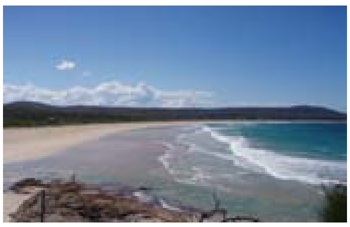
Draft Final Report

Eurobodalla Shire Coastal Hazards Scoping Study

October 2010 3001805



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PREPARATION, REVIEW AND AUTHORISATION

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Eurobodalla Shire Coastal Hazards Scoping Study

For: Eurobodalla Shire Council

DRAFT OCTOBER 2010

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1 INTRODUCTION

Eurobodalla Shire is located on the NSW South Coast approximately 280 km south of Sydney. The shire coastline stretches approximately 112 km, with major settlements at Batemans Bay, Moruya and Narooma.

Council has initiated the Coastline Management process throughout the shire, with a Coastal Hazards Management Plan completed for Batemans Bay in 2001. However, there is a lack of coastal hazard risk information in other parts of the Shire. Given the length of coastline and vast network of estuaries, beaches and lagoons within the Shire, there is a need to target comprehensive coastal hazard investigations to priority areas. This report identifies the priority areas for targeted assessments, as well as critical data acquisition requirements for the development of a Coastline Management Study and Plan for the entire coastline.

While much of the coastline remains in its natural state, there are areas where development encroaches onto the coastline, raising questions as to the degree of coastal hazard risk. The existing Batemans Bay Coastline Hazard Management Plan identified coastal hazards in the following areas within the Batemans Bay embayment downstream of the Princes Highway Bridge:

- Maloneys Beach,
- Long Beach,
- Cullendulla Beach and Surfside Beach,
- North Batemans Bay (Wharf Road),
- Batemans Bay Central Business District,
- Batemans Bay Beach Road (Boat Harbour West),
- Batemans Bay Hanging Rock (Boat Harbour East),
- Catalina (Corrigans Beach)
- Batehaven (Casey Beach).

Other coastal areas in the Eurobodalla Local Government Area may potentially be at risk of damage to public assets and impacts on recreational amenity caused by coastal hazards. These other coastal areas identified in this report are listed below:

- South Durras
- Sunshine Bay
- Denhams Beach
- Surf Beach
- Lilli Pilli
- Malua Bay and Mc Kenzie Beach
- Rosedale
- Guerilla Bay and Burrewarra Point
- Tomakin and Barlings Beach
- Mossy Point and Tomaga River entrance
- Broulee and Broulee Island
- Moruya (Airport, River and Beach)

- Congo
- Meringo
- Bingie
- Tuross Head (Including Coila Lake and Tuross Lakes Entrances)
- Potato Point
- Dalmeny
- Kianga
- Narooma and Islandview Beach resort
- Mystery Bay
- Akolele and Wallaga Lake.

These locations are illustrated in Figure 1.1.

The coastal hazard is likely to increase with time given current scenarios for climate change and projected sea level rise.

Increasing pressures on the natural resources along the coast are significant, and include population growth, growing residential development needs along the foreshore, coastal development and tourism.

In recognition of the growing pressures and complex interactions between coastal processes that operate within the coastal zone, Council has resolved to review the existing coastal hazard studies, for comprehensiveness and to take account of contemporary scenarios for long term sea level rise and climate change. In addition to this review, a gap analysis of coastal hazard assessment studies was carried out to identify areas requiring detailed assessment. Updated aerial photography, recent information regarding Climate Change and ALS data has allowed much greater accuracy to be obtained in defining coastal hazard risks along Eurobodalla Council's beaches.

The scope and objectives of this study include:

- review existing coastal hazard studies for comprehensiveness, adequacy and currency especially in light of Sea Level Rise and climate change;
- complete a gap analysis of coastal hazard analysis assessment studies and a Shire-wide Coastal Zone Management Plan;
- nominate and prioritise geographic locations for targeted studies and management responses;
- identify and prioritise data acquisition requirements for future studies;
- provide an Action Plan setting out a clear list of priorities, time frames and approximate budgets for the development of a comprehensive Coastal Zone Management Study and Plan;
- identify opportunities and initiatives to progress Eurobodalla's coastal management program; and
- provide a detailed methodology of selection criteria applied to identifying priority sites

2 REVIEW OF EXISTING STUDIES

As part of the scoping study, a review of the previous available reports and data has been undertaken. Details of the previous studies reviewed is provided below.

2.1 Batemans Bay Drainage Study – Willing and Partners, 1984

This drainage study focused on the commercial/industrial area south of Beach Road at Batemans Bay. This report concludes that retarding basins would be required but the location was to be determined.

Action – This report requires updating of results as it is more than 25 years old.

2.2 Batemans Bay Inundation Study – Willing and Partners, 1988

This report studies different scenarios of Batemans Bay CBD inundation and combination of rainfall and oceanic inundation to obtain a 1:100 AEP flood event. The worst case was determined for a 1:100 AEP oceanic level. The result of this 1:100 AEP flood event was mapped for Batemans Bay Soldiers Club. However, this calculation only takes still water level and not wave action into account.

Action – This report is limited by its age as it is more than 20 years old and additional studies have been undertaken since then.

2.3 Joes Creek Flood Study - Final Report – Willing and Partners, 1989

This report studies the flood behaviour of Joes Creek landward of Corrigans Beach. It provides flood levels for the 5, 20, 50 and 100 year ARI events at various profiles and cross-sections along Joes Creek with a summer solstice high water level of 0.94m AHD and oceanic water levels of 2.25 and 2.55m AHD.

Action – Report is old but water levels provided in this report appear to be reasonable.

2.4 Short Beach Creek Flood Study – Willing and Partners, 1989

This report documents a flood study of Short Beach Creek whose outlet is at the southern end of Casey Beach. Flood levels and peak flow estimates were provided for the 1:5, 1:20, 1:50 and 1:100 AEP flood events at several cross-sections along the creek. Flood levels were calculated using a high tide level of 0.94m AHD and a 100 year ARI still water level of 2.43m AHD. There could be a possible sand bar build up at Casey Beach blocking flow through Beach Road bridge but the risk is low. Mitigation options were assessed and compared. These mitigation options include:

- Construction of a single retarding basin upstream of Batehaven Bypass;
- Construction of two retarding basins including the previously mentioned and an additional one north of Valley Road;
- Bridge modification by increasing the span by 30 to 40m;
- Sunshine Bay Road culverts modification including:
  - Increase of the number of culverts;
  - Replacement of pipe culverts with reinforced concrete box culverts (RCBCs);
  - Provided RCBCs in conjunction with the existing culverts; and
  - Lower roadway level.

- Widening of channel downstream of Sunshine Bay Road (short term mitigation option); and
- Clearing of vegetation upstream of the road (short term mitigation option).

The preferred option consists of a combination of the two short term mitigation options and the replacement of the existing pipes by 3x2700x1200 RCBCs.

Action – Water levels and mitigation options are reasonable.

2.5 Reedy Creek Flood Study and Reedy Creek Flood Study: Additional Options – Willing and Partners, 1989 and 1990

This report documents a flood study of the whole Reedy Creek Catchment and provides flood levels for a 1:5, 1:20, 1:50 and 1:100 rainfall event for various urbanisation scenarios and for a 0.94m AHD high tide level and with a 2.60m AHD and a 2.80m AHD storm surge water levels. Cross-sections were provided at several locations along the creek. Management options, mitigation measures (e.g. culverts) and recommendations were provided. The additional option was the creation of retarding basins and the augmentation of George Bass Drive culverts. The latest option mitigates flooding but dwellings immediately upstream of George Bass Drive were still prone to flooding from floods smaller in magnitude than a 100 year ARI flood.

Action – Report is old but suggested oceanic levels and results appear to be reasonable.

2.6 Review Of Reedy Creek Levee, Malua Bay – Willing And Partners, 1991

This report supplements the previous Reedy Creek Flood Study (1989) and Reedy Creek Flood Study: Additional Options (1990). It studies the influence of the construction of a new levee to protect the houses located directly upstream of George Bass Drive from up to a 100 years ARI flood events. Several options were studied and a preferred option, being the construction of an extended levee, was selected.

Action – Complement results of the two previous studies of Reedy Creek.

2.7 Reed Swamp - Long Beach Flood Study – Willing and Partners, 1991

This report studies the flooding of Sandy Place due to Reed Swamp outflows at Long Beach for 100 year, 20 year and 5 year ARI flood events. The high water summer solstice level of 0.94m AHD was selected and a 100 year ARI still water level (50^{th} percentile) was estimated to be 2.48m. Flood levels were determined for existing and fully developed catchment conditions at several cross-sections between Reed Swamp and Batemans Bay. Mitigation measures were compared and recommendations were given to limit the flooding in this area.

Action – Results of this report are clear and appear to be reasonable and adequate.

2.8 Batemans Bay Vulnerability Study – Coastal and Riverine Management Directorate, 1996

The storm bite and beach recession due to different sea level rise scenarios (i.e. low, midrange and high) by 2050 were described for the different beaches of the Bay. Wave run-up and still water levels for a 50 year ARI event were given for different sea level rise scenarios (see Table 2.1). Sea level rise values were only given for the 2050 planning period but not for the 2100 planning period. Impacts of climate change on wave climate, wind, temperature and rainfall were described.

Photogrammetric analysis was carried out from aerial pictures dating from 1942 to 1993. Flood history between 1864 and 1995 was provided.

Hazard lines and erosion/accretion areas for different dates were mapped as well as a conceptual model of sand transport pathways.

Risk assessment and management options are given for each beach of Batemans Bay.

Action – Report should be completed with more recent data as the flood history stops in 1995 and the photogrammetry in 1993. In addition, the sea level rise should be studied for the 2100 planning period.

Table 2.1 – Design still water levels and run-up height within Batemans Bay (Coastal and Riverine Management Directorate, 1996)

Location	Survey Cross Section	SWL(m) for RI of 50 yrs	SWL+ SLR(low) (m)	SWL+ SLR(mid) (m)	SWL+ SLR (high) (m)	Wave Run-up (m)
1	Casey 1	2.7	2.8	2.9	3.1	1.8
2	Casey 2	2.6	2.7	2.8	3.0	4.6
3	Casey 3	2.6	2.7	2.8	3.0	2.0
4	Corrigan 2	2.5	2.6	2.7	2.9	4.0
5	Corrigan 3	2.5	2.6	2.7	2.9	0.9
6	Section C	2.3	2.4	2.5	2.7	1.6
7	Section B	2.6	2.7	2.8	3.0	1.1
8	Section A	2.7	2.8	2.9	3.1	1.1
9	Wharf Rd 4	2.6	2.7	2.8	3.0	1.8
10	Surfside 1	2.7	2.8	2.9	3.1	1.4
11	Surfside 2	2.7	2.8	2.9	3.1	1.0
12	Cullendulla 2	1.9	2.0	2.1	3.0	0.8
13	Long Beach 1	2.7	2.8	2.9	3.1	2.0
14	Long Beach 2	2.7	2.8	2.9	3.1	1.5
15	Long Beach 3	2.7	2.8	2.9	3.1	1.2
16	Maloneys Beach 1	2.9	3.0	3.1	3.3	2.0
17	Maloneys Beach 1	2.8	2.9	3.0	3.2	2.0

N.B.: Wave run-up heights are above the appropriate still water level.

2.9 Congo Creek Flood Study – Willing and Partners, 1997

This report studies the inundation of Congo Road. Four improvement options were assessed and compared. The conclusion of this report was to raise Congo Road where it crosses Congo Creek to the level of the existing cattle grid located 20 metres south of the existing bridge (i.e. 1.47m AHD). Cost estimates were also provided.

Action – Bridge at Congo Road described in the report has already been modified since publication of this report.

2.10 Drainage Report Wharf Road-Surfside – Eurobodalla Shire Council, 1997

This report documents the stormwater assets located between Wharf Road and Surfside. Methods to improve them were assessed and a cost estimate was provided. Flood events were modelled for high tide levels of RL1.1m and 100 year ARI ocean inundation of RL 2.7m. Design still water and wave run-up heights used in this study were the same as the ones used by the Coastal and Riverine Management Directorate in 1996 (Table 2.1). The proposed floor levels needed for each area was provided.

These levels were calculated with a sea level rise of 0.20m by 2050 which should be replaced by the value of 0.40m from the NSW Sea Level Rise Policy.

Action – Report to be updated to reflect current NSW Sea Level Rise Policy and the 2100 planning period should be developed.

2.11 Batemans Bay Waterway Infrastructure Strategy – WMA, 2002

This report describes the condition of the various waterway infrastructure (e.g. boat ramps, carparks, jetties, toilet blocks, wharves, etc.) along the bay and its estuary up to the town of Nelligen. It details constraints and opportunities and provides cost estimates and priority of possible development options.

Action – Results of this relatively recent report are comprehensively presented and adequate.

2.12 Batemans Bay Wharf Road Development - Soft Option Coastal Engineering Assessment – WMA, 2005

This report describes a sand transport model and the historical foreshore alignment evolution between 1898 and 1999. The high water mark adopted by Council was chosen from the 1964 most eroded shoreline (100% historical data line). It was assumed that buildings are unlikely to be flooded landward of it. Possible mitigation options were provided as well as wave assessment of erosion, coastal inundation (including setup levels and wave run-up) and sea level rise. Sea level rise value of 0.20m by 2050 and 0.50m by 2100 were selected which should be updated to the benchmarks from the NSW Sea Level Rise Policy (2009) being 0.40m by 2050 and 0.90m by 2100. It was found that run-up could approach 5m AHD. In addition, advice on the construction of three buildings on the low-lying beach area of Wharf Road was given.

Action – This relatively recent report is adequate but should be updated to reflect the new sea level rise values.

2.13 Addendum to Batemans Bay Wharf Road Development Soft Option - Coastal Engineering Assessment – WMA, 2005

This report consists of a review of the previous report *Batemans Bay Wharf Road Development - Soft Option Coastal Engineering Assessment (WMA, 2005a)* using a new 100% historical data line more landward than the previous one.

Action – Report complements and updates previous report.

2.14 Reedy Creek, Malua Bay Floodplain Risk Management Study And Plan – Peter Spurway And Associates, 2005

This flood study focuses on houses directly adjacent to and upstream of George Bass Drive along Reedy Creek. A Floodplain risk management study and plan were undertaken and flood mitigation options were provided with cost estimates and efficiency ratings. An inundation map was created showing that most developments located within the triangle formed by George Bass Drive, Sylvan Street and Reedy Creek are lying on flood prone land. Calculations were carried out for a 1:5, 1:20, 1:50 and 1:100 rainfall events and assuming a 0.94m AHD high tide level.

Action – This relatively recent report is comprehensively presented with inundation mapping.

2.15 Wagonga Inlet Flooding Investigation – Gary Blumberg and Associates/Patterson Britton and Partners, 2005

This report studies the inundation of Wagonga Inlet in Narooma. Bed sediments and salinity data were available within the entrance channel. History of the construction of the breakwater and training wall along the channel was provided. Design flood levels for a 1 in 20, 1 in 50 and 1 in 100 year ARI flood events were identified for the entrance, Narooma Public wharf, the Inlet Basin and Narooma Flat. The estuary was identified as being significantly impacted by oceanic influence in its flood behaviour. The 100 year ARI design flood levels were estimated to be 1.9m AHD at Wagonga Inlet entrance and Narooma Public Wharf and 2.2m AHD in the Inlet Basin, at McMillan/Brice Street Depression and the Oval.

Results are limited by limited available flood and tidal gauging data for Wagonga Inlet and the adjacent areas of Narooma Flat. The study highlighted a need for further peak water level gradients and channel scour data as well as flood records and topographic information.

Action – Additional flood, peak water level gradients, channel scour, topographic and tidal gauging measurement to be undertaken for Wagonga Inlet and Narooma Flat.

2.16 Flood Risk Assessment – URS, 2006

This report documents a flood analysis for the entire Council area of Eurobodalla Shire. It lists the floodprone areas within the Council boundaries. It reviews the past flood studies. Sea level rise recession of the sandy beaches was found to be ranging between 4.5 and 88 m by 2100. The impact of climate change on sea level rise, wind and rainfall was described. Floodplain risk management options were prioritised and preliminary cost estimates were provided. The report also provides a proposed program of flood studies, risk management studies and risk management plans over the eight years following the report.

Action – Report is recent and gives limited details but flood action plan is adequate.

2.17 Batemans Bay Coastline Hazard Management Plan – Webb, McKeown & Associates, 2006

This report documents management options for the whole Batemans Bay coastline from Maloneys Beach in the north to Casey Beach in the south. The conclusions were that the main issues are:

- coastal inundation in the inner bay (Batemans Bay CBD and Wharf Road);
- coastal inundation, beach recession and erosion at Surfside, Cullendulla and Long Beach;
- storm bite at Maloneys Beach; and
- wave overtopping inundation along the southern zone (i.e. Hanging Rock to Casey Beach) with additional erosion and recession issues at Corrigans Beach due to climate change.

Runup levels, erosion rates, beach recession rates, inundation level, wave setup, wave height and dune height were provided for the different beaches as shown in Table 2.2.

Detailed management options with cost estimates and impacts on various criteria (land ownership, aesthetics, ecology, recreational amenity, social issues, economic issues and climate change) were studied as well as the present value of likely future damage over the next 50 years.

A preferred option was selected for each beach.

This report is well detailed and precise. However, it has been realised using previous sea level rise benchmarks and should be updated using the new sea level rise value from the NSW Sea Level Rise Policy (2009).

The beach erosion rates quoted in this report are probably too low given the existence of refracted swell waves impacting the beach. These refracted swell waves are contributing to the erosion of Cullendulla Beach by generating an eastward longshore drift all along the beach, transporting the sand in front of the entrance of Cullendulla Creek where the sand moves offshore at the edge of the shallows visible on the aerial photographs. The 50 year beach recession rates are also relatively low except at Cullendulla where the rate is significant. However, the inundation levels appear to be reasonable.

Action – Report is recent. Inundation levels appear adequate but erosion rates should be confirmed as most values are relatively low.

2.18 Wharf Road Coastal Hazard Assessment And Hazard Management Plan – BMT WBM, 2009

This report provides an oceanic inundation level at Wharf Road. The risk of overtopping was detailed and the sedimentation processes assessed. It was found that 80% of the sand supplied from the river to the bay was accreting on Corrigans Beach at the expense of the beaches along the northern side. The historic shoreline behaviour analysis at Wharf Road was analysed and the estuarine processes within Batemans Bay were described. Percentage exceedance lines for the historical shoreline alignment were identified and storm tide levels including sea level rise were calculated. It was found that the Wharf Road East precinct will be impacted by non-storm tidal inundation by 2100. Short, medium and long term erosion was assessed. A recession of around 18m is expected with a sea level rise of 0.91m by 2100. The existing seawall at the corner of Wharf Road was found to be at high risk of failure due to erosion, overtopping and undersize armour. Some sewer and water supply pipes might also be at possible risk.

Coastal values and significance of the Clyde River estuary and Batemans Bay were described. Management options were assessed and ranked. Voluntary resumption was selected as the preferred option.

Action – Report is recent and comprehensively presented; its results appear to be adequate.

Table 2.2 – Summary of 1% AEP Coastal Hazard for Batemans Bay (WMA, 2006)

Area		Average Dune/Wall Height (mAHD)	Assessed 1% AEP Foreshore Setup (mAHD)	Theoretical Nearshore Wave Height (m)	Theoretical Wave Runup (m)	Estimated Overtopping Rate (m^3/s)	Adopted Beach Erosion Rate ($m^3/m/event$)	Adopted Beach Recession Rate (m/50 years)	Adopted Foreshore Inundation Level (mAHD)	Adopted Backshore Inundation Level (mAHD)
CBD		1.7 to 2.2	2.0	1.0	1.1	360	-	-	2.4	2.2
Beach Road	**(BH West)**	1.8 to 2.2	2.0	1.5	1.6	450	-	-	2.4	2.2
Wharf Road	**West** **East**	1.5 to 2.0 1.5	1.8 1.8	1.4 1.4	1.4 1.8	160 160	-	-	2.4 2.5	2.0 2.0
Surfside Beach	**West** **East**	2.5 3.0	2.8 2.8	1.5 1.5	1.4 1.0	100 -	25 40	5 5	<3.8 <3.8	2.3 2.3
Cullendulla Beach	**West** **Middle** **Creek**	1.5 to 2.0 1.5 to 2.0 -	2.0 2.0 2.0	1.5 - -	0.8 - -	250 - -	20 8 -	70 28 90	>2.2 >2.2 -	2.2 2.2 2.2
Long Beach	**West** **Middle** **East**	5.0 5.0 3.0 to 3.5	2.7 2.7 2.7	1.5 1.5 1.5	2.0 1.5 1.2	zero 5 15	20 35 10	8 8 8	- - >2.7	- 3.5 3.5
Maloneys Beach	**Middle**	6.0	2.9	1.6	2.1	-	9	12	<3.6	3.5
Hanging Rock	**(BH East)**	1.8 to 2.2	2.0	1.4	2.1	810	-	-	2.5	2.0
Corrigans Beach	**North** **South**	3.5 2.5	2.5 2.5	1.5 1.5	0.9 0.9 to 4.0	zero 400	- 40	6 6	- 2.6	- 2.5
Caseys Beach	**North** **South**	4.0 3.0	2.6 2.6	2.5 2.5	4.6 4.6	- 140	- -	- -	<5.0 <5.0	>2.5 >2.5

3 SITE OBSERVATIONS

3.1 Introduction

In addition to the assessment of coastal hazards by analysis of the available data and previous reports, site observations were made about the different beaches and characteristic places along Eurobodalla Shire Coastline. A site visit was conducted by SMEC's project team between 15 and 18 March 2010. Notes from that site visit are provided below.

3.2 South Durras

3.2.1 Durras Lake Entrance and Caravan Park (Northern Beach)

The dune of South Durras Beach near the lake entrance is healthy with a full dune and foredune and a good succession of vegetation (Figure 3.1). The access road is located behind the dune and is not at immediate risk. The beach is fully exposed to an open ocean wave climate. Offshore reef and Wasp Island provide some sheltering. There is no development present on the dune. Some evidence of an old scarp is noticeable within the dune area. The beach is composed of fine grained sand and has a relatively flat gradient. The beach accessways are uncontrolled and fencing should be considered to prevent damage to the dune from foot traffic. The southern end of the beach is very narrow and a creek outlet creates a gully. However nothing is at risk except a boat ramp covered with sand (Figure 3.2). There is some evidence of tyre tracks and the sandy part of the beach is used as a turning area. The flooding of the creek due to elevated tailwater level may impact a couple of low-lying houses.

The caravan park is located behind the dune and is at least three metres above the lake level. The flooding risk is therefore very low. Saltmarshes were observed between the low-lying houses located along Lakeside Drive and the lake entrance channel (Figure 3.3). This shows that this area is flooded regularly and the low-lying dwellings might become at risk from inundation in the future due to sea level rise.

3.2.2 Murramarang Resort (Southern Beach)

Some stormwater erosion was noticeable at the southern end of the beach north of the resort (Figure 3.4). The small ICOLL located behind this beach is currently closed and does not appear to generate a major immediate hazard but may generate some flooding issues for a couple of lots (but no dwellings) in case of breakthrough. In the long term, the hazards may be more significant due to an increased risk of breakthrough of the beach berm and an elevated tailwater level.

Some cabins of the resort are close to the edge of the beach and there is some evidence of minor erosion along beach (Figure 3.5). Another gully is visible at the southern end of the beach. There are only a few facilities for day visitors outside the caravan park. The beach is well-protected by reefs and Wasp Island and appears to be underlain by bedrock.

3.3 Maloneys Beach

The dune has been mown over and some trees appear to be poisoned and cut (Figure 3.6). The dune seems artificial given the very steep dune face. The wave climate is low and the beach well-protected. The reef at the eastern end is very exposed at low tide. Some housing and Northcove Beach Road/Maloneys Drive are located behind the dune. A toilet block and a small car park are located further back from the beach. It is suggested that the dune be replanted, fenced off and some formal access should be provided.

There generally is a low immediate risk for the properties at Maloneys Beach. However, the road and around five dwellings located around 30-40m away from the dune might be subject to future risk at the western end of the beach as a consequence of beach recession due to sea level rise (Figure 3.7). The loss of the road may cut the access to the town. This part of the beach is a little more exposed to waves than the eastern half but a reef protects the bay from the largest swell.

There is a small creek entrance at the western end of the beach that may generate flooding issues for one house located along the creek near the entrance. Some houses may be subject to geotechnical (slope stability) hazard along the headland west of the beach as the rock is very erodible (soft siltstone).

3.4 Long Beach

The dune is very low at the eastern end of the beach with the road and housing behind it (Figure 3.8). The beach is very narrow at high tide. The embankment on the eastern side is very steep and some erosion is undercutting the slope (Figure 3.9). There is a stormwater outlet at the end of Fauna Avenue with buried rock seawall along either end but the full extent of the seawall – possibly all along Fauna Avenue – is unknown (Figure 3.10). An erosion scarp was observed at the western end of Bay Road.

The dune increases in height at the western end as does the wave climate (perhaps 50% of the full ocean wave energy). The new estate located behind the main dune heavily invaded by lawn grass is not at immediate risk (Figure 3.11). Rabbits were observed during the site visit which may be damaging the dune vegetation.

Between Long Beach and Maloneys Beach, the rock is composed of soft siltstone and several houses are located directly on the edge of the cliff (Figure 3.12). The wave climate there is low. Some malodorous sludge was seen to be leaking through the groundwater onto a small beach below the cliff (Figure 3.13).

Breaching of the lagoon located behind the centre section of the beach does not appear to be an immediate issue or an issue by 2100.

3.5 Cullendulla Beach

Cullendulla Beach is actively eroding with some trees falling due to undercutting by waves (Figure 3.14). However, there is no development behind this beach and no infrastructure is at risk. A future development is at the planning stage between Cullendulla and Surfside Beach.

3.6 Surfside

3.6.1 Eastern End (Surfside Beach)

Houses at the eastern end of the beach are low-lying and very close to the dune and a scarp is visible on the dune (Figure 3.15). The beach is exposed to some swell energy and a storm water pipe has already been lost (Figure 3.16).

3.6.2 Western End (McLeod Street and Timbara Crescent)

Wave energy at this location is relatively high. Most houses at the western end of Surfside are low-lying (Figure 3.17). An active erosion scarp of 50-60cm is visible in front of some beach houses of Timbara Crescent and along McLeod Street. The latter is very close to the beach. Both houses and road are at threat of inundation and erosion. The pipes under McLeod Street bridge are covered with sand (Figure 3.18). The creek on the landward side of the bridge appears to suffer from poor water quality.

3.7 North Batemans Bay (Wharf Road)

The beach is actively eroding with a visible scarp and exposed vegetation (Figure 3.19). There is a seawall protecting the road and Easts Riverside Holiday Park (Figure 3.20) and a small groyne has been illegally built at the eastern end. Some properties are very low lying. Wave exposure through Batemans Bay is high and there is a direct impact of offshore swell, particularly at high tide.

3.8 Batemans Bay CBD and Boat Harbour

The seawall all along the harbour (from Batemans Bay CBD to Hanging Rock) is in fairly good condition (Figure 3.21). CBD shops located along the water have elevated floor levels. Houses inside the marina near Hanging Rock are very low and protected by different types of seawalls in varying condition. Some housing has no protection (Figure 3.22). A lot of sand is present within the marina. Hanging Rock boat ramp is in good condition (Figure 3.23). The area is protected from waves with waves breaking on offshore shoals (Figure 3.24).

3.9 Corrigans Beach

The northern end is more exposed to wave climate than the southern end which is protected by reefs. The dune is steeper and in poor condition at the northern end. There are many weeds and no formal access (Figure 3.25). However, there is a significant buffer to development. Joes Creek coming out within the northern half of the beach is relatively high and may create inundation issues in the future.

At the southern end, it was observed that only around 20% of the swell wave energy is reaching the beach. The creek leading to the beach is polluted with an incised morphology (Figure 3.26). A Gross Pollutant Trap within the creek (GPT) is blocked by sediments and rubbish (Figure 3.27). The caravan park is very close to both the beach and the creek. Hence it may be at risk from inundation. The beach has a flat gradient. However there would be enough buffer to build a new vegetated dune to protect the caravan park currently at immediate inundation risk.

Around 3-4 houses are on a bluff facing Corrigans Beach which is possibly unstable (Figure 3.28).

3.10 Casey Beach

There is an unstable cliff at the lookout facing Casey Beach with some trees close to fallling (Figure 3.29 and 3.30). There could be possible housing at risk from slope stability hazards at the top of the headland. The northern half of Casey Beach is influenced by strong wave climate while the southern end is more protected by Tollgate Islands and offshore reefs – around 30% of ocean wave climate.

The beach is protected by a seawall which appeas to not be underlain by geotextile. This seawall protects the road and housing located along the beach. The northern end of the seawall is very steep and both the northern and southern ends are subject to erosion at the top of the seawall (Figure 3.31). The seawall has already been severely damaged during storm events and fixed in the past. The beach has been lost at high tide in front of the seawall.

The bridge over Short Beach Creek is protected by rocks around its abutments (Figure 3.32). This rock protection is in fair condition. The access onto the beach is limited over the seawall. Some trees are undermined where there is a gap in seawall protection directly south of Short Beach Creek mouth, probably due to edge effects of the seawall (Figure 3.33). The sewage pumping station is at risk of damage due to wave attack.

At the southern end of the beach, several houses are at the top of the obviously eroding bluff with large areas of erosion at the base of the cliff (Figure 3.34).

3.11 Sunshine Bay

There is a low wave climate due to the presence of extensive rock reef all along the bay. Housing is on the edge of the bluff at the northern end of the beach. There is no natural dune and some noticeable erosion was observed along the beachfront and the car park (Figure 3.35). Beach sand is coarse with grain size larger than 1mm. The dune has a very steep gradient and is backed by housing close to the beach but these buildings seem founded on hard clay (Figure 3.36). A low-lying timber shack protected by a poor quality timber wall is located at the southern end of the beach and is at immediate risk (Figure 3.37).

3.12 Denhams Beach

Around 40% of the open wave climate reaches the beach due to the presence of offshore reefs and islands. The only potential issue is housing on the southern headland being at long term risk of bluff erosion (Figure 3.38). There is no natural dune and nothing is at risk on the beach.

3.13 Surf Beach

3.13.1 Surf Beach

This pocket beach is subject to moderate wave climate (around 50% of open wave climate). There is some housing on eroding bluffs on both ends. Housing at the top of the bluff is at a certain distance from the edge and might only be subject to long term risk due to bluff erosion. The dune is in good condition, fenced and has formal accessways (Figure 3.39). Two buildings (possible pumping station and toilet amenities) on the beachfront at the northern end of the beach would be at possible long term risk. There is a small creek entrance at the southern end of the beach. Sewer lines are located very close to the beach and may eventually be at risk.

3.13.2 Wimbie Beach

This small pocket beach directly south of Surf Beach is well-protected (around 20% of open wave climate). One house near the creek entrance located behind the beach might be subject to future inundation issues. As along Surf Beach, some sewer lines are located very close to the beachfront and may be at risk.

3.14 Lilli Pilli

3.14.1 Circuit Beach (Northern Beach)

This pocket beach is subject to a low-moderate wave climate. The only developments are located a substantial distance from the shoreline. A small creek comes out within the bay and creates a gully. The road is close to the cliff edge but nothing is at immediate risk.

3.14.2 Lilli Pilli Beach (Southern Beach)

This small pocket beach is surrounded by bluffs and subject to low wave climate due to the presence of rock reefs. Some developments exist but are a long way back from the beach.

3.15 Malua Bay and McKenzie Beach

3.15.1 Mosquito Bay

This narrow bay is subject to slope stability issues with housing close to cliff edge on both sides. Some evidence of movement is already evident along Iluka Avenue (Figure 3.40). A boat ramp is present within the bay. A small creek comes out in the middle of the bay.

3.15.2 Garden Bay

Some housing is close to the edge along the southern side but is probably founded on rock. Some evidence of light erosion is noticeable along the beach (Figure 3.41). A small creek comes out in the middle of the small beach. Wave climate is low due to the orientation of the beach and the presence of numerous reefs.

3.15.3 Malua Beach

Houses and shops at the northern end of the beach seem high enough to be safe from immediate coastal hazards (Figure 3.42). The beach is subject to moderate wave climate (around 80% of open wave climate). Some houses at the southern end are close to the beach with one house in particular on the berm (Figure 3.43). The seaward houses might be at immediate risk while the ones further inland might be at future risk. Good grass area and amenities (toilets, BBQ and picnic areas) are provided at the back of the beach. There is no natural dune and the gradient is very low. The low dune could be built up to protect the surf club and houses at the back of the beach.

3.15.4 McKenzie Beach

No issues were observed as there is no development on the beach and the road is far back and high enough compared to the beach, not to be impacted by wave impact.

3.16 Rosedale

The beach is subject to moderate wave climate (around 60% of open wave climate). There is a lot of sand on the beach forming a large healthy dune. Some boatsheds are on the beach at the northern end of the beach and some low-lying log cabins are at the southern end (Figure 3.44 and 3.45). Some housing is located on bluffs on both sides of the beach but the risk is low.

3.17 Guerilla Bay and Burrewarra Point

Nothing is at coastal risk at Guerilla Bay and Burrewarra Point. Northern end of Guerilla Bay Beach is considered a National Heritage Area.

3.18 Tomakin and Barlings Beach

The existing caravan park located at the eastern end of the beach is located at a fair distance back from the beach.

A new estate is under construction landward of the beach. The dune along the beach is healthy but marked by a high scarp of around one metre observed at the top of the dune (Figure 3.46). The beach has a relatively open wave climate (around 80% of open wave climate) especially towards southerly waves.

Developers of the new estate are preparing a separate Coastal Hazard Study as part of the Part 3A Assessment for the site.

3.19 Mossy Point and Tomaga River entrance

There is a high risk of breakthrough of the dune into the estuary where the dune arm is very narrow (Figure 3.47). The risk will be exacerbated by sea level rise. The breakthrough of the Tomaga River could change the beach morphology and some housing could become at risk upstream of the new entrance formed midway along the beach. The wave climate at Tomakin Beach is relatively strong (around 60% of open wave climate) and a high scarp of a recent storm (possibly the 2007 storm) was observed along most of the beach and particularly near the Tomaga River entrance (Figure 3.48).

At Mossy Point, several houses, private jetties and boatsheds along Tomaga River near the river entrance are low-lying and could be subject to future flooding (Figure 3.49). This flooding risk might be increased in case of breakthrough of the river where the dune arm is very narrow.

3.20 Broulee and Broulee Island

3.20.1 Broulee Beach (North Broulee)

Some houses along Candlagan Creek are low-lying near the entrance and are close to the shoreline. Some more houses at the northern end are relatively low but seem to be founded on rock (Figure 3.50). Wave climate at Broulee is around 80% of an open wave climate. The dune is in good condition and there appears to be a good buffer between the beachfront and development. The road could be at risk after 100 years.

3.20.2 Broulee Island

The tombolo linking Broulee Island to the coast is relatively narrow and there is a risk of breakthrough across the spit which has occurred in the 1970s. Moreover, there is a 4-wheel drive informal access flattening the dune at the narrowest area (Figure 3.51). There is no development directly at risk but the breakthrough might change the dynamics and the morphology of the whole area and lead to loss of snorkelling areas. Therefore, it is advised to close the informal 4-wheel drive access, or to at least regulate it by installing a formal vehicular board and chain access.

3.20.3 Bengello (South Broulee)

Some developments are present at the northern end of the beach, the rest of the beach remaining mainly natural (Figure 3.52). Broulee SLSC is far back from the beach and the only infrastructure at risk is the road and carpark located along the base of the northern headland. The dune is in good condition and the beach is fully exposed to wave climate.

3.21 Moruya

3.21.1 Moruya Airport

The wide natural dune along Moruya Airport is in good condition (Figure 3.53). The northern end of the airport grounds might be at possible risk in the long-term given the orientation of the runway. There is a camping area directly south of the airport. Moruya River entrance is formed of numerous extensive breakwaters.

3.21.2 Moruya River

George Bass Drive is very low with some low-lying houses along the river. Some saltmarshes and mangroves were observed in significant low-lying lands on both sides of the road. Both embankments of the river are mostly protected by seawalls but some erosion was visible at the time of the site visit along George Bass Drive at some locations with some trees falling into the river (Figure 3.54). There is some sand deposition in the middle of the river upstream of Princes Highway Bridge, exposed at low tide (Figure 3.55).

3.21.3 Moruya Heads

Moruya Heads Beach is fully exposed to wave climate. The wide dune there appears to be accreting and the SLSC and toilet blocks are far back. The beach is currently recovering from summer storms.

3.22 Congo

Some low-lying houses are located at the northern end of the town along Congo Creek. The dune at Congo Beach is in good condition and high so there would not be any erosion issues despite the open wave climate (Figure 3.56). Flooding of access into town can occur which could isolate the town in case of a significant storm. Moreover, access roads on both sides to the town are unsealed and the unsealed section of the northern access to the town is private.

3.23 Meringo

Developments at Meringo are located at the top of bluffs with a fair distance from the edge and there is therefore no coastal hazard in this area.

3.24 Tuross Head

The whole coastline along Tuross Head is subject to open wave climate and is formed of small pocket beaches.

3.24.1 Coila Lake

Some 3-4 low-lying houses are located along Coila Lake on Monash Avenue (part of the road west of the golf club). Some stormwater issues were observed next to Coila Lake entrance along Tuross Boulevard due to the February 2010 flood event (Figure 3.57). The lake entrance is natural and composed of a high sand berm and the lake opens at the southern end (Figure 3.58).

3.24.2 Tuross Beaches

Houses along Tuross Head coastline are relatively high and the coastline is composed of natural rocks. Several pocket beaches are present along Tuross Head. The beach located between Tarandore Point and Boogumgoridge Point is composed of a large dune with a remnant scarp of around one metre resulting from the 2007 storm event (Figure 3.59). No development is at risk in this area. Some erosion is visible in front of a carpark behind One Tree Beach south (Figure 3.60).

3.24.3 Tuross Beach Holiday Park

Tuross Beach Holiday Park is located north of Tuross Lake entrance. It is directly exposed to southerly swells through the lake entrance and the timber cabins are very close to the embankment which appears to be fill material. A seawall with geotextile appears recently built in front of the caravan park (Figure 3.61). There are creeks on either end of the caravan park. The dune south of the caravan park seawall is eroding. Recent culverts have been installed (Figure 3.62).

3.24.4 Tuross Lake

Many shoals are present within Tuross Lake. The berm at the entrance is very low and the entrance is very dynamic (Figure 3.63). Tuross Lakeside Holiday Park at the northern end of the lake and Hector McWilliams Drive at the level of the holiday park are very low-lying and could be subject to flooding. Likewise, some shops at the south-western tip of Tuross Head have a low elevation.

3.25 Potato Point

Beachcomber Holiday Park access is over a small bridge directly north of Potato Point and along a road located directly behind the dune. The access could therefore be at risk of inundation and erosion. The dune of the beach north of Potato Point is high and in good condition. Most developments at Potato Point are at the top of a cliff and have some buffer (Figure 3.64). Possible inundation can occur at some locations near ICOLLs – i.e. at Borang and Riverview Streets – as well as flooding of the access road from Princes Highway.

3.26 Dalmeny

Some low-lying areas around Mummuga Lake could be subject to flooding (e.g. along Myuna Street and along Mort Avenue near the tennis courts. Cliff top areas are sufficiently back from the edge and the risk is low (e.g. Ocean Parade). Duck Pond at Ocean Drive is coming out on Yabbarra Beach where storm erosion is visible but no development is at risk (Figure 3.65). Duck Pond is subject to inundation and there is only a very small culvert under Ocean Drive (Figure 3.66). Duck Pond might be subject to water quality issues and the road could be flooded. However, most houses seem high enough not to be impacted by flooding (Figure 3.67).

3.27 Kianga

Parts of Ocean/Dalmeny Drive located between Dalmeny and Kianga are very low elevated and the dune is also very low (Figure 3.68). A high risk of flooding of the road is expected. Loss of Dalmeny Drive at Kianga Lake entrance occurred in the 1970s. The road and bridge are low lying and could be subject to inundation and erosion issues. The beach appears to be suffering from low sand supply as there is no fully developed dune.

Kianga village homes are quite high and built on hard ground. At the southern end of Kianga, low lying cycleways are present along Dalmeny Drive. Williamson Drive is also very low and could be subject to flooding.

3.28 Narooma and Islandview Beach Resort

3.28.1 Narooma

There is a risk of inundation at Narooma Flats as this area is very low. Likewise, Williamson Drive and Centenary Drive are also very low. Small breakwaters within the entrance are overtopped by tidal flow due to a tidal lag and a head difference of around 0.5m between both sides of the breakwater.

The Surf Club at Narooma Beach seems far back but there is not much dune in front of it (Figure 3.69). Little Lake could easily break through given the low-lying berm at the entrance in front of the SLSC (Figure 3.70). The northern end of Narooma Beach is an old quarry and the beach is still being influenced by this change of morphology of the coast. Some cabins are close to the edge of the cliff near Narooma SLSC (Figure 3.71). The cemetery facing the SLSC is also near the cliff top.

3.28.2 Islandview Beach Resort

The beach along the resort is almost fully exposed to offshore swell (around 80% of open wave climate). An old scarp was visible on the dune. The beach may be subject to long-term recession. There are offshore rocks and some nearshore rocks act as a natural groyne at the northern end of the beach (Figure 3.72). Access to the beach is currently flattening a part of the dune and this access could be improved to avoid wave inundation and overtopping of the dune.

There is a fair buffer between the resort and the shoreline and the erosion risk is low. However, the caravan park has a low area alongside Nangudga Lake entrance which could be subject to inundation issues.

3.29 Mystery Bay

A small camping area is located close to the shoreline at the northern end of Mystery Bay but there is nothing at risk at this location. Mystery Bay Road is low-lying around the intersection with Lamont Young Drive. Mystery Bay Road is at geotechnical slope stability risk near the intersection with Negus Drive as the cliff is eroding and the road is very close to the edge (Figure 3.73).

The beach at Mystery Bay does not have much dune and is underlain by bedrock. It is protected from offshore swell by reefs and is subject to around 50% of open wave climate.

The southern end of Mystery Bay Road could be subject to inundation and erosion as it is very low lying (Figure 3.74). Some trees are falling down the slope at the back of the road.

3.30 Akolele and Wallaga Lake

There is only one road at low level near Wallaga Lake and one property near Merriwinga Creek. However, this property seems high enough not to be impacted by inundation from Wallaga Lake.

4 COASTAL HAZARDS

4.1 Introduction

Hazards in this context are restricted to the operation of physical processes in the coastal landscape. They include:

- Erosion of beaches and dunes – The impact of coastal erosion can be on infrastructure, recreational facilities, residences, ecological communities/habitat or cultural heritage values, with indirect impact on local economic values;
- Stability of existing coastal protection structures – whether existing seawalls and other coastal protection structures are providing sufficient erosion protection for the coastline or whether they need reconstruction to current engineering standards;
- Inundation of coastal land by raised sea levels – Sea level may be raised in the short term by storm surge, storm wave set-up and wave run-up (resulting in overtopping of low lying barriers) which, in the longer term, may be exacerbated by a climate change induced sea level rise;
- Landslip on coastal bluffs and headlands (both in rock and unconsolidated sediments) – Landslip may create public safety hazards, threaten infrastructure and may also reduce foundation capacity (e.g. behind a slumped dune erosion escarpment).
- Estuary entrance stability – Where coastal lakes and river estuaries enter the ocean shoreline or foreshore fluctuations can be intensified (this may be an issue at many of the ICOLL and river entrances).
- Stormwater erosion creating incised morphology across beaches and dunes.
- Aeolian (wind blown) sand transport can comprise a coastal hazard by inundating property and inducing coastal recession.

The principal hazards induced by the coastal processes that are relevant for a coastal engineering study of the Eurobodalla LGA coastline include:

- short-term beach fluctuations including coastal erosion that may result from severe storms or the behaviour of estuary entrances, and slope instability;
- long term coastline recession including that resulting from any imbalance in the sediment budget of a coastal compartment, such as may be caused by aeolian sand transport, changes in wave climate induced by anthropogenic sources, beach rotation in response to decadal climate oscillations and shoreline response to a rising sea level induced by climate change; and
- oceanic inundation of low lying areas.

Further coastal hazards to be considered that may be relevant for the study area include:

- sand drift;
- beach rotation with change in net wave direction;
- stormwater erosion;
- geotechnical stability of cliffs and bluffs.

4.2 Short Term Coastal Erosion

4.2.1 Storm Erosion / Dune Stability Schema

A generalised dune stability schema relating from storm erosion is presented schematically in Figure 4.1. The following four stability zones (*Zone of Wave Impact*, *Zone of Slope Adjustment*, *Zone of Reduced Foundation Capacity* and *Stable Foundation Zone*) have been delineated as follows (after Nielsen *et al*., 1992):

- The *Zone of Wave Impact* delineates an area where any structure or its foundations would suffer wave attack during a severe storm. It is that part of the beach that is seaward of the dune erosion escarpment.
- A *Zone of Slope Adjustment* encompasses that portion of the seaward face of the dune that would slump to the natural angle of repose of the dune sand following removal by wave erosion of the *Design Storm Erosion Demand*. That presents the steepest stable dune profile under the conditions specified.
- A *Zone of Reduced Foundation Capacity* for building foundations was delineated to take account of the reduced bearing capacity of the sand adjacent to the dune erosion escarpment. It was considered that structural loads should be transmitted only to soil foundations outside the zone within which the *Factor of Safety* was less than 1.5 during extreme scour conditions at the face of the dune. This allows for the design assumption that the soil may develop its full bearing capacity.
- The *Stable Foundation Zone* is that portion of the dune that is unaffected by the wave erosion processes and within which no special foundation requirements need to be made.

To determine the impact of storm erosion on a homogeneous sand dune, the *design storm erosion demand* is subtracted from the available sand storage on the beach. The slumped storm erosion profile is idealised as comprising a steep dune escarpment at a slope (i) equal to the natural angle of repose of dune sand (φ) to the top of the swash zone at low tide, taken to be RL 2 m (approximately on AHD), then a steep nearshore beach face of slope 1:10 down to RL 0 m (AHD − the datum for the reference volume calculations; see Figure 4.2). A flatter slope (α) extending landward from the limit of beach scour and incorporating a Factor of Safety of 1.5 ($\tan\alpha = \tan\varphi/1.5$) defines the limit of the *Zone of Reduced Foundation Capacity* beyond which surface footings can be used safely.

For the assessment of slope stability of eroded dunes, a value of 34° has been adopted for the angle of internal friction for dune sands.

4.2.2 Storm Cut

A beach typically comprises unconsolidated sands that can be mobilised under certain meteorological conditions. The dynamic nature of beaches is witnessed often during storms when waves remove the sand from the beach face and the beach berm and transport it, by a combination of longshore and rip currents, beyond the breaker zone where it is deposited in the deeper waters as sand bars (Figure 4.3). During severe storms, comprising long durations of severe wave conditions, the erosion continues into the frontal dune, which is attacked, and a steep erosion escarpment is formed. This erosion process usually takes place over several days to a few weeks. Within Eurobodalla Shire Council, most beaches are separated by rocky headlands, forming discrete beach compartments which are largely self-contained. Several pocket beaches are present in the study area. These beaches are often well protected by the adjacent headlands and offshore reefs.

The amount of sand eroded from the beach during a severe storm will depend on many factors including the state of the beach when the storm begins, the storm intensity (wave height, period and duration), direction of wave approach, the tide levels during the storm and the occurrence of rips. Storm cut is the volume of beach sand that can be eroded from the subaerial (visible) part of the beach and dunes during a *design* storm. Usually, it has been defined as the volume of eroded sand as measured above mean sea level (~ 0 m AHD datum). For a particular beach, the storm cut (or storm erosion demand) may be quantified empirically with data obtained from available photogrammetric surveys, or it may be quantified analytically using a verified numerical model. Photogrammetric surveys are the best data available for the estimation of the past erosion but regular ALS survey would be much more accurate for future studies.

Photogrammetric data were only available for a few locations and given the limited data the determination of an accurate stormbite was not always possible. Estimated storm cut for the different locations as well as the associated storm and the date of the photogrammetric profiles that have been compared to determine the storm cut, are given in Table 4.1. Table 4.2 shows an estimation of the beach exposure to the ocean wave climate along with an estimated range for storm cut based on the wave climate. The results presented in this table are indicative only as the storm bite cannot be approximated as directly proportional to the local wave height and depends on numerous factors. This method was selected due to the lack of data that would allow more accurate results.

Table 4.1 – Storm cut determined from the available photogrammetric data

Location	Storm cut (m^3/m)	Storm(s) associated with the storm cut	Date of the compared photogrammetric profiles	Estimated wave climate (% of open coast)	Storm cut from past studies (m^3/m)
Barlings Beach	170	May-June 1974	1972 and 1975	80	N/A
Surfside Beach	60	May-June 1974 and May 1978	1972 and 1990*	40	25-40** (WMA, 2006)
Cullendulla Beach	40	May-June 1974 and May 1978	1972 and 1977	20	8-20** (WMA, 2006)
Long Beach (Western Half)	120	May-June 1974 and May 1978	1972 and 1990*	50	20-35** (WMA, 2006)
Long Beach (Eastern Half)	70	May-June 1974 and May 1978	1972 and 1990*	40	10-35** (WMA, 2006)
Maloneys Beach	45	May-June 1974 and May 1978	1972 and 1990*	30	9** (WMA, 2006)
Moruya Beach	210	September 1967 and May-June 1974	1962 and 1975	100	N/A

**the storm cut might be inaccurate given the long period separating the two photogrammetric dates. However, the results appear reasonable with open-coast beaches as Barlings and Moruya Beaches having a significant stormcut and the beaches protected within Batemans Bay having low storm cut.*

***values calculated by WMA (2006) are much lower than the ones calculated within this report. This may be due to the use of a different calculation method. However, it can be seen that Maloneys and Cullendulla Beaches have a lower storm cut than Long and Surfside Beaches.*

Table 4.2 – Estimated range for storm cut determined from observed wave climate estimate

Location	Estimated wave climate (% of open coast)	Estimated Range for Storm Bite (m^3/m)
South Durras Beach	100	200-250
Murramarang Resort	30	40-90
Maloneys Beach	30	40-90
Long Beach (Eastern Half)	40	60-110
Long Beach (Western Half)	50	80-130
Cullendulla Beach	20	20-70
Surfside Beach	40	60-110
Corrigans Beach (Northern Half)	40	60-110
Corrigans Beach (Southern Half)	20	20-70
Casey Beach (Northern Half)	50	80-130
Casey Beach (Southern Half)	30	40-90
Sunshine Bay	20	20-70
Denhams Beach	40	60-110
Surf Beach	50	80-130
Wimbie Beach	20	20-70
Lilli Pilli (Northern Pocket Beach)	40	60-110
Lilli Pilli (Southern Pocket Beach)	40	60-110
Mosquito Bay	20	20-70
Garden Bay	10	0-50
Malua Beach	60	100-150
McKenzie Beach	60	100-150
Rosedale Beach	60	100-150
Guerilla Bay	40	60-110
Barlings Beach	80	150-200
Tomakin Beach	30	40-90

Location	Estimated wave climate (% of open coast)	Estimated Range for Storm Bite (m^3/m)
Tomaga River Entrance	60	100-150
Broulee Beach (Northern Beach)	80	150-200
Broulee Beach (Southern Beach)	100	200-250
Moruya Beach	100	200-250
Congo Beach	100	200-250
Coila Lake Entrance	100	200-250
Tuross Head Beaches	70	130-180
Tuross Lake Entrance	100	200-250
Beachcomber Holiday Park	80	150-200
Potato Point (Northern Beach)	80	150-200
Potato Point (Southern Beach)	90	170-220
Yabbarra Beach (at Duck Pond)	90	170-220
Dalmeny to Kianga	90	170-220
North of Wagonga Inlet Entrance	100	200-250
Narooma Beach	80	150-200
Islandview Beach Resort	80	150-200
Mystery Bay	50	80-130

4.2.3 Slope Instability

Following storm cut the dune face dries out and may slump. This results from the dune sediments losing their apparent cohesive properties that comes from the negative pore pressures induced by the water in the soil mass. This subsequent slumping of the dune face causes further dune recession.

Dune slumping is treated as a slope instability hazard and can be quantified with stability computations, which can serve as a guide to determining safe setback distances on frontal dunes that are prone to wave attack and slumping during storms.

4.2.4 Coastal Geotechnical Hazard

Bluffs directly impacted by wave action can suffer from coastal erosion. The base of the cliff can be undermined making the whole bluff unstable and subject to immediate hazard. Properties located at the top of the cliff can therefore be at risk. The different areas and estimated number of properties along Eurobodalla Shire Council subject to this issue in the short, medium or long term are listed below:

- Between Long Beach and Maloneys Beach: 5-10 properties
- Corrigans Beach: 3-4 properties at the southern end
- Casey Beach: one property at the northern end and 3-4 at the southern end
- Sunshine Bay: 1-2 properties at the northern end
- Denhams Beach: 5-6 dwellings along Beach Road north of the intersection with Barbara Crescent, around nine properties along Barbara Crescent and one property south of the beach
- Surf Beach: 2-3 properties
- Mosquito Bay: around 3 properties on the northern side and 3-4 properties on the southern side
- Mystery Bay: Mystery Bay Road at risk at the intersection with Negus Drive

4.2.5 Behaviour Of Estuary Entrances

Various coastal hazards can be created by both trained and natural estuary entrances. Several estuary entrances are located within the study area. These entrances are:

- Durras Lake entrance at South Durras
- Creek at the southern end of South Durras Northern Beach
- Small ICOLL behind South Durras Southern Beach
- Creek west of Maloneys Beach
- Surfside Creek west of Surfside
- Cullendulla Creek east of Cullendulla Beach
- Clyde River at Batemans Bay
- Joes Creek at Corrigans Beach
- Short Beach Creek at Casey Beach
- Creek behind Surf Beach
- Small creek at Wimbie Beach
- Reedy Creek at Malua Beach
- Creek north of Rosedale Beach
- Tomaga River between Mossy Point and Tomakin
- Candlagan Creek at the northern end of Broulee Beach
- Moruya River at Moruya
- Congo Creek at Congo
- Coila Lake north of Tuross Head
- Tuross Lake south of Tuross Head
- Mummuga Lake north of Dalmeny
- Duck Pond south of Dalmeny
- Kianga Lake at Kianga
- Wagonga Inlet and Little Lake at Narooma
- Nangudga Lake behind Island view Resort
- Wallaga Lake at Akolele

Most entrances are relatively natural while some of them are trained or influenced by anthropogenic factors. Wagonga Inlet is a very complex trained entrance with two very large breakwaters on the ocean side and several small breakwaters training the first seaward kilometre of the river. Moruya River entrance is also trained by a massive breakwater on the northern side. Landward of this large seawall is a complex layout of several small breakwaters and another small breakwater trains the river over around 1.5km from the ocean.

Duck Pond, Kianga Lake, Candlagan Creek and Short Beach Creek's inlet pass under roads or bridges which constrict the entrance. These constrictions may cause some issues in case of significant flow. The same issue is present at the entrance of the creek of Surfside, Maloneys and South Durras.

Several lakes and creeks have a management policy with opening triggers when water levels reach a certain height:

- Tuross Lake has a 2m trigger value or a 0.8m for 14 days due to the low-lying shops located along the lake shoreline (BMT WBM, 2010)
- Coila Lake has a 2m trigger value or 1.80m for more than 3 months (BMT WBM, 2010)
- Kianga Lake has a 2m trigger value or 1.80m for 14 days (BMT WBM, 2010)
- Little Lake has a 2.2m trigger value (BMT WBM, 2010)
- Nangudga Lake has a 1.3m trigger value (BMT WBM, 2010)
- Joes Creek has a 1.4m trigger value or a value between 1.2 and 1.4m with heavy rain predicted in the catchment (WBM, 2004)
- Wimbie Creek has a 2.0m trigger value or a value between 1.8 and 2.0m with heavy rain predicted in the catchment (WBM, 2004)
- Short Beach Creek has a 1.3m trigger value or a value between 1.0 and 1.3m with heavy rain predicted in the catchment (WBM, 2004)
- Surfside should be excavated immediately prior to when the water level in Surfside Creek reaches the top (i.e. obvert) of the culverts (at approximately 1.5 m). (WBM, 2004)

Another entrance issue is found in Tomaga River where the sand arm separating the river from the ocean is very narrow and could be subject to breakthrough which would change the morphodynamics of the area. The dune has therefore been fenced to help prevent this from occurring. The ICOLL located behind South Durras Beach may open in the long term which may generate flooding issue due to increased sea level rise.

4.3 Longer Term Beach Changes And Shoreline Recession

Following storms, ocean swell replaces the sand from the offshore bars onto the beach face where onshore winds move it back onto the frontal dune. This beach building phase, typically, may span many months to several years. Following the build-up of the beach berm and the incipient foredunes, and the re-growth of the sand trapping grasses, it can appear that the beach has fully recovered and beach erosion has been offset by beach building (Figure 4.4).

However, in some instances, not all of the sand removed from the berm and dunes is replaced during the beach building phase. Sand can be lost to sinks, resulting in longer term ongoing recession of the shoreline. Further, over decadal time scales, changes in wave climate can result in beach rotation.

4.3.1 Sediment Budget Deficit

Once the sand has been transported offshore into the surf zone, it may be moved alongshore under the action of the waves and currents and out of the beach compartment. Some of the sand that is transported directly offshore during storms may become trapped in offshore reefs, thereby preventing its return to the beach. Other direct losses of material from the beach may include the inland transport of sand under the action of onshore winds; this mechanism being called aeolian sand transport. Over the longer term, should the amount of sand taken out of the compartment by alongshore processes exceed that moved into the compartment from adjacent beaches or other sources, then there will be a direct and permanent loss of material from the beach and a deficit in the sediment budget for the beach (Figure 4.5). This will result in an increasing potential for dune erosion during storms and long term beach recession (Figure 4.6).

Obvious processes that may lead to a deficit in the sediment budget of a beach include wind blown sand off the beach (aeolian sand transport causing transgressive dune migration), mining the beach for heavy minerals and beach sand extraction operations. Other processes, which are not so obvious because they occur underwater, include the deposition of littoral drift into estuaries and the transport of quantities of littoral drift alongshore and out of a beach compartment, which may be larger than any inputs.

The quantification of sediment budgets for coastal compartments is exceedingly difficult. The usual practice is to identify the processes and to quantify the resulting beach recession using photogrammetric techniques. Long term rates of shoreline recession have been quantified for the different beaches along the Eurobodalla coastline using photogrammetric techniques where available. It was found that most beaches are either stable or accreting, except Barlings Beach which was receding at a rate of approximately 0.09m/yr and Maloneys Beach receding by a low rate of around 0.04m/yr. However, sea level rise that occurred between the first photogrammetric data (i.e. 1942) and 1990 may be considered in the determination of the long-term recession. A sea level rise rate of 1.8mm/yr was observed over this period by the IPCC (2007) and using the Bruun Rule method described in detail in Section 4.3.4, it was found that this increase of 1.8mm/yr in sea level rise would generate a beach recession rate of 0.04m/yr at Maloneys Beach and 0.09m/yr at Barlings Beach. These rates are of the same order as the recession rates observed in the photogrammetric data. For this reason, the observed long term recession at these two beaches may be a result of historical sea level rise that occurred during the period covered by the photogrammetric data and underlying long term recession due to other factors is negligible. In the case of stable or accreting beaches, the long term recession rate was conservatively considered as nil. The impact of the sea level rise that already occurred would increase the positive value of the long term accretion rate and was conservatively not taken into account. Therefore, long term recession rates used for the calculation of the future hazard lines (see Section 5) were considered as nil.

4.3.2 Beach Rotation

Studies of embayed beaches on the NSW coast have identified a sensitivity of shoreline alignment to wave direction (Short *et al*., 2000). This has been linked to the Southern Oscillation Index (SOI; Ranasinghe *et al*., 2004; Goodwin, 2005), which is a number calculated from the monthly or seasonal fluctuations in the air pressure difference between Tahiti and Darwin.

Sustained negative values of the SOI usually are accompanied by sustained warming of the central and eastern tropical Pacific Ocean, a decrease in the strength of the Pacific Trade Winds and a reduction in rainfall over eastern and northern Australia. This is called an *El Niño* episode. During these episodes, a more benign south-easterly wave condition is expected on the NSW coast.

Positive values of the SOI are associated with stronger Pacific trade winds and warmer sea temperatures to the north of Australia, popularly known as a *La Niña* episode. Waters in the central and eastern tropical Pacific Ocean become cooler during this time. Together, these give an increased probability that eastern and northern Australia will be wetter than normal and, during these episodes, severe storms may be expected on the Australian Eastern seaboard.

Beach rotation is observed when one extremity of a beach recedes while the opposite side accretes. Goodwin (2005) reported that the annual offshore mean wave direction can vary from 127°TN to 140°TN. This change of offshore direction would result in a nearshore change of mean wave direction of typically less than 2°. As the beach planform is typically normal to the MWD, the beach rotation that would be expected would be of the same order, with the effects seen most greatly at the extreme ends of the beaches. Assuming that the beach can be approximated by a straight line, the beach fluctuations due to rotation are estimated by the following formula:

$$R = dist \times \tan(r)$$

where *R* = beach fluctuation in metres at the location of interest

dist = distance in metres from the centre of the beach

r = estimated change in nearshore wave angle in degrees.

From this formula, it is noticeable that the longer the beach, the more significant is the impact of beach rotation. Moreover, beach rotation would be limited by the presence of the rock outcrops at the extremities of the beaches.

4.3.3 Enhanced *Greenhouse* Effect

Another factor that may affect the long-term trends on beaches is a rise in sea level resulting from the *Greenhouse Effect*. A rising sea level may result in beach recession on a natural beach and an increased potential for dune erosion on a developed beach where the dune line may be being held against erosion by a seawall.

In the longer term, there may be global changes resulting from a postulated warming of the earth due to the accumulation in the atmosphere of certain gases, in particular carbon dioxide, resulting from the burning of fossil fuels (the *Greenhouse Effect*). The current consensus of scientific opinion is that such changes could result in global warming of 1.5° to 4.5°C over the next 100 years. Such a warming could lead to a number of changes in climate, weather and sea levels. These, in turn, could cause significant changes to coastal alignments and erosion.

Global warming may produce also a worldwide sea level rise caused by the thermal expansion of the ocean waters and the melting of some ice caps. According to the Intergovernmental Panel on Climate Change (IPCC, 2007), the upper range estimate for sea level rise for the 21st century is 0.59 m (Figure 4.7). This is made up of various components, including thermal expansion of the oceans (the largest component), melting of the Greenland and Antarctic ice sheets and melting of land-based glaciers. There is considerable uncertainty also in the level of ice-sheet discharge, which could contribute, at a maximum, an additional 0.17 m to the worst-case scenario global average sea level rise. In addition to the effects of climate change, there is also an existing underlying rate of sea level rise which includes the effects of current local rates of isostatic and tectonic land movements. Mitchell et al. (2001) quantified underlying rates of existing sea level rise at various tide gauge locations around Australia. The sum total of these influences would give an upper bound sea level rise of 0.90 m for a 100 year planning period. The IPCC were unable to exclude larger values and there is emerging evidence in the current measurements and observations, suggesting the IPCC’s 2007 report may have underestimated the future rate of sea level rise. Therefore, the NSW Government through the NSW Sea Level Rise Policy Statement have set the NSW Sea Level Rise Planning benchmark at the upper bound levels of a 0.40 m increase above 1990 levels by 2050 and 0.90 m by 2100. Measured Sea Level Rise by the CSIRO shows that sea level already rose by around 0.06 m between 1990 and 2010 (Figure 4.8). Therefore, values of 0.34m by 2050 and 0.84m by 2100 were chosen for the sea level rise above 2010 levels.

There are no predictions for any increase in winter storm wind speeds and, hence, wave heights for this part of the NSW coast as a result of climate change (Figure 4.9).

4.3.4 Impacts Of Sea Level Rise

4.3.4.1 Bruun Rule

The most widely accepted method of estimating shoreline response to sea level rise is the Bruun Rule (Bruun, 1962; 1983). Bruun (1962, 1983) investigated the long term erosion along Florida's beaches, which was assumed to be caused by a long term sea level rise. Bruun (1962, 1983) hypothesised that the beach assumed an *equilibrium profile* that kept pace with the rise in sea level without changing its shape, by an upward translation of sea level rise (S) and shoreline retreat (R).

Figure 4.10 illustrates the concept of the Bruun Rule. The Bruun Rule equation is given by:

$$R = \frac{S}{(h_c + B)/L}$$

where: R = shoreline recession due to sea level rise;

S = sea level rise (m)

h_c = closure depth

B = berm height; and

L = length of the active zone.

The Bruun model assumes that the beach profile is in an equilibrium state. It is noted that the depth of nearshore rock layers would mark the seaward extent of the equilibrium beach profile. Where the location and depth of nearshore rock is known, this has been taken into account in determining equilibrium profile slopes and length of the active zones for use in the Bruun Rule calculations.

Berm height is taken to be the average height of the dune along the beach, and closure depth is the depth at the seaward extent of measurable sand movement. The length of the active zone is the distance offshore along the profile in which sand movement still occurs.

It is noted that the Bruun Rule is a two-dimensional model and does not take into account three-dimensional effects at beaches such as Cullendulla, so will not produce accurate results at all the beaches. However, due to the lack of a more satisfactory model at this time, it has been assumed that the Bruun Rule could be applied uniformly along the beaches.

4.3.4.2 Determination Of Bruun Rule Parameters

Several schemas exist, based on analytical and laboratory studies, to determine closure depth and length of the active zone. Bruun (1954) proposed a simple power law to describe the relationship between water depth, h, and offshore distance, x, measured at the mean sea level:

$$h = Ax^{\frac{2}{3}}$$

where A is a dimensional shape factor, mainly dependent on the grain size. Figure 4.11 (from Dean, 1987) gives an empirical relationship between A and grain size, D. This gives a value of *A* for the different beaches along Eurobodalla Shire coast, based on an assumed median grain size of around 0.25 mm, of approximately 0.1. Analysis of the data from the Australian and Admiralty Chart AUS 191 and the ones from the Aerial Laser Survey (ALS) provided by Eurobodalla Shire Council showed that the wave-induced sediment transport would be observed down to a depth of around 6 m or less and the length of the profile impact by wave-induced sediment movement is varying between 80 and 250 m (Table 4.3). It should be noted that the depth of nearshore rock layers would mark the seaward extent of the equilibrium beach profile. Where the location of nearshore rock is known, this has been taken into account in determining equilibrium profile slopes and length of the active zones for use in the Bruun Rule calculations. From the numerous reefs and bedrock present along the study area, short equilibrium profile lengths and low closure depths are present at many locations. Table 4.4 gives an approximation of the average slope and the berm height for the different beaches along Eurobodalla Shire Council. These slopes have been based on very limited data and at some of these beaches, beach response due to sea level rise cannot be predicted using the Bruun Rule because of the three-dimensionality of the beach processes. In particular, beaches that are within estuaries such as Wharf Road and Cullendulla Beach would not undergo a sea level rise recession that could be accurately calculated using the Bruun Rule as their offshore profiles are dominated by the dynamics of the tidal delta and three-dimensional sediment transport processes. Sea level rise recession was not calculated for all beaches due to the impossibility of determining an accurate closure depth.

Table 4.3 – Determination of the berm height, the closure depth and the profile length per continuous beach from bathymetric and topographic data.

Beaches Name	Av. Dune height B (m AHD)	Av. Closure depth h_c (m AHD)	Av. Profile length L (m)	Average slope per block (1:X)
Maloneys Beach	5.9	-5.8	250	22
Long Beach	3.6	-2.6	140	22
Surfside Beach	3.3	-0.7	80	20
Barlings Beach	5.8	N/A*	N/A*	50*
Moruya Beach	5.6	-2.7	190	23

**A slope value of 1:50 was selected for Barlings Beach given the lack of bathymetric data and because this value is a generic slope used for open beaches along the NSW coastline*

Table 4.4 – Dune height and average equilibrium profile slope for the different beaches

Location	Estimated Dune Height (m AHD)	Estimated Average Slope* (1:X)
South Durras North	7.0-7.5	40
South Durras South	6.5-8.5	50-55
Murramarang Resort	5.0	40
Maloneys Beach	5.0-6.0	20
Long Beach (Eastern Half)	3.0-4.0	20
Long Beach (Western Half)	5.0	25

Location	Estimated Dune Height (m AHD)	Estimated Average Slope* (1:X)
Surfside Beach	2.5-3.0	85-95
Corrigans Beach	4.0	100
Casey Beach	3.0-6.0	60-70
Sunshine Bay	6.0-12.0	45-60
Denhams Beach	>15.0	40
Surf Beach	5.0	60
Wimbie Beach	4.0-5.0	55
Circuit Beach	>12.0	30
Lilli Pilli Beach	>13.0	35
Mosquito Bay	7.0	55
Garden Bay	9.0	45
Malua Bay	5.5-7.5	40-45
McKenzie Beach	4.0-8.0	50-60
Rosedale Beach	4.0-6.0	45-50
Guerilla Bay	4.0-5.0	25-30
Barlings Beach	6.0-9.0	70-85
Tomakin Beach	4.0-5.0	85-90
Tomaga River	4.0-7.0	75-90
Broulee Beach	5.0-8.0	65-75
Bengello Beach	6.0-8.0	65-75
Moruya Airport	4.0-6.0	35-45
Moruya Beach	7.0-9.0	55-60
Congo Creek	4.0-5.5	50-55
Congo Beach	>15.0	35
Tuross Beach North	7.0	40
Tuross Beach South	11.0	35
Tuross Caravan Park	7.0	50

Location	Estimated Dune Height (m AHD)	Estimated Average Slope* (1:X)
Potato Point to Caravan Park	4.5-5.0	65-70
Potato Point	>10.0	50
Yabbarra Beach (Duck Pond)	4.5-5.0	35
Dalmeny to Kianga	4.5-5.0	35
North of Wagonga Inlet Entrance	4.0-5.0	35-40
Narooma Beach	5.0-6.0	35-40
Mystery Bay	>10.0	40

**The equilibrium profile slopes have been estimated using very limited bathymetric (10m- or 20m-contour bathymetric data) values and further bathymetric sounding would be necessary to obtain more accurate values. The slope values were estimated from the equilibrium profile (where available) or between the top of the dune and the first available bathymetric data (where bathymetric data were limited).*

The closure depths and the equilibrium profile lengths (and therefore the slope) have been assessed from the beach profile graph. These two characteristics are the coordinates of the last point fitting with the theoretical equilibrium profile.

The computed nearshore profile slope at some of the beaches takes into account the presence of several reefs and for the beaches located within Batemans Bay, are subject to a reduced wave climate. A common approach used in many coastal hazard assessments of open coast beaches in NSW is to apply a generic beach slope of 1:50 for use with the Bruun Rule and this generic approach was used for the beaches (e.g. Barlings Beach) where the lack of bathymetric data did not allow determination of an accurate closure depth from the beach profile graphs.

A comparison plot of the shore-normal profile at Maloneys Beach and the estimated equilibrium profile is given in Figure 4.12. It should be noted that the nearshore profile is based on limited data as the application of the Bruun Rule is limited to the portion of the profile in equilibrium with the wave climate.

4.3.4.3 Beach Response

Results of the Bruun analysis are given in Table 4.5.

*Table 4.5 – Predicted beach erosion due to sea level rise (**bold** values have been calculated using a generic slope of 1:50 due to a lack of bathymetric data)*

Location	Total Predicted Sea Level Rise (m)		Total Beach Recession (m)		Total Beach Erosion (m3/m)	
	2050	2100	2050	2100	2050	2100
South Durras North	0.34*	0.84*	**17.0**	**42.0**	**98.6**	**243.6**
South Durras South			**17.0**	**42.0**	**98.6**	**243.6**
Maloneys Beach			7.3	18.1	43.2	106.7
Long Beach East			7.5	18.4	26.8	66.3
Long Beach West			7.9	19.6	39.6	97.8
Cullendulla			N/A**	N/A**	N/A**	N/A**
Surfside			6.6	16.4	21.9	54.1
Wharf Road			N/A**	N/A**	N/A**	N/A**

Location	Total Predicted Sea Level Rise (m)		Total Beach Recession (m)		Total Beach Erosion (m3/m)	
	2050	2100	2050	2100	2050	2100
Batemans Bay CBD			N/A**	N/A**	N/A**	N/A**
Corrigans North			12.5	30.9	47.5	117.4
Corrigans Center			12.5	30.9	23.4	57.8
Casey North			9.8	24.3	38.3	94.7
Casey South			9.6	23.8	37.1	91.6
Sunshine Bay			21.0	51.9	73.6	181.8
Denhams			27.5	68.0	39.9	98.6
Surf Beach North			20.8	51.3	76.5	188.9
Surf Beach South			24.8	61.2	37.6	93.0
Wimbie Beach			23.9	59.0	35.8	88.5
Mosquito Bay			26.4	65.3	13.2	32.7
Garden Bay			19.0	46.9	83.5	206.3
Malua Bay North			15.9	39.4	66.9	165.4
Malua Bay south			16.6	41.0	79.7	197.0
Rosedale North			18.5	45.7	59.2	146.2
Rosedale South			16.8	41.5	50.4	124.6
Guerilla Bay			11.8	29.2	37.8	93.4
Barlings Beach			**17.0**	**42.0**	**98.6**	**243.6**
Tomakin			**17.0**	**42.0**	**98.6**	**243.6**
Tomaga River			**17.0**	**42.0**	**98.6**	**243.6**
Broulee North			**17.0**	**42.0**	**98.6**	**243.6**
Broulee South			**17.0**	**42.0**	**98.6**	**243.6**
Moruya Airport			**17.0**	**42.0**	**98.6**	**243.6**
Moruya South of Airport			11.0	27.1	37.2	92.0
Moruya Beach			7.8	19.3	43.8	108.2
Congo			**17.0**	**42.0**	**98.6**	**243.6**
Tuross Caravan Park			**17.0**	**42.0**	**98.6**	**243.6**
Potato Point to Caravan Park			**17.0**	**42.0**	**98.6**	**243.6**
Dalmeny Duck Pond			10.9	26.9	41.4	102.2
Dalmeny to Kianga 1			12.1	29.8	54.4	134.3
Dalmeny to Kianga 2			10.9	26.8	46.7	115.4
Dalmeny to Kianga 3			10.9	26.9	56.7	140.0
Dalmeny to Kianga 4			12.3	30.4	61.4	151.8
Narooma			12.6	31.2	54.3	134.0
Narooma Beach			13.3	32.8	63.6	157.2
Mystery Bay			13.4	33.2	85.9	212.3

** These values represent the NSW Sea Level Rise Policy (2009) benchmarks (values above 1990 levels) from which sea level rise that already occurred between 1990 and 2010 was deducted (equivalent to values above 2010 levels).*
*** Sea level rise recession determination at these locations was not possible using the Bruun Rule due to the presence of extended shallows generated by the Clyde River and Cullendulla Creek.*

For a sea level rise scenario in line with the NSW Sea Level Rise Policy Statement, the total beach recession relative to 2010 levels expected would be **around 6.6-27.5 metres by 2050** and **16.4-68 metres by 2100** along Eurobodalla Shire coastline.

It should be noted that these recession rates assume that the dune is composed of erodible material. Where a superficial layer of sandy beach overlies bedrock (e.g. Sunshine Bay or Mystery Bay) the erosion would be limited. Also, on beaches backed by a cliff (e.g. Denhams Beach) or by a seawall (e.g. Casey Beach) the erosion will stop at the level of the cliff or structure (if properly designed).

4.4 Coastal Inundation

4.4.1 Introduction

Critical to a coastline hazard risk assessment is the definition and quantification of waves and water levels that shape the beaches.

4.4.2 Wave Climate And Storms

The offshore swell wave climate (wave height, period and direction occurrences) has been recorded by the NSW Government Manly Hydraulics Laboratory with Waverider buoys located at Batemans Bay since May 27th 1986. The Waverider buoy located at Batemans Bay has also measured wave direction since February 23rd 2001.

Wave statistics summaries are available from the Manly Hydraulics Laboratory (*e.g*. as published in Lord and Kulmar, 2000). The wave data show that the predominant swell wave direction is south-southeast (SSE) with over 70% of swell wave occurrences directed from the SSE quadrant. The average deep water *significant* wave height, as measured at Batemans Bay, is around 1.5 m (Figure 4.13) and the average wave period is around 9.5 s (Kulmar *et al.* 2005). Analysis of storms recorded at Batemans Bay has provided wave height/duration data for various annual recurrence intervals.

Some large storms occurred during the 1970s, as shown in Figure 4.14. These storms included the storms of May-June 1974 whose impacts were greatest felt all along the NSW coast. The storms of May-June 1974 caused widespread damage to coastal structures and beaches along the coast of New South Wales (Foster *et al.,* 1975). These storms were associated with an intense low pressure cell adjacent to the coast near Sydney. Because nearshore waves causing dune erosion are depth-limited, wave duration of moderate wave heights becomes a more important factor for dune erosion than peak offshore wave heights of short duration. It was the long duration of moderately high waves coupled with high water levels that made this particular 1974 storm so destructive. The 1974 storm event was coincident with maximum spring tides, with a maximum storm surge measured at Fort Denison of 0.59 m and a maximum ocean water level of 1.48 m on AHD (Kulmar and Nalty, 1997).

Such storms, which occur along the NSW coastline at irregular intervals, are responsible for episodic events of sand transport and erosion, which are evident when examining photogrammetric data. It is important, therefore, to document the history of storms along the Eurobodalla Shire Council coastline to ascertain whether the observed beach changes can be related to the specific occurrence of such storms. The aim is to delineate which observed changes are caused by episodic events, such as large coastal storms, and which changes have underlying causes that may be due to long-term cycles, natural fluctuations or are caused by anthropogenic influences.

This study draws upon storm histories developed from synoptic charts, as well as historical data from the NSW Government Waverider buoys, to determine the dates and severity of the extreme storm events that have occurred over the period of the photogrammetry.

Figure 4.14 documents the extreme storm events that occurred between 1950 and 2004, with the estimated *significant* wave heights for these events from the Batemans Bay and the Port Kembla Waverider Buoys. It plots also the dates for which beach photogrammetry was available for analysis.

4.4.3 Extreme Water Levels

During storms, the ocean water level and that at the shoreline is elevated above the normal tide level. While these higher levels are infrequent and last only for short periods, they may exacerbate any storm damage on the foreshore. Elevated water levels allow larger waves to cross the offshore sand bars and reefs and break at higher levels on the beach. Further, they may cause flooding of low lying areas and increase tail water control levels for river or creek flood discharges.

The components of these elevated water levels comprise the astronomical tide, barometric water level setup, wind setup, wave setup and runup (Figures 4.15 and 4.16). All of the components do not act or occur necessarily independently of each other but their coincidence and degree of inter-dependence, generally, is not well understood.

The tides of the NSW coast are semidiurnal with a diurnal inequality. This means that there are two high tides and two low tides each day and there is a once-daily inequality in the tidal range. The mean tidal range is around one metre and the tidal period is around 12.5 hours. Tides vary according to the phases of the moon. The higher spring tides occur near and around the time of new or full moon and rise highest and fall lowest from the mean sea level. The average spring tidal range is 1.3 metres and the maximum range reaches two metres. Neap tides occur near the time of the first and third quarters of the moon and have an average range of around 0.8 metres.

Storm surge is the increase in water level above that of the normal tide that results from the low barometric pressures, which are associated with severe storms and cause sea level to rise, and strong onshore winds that pile water up against the coast. Measured values of storm surge at Sydney include 0.59 m for the extreme storm event of 25 – 26 May 1974 and 0.54 m for the extreme storm event of 31 May – 2 June 1978, which were computed to have recurrence intervals of 77 and 39 years respectively (Haradasa *et al.*, 1991). Both of these extreme events were coincident with spring high tides with the water level in the 1974 event reaching the maximum recorded at Fort Denison of 1.48 m AHD.

Return periods for storm significant wave height at Eden, which are representative of the study area, that have allowed the calculation of the wave runup using SBEACH are presented in Figure 4.17.

Several locations along Eurobodalla Shire coastline may be at risk of coastal inundation. To determine the inundation risks, run-up levels were calculated at various beaches along the shoreline and tailwater level of the main lakes and rivers was determined.

4.4.4 Tailwater and Run-up Levels

Many rivers and lakes along Eurobodalla Shire coastline have already been studied and flood studies have determined their tailwater levels. At these locations the results of the previous studies were accepted. Where no data was available, tailwater level has been estimated as per below.

To determine the tailwater level, it is necessary to determine each of its components (Figure 4.16). The various components are:

- Astronomical tide: this level was selected as being the high water summer solstice level (i.e. 0.94m along Eurobodalla Shire Council).
- Wind setup: a wind setup of 0.3 m was estimated along the central coast during the May 1974 storm, which was the most significant storm measured along the NSW coastline. Therefore, this value has been adopted along the Eurobodalla Shire coastline.

- Barometric setup: this is related to the measured barometric pressure with water level rising by 1 cm per hectopascal that the pressure falls below 1013hPa. The NSW south coast is not a cyclonic area and is rarely reached by cyclones. Only three cyclones passed within 400 km from Batemans Bay (two in February 1956 and one in April 1972) with a central pressure of 992hPa or more. Moreover, a storm (East Coast Low) that occurred on the 30th of May 2010 reached an atmospheric pressure of 995hPa at Tuross Heads. Assuming a pressure value of 990hPa, a barometric setup of 23cm would be observed. Hence a barometric setup of 0.25m was selected for the study area.
- Wave setup: this component was determined using the nearshore wave transformation software SBEACH (32 Version 2.0). SBEACH (**S**torm-Induced **BEA**ch **CH**ange 32) is an empirically based, two-dimensional, morphological, numerical model for simulating, *inter alia*, wave setup and runup water levels and wave-height variation across the surf zone. The model is founded on extensive large wave tank and field data measurements and analysis (Rosati *et al*., 1993; CERC, 1994). The model accepts as data:
  - surveyed beach profiles;
  - time-varying water levels;
  - regular or irregular wave heights and periods;
  - wave angles;
  - wind speeds and wind directions; and
  - an arbitrary grain size in the fine-to-medium sand range.

A more accurate wave setup can be estimated using a 2D hydrodynamic model. However, such a detailed calculation is out of the scope of the study.

A 1-in-100 year significant wave height of 8.5m and a 12 second wave period were used as input in SBEACH as well as the 1.50m water elevation resulting from the tide and storm surge (i.e. 0.94m high tide level + 0.25m barometric setup + 0.30m wind setup ≈ 1.50m). Tailwater levels ranging from 2.4 to 2.6m were assessed along Eurobodalla Shire coastline from the results of the nearshore transformation.

Wave runup levels at Eurobodalla Shire were estimated using the Automated Coastal Engineering Software (ACES) in which the value of the nearshore significant wave height calculated with SBEACH software was used as input. The wave runup module of ACES was used to determine the levels, which assumes a smooth slope, linear beach.

The nearshore boundary conditions for ACES that have been adopted for various locations along the coastline are shown in Table 4.6. The assumed nearshore beach profile is measured from approximately 2 m below AHD to the top of the dune, to obtain a beach slope for use in the wave runup calculation. The runup level has been calculated by adding up the runup calculated by ACES to the storm surge previously determined in this Section 4.4.4 (High Tide level + barometric setup + wind setup ≈ 1.50m) and the 1 in 1000 year water level calculated in SBEACH using a 10m significant wave height. The 1 in 1000 year water level was used for the runup calculation instead of the 1 in 100 year water level to determine the maximum wave run-up.

The maximum expected wave runup, 2% wave runup (runup level exceeded by 2% of waves) and significant wave runup (average of the highest third of the runup levels) are given in Table 4.6. The 100 year ARI tailwater levels for estuary entrances are provided in Table 4.7.

Due to climate change induced sea level rise, these levels presented in Table 4.6 and 4.7 would increase. Given the estimated sea level rise of 0.90m above 1990 level by 2100, an increase in wave runup and tailwater levels of around one metre will be expected where there is a rocky sea bed or reefs. In this case, a 0.90m sea level rise would allow larger waves to reach the shore which would increase the wave setup at the beach by a couple of centimetres. Hence, the nearshore sea level and hence, wave runup would increase by slightly more than 0.90m by 2100. In the case of sandy beaches, the beach profile will move upward and shoreward with sea level rise and the run-up level relative to future mean sea level would be expected to remain the same.

*Table 4.6 – Run-up levels at different location along Eurobodalla Shire coastline (***Bold** *values represent areas where dune overtopping will occur and* italic *value the locations where dune overtopping may occur)*

Location	Dune or Wall Level (m AHD)	Nearshore Wave Setup (m)	2% Wave RunUp Level		Significant Wave Runup Level		Maximum Wave RunUp Level	
			From ACES (m)	m AHD	From ACES (m)	m AHD	From ACES (m)	m AHD
South Durras North	7.6	1.37	1.72	4.59	1.29	4.16	2.07	4.94
South Durras South	7.1	1.05	1.59	4.14	1.19	3.74	1.91	4.46
Maloneys Beach	5.9	1.24	2.12	4.86	1.57	4.31	2.73	5.47
Long Beach East	*4.0*	*1.31*	*1.19*	*4.00*	*0.88*	*3.69*	*1.45*	*4.26*
Long Beach West	**5.0**	**1.11**	**2.46**	**5.07**	**1.82**	**4.43**	**2.89**	**5.50**
Surfside Beach	**3.2**	**1.16**	**0.90**	**3.56**	**0.68**	**3.34**	**1.03**	**3.69**
Wharf Road	**1.9**	**1.18**	**0.26**	**2.94**	**0.20**	**2.88**	**0.27**	**2.95**
Batemans Bay CBD	**3.5**	**1.27**	**0.68**	**3.45**	**0.51**	**3.28**	**0.78**	**3.55**
Corrigans Beach North	**4.0**	**1.14**	**1.65**	**4.29**	**1.24**	**3.88**	**1.93**	**4.57**
Corrigans Beach Center	**1.9**	**1.26**	**1.39**	**4.15**	**1.04**	**3.80**	**1.64**	**4.40**
Casey Beach North	**3.9**	**0.97**	**2.22**	**4.69**	**1.65**	**4.12**	**2.68**	**5.15**
Casey Beach South	**3.9**	**1.07**	**2.23**	**4.80**	**1.66**	**4.23**	**2.69**	**5.26**
Sunshine Bay	*3.5*	*0.90*	*0.94*	*3.34*	*0.71*	*3.11*	*1.06*	*3.46*
Denhams	7.0	0.95	1.57	4.02	1.17	3.62	1.89	4.34
Surf Beach North	*3.7*	*0.95*	*1.03*	*3.48*	*0.77*	*3.22*	*1.19*	*3.64*
Surf Beach Center	5.4	0.94	0.97	3.41	0.73	3.17	1.12	3.56
Surf Beach South	3.9	1.06	0.59	3.15	0.44	3.00	0.66	3.22
Mosquito Bay	7.0	1.13	1.38	4.01	1.03	3.66	1.63	4.26
Garden Bay	*4.4*	*1.11*	*1.29*	*3.90*	*0.97*	*3.58*	*1.52*	*4.13*
Malua Bay North	5.8	1.12	1.63	4.25	1.22	3.84	1.94	4.56
Malua Bay South	7.4	1.10	1.42	4.02	1.07	3.67	1.68	4.28
Rosedale Beach North	7.1	1.14	1.67	4.31	1.24	3.88	2.00	4.64*
Rosedale Beach South	*4.3*	*1.12*	*1.31*	*3.93*	*0.98*	*3.60*	*1.54*	*4.16*

Location	Dune or Wall Level (m AHD)	Nearshore Wave Setup (m)	2% Wave RunUp Level		Significant Wave Runup Level		Maximum Wave RunUp Level	
			From ACES (m)	m AHD	From ACES (m)	m AHD	From ACES (m)	m AHD
Guerilla Bay	5.2	1.22	1.62	4.34	1.22	3.94	1.92	4.64
Barlings Beach	7.0	1.08	1.05	3.63	0.79	3.37	1.22	3.80
Tomakin	4.3	1.08	0.75	3.33	0.57	3.15	0.85	3.43
Tomaga River	5.0	1.03	1.01	3.54	0.76	3.29	1.17	3.70
Broulee North Beach	7.1	0.96	1.18	3.64	0.88	3.34	1.39	3.85
Broulee South Beach	7.0	1.08	1.18	3.76	0.89	3.47	1.39	3.97
Moruya Airport North	6.2	0.99	1.89	4.38	1.41	3.90	2.28	4.77
Moruya Airport South	5.2	1.10	1.66	4.26	1.24	3.84	1.96	4.56
Moruya Beach	6.2	1.37	2.35	5.22	1.76	4.63	2.83	5.70
Congo Beach	7.9	1.16	1.72	4.38	1.29	3.95	2.07	4.73
Tuross Caravan Park	7.1	1.10	0.93	3.53	0.70	3.30	1.07	3.67**
Beachcomber Holiday Park to Potato Point	6.0	1.01	1.44	3.95	1.08	3.59	1.72	4.23
Dalmeny at Duck Pond	**3.8**	**1.29**	**1.58**	**4.37**	**1.18**	**3.97**	**1.84**	**4.63**
Dalmeny to Kianga 1	**4.5**	**1.21**	**2.00**	**4.71**	**1.49**	**4.20**	**2.41**	**5.12**
Dalmeny to Kianga 2	*4.9*	*1.20*	*1.77*	*4.47*	*1.33*	*4.03*	*2.11*	*4.81*
Dalmeny to Kianga 3	*5.3*	*1.21*	*1.89*	*4.60*	*1.41*	*4.12*	*2.27*	*4.98*
Dalmeny to Kianga 4	5.0	1.26	1.46	4.22	1.09	3.85	1.70	4.46
Narooma	**4.3**	**1.17**	**1.59**	**4.26**	**1.19**	**3.86**	**1.89**	**4.56**
Narooma Beach	7.3	1.15	1.84	4.49	1.38	4.03	2.21	4.86
Mystery Bay	6.5	1.16	1.32	3.98	0.99	3.65	1.54	4.20

* Boatsheds on the beach will be reached by wave run-up as they are seaward of the high berm

** Tuross Caravan Park may be impacted by wave run-up as it is located in front of the dune

N.B.: The estimated wave runup levels do not include the effects of wave refraction which may be significant in areas within Batemans Bay

Table 4.7 – Tailwater level for a 1 in 100 year event along Eurobodalla Shire coastline

Location	EstimatedTailwater level / Oceanic Still Water Level (m AHD)
South Durras Lake (estimated)	2.6 m
South Durras Creek and ICOLL (estimated)	2.45 m
Maloneys Beach Creek (estimated)	2.6 m
Surfside Creek (estimated)	2.4 m
Joes Creek (from Willing & Partners, 1989b)	2.25 m (50^{th} percentile) 2.55 m (95^{th} percentile)
Short Beach Creek (from Willing & Partners, 1989a)	2.43 m
Surf Beach Creek (estimated)	2.5 m
Wimbie Beach Creek (estimated)	2.65
Reedy Creek (from Willing & Partners, 1989c)	2.60 m (50^{th} percentile) 2.80 m (95^{th} percentile)
Rosedale Beach Creek (estimated)	2.5 m
Tomaga River (estimated)	2.4 m
Candlagan Creek (estimated)	2.4 m
Congo Creek (estimated)	2.5 m
Coila Lake (estimated)	2.5 m
Tuross Lake (estimated)	2.4 m
Mummuga Lake Entrance (estimated)	2.5 m
Kianga Lake (estimated)	2.5 m
Wagonga Inlet (from Gary Blumberg & Associates, 2002)	2.20 m (inlet basin and Narooma Flats) 1.90 m (entrance and public wharf)
Little Lake (estimated)	2.5 m
Nangudga Lake (estimated)	2.5 m

5 CALCULATION OF HAZARD LIMITS

The limits of the *Zone of Wave Impact and Slope Adjustment* and the *Zone of Reduced Foundation Capacity* have been calculated using the values for design storm erosion demand, with reference to Figures 5.1 to 5.5 for the 2050 and 2100 planning periods, adding the estimated recession allowed for as a result of upper range sea level rise prognoses as advocated by the NSW Sea Level Rise Policy.

To obtain the location of the various zones, ALS data were used, which provides a greater density of data. For calculation of the zones, it has been assumed that the ALS data is relatively representative of average beach conditions as it is the most accurate data available.

The immediate hazard limits due to the design storm erosion volume are shown in Figures 5.6 to 5.10 for the different beaches where photogrammetric data were available. They have been calculated in terms of chainage along each profile.

For the 2050 and 2100 planning periods, a nil long term beach recession was used and sea level rise limits were added to the design storm recession for several locations along the beach, to determine the seaward limits of the *Zone of Reduced Foundation Capacity* and *Stable Foundation Zone*.

Figures 5.11 to 5.15 illustrate the hazard limits for 2050 and 5.16 to 5.20 illustrate the hazard limits for 2100.

Wave run-up and tailwater levels at several locations along Eurobodalla Shire Coastline are illustrated in Figures 5.21 to 5.47

6 RISK ASSESSMENT

Coastal process hazards can be defined within the framework of a risk management approach. Risk is assessed by considering the likelihood (probability) and consequences of the selected events. In the coastal processes context, the likelihood of certain events is determined in part by the recurrence interval of storms of various magnitudes, in part by other natural processes (such as flooding or drought) and in part by a combination of human induced/influenced processes or activities.

The consequence of an event is the predicted extent of impact or loss associated with the event. Consequences can include:

- Loss of or damage to built structures, including homes, surf clubs, other recreational facilities such as rock pools, etc. As housing values along the coastline escalate, the hazards of coastal storms can result in increasing economic consequences and therefore risks.
- Loss of beach user safety. Aspects of beach user safety that can be considered include dangerous access on beaches or unfenced headlands; persistent rips associated with eroded beach conditions, poor water quality in the surf zone, exposed boat ramps, etc.
- Loss of or reduced integrity of Aboriginal cultural heritage places (individual sites or cultural landscapes). To some extent, these consequences may be modified by the presence of similar cultural heritage values in conservation management in the local area.
- Loss of or damage to historic heritage structures, such as wharves, boat sheds, etc.
- Loss of or reduced viability of Endangered Ecological Communities, threatened species habitat or other habitat considered to be important by the community because of its natural values. As for cultural heritage values, some consequences may be modified or reduced by the protection of equivalent habitat in formal, long term conservation management.
- Loss of visual amenity associated with litter from stormwater outlets, poorly located or designed development, overshadowing, etc.
- Loss of recreational amenity. Consequences would be modified by the number and diversity of users who are affected, the relevance of the facilities to local or regional users, the level of previous investment in construction and maintenance, associated safety consequences, etc.

Where the above impacts could be determined, they were considered in the risk assessment.

The risk assessment identifies:

- discrete localities for assessment
- potential coastal hazards at each locality
- potential severity of the coastal hazard at each locality
- consequences of the coastal hazard at each locality
- existing coastal hazard information at each locality, coverage and requirements.

Several coastal management structures such as dune stabilisation fencing and stormwater outlet scour protection works were observed within the study area during the site visit. Some of these protection works do not meet contemporary coastal engineering standards for design, so an assessment of the adequacy of these structures based on visual observations was carried out.

From a comprehensive field inspection and analysis of available data at each site, each location was classified in terms of the following criteria:

- wave climate and coastal processes (for example, an open coast beach with a high wave climate, or a protected beach with a low-moderate wave climate);
- potential coastal hazards at each site, their severity and the likelihood that they would cause damage within a set planning period;
- Consequence of the coastal hazard (for example, is the beach backed by high value residential or commercial development which is likely to be impacted by coastal hazards, or is there very little or no development at risk?)
- What existing studies are available at each site and how comprehensive are they?
- Is the site protected by coastal protection works and would these works provide adequate protection against coastal hazards?
- What are the main coastal management issues that exist at each site?

In discussions with Council the above selection criteria were further developed and used to identify priority sites for detailed assessment. However, this report provides a first pass qualitative assessment for all sites within the Eurobodalla LGA. The qualitative assessment identifies coastal processes and hazards at each site through the analysis of existing data and comprehensive field inspections by SMEC coastal engineers.

The coastal hazard risk at each site was rated as low, moderate, high or extreme. Risk was assessed as the product of likelihood and consequence at each location (rating methodology of the likelihood and consequences are given in Table 6.1. Locations were ranked in terms of their risk rating and the other criteria listed above. The risk analysis is presented as a matrix shown in Appendix 1. The aim of the matrix is to prioritise studies and individual lots/properties will undertake a separate merit based assessment of risk when the detailed studies are completed.

Table 6.1 – Table of the consequence and likelihood rating used for the risk assessment

	Consequences Rating	1	2	3	4	5
Likelihood Rating	Consequences Description / Likelihood Description	minor structures / assets impacted	<5 lots impacted	5 to 20 lots impacted	20 to 100 lots impacted	>100 lots impacted
1	100 year erosion/inundation risk or low likelihood	1	2	3	4	5
2	50 inundation risk or possible likelihood	2	4	6	8	10
3	50 year erosion risk or moderate likelihood	3	6	9	12	15
4	Immediate inundation risk or high likelyhood	4	8	12	16	20
5	Immediate erosion risk or certain/almost certain likelihood	5	10	15	20	25

Low Risk	Moderate Risk	High Risk	Extreme Risk

7 DATA REQUIREMENT

After analysis of the existing documents, studies and reports as well as the available data, a gap analysis of the data was carried out.

Data required for future studies are listed in Table 7.1 below.

Table 7.1 – Data Requirement for Future Studies

Data Requirement	Location Covered	Study needing data	Time
Bathymetric survey data within the bay Regular ALS topographic data Historic photogrammetric data	Maloneys Beach Long Beach Cullendulla Beach Surfside Wharf Road Batemans Bay CBD Corrigans Beach Casey Beach	Coastal Hazard Study Review of Batemans Bay	Short term
Tidal gauge data at the different locations Peak Water level gradient at the different locations Channel scour measurement within the Tomaga River Updated ALS topographic data Update of flood level history	Mummuga Lake Narooma Flats Tomaga River	Flood and Tailwater Study of Narooma Flats, Mummuga Lake and Tomaga River	Short Term
Tidal gauge at the different locations Peak Water level gradient at the different locations Channel scour measurement within the Creeks/River Updated ALS topographic data Update of flood level history	Durras Lake, creek and ICOLL Short Beach Creek Candlagan Creek Moruya River Congo Creek	Flood and Tailwater Level Study	Medium Term
Bathymetric survey data Regular ALS topographic data Historic photogrammetric data	Sunshine Bay Denhams Beach Surf Beach Wimbie Beach Malua Beach Guerilla Bay Mosquito Bay Garden Bay Broulee Moruya Beach and Airport Beachcomber Holiday Park Dalmeny Kianga Mystery Bay	Coastal Hazard Study and Geotechnical Study	Medium Term
Tidal gauge at the different locations Peak Water level gradient at the different locations Channel scour measurement within the Creeks/River Updated ALS topographic data Update of flood level history	Joes Creek Reedy Creek Potato Point Wallaga Lake	Flood and tailwater level assessment	Long Term
Water Quality Sampling and Analysis	Between Maloneys and Long Beach Surfside Creek Creek at southern end of Corrigans Beach Duck Pond	Water Quality Monitoring	Short Term
Bathymetric survey data Regular ALS topographic data Historic photogrammetric data	Rosedale Beach One Tree Beach Islandview Beach Resort	Coastal Hazard Study	Optional

8 CONCLUSIONS AND RECOMMENDATIONS

The 112km of coastline along Eurobodalla Shire Council was studied and the different coastal hazards and risks were identified. For this purpose, past reports were reviewed, a site visit was undertaken and the different types of hazard were described, including determination of the storm cut and long-term recession rate where data were available, mapping of the hazard lines for these locations, calculation of the tailwater and runup levels at several locations along the coast, assessment of the impacts of sea level rise and mapping of the inundation levels.

Once the coastal hazard risks were identified, these risks were prioritised as a function of the likelihood and consequences of each hazard allowing the determination of risk ratings.

The locations where the coastal hazard risk is the most significant are:

- the eastern half of Long Beach (risk of erosion and inundation);
- the western end of Surfside (risk of erosion and inundation);
- Batemans Bay CBD (risk of inundation);
- Casey Beach (risk of erosion, inundation and seawall failure);
- Mossy Point along Tomaga River (risk of inundation and breakthrough of estuary entrance);
- Dalmeny along Mummuga Lake (risk of inundation); and
- Narooma Flats (risk of inundation).

Recommendations

- The above-mentioned high coastal hazard risks should be considered as first priority
- Further photogrammetric aerial pictures should regularly be taken to avoid large gaps in data such as the lack of data between 1972 and 1990 at Surfside, Long and Maloneys Beaches. Alternatively, LIDAR data could be regularly flown in the future.
- Update wave climate study of Batemans Bay undertaken by the Coastal and Riverine Management Directorate in 1996 to understand wave climate, wave refraction effects and degree of exposure at the various beaches within Batemans Bay.
- Coastal geotechnical hazards should be assessed by a qualified geotechnical engineer at the locations identified as “bluff / cliff / slope stability” hazard in Table B of Appendix 1
- Future developments between Surfside and Cullendulla Beach should consider the high rate of erosion occurring along Cullendulla Beach
- Emergency action plans should be implemented in locations described as inundation prone areas in Table B of Appendix 1
- Tomaga River entrance should be carefully monitored to avoid any breakthrough of the river
- Informal 4-wheel drive access located at the narrowest section of Broulee Island tombolo should be closed or formalised as a board and chain vehicular access
- Secondary access to Congo should be developed to avoid the town becoming isolated in case of a flood event blocking the existing road accesses, or the existing accesses should be improved
- Detailed Coastal hazard studies should be undertaken as part of a detailed Shirewide Coastal Hazard Assessment where erosion hazards have been identified in Table B of Appendix 1.

Table 8.1 provides an Action Plan with priority, estimated timeframe and estimated budget. Many of the actions listed can be combined to reduce overall costs.

Table 8.1 –Action Plan for the development of a comprehensive Coastal Zone Management Study and Plan

Location	Priority Score	Action to Undertake	Commencement*	Estimated Timeframe**	Estimated Budget (A$)
Long Beach	20	Update of Coastal Hazard Study (Erosion and Inundation)	Short term	6 months	10,000-15,000
		Management Options Assessment	Short term	6 months	20,000
Narooma Flats	20	Update of Tailwater Level Study for Wagonga Inlet	Short term	2 months	5,000
		Management Options Assessment	Short term	3 months	15,000
Mummuga Lake	16	Tailwater Level Study	Short term	3 months	10,000
		Entrance Management and Options Study	Short term	6 months	20,000
Mossy Point/ Tomaga River	16	Tailwater Level Study of Tomaga River and Coastal Hazard Study (Erosion and Inundation)	Short term	3 months	10,000
Casey Beach	16	Update of Coastal Hazard Study (Erosion, inundation and seawall assessment)	Short term	6 months	10,000-15,000
		Management Options Assessment	Medium term	3 months	15,000
Batemans Bay CBD	16	Update of Coastal Hazard Study (Inundation)	Short term	3 months	5,000
		Council to review existing development controls	Short term	3 months	Can be done with existing Council resources
Surfside (Western Beach)	16	Update of Coastal Hazard Study (Erosion and Inundation)	Short term	3 months	15,000
		Management Options Assessment	Short term	6 months	20,000
Maloneys Beach	15	Update of Coastal Hazard Study (Erosion and Inundation)	Short term	3 months	10,000
		Management Options Assessment	Medium term	3 months	15,000
Surfside (Eastern Beach)	12	Update of Coastal Hazard Study (Erosion and Inundation)	Can be done in conjunction with Surfside (Western Beach) Study		
Wharf Road	12	Update of Coastal Hazard Study (Erosion and Inundation)	Can be done in conjunction with Surfside (Western Beach) Study		
Batemans Bay Marina	12	Coastal Hazard Study (Inundation)	Can be done in conjunction with Batemans Bay CBD Study		
Malua Beach	12	Coastal Hazard Study (Erosion and Inundation)	Medium term	3 months	10,000
		Consider options assessment for SLSC	Medium term	2 months	5,000
Dalmeny to Kianga	12	Coastal Hazard Study (Erosion and Inundation)	Medium term	3 months	10,000
		Management Options Assessment	Medium term	3 months	15,000
Durras Lake, Creek and ICOLL	12	Tailwater Level Study	Medium term	4 months	15,000
		Council to update flood mapping	Medium term	N/A	Can be done with existing Council resources
Short Beach Creek	12	Update of Tailwater Level	Medium term	3 months	5,000

Location	Priority Score	Action to Undertake	Commencement*	Estimated Timeframe**	Estimated Budget (A$)
		Study			
		Council to update flood mapping	Medium term	N/A	Can be done with existing Council resources
Broulee North and Candlagan Creek	12	Coastal Hazard Study (Erosion and Inundation) and Tailwater Level Study	Medium term	3 months	10,000
		Council to review existing development controls	Medium term	3 months	Can be done with existing Council resources
Moruya River	12	Tailwater Level Study	Medium term	6 months	15,000
		Council to update flood mapping	Medium term	N/A	Can be done with existing Council resources
Congo Creek	12	Update of Tailwater Level Study	Medium term	2 months	3,000
		Consider Council purchase of access road and upgrade	Long term	N/A	To be discussed with owner and funds to be obtained from outside of coastal grant program
Tuross Lake	12	Incorporate Entrance Management Policy recommendations into Coastal Management Plan	Medium term	N/A	N/A
Kianga Lake	12	Incorporate Entrance Management Policy recommendations into Coastal Management Plan	Medium term	N/A	N/A
Corrigans Beach	10	Update of Coastal Hazard Study (Erosion, inundation and emergency evacuation plan for caravan parks)	Medium term	3 months	10,000
Casey Beach	10	Coastal Geotechnical Study	Medium term	3 months	10,000-15,000
		Council to develop geotechnical hazard development policy	Medium term	N/A	Can be done with existing Council resources
Mosquito Bay	10	Coastal Geotechnical Study	Medium term	3 months	10,000
		Council to develop geotechnical hazard development policy	Medium term	N/A	Can be done with existing Council resources
Between Maloneys and Long Beach	9	Coastal Geotechnical Study	Medium term	3 months	10,000
		Council to develop geotechnical hazard development policy	Medium term	N/A	Can be done with existing Council resources
Sunshine Bay	9	Coastal Geotechnical Study and Wave Inundation Study	Long term	3 months	10,000
Potato Point	8	Inundation Assessment	Long term	1 month	3,000
Guerilla Bay	8	Coastal Hazard Study (Inundation)	Long term	1 months	3,000
Corrigans Beach	6	Coastal Geotechnical Study	To be done as part of Casey Beach Coastal Geotechnical Study		
Beachcomber Holiday Park	6	Coastal Hazard Study (Erosion, Inundation and Emergency Response Plan)	Long term	3 months	10,000
Kianga	6	Coastal Hazard Study (Inundation)	To be done as part of Dalmeny to Kianga Coastal Hazard Study		
Nangudga Lake at Islandview Beach Resort	6	Incorporate Entrance Management Policy recommendations into Coastal Management Plan	Medium term	N/A	N/A
Mystery Bay	6	Coaastal Hazard Study	Long term	3 months	10,000

Location	Priority Score	Action to Undertake	Commencement*	Estimated Timeframe**	Estimated Budget (A$)
		(Erosion and Inundation) and Coastal Geotechnical Study			
Surf Beach and Wimbie Beach	6	Coastal Hazard Study (Erosion and Inundation) and Coastal Geotechnical Study	Long term	3 months	10,000
Wallaga Lake	6	Tailwater Level Study	Long term – To be considered in conjunction with Bega Valley Shire Council		
Between Maloneys and Long Beach	5	Water Quality Study and Monitoring	Short term	1 month	Can be done with existing Council resources
Broulee Southern Beach	5	Coastal Hazard Study (Erosion and Inundation)	Long term	2 months	5,000
Cullendulla Beach	5	Update of Coastal Hazard Study (Erosion and Inundation)	To be considered as part of Updated Surfside Coastal Hazard Assessment		
Surfside Creek	5	Water Quality Study and Monitoring	Short term	1 month	Can be done with existing Council resources
Creek at southern end of Corrigans Beach	5	Water Quality Study and Monitoring	Short term	1 month	Can be done with existing Council resources
Rosedale Beach	5	Coastal Hazard Study (Erosion and Inundation)	Optional	2 months	5,000
One Tree Beach South, Tuross Head	5	Coastal Hazard Study (Erosion and Inundation)	Optional	1 month	3,000
One Tree Beach South, Tuross Head	5	Council maintenance of carpark / erosion damage	As required	As required	Can be done with existing Council resources
Joes Creek	4	Update of Tailwater Level Study	Long term	2 months	5,000
Coila Lake	4	Incorporate Entrance Management Policy recommendations into Coastal Management Plan	Medium term	N/A	N/A
Little Lake, Narooma	3	Incorporate Entrance Management Policy recommendations into Coastal Management Plan	Medium term	N/A	N/A
Reedy Creek	3	Update of Tailwater Level Study	Long term	2 months	5,000
Broulee Island	3	Tombolo Stability Study	To be done as part of Broulee North Coastal Hazard Study		
Moruya Beach	3	Coastal Hazard Study (Erosion and Inundation)	Long term	2 months	5,000
Duck Pond	3	Water Quality study and Monitoring	Short term	1 month	Can be done with existing Council resources
Denhams Beach	2	Coastal Geotechnical Study	To be done as part of Surf Beach and Wimbie Beach Coastal Geotechnical Study		
Garden Bay	2	Coastal Geotechnical Study	To be done as part of Mosquito Bay Coastal Geotechnical Study		
Islandview Beach Resort	2	Coastal Hazard Study (Erosion and Inundation)	Optional	2 months	5,000
Moruya Airport	1	Coastal Hazard Study (Erosion and Inundation)	Long term	2 months	5,000

**Short term: 0 to 2 years / Medium term: 2 to 5 years / Long term: >5 years*

***Estimated timeframe is the estimated duration of the work*

Table 8.2 – Suggested Combined Studies

Study	Location Covered	Action to Undertake	Commencement*	Estimated Timeframe**	Estimated Budget (A$)
Coastal Hazard Study Review of Batemans Bay	Maloneys Beach Long Beach Cullendulla Beach Surfside Wharf Road Batemans Bay CBD Corrigans Beach Casey Beach	Update of Coastal Hazard Study including erosion and inundation for the different locations Inundation Study for Batemans Bay Marina Seawall assessment for Casey Beach Emergency evacuation plan for Corrigans Beach caravan parks Coastal Geotechnical Study between Maloneys and Long Beach, at Corrigans and Casey Beach	Short term	14 months	90,000
Review of exisiting development control	Batemans Bay CBD Broulee North	Council to review existing development controls	Short term	5 months	Can be done with existing Council resources
Batemans Bay Management Option Assessment	Maloneys Beach Long Beach Surfside Casey Beach	Management Options Assessment for the different location	Short-Medium Term	12 months	70,000
Flood and Tailwater Study of Narooma Flats, Mummuga Lake and Tomaga River	Mummuga Lake Narooma Flats Tomaga River	Update of tailwater level study and management options assessment for Wagonga Inlet Tailwater level study and entrance management and option study for Mummuga Lake Tailwater Level Study of Tomaga River and Coastal Hazard Study of Tomaga River Entrance	Short Term	10 months	60,000
Review of exisiting development control for North Broulee	North Broulee	Council to review existing development controls	Short term	3 months	Can be done with existing Council resources
Flood and Tailwater Level Study	Durras Lake, creek and ICOLL Short Beach Creek Candlagan Creek Moruya River Congo Creek	Tailwater Level Study for Durras Lake, creek and ICOLL, Candlagan Creek and Moruya River Update of tailwater level study for Congo Creek and Short Beach Creek Update of Flood Mapping for South Durras, short Beach Creek and Moruya River Consider Council purchase of access road and upgrade along Congo Creek	Medium Term	8 months	45,000
Incorporation of Entrance Management Policy recommendations into Coastal Management Plan	Tuross Lake Coila Lake Kianga Lake Little Lake Nangudga Lake	Incorporation of Entrance Management Policy recommendations into Coastal Management Plan	Medium Term	N/A	N/A
Coastal Hazard Study and Geotechnical Study	Sunshine Bay Denhams Beach Surf Beach Wimbie Beach Malua Beach Guerilla Bay Mosquito Bay Garden Bay Broulee Moruya Beach and Airport Beachcomber Holiday Park Dalmeny Kianga Mystery Bay	Coastal Geotechnical Study at the different locations nominated in Table 8.1 Council to develop geotechnical hazard development policy Coastal Hazard Study including Erosion and Inundation for the different locations nominated in Table 8.1 Emergency response plan for Beachcomber Holiday Park Options Assessment for Malua Bay SLSC Management Option Assessment for the road between Dalmeny and Kianga Study of Tombolo stability at Broulee Island	Medium Term	15 months	100,000
Flood and tailwater level assessment	Joes Creek Reedy Creek Potato Point Wallaga Lake	Tailwater level study of Wallaga Lake and Potato Point Update of tailwater level study for Joes Creek and Reedy Creek	Long Term	3 months	15,000 + cost for Wallaga Lake to determine in conjunction with Bega Valley Shire
Water Quality Monitoring	Between Maloneys and Long Beach Surfside Creek Creek at southern end of	Water Quality Study and Monitoring	Short Term	3 months	Can be done with existing Council

Study	Location Covered	Action to Undertake	Commencement*	Estimated Timeframe**	Estimated Budget (A$)
	Corrigans Beach Duck Pond				resources
Coastal Hazard Study	Rosedale Beach One Tree Beach Islandview Beach Resort	Coastal hazard study including inundation and erosion Council maintenance of carpark / erosion damage	Optional As Required	4 months As Required	13,000 Can be done with existing Council resources

**Short term: 0 to 2 years / Medium term: 2 to 5 years / Long term: >5 years*

***Estimated timeframe is the estimated duration of the work*

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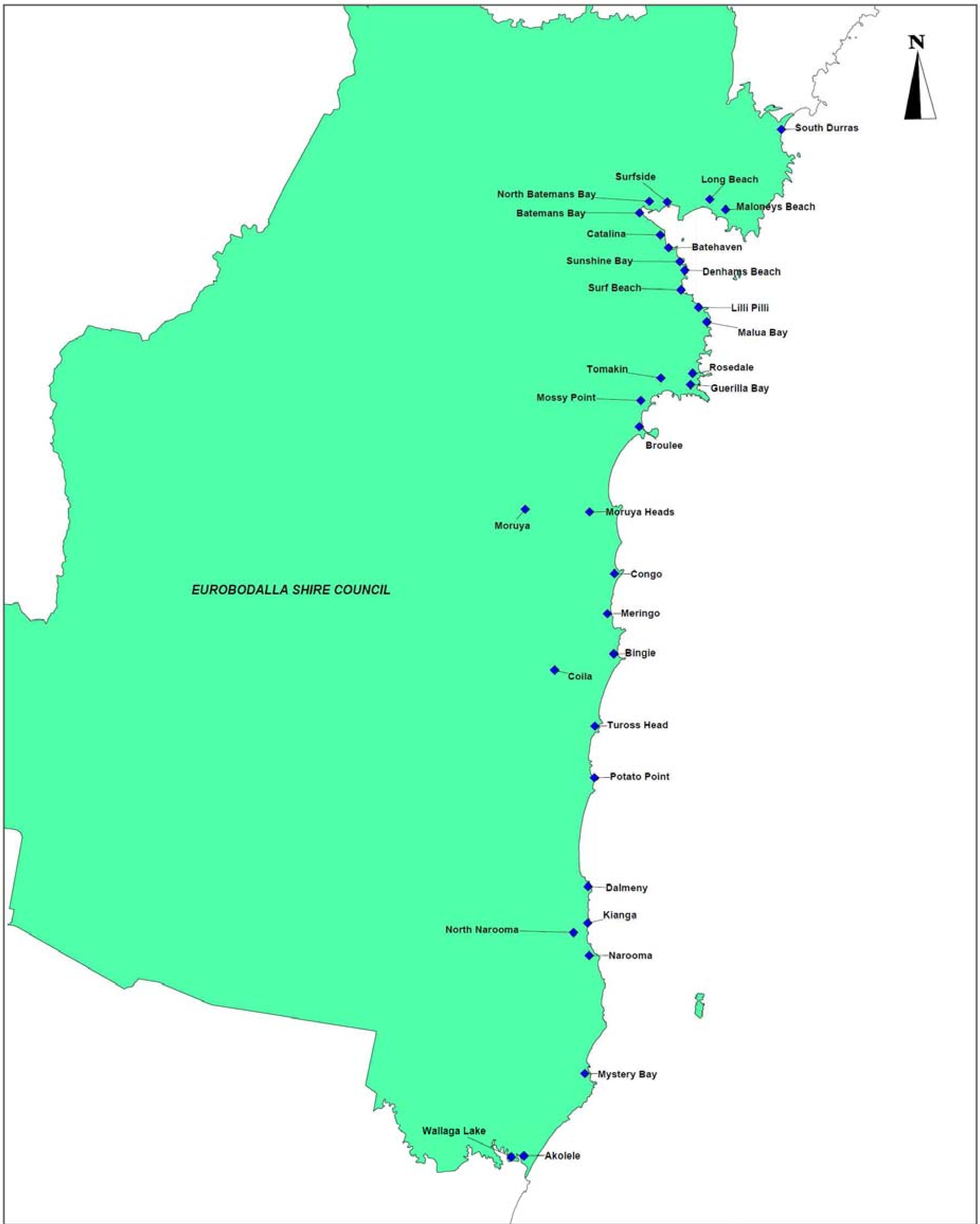

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PROJECT NO. 3001805	PROJECT TITLE Eurobodalla Shire Coastal Hazards Scoping Study	
FIG NO. 1.1	FIGURE TITLE Locality Map	
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Figure 3.1 – Healthy dune at South Durras near Durras Lake entrance (March 15th 2010)

Figure 3.2 – Boat ramp at the southern end of South Durras northern beach (March 15th 2010)

Figure 3.3 – Saltmarshes between Lakeside Drive and Durras Lake (March 15th 2010)

Figure 3.4 – Stormwater erosion at the southern end of South Durras southern beach (March 15th 2010)

Figure 3.5 – Cabin close to the edge of the beach at South Durras Murramarrang Resort (March 15th 2010)

Figure 3.6 – Mown over dune at Maloneys Beach (March 15th 2010)

Figure 3.7 – Houses and road located close to the dune at the western end of Maloneys Beach (March 15th 2010)

Figure 3.8 – Very low dune at the eastern end of Long Beach (March 15th 2010)

Figure 3.9 – Undercutting due to wave action at the bottom of a very steep slope east of Long Beach (March 15th 2010)

Figure 3.10 – Stormwater outlet protected by a buried rock seawall in front of Fauna Avenue at Long Beach (March 15th 2010)

Figure 3.11 – Higher dune at the western end of Long Beach but heavily covered in lawn grass (March 15th 2010)

Figure 3.12 – Houses located at the edge of the cliff between Long and Maloneys Beach (March 15th 2010)

Figure 3.13 – Septic sludge leaking through groundwater between Long and Maloneys Beach (March 15th 2010)

Figure 3.14 – Erosion and falling trees at Cullendulla Beach (March 15th 2010)

Figure 3.15 – Low-lying houses close to the eroding dune at the eastern end of Surfside Beach (March 15th 2010)

Figure 3.16 – Damaged stormwater pipe at Surfside Beach (March 15th 2010)

Figure 3.17 – Very low-lying houses located very close to the shore and visible erosion at the western end of Surfside (March 15th 2010)

Figure 3.18 – Visible erosion along McLeod Road damaging bridge's seawall protection and pipes under bridge covered with sand (March 15th 2010)

Figure 3.19 – Active erosion with scarp and exposed vegetation (March 15th 2010)

Figure 3.20 – Seawall along the road and the holiday park (March 15th 2010)

Figure 3.21 – Seawall protecting Batemans Bay Boat Harbour
(March 16th 2010)

Figure 3.22 – Varying condition of seawall and unprotected low-lying houses within Batemans Bay Marina
(March 16th 2010)

Figure 3.23 – Hanging Rock boat ramp
(March 16th 2010)

Figure 3.24 – Waves breaking on offshore shoals at Batemans Bay
(March 16th 2010)

Figure 3.25 – Northern end of Corrigans Beach
(March 16th 2010)

Figure 3.26 – Erosion of creek along the low-lying caravan park at the southern end of Corrigans Beach
(March 16th 2010)

Figure 3.27 – GPT blocked by rubbish behind southern caravan park at Corrigans Beach (March 16th 2010)

Figure 3.28 – Houses possibly at geotechnical risk at the southern end of Corrigans Beach (March 16th 2010)