geotechnical assessments to date, may warrant reassessment of predicted hazard lines.

Table 4-1 Adopted values of Shoreline Recession for Deterministic Erosion Hazard Definition from WRL (2017)

Beach	Section	WRL D_{50} (mm)	Storm Erosion		Recession Due to SLR			Underlying Recession			Total Recession (m)	
			Storm Demand (m^3/m beach)*	Swash Elevation (mMSL)	Bruun Factor	2050 (m)	2100 (m)	Trend (m/yr)	2050 (m)	2100 (m)	2050	2100
Long Beach	East	0.24	70	2	20	-4.4	-14.2	0.07	2.3	5.8	-2.1	-8.4
	Central	0.24	100	2	20	-4.4	-14.2	-0.08	-2.6	-6.6	-7.0	-20.8
	West	0.24	120	2	20	-4.4	-14.2	0.07	2.3	5.8	-2.1	-8.4
Surfside Beach (East)	North	0.25	50	1	25	-5.5	-17.8	-0.13	-4.3	-10.8	-9.8	-28.5
	South	0.25	60	1	25	-5.5	-17.8	0.07	2.3	5.8	-3.2	-11.9
Surfside Beach (West)	Central	0.21	20	1	20	-4.4	-14.2	0	0	0	-4.4	-14.2
Malua Bay	Central	0.34	120	2	30	-6.6	-21.3	-0.18	-5.9	-15.0	-12.5	-36.2
Tomakin Cove	Central	0.19	90	1	25	-5.5	-17.8	-0.08	-2.6	-6.6	-8.1	-24.4
Broulee Beach	North	0.21	110	2	30	-6.6	-21.3	-0.03	-1.00	-2.5	-7.6	-23.8
	Central	0.21	90	2	30	-6.6	-21.3	0.12	4.0	10.0	-2.6	-11.3
	South	0.21	70	1	30	-6.6	-21.3	0.12	4.0	10.0	-2.6	-11.3

* defined as m^3/m of beach above 0mMSL

4.3 Beach Erosion Assessment

Beach erosion extents along beach compartments were defined in WRL (2017) through site specific estimates of the storm demand from numerical modelling (waves and sediment transport) and consensus review from coastal engineering experts. The landward extent of erosion was then defined by calculating the Zone of Slope Adjustment (ZSA) and Zone of Reduced Foundation Capacity (ZRFC) as per the methodology of Nielsen et. al. (1992) and as summarised in Appendix G of WRL (2017). As per WRL (2017), all erosion extent calculations were undertaken volumetrically based on measured beach cross sections at regular intervals along the beach compartment (e.g. photogrammetry data). In this way the variability in the dune crest along a beach compartment, where present, is captured based on available data. Values for swash elevation, scour level and the angle of repose, along with the beach profile dataset for each compartment, was applied consistent with those adopted in WRL (2017). However, the Mcleod's Beach (Surfside West) analysis completed in Stage 2 adopted a photogrammetry profile of a conservative present-day beach position, where 0 mAHD and dune elevation is similar to present levels.

The adopted parameters for the development of deterministic erosion extents, including the estimated landward distance of the ZSA and ZRFC, are summarised in **Table 4-2**. The consensus values for storm demand, from Table 6-1 in WRL (2017), were adopted.

Table 4-2 Deterministic values for ZSA and ZRFC at beaches previously mapped by WRL (2017) using the probabilistic method

Beach	Section	Photogrammetry Date	Storm Demand (m^3/m beach)*	ZSA Distance from the mean shoreline position (m)	ZRFC Distance from ZSA (m)
Long Beach	East	27/11/2014	70	63.2	9.0
	Central	27/11/2014	100	59.4	9.7
	West	27/11/2014	120	66.8	8.7
Surfside Beach (East)	North	27/11/2014	50	63.2	9.0
	South	27/11/2014	60	47.1	4.5
Mcleod's Beach	Central	21/06/1942	20	41.1	3.8
Malua Bay	Central	28/11/2014	120	66.8	5.2
Tomakin Cove	Central	23/11/2014	90	52.1	3.7
Broulee Beach	North	23/11/2014	110	73.4	5.6
	Central	23/11/2014	90	70.0	7.9
	South	23/11/2014	70	55.2	6.4

Data from the geotechnical assessment was considered in the determination of the erosion hazard lines, however as noted in **Section 4.1** the level of competent bed rock was found to be below the erosion scour level and hence would not influence the landward extent of the calculated erosion. The values for ZSA and ZRFC assume the full profile is erodible above the adopted scour level of -1mmAHD.

At Long Beach, there exists a low crested sea wall that extends from the culvert structure at the end of Fauna Ave. Given the identified level of competent rock and the observed profile of the sea wall, the wall is unlikely to be founded on bed rock, be constructed to contemporary engineering standards including material utilised and design and therefore reliably provide protection during a storm event. As such, updated erosion hazard lines at Long Beach do not account for the presence of the seawall.

4.4 Beach Erosion Mapping

The 100 Year ARI erosion extents for existing, 2050 and 2100 sea levels are shown in **Map Series RG-04-01**. The erosion extents demonstrate the landward extent of the Zone of Reduced Foundation Capacity (ZRFC) following an extreme coastal event with the inclusion of future estimated shoreline recession. Mapping of coastal hazard lines to identifies areas prone to coastal hazards and provides general guidance for coastal planning.

These maps can be supplemented with the work done by WRL (2017), for completeness, the relevant WRL (2017) deterministic erosion maps have been included in **Appendix C**. WRL (2017) probabilistic mapping has not been included in **Appendix C**. Guidance to the mapping is provided in **Table 4-3**.

Table 4-3 Beach Erosion Map List

Location	Erosion Risk	Map Location
Maloneys Beach	Revised deterministic erosion / recession 2017, 2100	Map Series RG-04-01
	Deterministic erosion / recession 2050, 2065	Appendix C
Long Beach	Revised deterministic erosion / recession 2017, 2100	Map Series RG-04-01
Surfside	Revised deterministic erosion / recession 2017, 2100	Map Series RG-04-01
Wharf Road	SMEC (2010) deterministic erosion / recession 2017, 2100	Map Series RG-04-01
Sunshine Bay	Revised deterministic erosion / recession 2017, 2100	Map Series RG-04-01
	Deterministic erosion / recession 2050, 2065	Appendix C
Malua Bay	Revised deterministic erosion / recession 2017, 2100	Map Series RG-04-01
Guerilla Bay (South)	Deterministic erosion / recession 2017, 2050, 2065 and 2100	Appendix C
Barlings Beach	Revised deterministic erosion / recession 2017, 2100	Map Series RG-04-01
	Deterministic erosion / recession 2050, 2065	Appendix C
Tomakin Cove	Revised deterministic erosion / recession 2017, 2100	Map Series RG-04-01
Broulee	Revised deterministic erosion / recession 2017, 2100	Map Series RG-04-01

5 Coastal Inundation Assessment

The flooding of coastal land may be driven by a variety of factors, including:

- Tidal inundation or nuisance flooding;
- Flooding from storm tides;
- Permanent inundation due to subsidence; and
- Changes in tidal range or sea level.

Risks from coastal flooding include:

- habitability of low-lying coastal land, including public health and maintaining public infrastructure such as stormwater and sewerage systems
- tenure of permanently inundated land
- contamination of soils and groundwater by salt water
- change of ecological character and spatial extent of coastal wetlands
- loss of access and isolation of coastal settlements
- loss of foreshore recreational access and opportunities
- increase in flooding upstream due to increased ocean and estuary tail-water levels.

The Stage 1 First Pass Risk Assessment identified high risk locations for updated and further inundation assessment and mapping. The details are provided in **Section 3.2**.

The additional assessment included:

- **Coastal inundation of beaches:** review coastal water levels against recent LIDAR and revision of mapping to only map hydraulically connected areas (**Section 5.2**).
- **Wave impact zone:** map for high risk beaches for 100 Year ARI ocean storm for existing and 2100 conditions (**Section 5.2**).
- **Creek entrance modelling:** undertake hydraulic modelling of the propagation of relevant coastal water levels into selected coastal creeks (**Section 5.3**).
- **Economic damages assessment:** assess the economic damage of potential future inundation to existing private properties (**Section 5.5**).

5.1 Existing Inundation Assessment (WRL, 2017)

Coastal inundation is the intrusion of sea water into coastal areas and is predominantly caused by elevated coastal water levels, and large co-incident waves. WRL (2017) performed detailed analysis to calculate the 'quasi-static' still water level for each beach for the 100-year ARI likelihood, which includes the 100-year ARI extreme water level, flood contribution, bay wind setup and wave setup.

To determine wave exposure areas, WRL (2017) calculated wave runup using empirical equations from Shand et al. (2011). For locations where the wave runup level exceeds the dune crest, the wave will propagate inland, with the distance dependent on runup elevation, crest elevation and backshore slope (WRL, 2017). WRL (2017) calculated bore propagation extent exceeded by 2% of wave bores at the peak of the storm event, with the wave runup extent set to be this distance from the dune crest.

This same approach has been adopted in this Stage 2 study (**Section 5.2**). The resulting maps identify separately the areas only affected by waves (i.e. the wave wash will be temporary) rather than by elevated coastal water levels (and in some cases also waves). See **Section 5.3** for more details.

5.2 Refined Coastal Inundation Assessment

5.2.1 Beach Compartments

Mapping of tidal and coastal inundation on beaches was reviewed as part of the Stage 2 at those locations identified as requiring more detailed information from the Stage 1 Risk Assessment.

Further recent high resolution LiDAR data across both foreshore and nearshore areas of the study area has allowed improved mapping of tidal and storm tide extents to be developed in addition to the utilisation of more advanced modelling techniques. LiDAR data at 1 m resolution from 2011, and 5 m resolution topographic and bathymetric datasets from 2018 were utilised provide more detail (Spatial Services NSW, (2011) and Department of Planning, Industry and Environment, 2018 respectively).

Peak still water level extents, resulting from tides and storm surge (including wave setup), were developed with consideration of flow paths and hydraulically connected areas. That is, if no hydraulic connection was identified, then the area was not considered at risk of inundation. This assumption should be reassessed if further information becomes available.

Tidal and coastal storm inundation was mapped for High High Water Solstice Springs (HHWSS), the 1 Year ARI (63% AEP), 20 Year ARI and 100 Year ARI events at the 2017, 2050, 2065 and 2100 planning periods, as per WRL (2017, Table 7-1).

Table 5-1 and **Table 5-2** presents the adopted coastal inundation parameters for each beach, from WRL (2017) Table 8-3 and Table 8-5.

Table 5-1 Tidal inundation input values (WRL, 2017)

Planning Period	HHWSS (mAHD)	63% AEP (mAHD)
2017	0.92	1.22
2065	1.25	1.55
2100	1.63	1.93

Table 5-2 Coastal Inundation input parameters for selected beaches at risk of coastal inundation under the 100 Year ARI event

Beach	Section	Total Still Water Level (inclusive of wave setup) (mAHD) (2017)	Total Still Water Level (inclusive of wave setup) (mAHD) (2100)	Wave Runup Level (mAHD)	Bore Propagation Distance (m)
Maloneys Beach	East	2.01	2.72	6.3	17.1
	West	2.13	2.84	6.7	15.7
Long Beach	East	2.14	2.85	4.9	13.0
	Central	2.31	3.02	5.3	9.6
	West	2.28	2.99	5.6	10.6
Surfside East	North	2.33	3.04	4.6	12.7
	South	2.36	3.07	4.7	13.2

Beach	Section	Total Still Water Level (inclusive of wave setup) (mAHD) (2017)	Total Still Water Level (inclusive of wave setup) (mAHD) (2100)	Wave Runup Level (mAHD)	Bore Propagation Distance (m)
Surfside West	-	2.10	2.77	2.7	9.1
Wharf Road	Dune Areas	2.14	2.61	3.0	9.9
	Seawall Areas	2.14	2.61	5.2	16
CBD	West	2.13	2.83	4.8	15.6
	Central	2.04	2.74	5.0	16.3
	East	2.22	2.93	5.0	16.3
Corrigans Beach	North	2.23	2.94	5.4	17.2
	South	1.82	2.52	3.0	9.5
Caseys Beach	North	2.10	2.81	5.0	9.4
	Central	1.70	2.41	4.9	9.0
	South	1.83	2.05	4.1	12.9
Malua	-	2.93	3.64	5.9	16.4
Tomakin Cove	-	1.97	2.68	4.6	7.3

It is noted that the consideration of future predicted sea level rise is based on ESC's sea level rise policy and planning framework (ESC, 2014; Whitehead & Associates, 2014) and has been applied as a constant increase to the coastal water levels. This approach does not include any future changes in beach geometry (that may influence exposure), incident wave conditions (from increased storminess or more intense wave conditions) or changes in rainfall and flooding, that may occur under future climate conditions. Prediction of such changes are uncertain and therefore cannot be included in the assessment at this time.

5.2.2 Creek Entrances

Within the study area, seven locations were identified as containing entrances or structures that may influence the inland propagation of the incoming coastal surge. These locations were:

- Northern Batemans Bay (Long beach, Surfside, Wharf road)
- Batemans Bay CBD (including Water Gardens)
- Boat Harbour (including Hanging Rock Creek)
- Corrigans Beach (including Joes Creek)
- Sunshine Bay/ Caseys Beach (including Shortbeach Creek)
- Malua Beach (including Reedy Creek)
- Broulee Beach (Candlagan Creek).

In order to accurately define the coastal inundation in these regions, hydraulic models were developed to define the extent of coastal flooding. The development and outputs of these models are discussed below.

5.2.2.1 Hydraulic Model Set Up

Hydraulic models for Long Beach, Surfside, Batemans Bay CBD, Boat Harbour, Corrigans Beach and Sunshine Bay were developed as part of the Batemans Bay Urban Creeks Flood Study (Rhelm, 2021).

Additional flood models for assessing coastal inundation at Malua Beach and Broulee Beach were developed as part of this study.

TUFLOW model parameters were adopted from the Batemans Bay Flood Study in order to ensure consistency across the models. Full details of the existing models are available in the Flood Study (Rhelm, 2021). Details of the Malua and Broulee models are provided in **Table 5-3** and **Table 5-4**.

Table 5-3 TUFLOW Inundation Model Parameters

Model Parameter	Details
Model Area	The model boundary was set at the 10mAHD contour, to ensure that the model boundary is beyond the extent of coastal flooding influence.
DEM	For the existing models, no changes were made to the DEM developed as part of the flood study. For Malua and Broulee, the model DEM was developed primarily with the 2018 5m topographic and bathymetric data collected as part of the NSW Marine LiDAR project. In regions of the model where this data was not available, the 2011 1m topographic data collected by NSW Spatial Services was adopted.
Structures	The full details of structures included in those areas discharging to Batemans Bay are detailed in the Flood Study (Rhelm, 2021). For the Malua and Broulee models, bridge structures were included at: • Beach Road crossing of Candlagan Creek • George Bass Drive crossing of Candlagan Creek • George Bass Drive crossing of Reedy Creek The bridge crests were taken from the LiDAR data, and the bridge deck depth and the location of any piers or abutments were taken from photographic data.
Roughness	Roughness zones were discretised based on aerial imagery and land use data. The roughness values adopted were taken from the Batemans Bay Urban Creeks Flood Study (Rhelm, 2021) to ensure consistency. The values adopted are shown in Table 5-4.
Catchment Inflows	Catchment inflows were excluded from these model runs, to assess the influence of catchment driven inundation only.
Entrance Condition	For the purposes of this assessment, all entrances were assumed to be fully open, to define the worst-case scenario of coastal inundation.
Downstream Boundary	A time varying tidal boundary was applied to each model area. The development of the downstream boundary is discussed in detail in Section 5.2.2.2.

Table 5-4 Adopted Roughness Values

Land Use	Manning's 'n'
Open space	0.035
Neighbourhood Centre (including building footprint)	0.250
Mixed Use (including building footprints)	0.200
Low Density Residential (including building footprints)	0.150
Recreation	0.040
Dense vegetation	0.080
Light vegetation	0.045
Medium Vegetation	0.060
Roads / Carparks	0.020

5.2.2.2 Downstream Boundary Conditions

For the hydraulic model, a dynamic tidal timeseries of the downstream coastal water level boundary condition was developed as follows:

- A representative predicted spring tide was selected based on the measured water levels at the Princess Jetty tide gauge
- A design peak storm surge was then selected for the desired ARI
- The selected peak storm surge was then added to the predicted tide, scaling up and down over a 48-hour period. This is consistent with the guidance in OEH (2015) that applied a similar method using a scaled May 1974 event.

Coastal water level timeseries were calculated for Batemans Bay, Malua Bay Beach and Broulee Beach, for the HHWS tide and 1, 20 and 100 Year ARI events Existing (2017), 2050, 2065 and 2100 planning periods.

The peak static coastal water levels for Batemans Bay, Malua Bay Beach and Broulee (North) were adopted from the Eurobodalla Coastal Hazard Assessment (WRL, 2017). Each value incorporates tide level (excluding setup and flood), flood contribution, wind setup and wave setup, to provide a total still water level (SWL). The design total SWLs is therefore the highest inundation level reached over the period of the storm.

For the 2050, 2065 and 2100 scenario, a sea level rise of 0.22, 0.33 and 0.71 m respectively was applied as a constant to the coastal water level timeseries.

The adopted ocean water levels are summarised in **Table 5-5**.

Table 5-5 Peak Ocean Levels for Inundation Assessment (mAHD)

Location	1 year ARI			20 Year ARI			100 Year ARI		
	2017	2065	2100	2017	2065	2100	2017	2065	2100
Long Beach	0.92	1.25	1.63	2.18	2.17	2.55	2.31	2.64	3.02

Location	1 year ARI			20 Year ARI			100 Year ARI		
	2017	2065	2100	2017	2065	2100	2017	2065	2100
Surfside	1.08	1.41	1.79	2.18	2.51	2.89	2.36	2.69	3.07
CBD	1.09	1.42	1.8	2.08	2.41	2.79	2.22	2.55	2.93
Boat Harbour	1.18	1.51	1.89	2.08	2.41	2.79	2.21	2.54	2.92
Corrigans	0.82	1.15	1.53	2.09	2.42	2.8	2.23	2.56	2.94
Caseys Beach	0.98	1.31	1.69	2.04	2.42	2.8	2.08	2.43	2.81
Malua	1.28	1.61	1.99	2.73	2.37	2.75	2.93	3.26	3.64
Broulee	0.97	1.3	1.68	1.93	2.23	2.61	2.2	2.53	2.91

5.2.3 Coincident Flooding

An assessment of coincident flooding arising from catchment rainfall events coupled with ocean flood events was undertaken for:

- Long Beach
- Surfside
- CBD
- Boat Harbour
- Corrigans Beach
- Sunshine Bay
- Malua Bay
- Broulee.

Each catchment was assessed for:

- 20 year ARI rainfall event with a 100 year ARI ocean event (for 2017, 2050, 2065 and 2100 ocean levels); and,
- PMF rainfall event with a 100 year ARI ocean event (for 2017, 2050, 2065 and 2100 ocean levels).

The results of the assessment are shown in Map Series RG-05-04.

The results show that predicted future changes in the downstream ocean level have little influence over the broader catchment flood behaviour but do have an impact in low lying lands. The changes in the downstream reaches of the catchments are driven by changes in the ocean level, and these extents are similar to those shown in Map Series RG-05-02 for coastal inundation, as the contributing rainfall does not offer a significant additional volume when compared to the bay or ocean downstream.

At the edge of the coastal inundation extent, where the driver of peak levels changes from ocean levels to catchment runoff, there are only minor changes in flood extent. These changes are due to the reduced capacity of the discharging systems as a result of the higher tailwater in future scenarios.

In the upstream reaches, beyond the influence of the ocean flood, there were no changes observed, as would be expected given the rainfall adopted was the same for all planning horizons.

5.3 Coastal Inundation Results

Tidal inundation figures are presented in **Map Series RG-05-01**.

The results of the coastal inundation assessment (1, 20 and 100 Year ARI events) are shown in **RG-05-02**.

100 Year ARI inundation depths area shown for the existing and 2100 scenarios for key inundation risk locations in **Map Series RG-05-03**.

The inundation extents associated with the coincidence of catchment and coastal flooding is provided in **Map Series RG-05-04**.

These maps can be supplemented with the work done by WRL (2017), for completeness, the relevant WRL (2017) deterministic erosion maps have been included in **Appendix C**. Guidance to the mapping is provided in **Table 5-6**.

Table 5-6 Coastal Inundation Map List

Location	Inundation Risk	Map Location
South Durras	HHWSS (2017, 2050, 2065, 2100)	Appendix C
	1, 20 and 100 Year ARI Inundation (2017, 2050, 2065, 2100)	Appendix C
Cookies Beach	HHWSS (2017, 2050, 2065, 2100)	Appendix C
	1, 20 and 100 Year ARI Inundation (2017, 2050, 2065, 2100)	Appendix C
Maloneys Beach	HHWSS (2017, 2050, 2065, 2100)	Appendix C
	1, 20 and 100 Year ARI Inundation (2017, 2050, 2065, 2100)	Appendix C
Long Beach	HHWSS (2017, 2100): Very little difference between 2017 and 2100 inundation extents resulted in 2050 and 2065 scenarios not being assessed	Map Series RG-05-01
	1, 20 and 100 Year ARI Inundation (2017, 2050, 2065, 2100)	Map Series RG-05-02
	Coincident Inundation (2017, 2050, 5065, 2100) – 20 Year ARI Catchment & 100 Year ARI Ocean – PMF Catchment & 100 Year ARI Ocean	Map Series RG-05-04
Cullendulla Beach	HHWSS (2017, 2050, 2065, 2100)	Appendix C
	1, 20 and 100 Year ARI Inundation (2017, 2050, 2065, 2100)	Map Series RG-05-02
Surfside and Wharf Road	HHWSS (2017, 2050, 2065, 2100)	Map Series RG-05-01
	1, 20 and 100 Year ARI Inundation (2017, 2050, 2065, 2100)	Map Series RG-05-02
	Coincident Inundation (2017, 2050, 5065, 2100) – 20 Year ARI Catchment & 100 Year ARI Ocean – PMF Catchment & 100 Year ARI Ocean	Map Series RG-05-04
CBD	HHWSS (2017, 2050, 2065, 2100)	Map Series RG-05-04
	1, 20 and 100 Year ARI Inundation (2017, 2050, 2065, 2100)	Map Series RG-05-02
	Coincident Inundation (2017, 2050, 5065, 2100) – 20 Year ARI Catchment & 100 Year ARI Ocean – PMF Catchment & 100 Year ARI Ocean	Map Series RG-05-04
Boat Harbour	HHWSS (2017, 2050, 2065, 2100)	Map Series RG-05-01
	1, 20 and 100 Year ARI Inundation (2017, 2050, 2065, 2100)	Map Series RG-05-02

Location	Inundation Risk	Map Location
	Coincident Inundation (2017, 2050, 5065, 2100) – 20 Year ARI Catchment & 100 Year ARI Ocean – PMF Catchment & 100 Year ARI Ocean	Map Series RG-05-04
Corrigans Beach	HHWSS (2017, 2050, 2065, 2100)	Map Series RG-05-01
	1, 20 and 100 Year ARI Inundation (2017, 2050, 2065, 2100)	Map Series RG-05-02
	Coincident Inundation (2017, 2050, 5065, 2100) – 20 Year ARI Catchment & 100 Year ARI Ocean – PMF Catchment & 100 Year ARI Ocean	Map Series RG-05-04
Caseys Bay	HHWSS (2017, 2050, 2065, 2100)	Map Series RG-05-01
	1, 20 and 100 Year ARI Inundation (2017, 2050, 2065, 2100)	Map Series RG-05-02
	Coincident Inundation (2017, 2050, 5065, 2100) – 20 Year ARI Catchment & 100 Year ARI Ocean – PMF Catchment & 100 Year ARI Ocean	Map Series RG-05-04
Sunshine Bay	HHWSS (2017, 2050, 2065, 2100)	Map Series RG-05-01
	1, 20 and 100 Year ARI Inundation (2017, 2050, 2065, 2100)	Map Series RG-05-02
	Coincident Inundation (2017, 2050, 5065, 2100) – 20 Year ARI Catchment & 100 Year ARI Ocean – PMF Catchment & 100 Year ARI Ocean	Map Series RG-05-04
Malua Bay	HHWSS (2017, 2050, 2065, 2100)	Map Series RG-05-01
	1, 20 and 100 Year ARI Inundation (2017, 2050, 2065, 2100)	Map Series RG-05-02
	Coincident Inundation (2017, 2050, 5065, 2100) – 20 Year ARI Catchment & 100 Year ARI Ocean – PMF Catchment & 100 Year ARI Ocean	Map Series RG-05-04
Guerilla Bay (South)	HHWSS (2017, 2050, 2065, 2100)	Appendix C
	1, 20 and 100 Year ARI Inundation (2017, 2050, 2065, 2100)	Appendix C
Barlings Beach	HHWSS (2017, 2050, 2065, 2100)	Appendix C
	1, 20 and 100 Year ARI Inundation (2017, 2050, 2065, 2100)	Appendix C
Tomakin Cove	HHWSS (2017, 2100): Very little difference in risk between 2017 and 2100 inundation extents resulted in 2050 and 2065 scenarios not being assessed	Map Series RG-05-01
	1, 20 and 100 Year ARI Inundation (2017, 2050, 2065, 2100)	Map Series RG-05-02
Broulee	HHWSS (2017, 2050, 2065, 2100)	Map Series RG-05-01
	1, 20 and 100 Year ARI Inundation (2017, 2050, 2065, 2100)	Map Series RG-05-02
	Coincident Inundation (2017, 2050, 5065, 2100) – 20 Year ARI Catchment & 100 Year ARI Ocean – PMF Catchment & 100 Year ARI Ocean	Map Series RG-05-04

6 Batemans Bay Conceptual Sediment Transport Model

The technical brief for the CMP requested a review of a suite of investigations relating to the Batemans Bay bridge assessments and the implications for coastal processes and hazards along the northern shorelines of Batemans Bay. The aim was to identify the predominant causes of coastal erosion and inundation, including consideration of previous works and their contribution to current risk exposure. Batemans Bay has a history of changing coastal landscapes that have occurred due to natural variability and human development. A focus on sediment transport processes allows the drivers for the dynamic coastal formations to be identified and then what management measures are required if needed.

To this end a conceptual sediment transport model was developed of Inner Batemans Bay, which has integrated analysis of available datasets and findings from relevant studies to provide a cohesive conceptual model of key processes. An expanded summary of the conceptual model development is provided in **Appendix B**.

6.1 Existing Data and Studies

The following primary datasets have been considered in the development of the conceptual model:

- Metocean data (wave and tide data)
- Historical aerial imagery (from 1949 to present)
- Historical photographs (from 1898 to present)
- Historical navigation charts (between 1864 and 1931)
- Bathymetric survey, most notably the high-resolution nearshore LiDAR data covering the entire Inner Bay at 5m resolution (OEH, 2018)
- Rainfall data and flooding records from 1860s to present
- Photogrammetry (sourced from the NSW Beach Profile Database, DPIE 2021)
- Previous model outputs of wave, current and sediment transport models (including WEL, 2017; WBM, 2000)
- Community understanding (extensive community consultation outputs).

In addition, a number of existing studies exist that have assessed and quantified key coastal processes, including:

- WRL (2017), Eurobodalla Coastal Hazard Assessment. WRL Technical Report 2017/09, October 2017
- BMT WBM (2009), Wharf Road Coastal Hazard Assessment and Hazard Management Plan, Report prepared for Eurobodalla Shire Council
- WBM Oceanics (2000), Batemans Bay/Clyde River Estuary Processes Study – Water Quality and Sedimentation Components, Report prepared for Eurobodalla Shire Council.

A review of prior studies and research reveals that competing processes occur within the bay, often dominating in cycles that can stretch over decadal timescales. WBM (2000) completed field sampling of surface sediments within the Inner Bay and identified that sediments are predominantly lithic sands with a higher proportion of angular (fluvial) quartz compared to well rounded (marine) quartz. The predominance of fluvially derived sediments indicates flood events are the significant contributor of sediment to the Bay.

6.2 Beach Compartment Scale

The conceptual model was developed by first considering processes at the beach compartment scale and then across Inner Batemans Bay wholistically.

Corrigans Beach

Significant and rapid accretion of the Southern Shoreline was observed following construction of the 1,300m long training wall along the CBD (completed 1905), with an additional extension having been constructed in 1991 (of ~150m in length).

The sediment accretion at Corrigans Beach is driven by northward longshore transport (driven by waves) that is trapped on the southern side of the training wall. The supply of sediment to this compartment appears to be predominantly from the ebb tide shoal at the end of the Clyde River channel with the sediment being predominantly lithic sands of fluvial origin with only minor marine sand content (WBM, 2000).

Figure 6-1 shows a snapshot of navigation chart and aerial imagery between 1899 and 1981 that demonstrates the rapid accretion of land behind the training wall.

Figure 6-1 Rapid accretion of land behind the training wall at Corrigans Beach

Cullendulla Beach

Cullendulla Beach is an embayed shoreline that stretches between Square Head and Hawks Nest Headland, with a notable chenier plains feature, and more recent beach ridges, that are variably spaced which is a function of the variable rate of falling sea level over the last ~6000 years. . More recently, under stable and/or rising sea levels an ongoing recession of the shoreline has been observed in the photogrammetry data. Since sea levels have stabilised (over the last ~1000 years) the seaward progression of the beach ridge system has slowed, and the current position of the shoreline is such that it is exposed to greater wave energy during storm events than was historically the case. The observed recession is driven by elevated coastal conditions (water levels and waves) that moves sediment in an easterly direction away from Hawks Nest Headland.

The compartment is relatively protected from incident waves with a significant flood delta having developed in the lee of Square Head, fed by flood flows from Cullendulla Creek. The embayment appears to be an isolated sediment compartment that feeds sediment into the Inner Bay via the flood delta however with no clear transport pathways from the Inner Bay back in to the Cullendulla compartment. This lack of sediment supply to the western end of the compartment generates the observed ongoing recessional trend.

Cullendulla Embayment is shown in **Figure 6-2** with Chenier Plains feature behind the beach and flood shoal extending from Cullendulla Creek in the lee of Square Head.

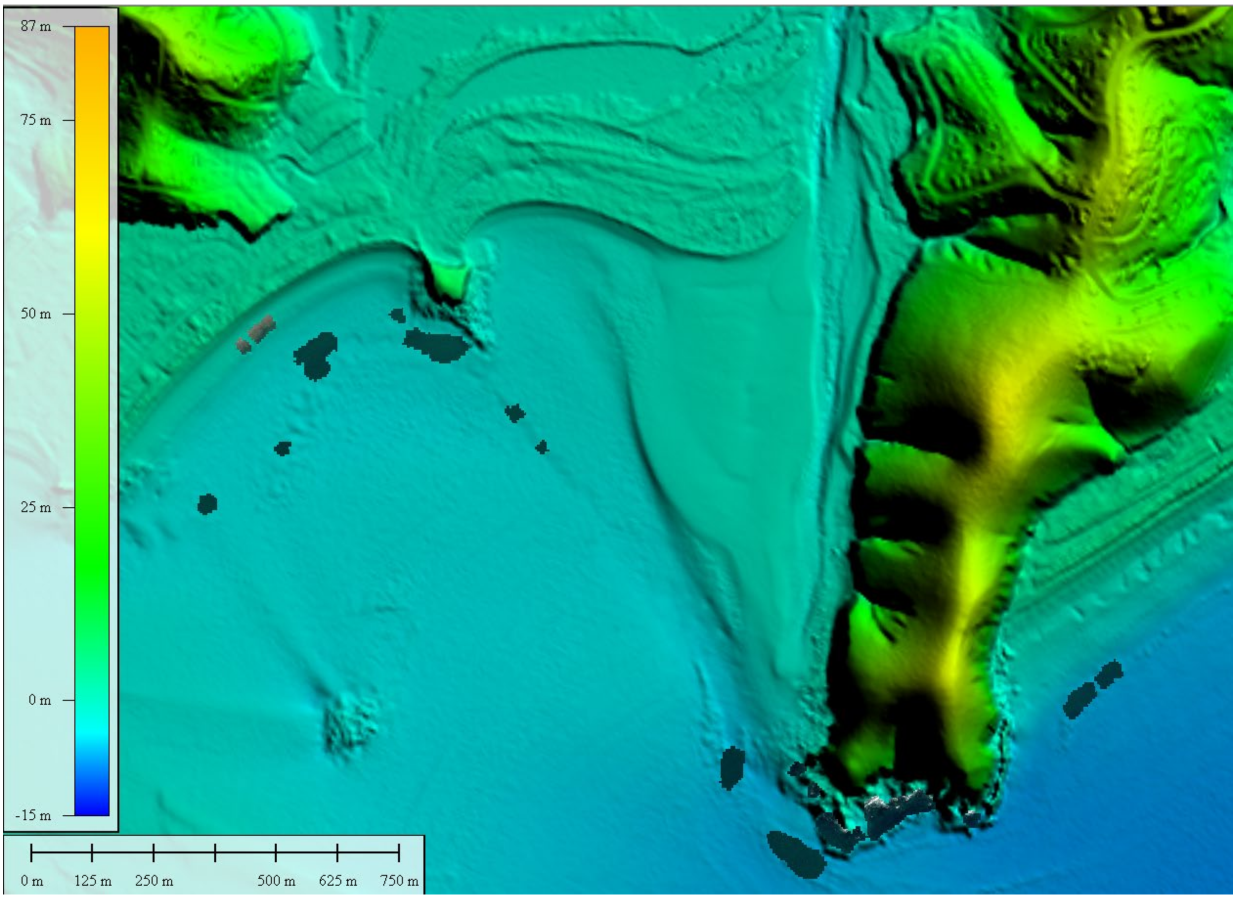

Figure 6-2 Surveyed terrain data of the Cullendulla Embayment

Surfside East

Surfside Beach

The Surfside Beach shoreline (east of Pinnacle Point) appears to be a relatively stable shoreline, that fluctuates in response to severe coastal storms, with no discernible long-term trend in shoreline position.

Low to negligible net longshore transport is predicted as the shoreline is generally in alignment with incident waves, with a trend toward southwest transport predominantly driven by elevated coastal conditions. Onshore transport is likely from nearshore bars, when the configuration of the bars allows.

The yearly mean shoreline position is shown in **Figure 6-3** along Surfside Beach between 1988 and 2019, indicating a relatively stable shoreline position.

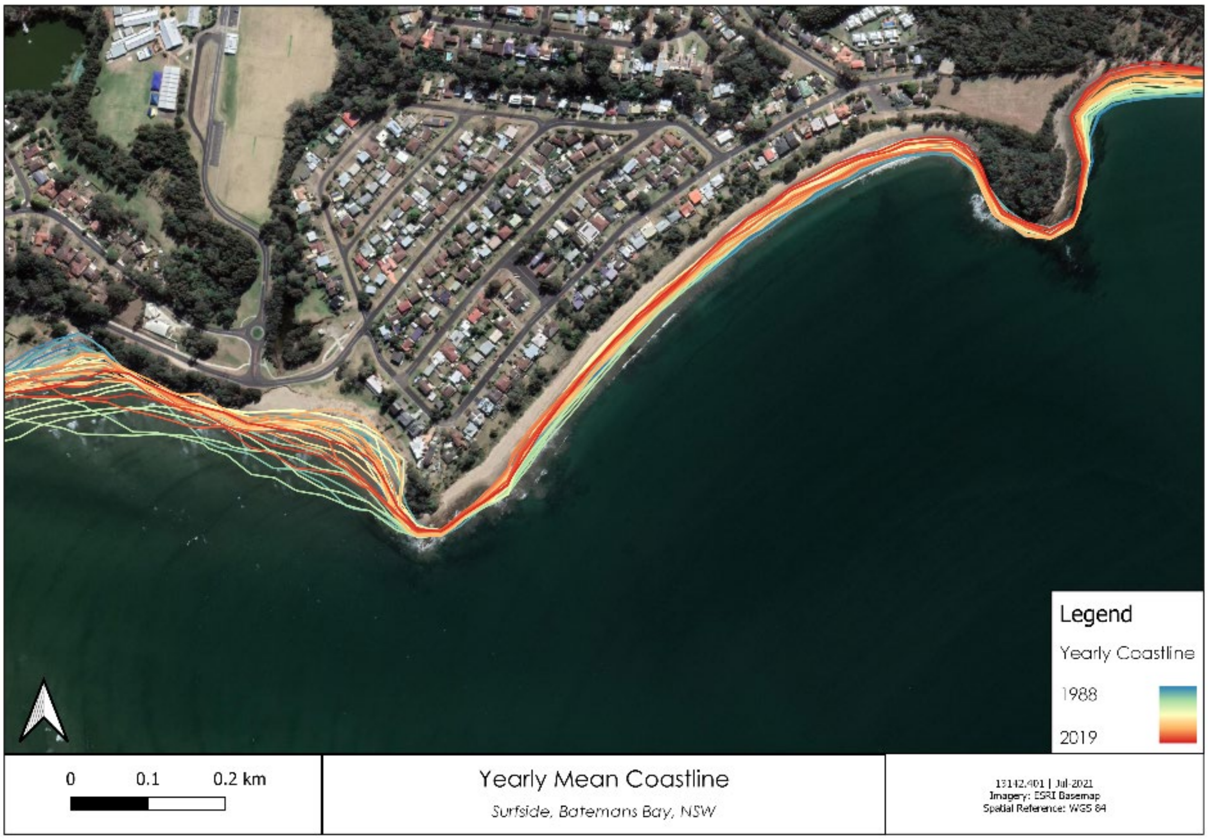

Figure 6-3 Yearly Mean Shoreline Position (approximately 0mMSL)- Surside Beach

Mcleods Beach / Wharf Road

The formation, location and change of sand shoals off Wharf Road and Surfside is shown to occur over decadal timescales, however significant changes can occur in the short-term, particularly during large catchment flood events and large coastal storm events.

River flows are the major influence on re-working of the Wharf Road shoreline and nearshore shoals, with large flows close to the beach and across the shoals leading to scour during major flood events. The predominant driver of sand shoal re-working over decadal timescales is the occurrence and frequency of flood events, where correlation between the disappearance of sand shoals and major floods has been identified.

After a flood event and corresponding breakthrough or re-working of the shoals has occurred, wave induced sediment transport during ambient and elevated offshore swell replenishes the Wharf Road shoreline over time. In addition, the longshore transport from east to west along Mcleod's Beachand Wharf Road beaches is driven by wave-induced currents at the shoreline and a flood tide inequality in the tidal flows.

The highly dynamic nature of this area, with large changes in the shoreline position and shoal formation, is considered a natural process governed by the contest between fluvial flows and coastal processes. Interrogation of historical chart, aerial and survey data identifies similar coastal landforms (in terms of shape and extent of the shoreline and shoals) extending from the Wharf Road area in both 1864 and 1981, well before and after the construction of the training wall along the CDB, respectively (**Figure 6-5**).

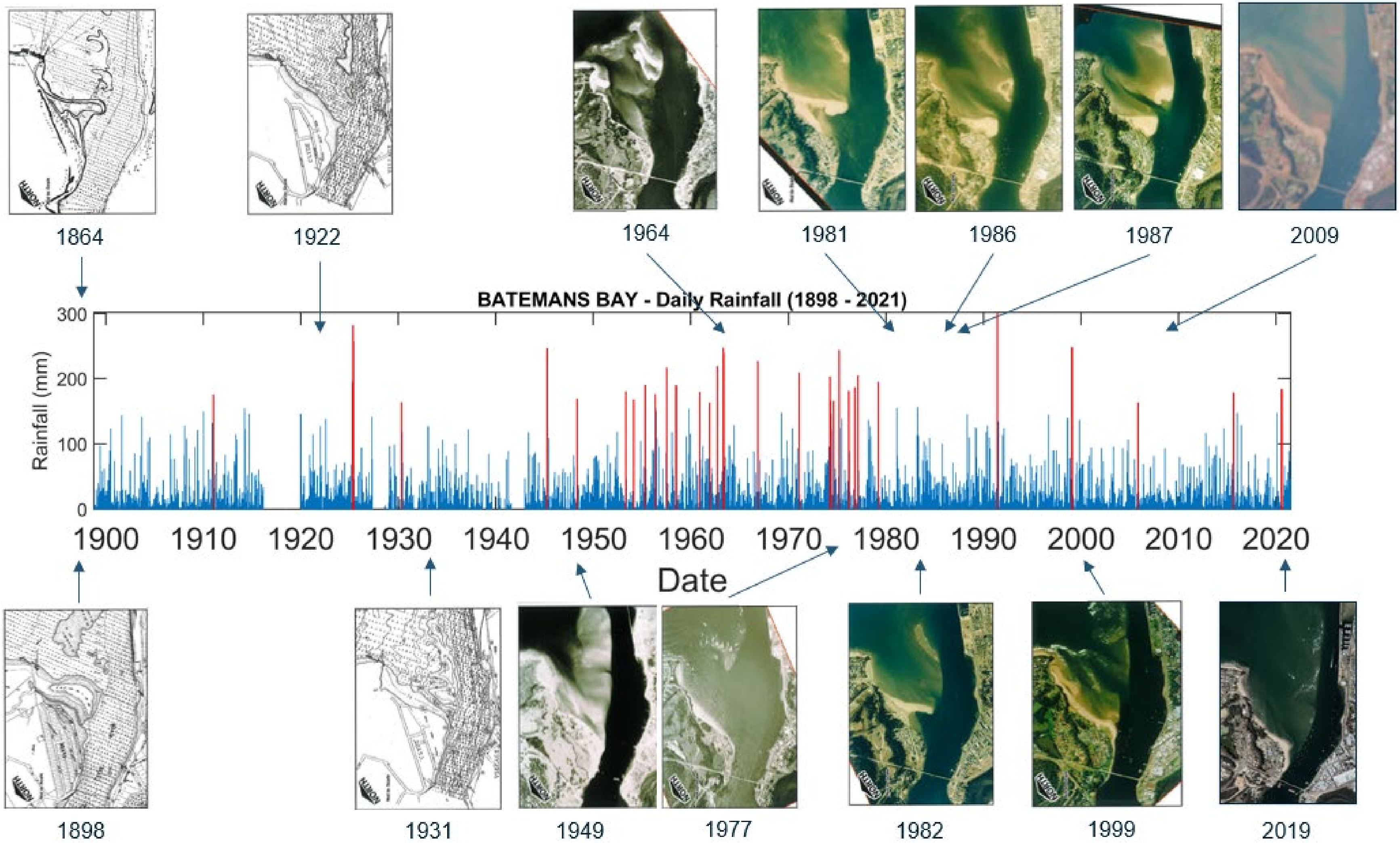

Figure 6-4 Timeline of Rainfall and the Wharf Road Shoreline and Nearshore Shoals indicating correlation between Clyde River Flood Flows and Nearshore Landform. Red lines indicate the top 30 daily rainfall totals.

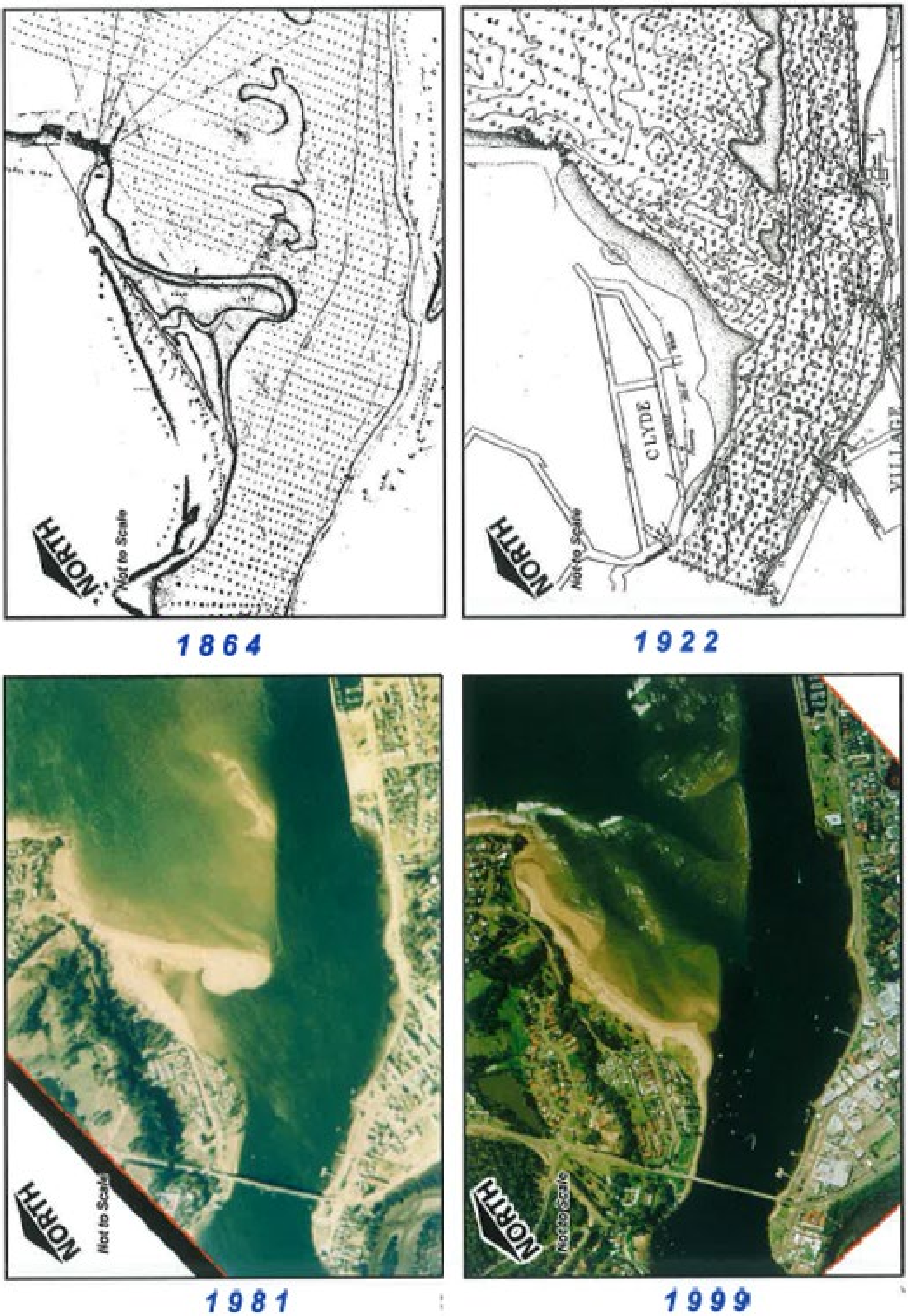

Figure 6-5 Shoreline and Shoal Formations along Wharf Road in 1864 (top left), 1922 (top right), 1981 (bottom left) and 1999 (bottom right) demonstrating the dynamic and recurrent nature of landforms along Wharf Road and Mcleod's Beach

Clyde River Channel and Entrance Shoal

With the construction of the training wall along the CBD at the start of the 20th century, a seaward migration of the entrance shoal by approximately 700m has occurred. This has resulted in an elongation of the ebb tide / flood flow delta.

The indicative positions of the flow delta feature at the end of the Clyde River Channel are shown in **Figure 6-6** in 1899 and 2019.

The delta feature is a contributor to the onshore transport of sediment towards the northern shoreline areas, and while the morphology of this feature has been modified over the last century which would impact the rate of northerly transport from the shoal, the volume of sediment available on the northern side of the Clyde River channel would have been only marginally affected.

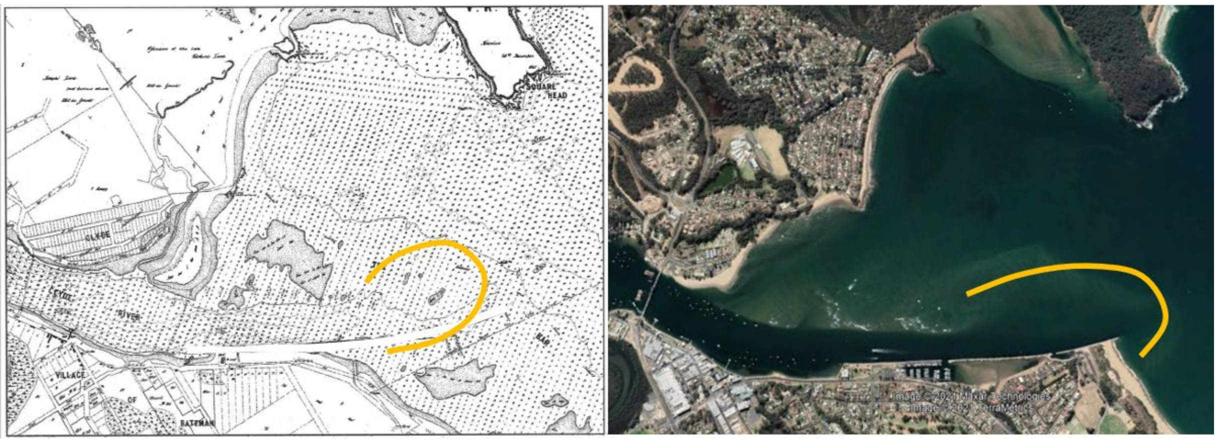

Figure 6-6 Clyde River channel flow delta feature in 1899 (left) and 2019 (right)

6.3 Inner Batemans Bay Conceptual Model

The analysis, compilation and interpretation of the available data and studies has culminated in the development of the conceptual sediment transport model across the Inner Batemans Bay area, as presented in **Figures 6.7 to 6.9**. The conceptual model is presented to identify the key processes that drive sediment transport throughout the bay and is not intended as a quantitative assessment of sediment transport or shoreline change. Three regimes are identified:

- Ambient conditions (**Figure 6-7)**, where sediment transport is dominated by waves (average) and tidal currents.
- Coastal Storm conditions (**Figure 6-8**), where sediment transport is dominated by larger waves and elevated water levels (causing shoreline erosion) and storm induced circulations (e.g. rips).
- Catchment Flood conditions (**Figure 6-9**), where sediment transport is dominated by significant flows out of the Clyde River, Creeks and ICOLL entrances.

The three regimes may or may not occur in combination with each other, depending on the climatic and coastal conditions at the time.

In general, the morphology of the Batemans Bay shoreline and seabed is a result of conflicting coastal and fluvial processes. Of note is the identification of flood dominated and coastal dominated regions that extend from Pinnacle Point. These provide an approximate delineation of areas that are dominated by flood or coastal processes over decadal timescales, noting that both flood and coastal processes are at work throughout the Inner Bay.

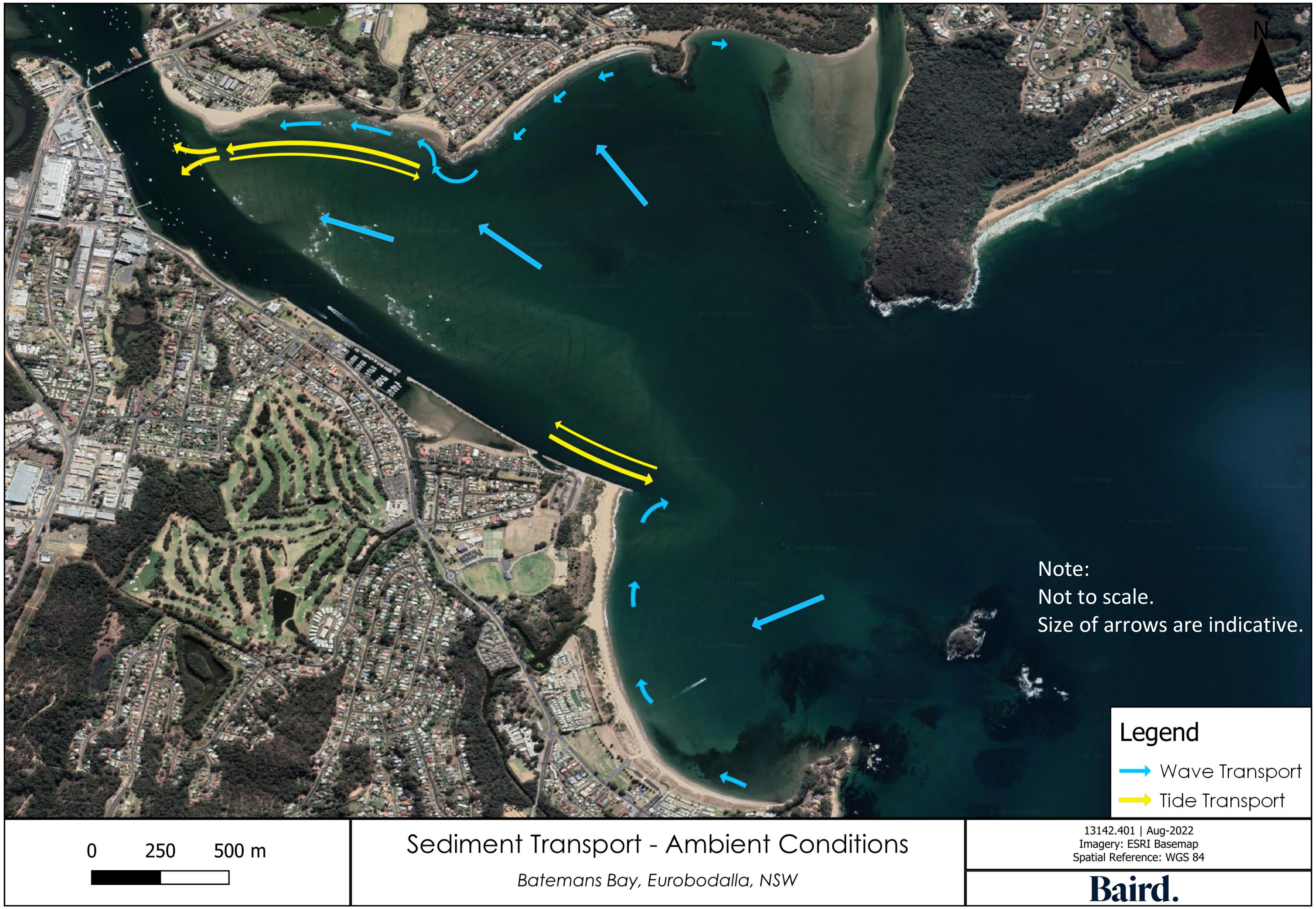

Figure 6-7 Conceptual sediment transport model of inner Batemans Bay under ambient conditions

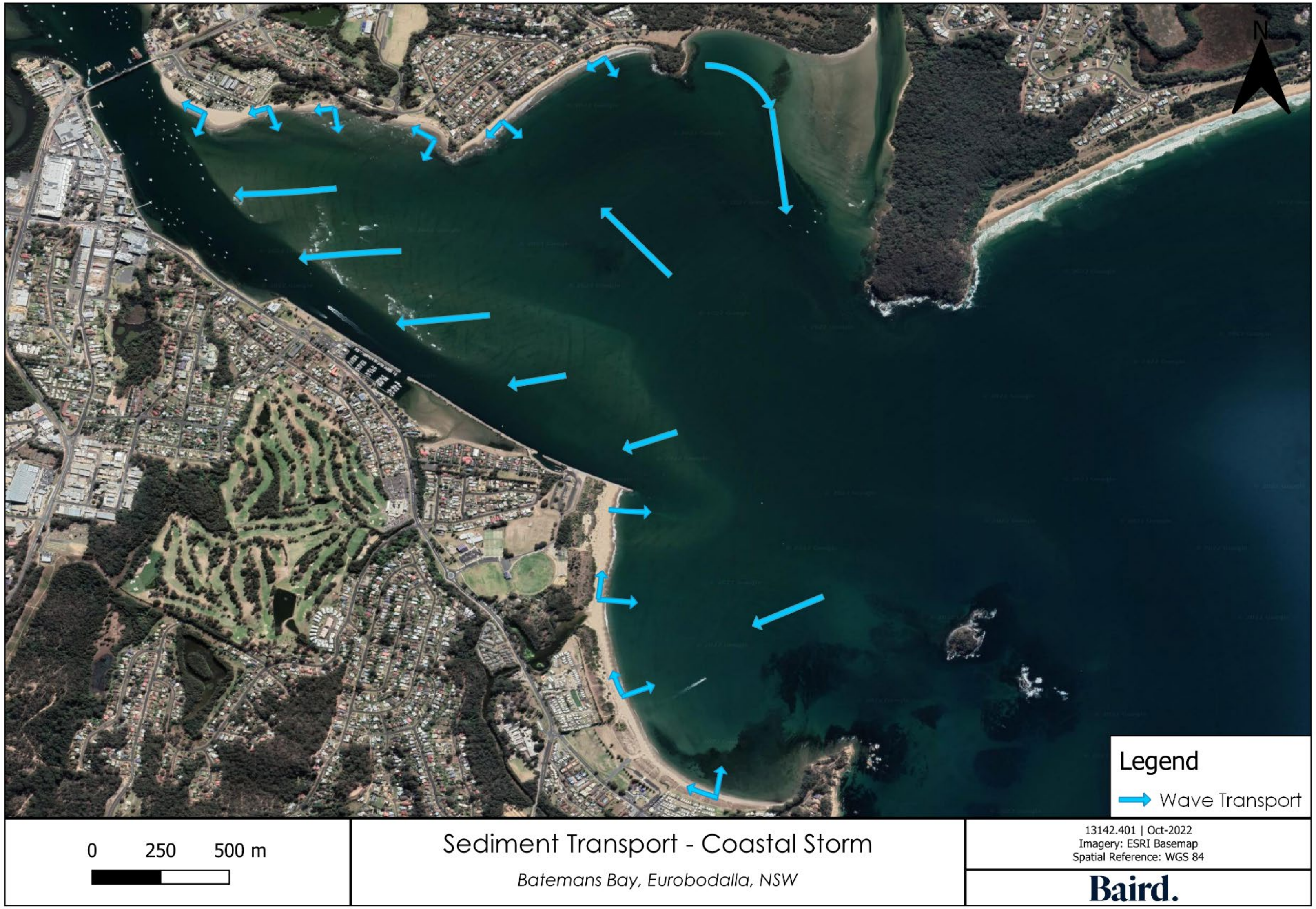

Figure 6-8 **Conceptual sediment transport model of inner Batemans Bay under coastal storm conditions**

Figure 6-9 Conceptual sediment transport model of inner Batemans Bay under catchment flood conditions

6.4 Influence of Historic Works on the Shorelines of Batemans Bay

Since its construction in the early 20th century, the training wall along the CBD has resulted in a large transformation of the embayment of Batemans Bay. Most notably the significant and rapid accretion of the Southern Shoreline to form Corrigans Beach, caused by the entrapment of northward longshore transport (driven by waves) on the southern side of the training wall, scouring of the Clyde River channel and seaward movement of the entrance bar.

However, the direct impact of this structure on the northern side of the bay is less evident. A seaward migration of the Clyde entrance shoal by approximately 700m has occurred, resulting in an elongation of the ebb tide / flood flow delta. The change in morphology of this feature would have influenced the rate of transport towards the northern shoreline areas however, the volume of sediment available on the northern side of the Clyde River channel would have been only marginally affected.

A review of available historical data suggests that the landform (shoreline position) and nearshore shoal features along the northern shorelines of Batemans Bay are dynamic and dominated by the magnitude and frequency of flood flows. That is, the dominant driver for an accreted shoreline position is the time since the last major flood in the Clyde River and/or coastal storm conditions, with coastal processes (waves and tides under average seasonal conditions) acting to replenish this area with sand between flood and coastal events.

The similarity in the shape and extent of the shoreline and shoals at times well before and after the construction of the training wall along the CDB (e.g. 1864 and 1981, see Figure 6-5) suggests that the construction of these works has not removed the ability of the area to be replenished with sand should climatic conditions allow.

This analysis does not disregard the influence of historic works on the shorelines of Batemans Bay; however, highlights the fact that the assessment of management options within the Inner Bay during Stage 3 must adequately consider the naturally dynamic processes that are the principal driver for observed shoreline change, particularly along the northern shoreline areas.

7 Moving on to Stage 3

The Stage 2 assessments contained in this document along with the previous coastal vulnerability assessments (WRL, 2017 and SMEC, 2010) and previous and ongoing engagement with the community and stakeholders will assist Council and community to understand the complexity of the issues and risks affecting the environmental, social and economic assets and values in each coastal management area.

During Stage 3 Council will identify and evaluate management options and actions that can be implemented to reduce vulnerability and risks. These actions will help build the community's resilience and ability to adapt to change.

The CM Manual identifies three levels of risk that direct the level of detail required in Stage 3 options assessment, as shown in **Figure 7-1**. The outcomes of each of the vulnerability assessments undertaken in this Stage 2 assessment (**Section 4 and 5**) are categorised against these three levels of risk to provide the framework and approach for Stage 3 (**Table 7-1**).

As described in **Section 3.1** the locations included in this Stage 2 assessment are those considered to have potential high risk or significant data gaps. However, it is acknowledged that previous vulnerability assessments were undertaken by WRL (2017) for a number of other low risk locations. The inundation and erosion maps for these locations have been included in **Appendix C** and will be considered in the development and assessment of management options in Stage 3. These location have not been included in **Table 7-1**. The erosion assessment undertaken by SMEC (2010) has been replicated in the mapping contained within this Stage 2 report, and as such is not included in **Appendix C**.

The Stage 3 options assessment will also consider the vulnerability and recommendations made in the *Geotechnical Slope Instability Risk Assessment* under taken for Batemans Bay by ACT Geotechnical of Engineers Pty Ltd in 2012.

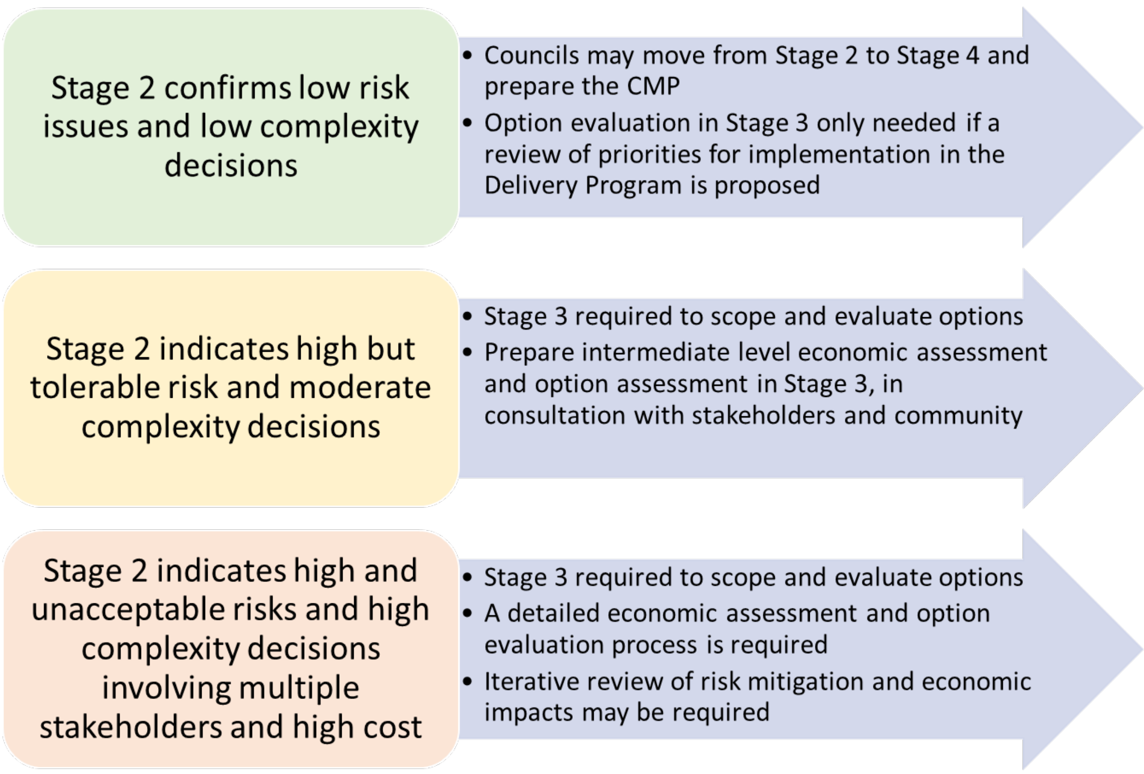

Figure 7-1 Outcomes of the hazards studies (Figure B2.29 in the CM Manual)

Table 7-1 Outcomes of Hazards Studies

Location	Description	Outcomes of the hazards studies as per Figure B2.29 in the CM Manual (See Figure 7-1)
Maloneys Beach	Potential future erosion risk to road	Stage 2 indicates low risk issues and low complexity decisions.
	100 Year ARI inundation could threaten Northcove Road.	Stage 2 indicates low risk issues and low complexity decisions.
Long Beach	Erosion risk under existing and future conditions threatens public land, roadways and private property at the eastern end of Long Beach.	Stage 2 indicates high but tolerable risk and moderate complexity decisions.
	100 Year ARI inundation impacts several private properties and Bay Road	Stage 2 indicates low risk issues and low complexity decisions.
Surfside	Existing erosion risk is limited to beach front and public land. Future (2100) erosion risk threatens private properties.	Stage 2 indicates high but tolerable risk and moderate complexity decisions.
	Future (2100) 1 Year ARI inundation risk threatens low lying properties and several roads.	Stage 2 indicates high but tolerable risk and moderate complexity decisions.
	Existing and Future (2100) 100 Year ARI inundation threatens large number of private properties and roads within Surfside.	Stage 2 indicates high but tolerable risk and moderate complexity decisions.
Wharf Road	Erosion risk to private properties seaward of Wharf Road to be managed under Wharf Road CZMP. Erosion risk to Wharf Road and adjacent infrastructure (e.g. Sewer) under existing and future (2100) conditions.	Stage 2 indicates high but tolerable risk and moderate complexity decisions.
	Future (2100) tidal inundation risk to a small section of Wharf Road to associated impacts on drainage.	Stage 2 indicates low risk issues and low complexity decisions.
	Future (2100) 1 Year ARI and Existing and Future (2100) 100 Year ARI inundation threatens large number of private properties and Wharf Road.	Stage 2 indicates high but tolerable risk and moderate complexity decisions.

Location	Description	Outcomes of the hazards studies as per Figure B2.29 in the CM Manual (See Figure 7-1)
Batemans Bay CBD	Future (2100) 1 Year ARI inundation risk to Clyde Street and a section of North Street.	Stage 2 indicates high but tolerable risk and moderate complexity decisions.
	Existing 100 Year ARI inundation risk threatens portions of the CBD including properties and roads. Future (2100) 100 Year ARI inundation risk significantly increases in depth and extent, with a larger number of properties and roads impacted.	Stage 2 indicates high but tolerable risk and moderate complexity decisions.
Boat Harbour	Future (2100) tidal risk and 1 Year ARI inundation risk to Beach Road and Herarde Street (and adjacent private properties).	Stage 2 indicates high but tolerable risk and moderate complexity decisions.
	Future (2100) tides also threaten large residential areas westward of Corrigans Beach.	Stage 2 indicates high and unacceptable risks and high complexity decisions, involving multiple stakeholders and high cost.
	Existing and Future (2100) 100 Year ARI inundation risk poses significant risk to private and public land include roads and other assets.	Stage 2 indicates high but tolerable risk and moderate complexity decisions.
Corrigans Beach	Existing and Future (2100) 100 Year ARI inundation risk poses significant risk to private and public land include roads and other assets.	Stage 2 indicates high but tolerable risk and moderate complexity decisions.
Caseys Beach	*Not assessed in this Stage 2 assessment, however, previous studies indicate a high erosion risk to foreshore assets (including roads) and potentially adjoining private properties.*	Stage 2 indicates high and unacceptable risks and high complexity decisions, involving multiple stakeholders and high cost.
	Future (2100) tidal and 1 Year ARI inundation risk to properties adjoining the lower reaches of Short Beach Creek.	Stage 2 indicates low risk issues and low complexity decisions.
	Existing and Future (2100) 100 Year ARI inundation risk poses risk to private properties adjoining the lower reaches of Short Beach Creek, Sunshine Bay Public School and Pleasurelea Tourist Park.	Stage 2 indicates high but tolerable risk and moderate complexity decisions.
Sunshine Bay	Existing erosion risk to public carpark. Future (2100) erosion risk to public carpark and private property.	Stage 2 indicates high but tolerable risk and moderate complexity decisions.

Location	Description	Outcomes of the hazards studies as per Figure B2.29 in the CM Manual (See Figure 7-1)
Malua Bay	Existing erosion risk to public land and roadway. Future (2100) erosion risk to private properties at northern end of beach.	Stage 2 indicates high but tolerable risk and moderate complexity decisions.
	Future (2100) 100 Year ARI inundation risk to private properties.	Stage 2 indicates low risk issues and low complexity decisions.
Barlings Beach	Future (2100) erosion risk to Barlings Beach Holiday Park.	Stage 2 indicates high but tolerable risk and moderate complexity decisions.
Tomakin Cove	Future (2100) erosion risk to private property	Stage 2 indicates high but tolerable risk and moderate complexity decisions.
Broulee	Future (2100) erosion risk to roadway and private properties at northern end of beach	Stage 2 indicates high but tolerable risk and moderate complexity decisions.
	Existing and future (2100) 100 Year ARI inundation risk (shallow) to a small number of properties on Candlagan Drive.	Stage 2 indicates low risk issues and low complexity decisions.

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9 Model Assumptions and Limitations

Coastal hazard extents presented in this report have been developed using modelling and analysis completed within the Eurobodalla Coastal Hazard Assessment (WRL, 2017). The Coastal Hazard Assessment (WRL, 2017) provides detailed calculations of erosion and recession; using photogrammetry analysis and numerical erosion modelling; and coastal wave levels, wave runup and overtopping; using data analysis, numerical modelling and empirical techniques. The assumptions and limitations of the adopted methodologies are outlined in WRL (2007) which is reproduced in **Appendix D** of this report.

Remapping of coastal hazard extents for some locations, as described in Sections 4 and 5, was completed as part of this Stage 2 report. The mapping methodology adopted is consistent with that applied in WRL (2017), noting that recent high resolution LiDAR data across both foreshore and nearshore areas of the study area has allowed improved mapping of tidal and storm tide extents to be developed with consideration of hydraulic connectivity of foreshore areas to the coast.

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