

# **Western Port Local Coastal Hazard Assessment Report 6 (R06) – Review of Representative Locations**



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**Cover Photo:** Merricks Creek and Balnarring (Photo: Neville Rosengren, 8 June 2013)

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## GLOSSARY

Aeolian	The erosion, transport and deposition of material by wind.
Australian Height Datum(AHD)	A common national plane of level corresponding approximately to mean sea level.
ARI	Average Recurrence Interval. The average or expected value of the periods between exceedances of a given event over a given duration.
AEP	Annual Exceedance Probability: The measure of the likelihood (expressed as a probability) of an event equalling or exceeding a given magnitude in any given year.
Alluvial	Water driven sediment transport process (non-marine).
Astronomical tide	Water level variations due to the combined effects of the Earth's rotation, the Moon's orbit around the Earth and the Earth's orbit around the Sun.
Backshore	The available width of beach extending between the average high-tide mark and the vegetation, which is affected by waves only during severe storms. Backshore sand lobe migration is the longshore transport of the beach width. Backshore sand lobe migration is a dynamic process that occurs due to variations in sediment transport processes along the sandy shoreline.
Brunn Rule	The first and best known model relating shoreline retreat to an increase in local sea level is that proposed by Per Bruun (1962). The Bruun rule states that a typical concave-upward beach profile erodes sand from the beach face and deposits it offshore to maintain constant water depth. The Bruun rule can be applied to correlate sea-level rise with eroding beaches. The Bruun rule estimates the response of the shoreline profile to sea-level rise. This simple model states that the beach profile is a parabolic function whose parameters are entirely determined by the mean water level and the sand grain size. The analysis by Bruun assumes that with a rise in sea level, the equilibrium profile of the beach and shallow offshore moves upward and landward.
Cainozoic	The geological era covering the period from 66 million years ago to present. This era includes the Quaternary and Tertiary geological periods.
Calibration	The process by which the results of a computer model are brought to agreement with observed data.
Chart Datum (CD)	Common datum for navigation charts. Typically relative to Lowest Astronomical Tide.
Chenier	Discrete, elongated, vegetated marine beach ridge, sandy hummock and/or shell bodies stranded on a coastal mudflat or marsh and roughly parallel to a prograding shoreline.
Coastal Hazard	A term to collectively describe physical changes and impacts to the natural environment which are significantly driven by coastal or oceanographic processes.
Colluvium	A term used to describe loose, unconsolidated sediments that have been deposited at the base of a slope or cliff.
Delta	A complex association of geomorphic settings, sediment types and ecological habitats, at a point where a freshwater sources enters an estuarine water body.
Diurnal	A daily variation, as in day and night.
DTM	Digital Terrain Model, a three dimensional representation of the ground surface.
Ebb Tide	The outgoing tidal movement of water resulting in a low tide.

Embayment	A coastal indentation which has been submerged by rising sea-level and has not been significantly infilled by sediment.
EVC	Ecological Vegetation Class. These are the basis mapping units used for biodiversity planning and conservation in Victoria. Each EVC represents one or more plant communities that occur in similar types of environments.
Equilibrium Shoreline Recession	The cross-shore movement (i.e. landward and shoreward) of the beach profile. Sometimes referred to as shoreline retreat. The best known model for relating equilibrium shoreline recession to increases in sea level rise is that proposed by Per Brunn (1962) – the Brunn Rule. In this report equilibrium shoreline recession refers to the specific equilibrium response of a sandy shoreline to sea level rise when everything else is held constant.
Estuaries	The seaward limit of a drowned valley which receives sediment from both river and marine sources and contains geomorphic and sedimentary conditions influenced by tide, wave and river processes.
Exceedance Probability	The probability of an extreme event occurring at least once during a prescribed period of assessment is given by the exceedance probability. The probability of a 1 in 100 year event (1% AEP) occurring during the first 25 years is 22%, during the first 50 years the probability is 39% and over a 100 year asset life the probability is 63%.
Flood Tide	The incoming tidal movement of water resulting in a high tide.
Foreshore	The area of shore between low and high tide marks and land adjacent thereto.
Geomorphology	The study of the origin, characteristics and development of land forms.
GIS	Geographical Information System.
Holocene	The period beginning approximately 12,000 years ago. It is characterised by warming of the climate following the last glacial period and rapid increase in global sea levels to approximately present day levels.
Hydrodynamic Model	A numerical model that simulates the movement of water within a defined model area.
Hydro-isostasy	Deformation (depression/uplift) of the earth's crust in response to loading/unloading of water into oceanic basins.
HAT	Highest Astronomical Tide: the highest water level that can occur due to the effects of the astronomical tide in isolation from meteorological effects.
H <sub>s</sub> (Significant Wave Height)	H <sub>s</sub> may be defined as the average of the highest 1/3 of wave heights in a wave record (H <sub>1/3</sub> ), or from the zeroth spectral moment (H <sub>m0</sub> ).
Intertidal	Pertaining to those areas of land covered by water at high tide, but exposed at low tide, eg. intertidal habitat.
Intertidal Flats	Intertidal flats are un-vegetated, generally low gradient and low energy environments that are subject to regular tidal inundation and consist of sandy mud and muddy sand.
Levee	Raised embankment along the edge of a coastal or riverine environment.
LiDAR	<b>Light Detection and Ranging</b> – also known as airborne laser scanning, is a remote sensing tool that is used to generate highly accurate 3D maps of the Earth's surface.
Lithology	A description of the physical character if a rock or rock formation.
Littoral Zone	An area of the coastline in which sediment movement by wave, current and wind

	action is prevalent.
Littoral Drift Processes	Wave, current and wind processes that facilitate the transport of water and sediments along a shoreline.
Meander	A description given to a bend or sinuous watercourse.
Mesozoic	The geological era covering the period from around 252 million years ago to about 66 million years ago.
MHHW	Mean Higher High Water: the mean of the higher of the two daily high waters over a long period of time. When only one high water occurs on a day this is taken as the higher high water.
MHWM	Mean High Water Mark, i.e. the mean of high water over a long period of time.
MHWS	Mean High Water Springs, i.e. the mean of spring tide water levels over a long period of time.
MLWM	Mean Low Water Mark, i.e. the mean of low water over a long period of time.
MSL	Mean Sea Level.
Neap Tides	Neap tides occur when the sun and moon lie at right angles relative to the earth (the gravitational effects of the moon and sun act in opposition on the ocean).
Nearshore	The region of land extending from the backshore to the beginning of the offshore zone.
Paleochannel	A remanent of an inactive river or stream channel that has been either filled or buried by younger sediment.
Palaeozoic	The geological area covering the period from about 541 to 252 million years ago. Incorporates the Devonian, Silurian, Ordovician, and Cambrian geological periods.
Paludal	Sediments that have accumulated in a marshy or swampy environment.
Physiography	The study of the physical patterns and processes of the environment to understand the forces that produce and change rocks, oceans, weather, and flora and fauna patterns.
Pleistocene	The period from 2.5M to 12,000 years before present that spans the earth's recent period of repeated glaciations and large fluctuations in global sea levels.
Regolith	A layer of unconsolidated weathered material overlying bedrock.
Semi-diurnal	A twice-daily variation, e.g. two high waters per day.
Shoal	A shallow area within a water body; a sandbank or sandbar.
Sea Level Rise (SLR)	A permanent increase in the mean sea level.
Spring Tides	Tides with the greatest range in a monthly cycle, which occur when the sun, moon and earth are in alignment (the gravitational effects of the moon and sun act in concert on the ocean).
Storm Surge	The increase in coastal water levels caused by the barometric and wind set-up effects of storms. Barometric set-up refers to the increase in coastal water levels associated with the lower atmospheric pressures characteristic of storms. Wind set-up refers to the increase in coastal water levels caused by an onshore wind driving water shorewards and piling it up against the coast.
Storm tide	Coastal water level produced by the combination of astronomical and meteorological (storm surge) ocean water level forcing.

Sub-aerial	Processes that take place on the land or at the earth's surface as opposed to underwater or underground.
Susceptibility	The sensitivity of coastal landforms to the impacts of coastal hazards such as sea-level rise and storm waves. This may include physical instability and/or inundation.
Tidal Planes	A series of water levels that define standard tides, eg. 'Mean High Water Spring' (MHWS) refers to the average high water level of Spring Tides.
Tidal Prism	The volume of water moving into and out of an estuary or coastal waterway during the tidal cycle.
Tidal Range	The difference between successive high water and low water levels. Tidal range is maximum during Spring Tides and minimum during Neap Tides.
Tides	The regular rise and fall in sea level in response to the gravitational attraction of the Sun, Moon and Earth.
Vulnerability	Vulnerability is a function of exposure to climatic factors, sensitivity to change and the capacity to adapt to that change. In this report it means the degree to which a natural system is or is not capable of adapting or responding to the impacts of coastal hazards to which they are physically susceptible and exposed.
Wind Shear	The stress exerted on the water's surface by wind blowing over the water. Wind shear causes the water to pile up against downwind shores and generates secondary currents.



# 1. INTRODUCTION

## 1.1 Background

Melbourne Water commissioned Water Technology to undertake the Western Port Local Coastal Hazard Assessment (WPLCHA) project. The project has come about through a partnership between Melbourne Water, the Department of Environment and Primary Industries, South East Councils Climate Change Alliance, Bass Coast Shire Council, Cardinia Shire Council, City of Casey and Mornington Peninsula Shire Council.

The WPLCHA is a component of the Department of Environment and Primary Industries Future Coasts program, and Western Port is one of four priority sites in which local coastal hazard assessments have or are currently being undertaken in Victoria.

## 1.2 Scope

As detailed in the project brief, the scope of the WPLCHA is to provide information on the extent of coastal hazards and their physical impacts for the Western Port coastal environment. The WPLCHA is focussed on assessing the physical hazards of erosion and inundation. It does not include any subsequent detailed assessment of impacts of the hazards on built, economic or social infrastructure, assets or values and does not include preparing adaptation responses to the physical hazards.

The information developed by the project will assist in planning for and managing coastal hazards. It will allow management agencies and other key stakeholders to identify and define triggers as the basis for short, medium and long term management responses. Specifically, the information will provide information, data and mapping to inform consistent policy and practice and support agencies in identification and management of risk, and undertake; strategic planning, statutory planning, infrastructure maintenance and replacement schedules, natural asset management, and business planning and budgetary processes that are responsive to a changing climate, its impacts and opportunities.

The boundaries of the study area for the WPLCHA project are described as follows:

- Cape Schanck to West Head, along the shoreline of Western Port to the bridge at San Remo
- Inland from the Western Port shoreline will remain undefined enabling the assessment to be as far into the catchment as relevant
- All of the coast of French Island and the north side of Phillip Island from the bridge at Newhaven to the western extremity of Phillip Island (Seal Rocks), but excluding the south side of Phillip Island from Seal Rocks to the Bridge at Newhaven.

The study itself was undertaken in two main components:

- Part A - a broad scale Western Port wide coastal hazard assessment, and
- Part B - four local scale coastal hazard assessments.

The broad scale of the Part A assessment refers to the spatial extent of the study area, while the Part B local scale assessments are focussed on specific sections of the Western Port shoreline. The scale of the outputs and any associated uncertainties from each component is discussed in detail within the relevant project reports.

## 1.3 Representative Locations

The Part A assessment comprised two aspects; an inundation hazard assessment, and an erosion hazard assessment at a Western Port wide scale. An outcome of these assessments was the

identification of a number of locations within the study area which were particularly vulnerable to significant hazard impacts from one or both of these sources and/or a significant degree of uncertainty in relation to the potential extent of the hazard impacts was considered to exist.

Recommendations were made at the completion of Part A as to which locations warranted further more detailed local scale investigations in Part B of the project. In developing these recommendations consideration was given to selecting sites that were:

- Representative of the range of shoreline types identified in Part A.
- Provided examples of the key physical processes, related to both inundation and erosion hazards, and
- Took into consideration a range of shoreline asset classes, such as economic, social/cultural, ecological, geological/geomorphological, and archaeological.

Based on discussions with the project steering committee, four locations were then selected as representative locations and agreed upon by the Steering Committee for the Part B assessment, and included:

- Somers (Mornington Peninsula Shire Council)
- Tooradin and coastal villages (City of Casey)
- Lang Lang shoreline – Main drain to Jam Jerrup (Cardinia Shire Council)
- Rhyll Inlet and Silverleaves (Bass Coast Shire Council)

An outline of each representative location study extent is shown in Figure 1-1. This report describes the assessment of the four representative locations.



**Figure 1-1 Outline of Part B Local Coastal Hazard Assessment Locations and Extents**



## 1.4 Reporting & Outputs

This document (Report 6) is part of a series of reports produced as part of the Western Port Local Coastal Hazard Assessment project. It should be read in conjunction with Part A of the project, which is documented in Reports 1-5, as follows:

- Report 1: Summary Report (R01)
- Report 2: Data Review (R02)
- Report 3: Methodology Overview (R03)
- Report 4: Inundation Hazards (R04)
- Report 5: Erosion Hazards (R05)
- **Report 6: Review of Representative Locations (R06)**

Accompanying these documents is a project geographical information system (GIS), which includes the following outputs from the inundation and erosion assessments:

- Digital geo-referenced data, including shape files of inundation and erosion hazard areas and maximum water surface level contours from the storm tide scenarios for the existing and future sea level rise scenarios.
- Digital field data acquired for the study, including location, elevation and summary output.
- Relevant model set-up and run files.

## 1.5 Methodology for Representative Location Assessments

### 1.5.1 Hazard Assessment

The focus of the representative location assessments in Part B has been to review available site specific data, knowledge and models for each location, with the objective of reducing or testing the extent of uncertainty in the potential coastal hazard impacts associated with sea level rise.

Due to the fundamental differences in the geology and physical environment at each location, the methodology employed to assess the potential extent of coastal hazards has been tailored to the specific geologic setting and representative processes of interest at each site. The methodology undertaken has however been structured with the following main components:

- A detailed review of:
  - The local geology, coastal geomorphology, and sediment movement;
  - The local hydrodynamic influences, such as waves or currents based on the existing hydrodynamic and wave models;
  - Existing coastal structures, focussing on those within the DEPI coastal asset database (Vic\_Coastal\_Protection\_Structures\_WP.shp, provided by DEPI on 29/1/13). The DEPI coastal asset database has been used as the basis for assessing the presence of coastal structures within each representative location. Informal or private structures were not specifically reviewed, except for the Lang Lang study area where informal levees and banks have a significant impact on the potential coastal inundation and erosion hazards, and at Silverleaves where a rock revetment along the front of the coastal dune was not included in the asset database but is a significant structure along this section of shoreline.
  - Where relevant, any potential groundwater impacts as identified during the high level review in Part A of the project.
- Identification of the key local hazards and assessment of historic changes and potential future rates of change under sea level rise scenarios;
- Evaluation of the significance and sources of uncertainty in the analysis;
- Updated mapping of coastal inundation and erosion hazard zones; and

- An example risk analysis of the potential likelihoods and consequences of the various hazards identified.

The analysis of local coastal hazards has adopted a precautionary approach with respect to the effect of existing coastal structures on inundation and erosion hazards. In locations where a coastal structure is present that is currently or has in the past provided some form of protection against local erosion the determination of the erosion hazard zone does not consider the presence of the structure in limiting potential future erosion, except for a small number of specific coastal infrastructure related structures detailed in Table 1-1. This is because many of the coastal structures in Western Port are informal and/or poorly designed and constructed and they are vulnerable to damage or failure due to extreme storm events or chronic exposure to wave action. Erosion hazards landward of these structures may develop quickly during future events if the structure is not maintained and upgraded to relevant engineering design standards. This approach is in keeping with the approach adopted for other coastal hazard assessments in Victoria and also in the recently released Queensland Coastal Hazard Technical Guidelines, EHP (2013).

In the locations detailed in Table 1-1 and shown in Appendix C (some of which are within the broad study area but outside the representative locations) the erosion hazard zone extent has been reduced due the presence of coastal engineering structures at these locations. These locations and associated coastal structures are typically major marine infrastructure such as ports, harbours, or boat ramps, and may include sections of rock seawall or revetments as part of the infrastructure. It has been considered that the coastal structures in these locations will be maintained and upgraded to an approved engineering design into the future and that any such repairs as are required would be promptly addressed.

**Table 1-1 Coastal structures specifically included within coastal hazard layers**

Location	Structure
Cowes	Jetty
Newhaven	Newhaven – Phillip Island Bridge
Tooradin	Rock wall adjacent to the tidal gates at Sawtells Inlet and rock revetment extending to the boat ramp.
Sommerville	Yaringa Boat harbour
Blind Bight	Boat Ramp
Hastings	Port of Hastings
Hastings	Hastings Marina
Crib Point	Jetty
Stony Point	Jetty
Cerberus	Defence Base

### 1.5.2 Summary of Coastal Hazards and Associated Uncertainty

A summary of the coastal hazard analysis including commentary around the uncertainty in particular erosion or inundation hazard processes, knowledge, or future conditions, for each representative location has been provided in tabulated form as guidance on the significance of the individual components of coastal hazard and to inform subsequent detailed risk assessments.

The summary provides information on the likelihood and uncertainty of each relevant coastal hazard component within the location over relevant timeframe/sea level rise scenarios this century. The likelihood scales has been adopted from the Victorian Coastal Hazard Guide (2012).

Table 1-2 displays a description and semi-quantitative probability that has been assigned to the range of coastal hazard likelihoods, while Table 1-2 outlines the various levels of uncertainty assigned to the different hazards. The purpose of the uncertainty rating is to highlight which aspects of the coastal hazard assessment may impact upon both the erosion or inundation hazard susceptibility, what the implications are in relation to utilisation of the information for decision making or adaptation planning, and options available to reduce this uncertainty.

**Table 1-2 Coastal Hazard Likelihoods**

Likelihood Level	Description
Very Unlikely	Hazard will only occur in exceptional circumstances
Unlikely	Hazard not likely to occur within the period
About as Likely as not	Hazard may occur within the period
Likely	Hazard likely to occur within the period
Virtually Certain	Hazard will occur within the period

**Table 1-3 Uncertainty and Implications on Decision Making**

Uncertainty	Description	Implications on Appropriate Scales for Decision Making	Options to Reduce Uncertainty
Low	Available data, theoretical basis and/or available assessment methods are sufficient such that a relatively low level of uncertainty as to the likely hazard extent is considered to exist for a given sea level rise/timeframe scenario.	The hazard assessment is considered to provide information that can support decision making at a lot/parcel scale with appropriate precautions.	Relatively minor refinement of existing assessments may improve local scale accuracy/ confidence at some locations.
Moderate	The theoretical understanding of the hazard may be sound; however the physical processes and/or rates of change may be sensitive to assumptions/limitations in available data and/or available assessment methods.  Alternatively, the hazard extent may be particularly sensitive to possible future adaptation responses to the hazard.	The hazard assessment may provide information that can support decision making at a lot/parcel scale however, consideration of the consequence of uncertainty/assumptions on expected rates of change and/or future adaptation responses should be evaluated to determine their potential significance to the particular location of interest.	Ongoing data collection and refinement of existing assessments as well as clarification of likely strategic adaptation responses would reduce uncertainty and improve confidence for decision making at a lot parcel/scale.
High	Available data, theoretical basis and/or available assessment methods contain fundamental deficiencies such that a high level of	The hazard assessment is only considered accurate to within an order of magnitude and is not suitable for lot/parcel scale	Significant additional data collection and major studies are required to reduce uncertainty.  The complexity of the



<b>Uncertainty</b>	<b>Description</b>	<b>Implications on Appropriate Scales for Decision Making</b>	<b>Options to Reduce Uncertainty</b>
	uncertainty in the physical processes/rates of change and subsequent hazard extent is considered to exist for a given sea level rise/timeframe scenario.	<p>decision making.</p> <p>The hazard assessment should only be considered for strategic decision making at landform/settlement scales.</p>	physical processes and their stochastic nature may however result in significant residual uncertainty that fundamentally limits the scale at which decision making can be sensibly applied to this hazard.

## 2. BALNARRING TO SOMERS

### 2.1 Overview

The Balnarring to Somers representative location shoreline extends from Point Sumner (eastern Merricks Beach), eastward to the beginning of the Sandy Point landform as displayed in Figure 2-2.

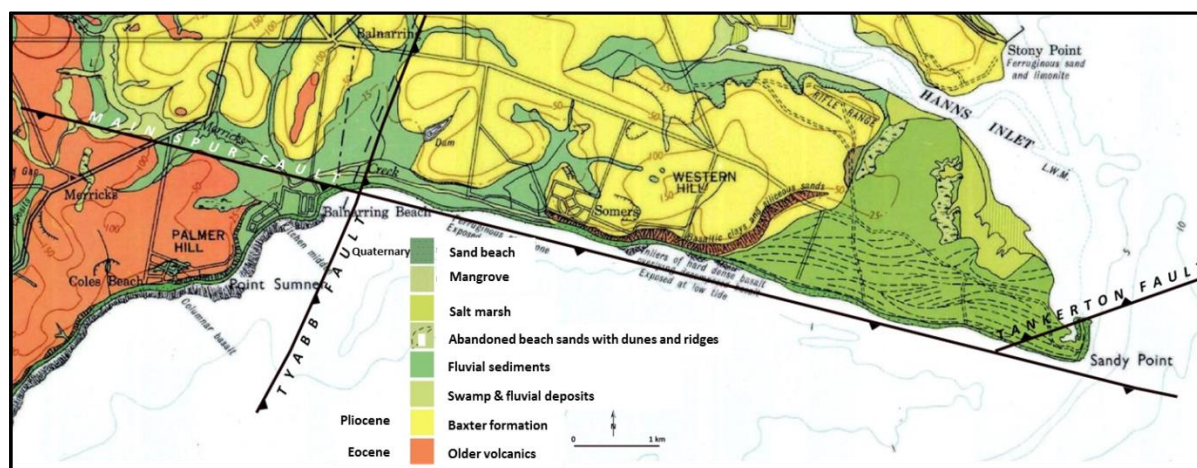
The assessment extent incorporates a relatively diverse range of shoreline types including platform beach and bluff and sandy spit type shorelines classes as defined in the Part A assessment, Report 5. It also includes an estuarine shoreline associated with the outlet of Merricks Creek.

The characteristics and susceptibility of this shoreline to coastal hazard impacts is integrally related to the nature and variations in geology, geomorphology and the hydrodynamic setting. The following sections provide an overview of the nature and variability of the physical environment of the critical location as a basis for understanding the potential type, extent and susceptibility of the shoreline to coastal hazards and sea level rise.

#### 2.1.1 Geology

##### *Faults*

The orientation and broad physical character of this area is determined by lithology and structural geology modified by sub-aerial and marine processes. The Tyabb Fault which extends from near Flinders to northwest of Hastings, and continues as the Clyde Monocline, was described by Keble (1950) as a bedrock strike fault with a displacement (uplift to the west) of approximately 60 metres producing the high coastline between Flinders and Balnarring. It is the major bounding fault of the western margin of the Western Port Sunland and the eastern margin of the Mornington Peninsula uplands. The west-east trending Main Spur Fault crosses the Tyabb Fault at Balnarring. The displacement decreases to the east but uplift to the north is sufficient to determine the position of the coast east of Balnarring (Figure 2-1).



**Figure 2-1 Geology and Structure, Balnarring to Sandy Point (after Western Port 1:63,360 Geological Map 1963, Jenkin 1962).**

##### *Older Volcanics & Baxter Formation*

Basalt lava, tuff and volcanic agglomerate are exposed east of Balnarring; the hard basalt is exposed as columnar jointed blocks in only two shore sectors at Balnarring. East of Somers, the basalt is overlain by deeply weathered ferruginised Baxter Formation sandstone and clay.

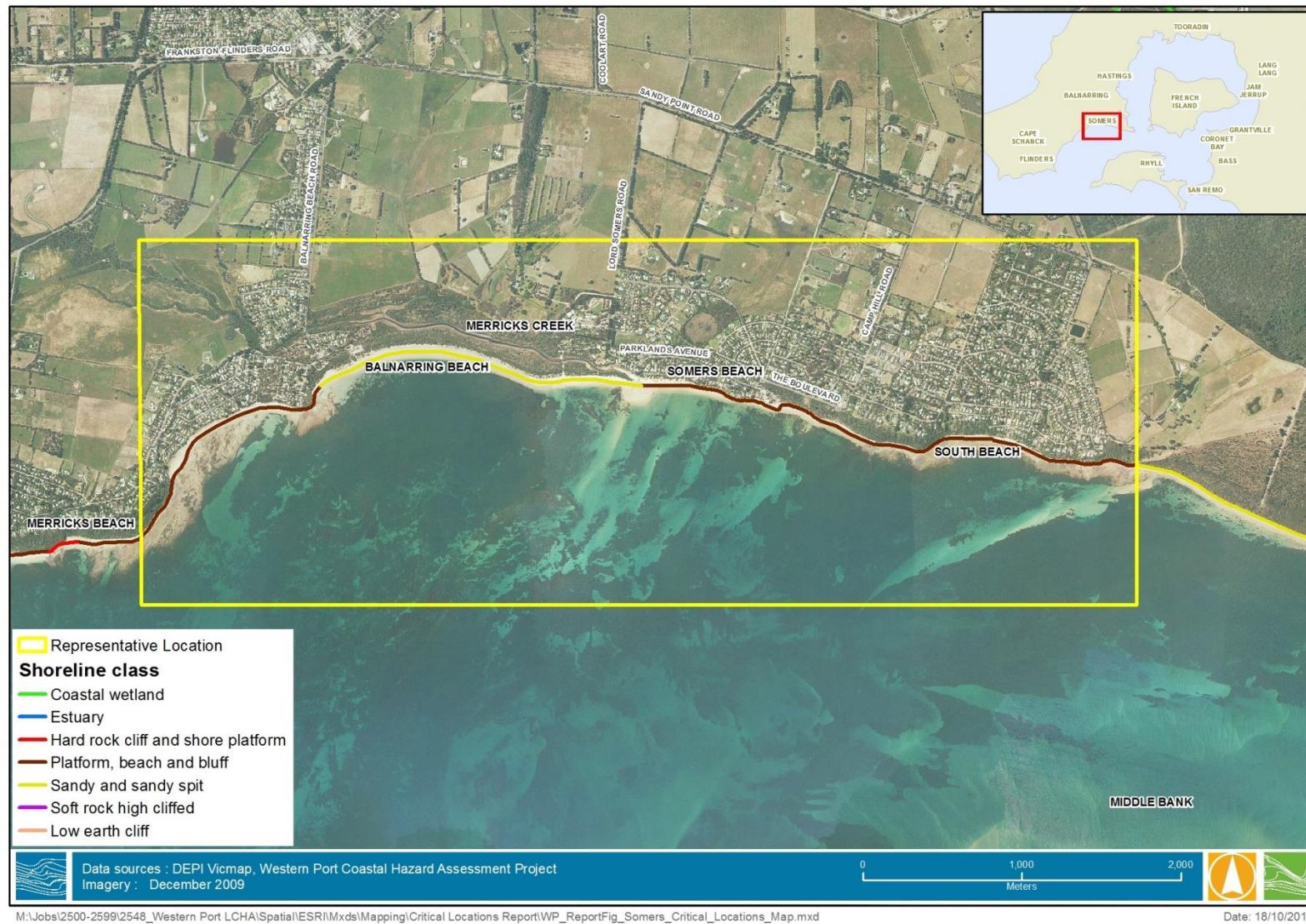


Figure 2-2 Somers Study Area Locality Plan



## Quaternary Sediment

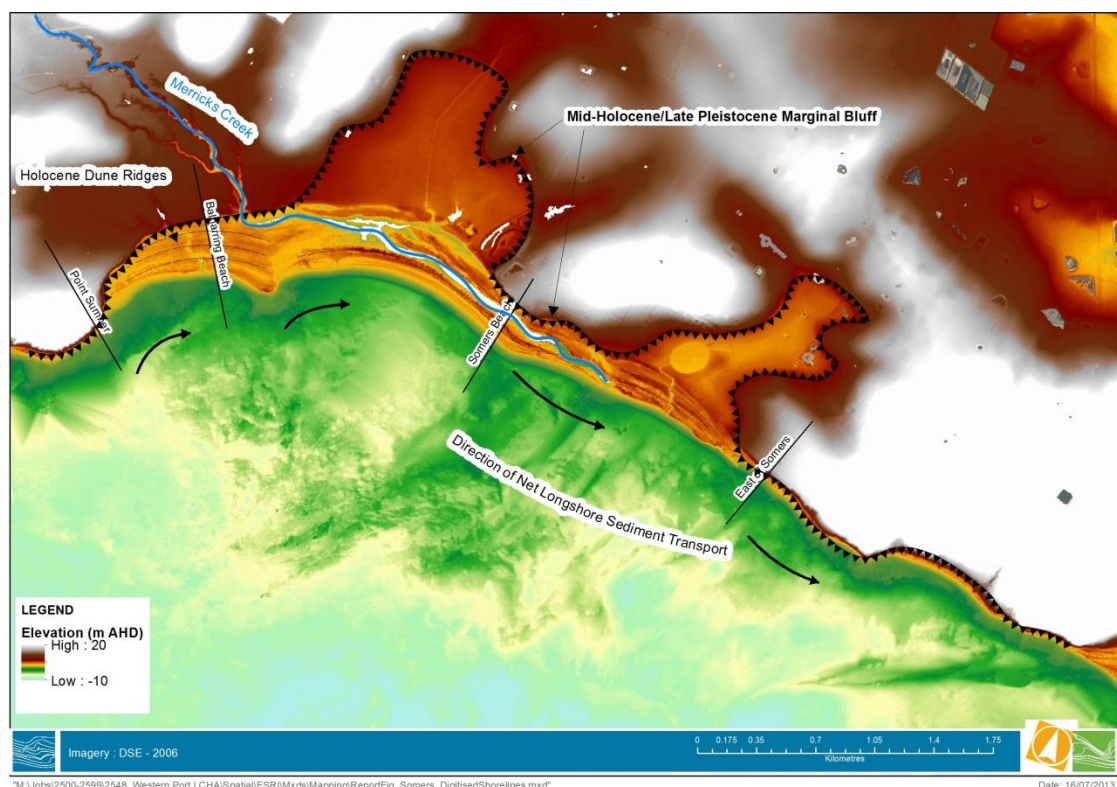
The basalt and sandstone formations are generally covered by a variable thickness of unconsolidated sediments of fluvial, colluvial, aeolian and marine origin. Coastal deposits are described in more detail below.

### 2.1.2 Coastal Geomorphology

During the mid-Holocene a shallow embayment existed between the headlands of Point Sumner and Somers. The landward margin of the embayment is delineated by a series of bluffs that mark the location of higher sea level cliffed shorelines, cut initially in the last interglacial and briefly reactivated during the mid-Holocene period. The embayment is now largely filled by longshore drifting sand that has been trapped between the headlands forming a broad sandy plain in front of the bluffs.

The immediate hinterland geomorphology is complex. Keble (1950) recognised several instances of river capture resulting in a composite system of active and relict valleys and channels. The flow of Merricks Creek has been augmented by capture of Coolart Creek, formerly the main tributary to East Creek (that enters just north of Point Leo). The valley of Tulum Creek (tributary of Merricks Creek west of Balnarring Beach Road) is one of two broad, low valleys either side of the Somers ridge. These are higher sea-level former embayments, now filled with sediment with weakly incised channels. The eastern valley may be a former outlet of Tulum Creek.

Middle Bank is a broad, shallow sandy body that extends from Sandy Point to the southwest towards Somers. Middle Bank is a particularly high energy environment where tidal current and wave action contribute to create a variety of sand wave bedforms. The orientation and asymmetry of these bedforms indicate a dominant west to east, flood tide transport across Middle Bank (Marsden & Mallet, 1974).



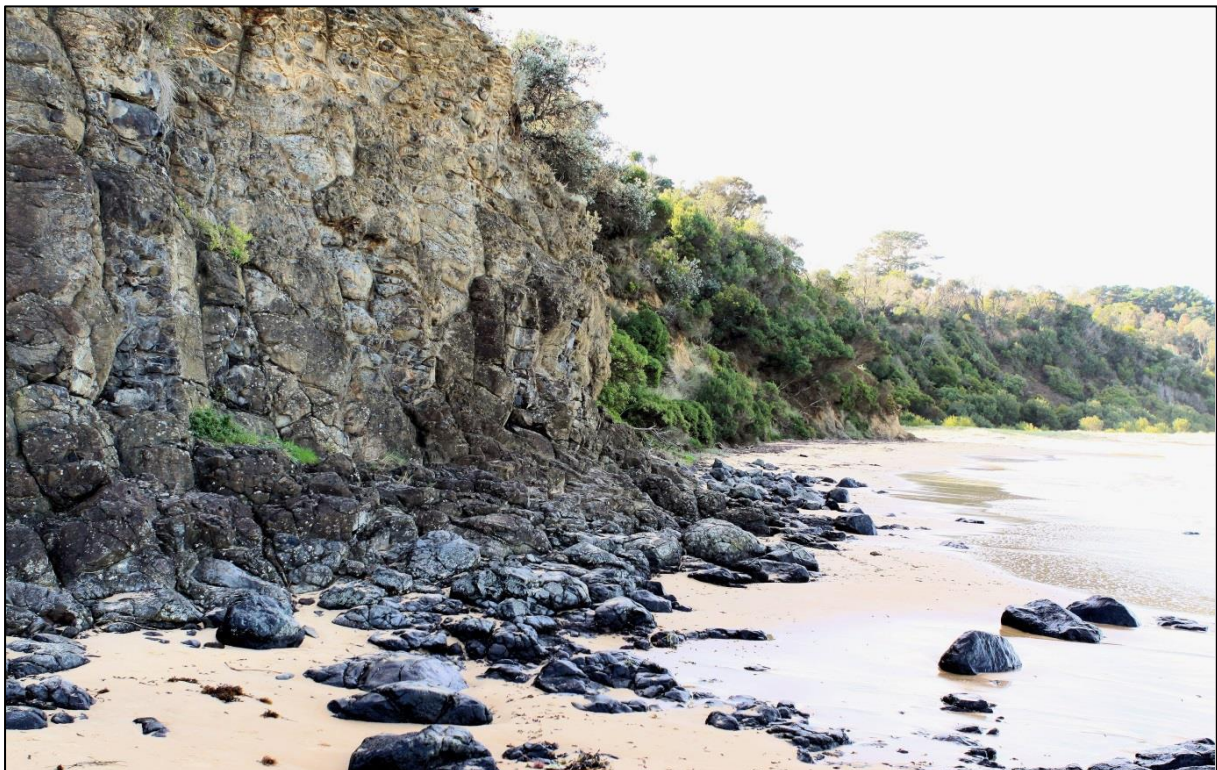
**Figure 2-3 Coastal Geomorphology of Balnarring-Somers Study Area**

### ***Platform Beach and Bluffs***

From Point Sumner east to South Beach, the shoreline is backed at a variable distance by steep slopes in consolidated rocks (mainly Older Volcanics with an overlay of Baxter Formation). Three very short sections of shoreline have active cliffs (Figure 2-4) of exposed basalt, but for the most part the slopes are scrub-covered bluffs fringed by platform beaches and foredunes.

These formations formed active cliffs at the last interglacial higher sea-level and were briefly reactivated during the mid-Holocene higher sea-level. Most of these earlier active cliffs are now regolith-covered coastal and valley-side bluffs with a continuous vegetation cover.

Although the shoreline and seafloor is likely to be underlain by an extensive planed-off rock shelf, there is only discontinuous exposure and the near shore depths are quite variable. A shore platform and reef flat of variable elevation is exposed at low tide between Point Sumner and Balnarring Beach foreland and also from Somers to South Beach. It is mainly composed of fresh to weathered basalt.

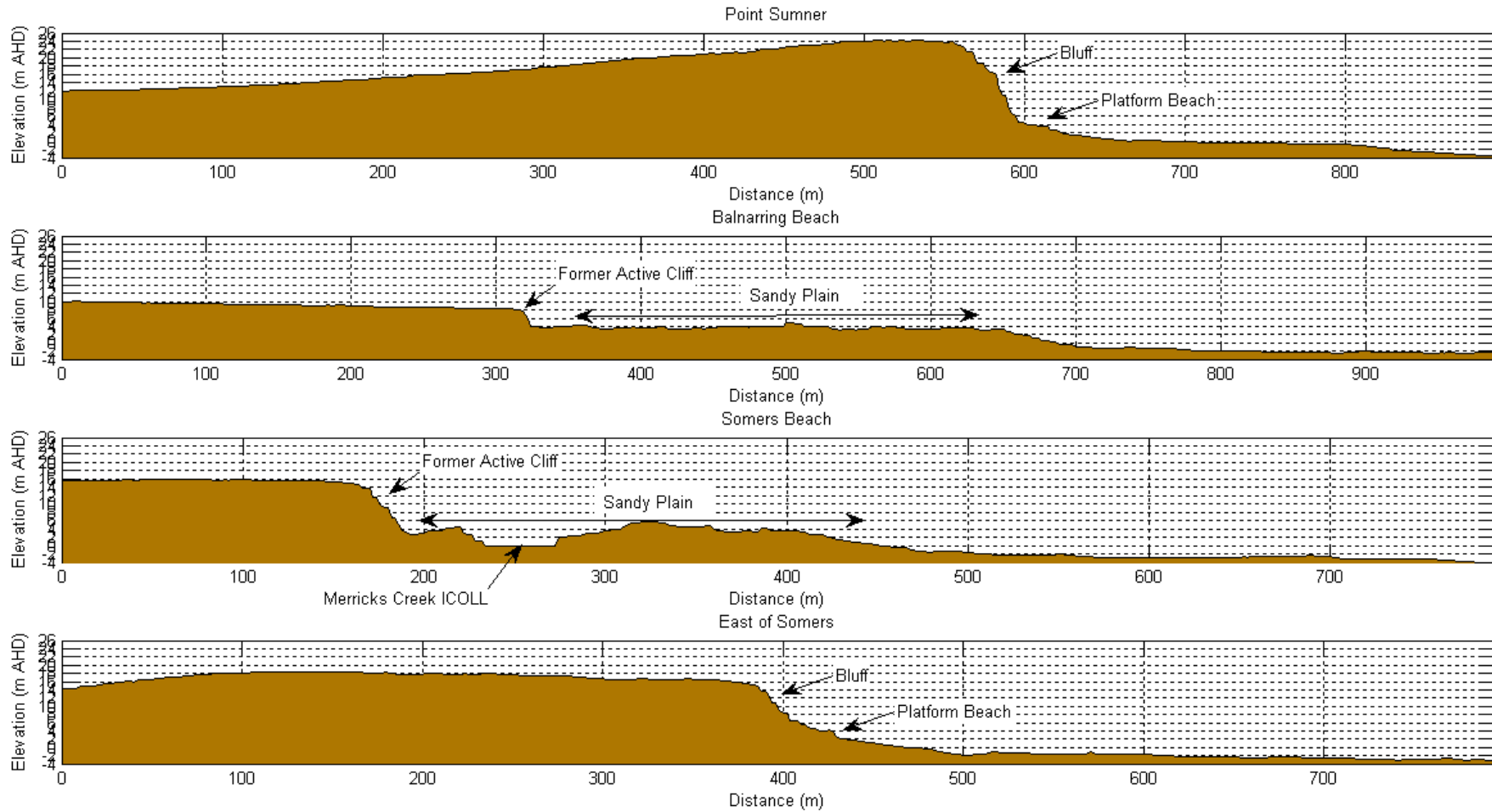


**Figure 2-4** Cliff of Columnar Basalt at Sumner Point. Weathered basalt at cliff top and in bluffs to the east. Sand covers the Shore Platform. (Photo: Neville Rosengren, 7 June 2013).

### ***Sandy and Sandy Spit***

A relatively continuous sandy beach backed by dune ridges and swales extends 4.5 km from Sumner Point to the headland east of Somers Beach. The beach is the outer edge of a broad sand plain that partially fills an embayment between these headlands. It is a complex terrain as it includes two defined sand barrier ridge systems, the swale between the ridges now being the estuarine-tidal channel of Merricks Creek (Balnarring Beach & Somers Beach cross sections as shown in Figure 2-5).

The beach face is generally narrow and steep. A substantial volume of seagrass can accumulate on the beach face at low tide and in places forms a cover up to one metre thick. The headland at Balnarring Beach is built on a slight rise in the level of the shore platform that anchors the foredune ridges.



**Figure 2-5 Representative Cross-Sectional Profiles of the Somers Study Area (cross-section locations displayed in Figure 2-3)**



### ***Merricks Creek Estuary***

The lower reaches of Merricks Creek are classed as an estuarine and tidal channel shoreline type and can be described as an 'intermittently closed and open lake or lagoon' (ICOLL). ICOLL's are common on wave dominated shorelines where waves have built a sandy barrier across a natural catchment outlet and where the catchment streamflows are relatively small or intermittent.

The Merricks Creek ICOLL has historically been deflected eastward by the longshore drifting of sediment. In the 1960s, however, the location of the creek entrance (mouth) was fixed by via the construction of training walls on either side of the creek outlet.



**Figure 2-6 Merricks Creek Mouth (Photo: Neville Rosengren, 8 June 2013)**

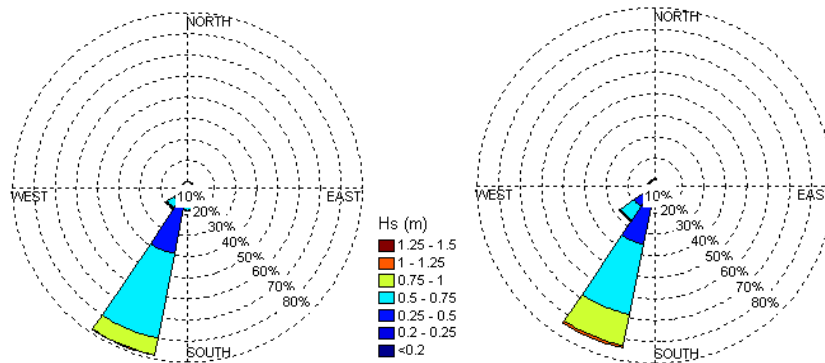
### **2.1.3 Hydrodynamic Setting**

The following section summarises aspects of the hydrodynamic setting of the Balnarring to Somers study area relevant for the assessment of coastal erosion and inundation hazards.

#### ***Waves***

The wave energy that arrives at the Balnarring-Somers study area is comprised of residual ocean swell waves that have been refracted through the Western Entrance of Western Port. These waves arrive almost exclusively from the south-south-west as can be seen from the results of the wave climate analysis shown in Figure 2-7. The wave climate is also influenced by locally generated wind waves within the Western Entrance of Western Port. Wave heights are generally relatively small at Somers with a significant wave height of generally less than 0.5 m.

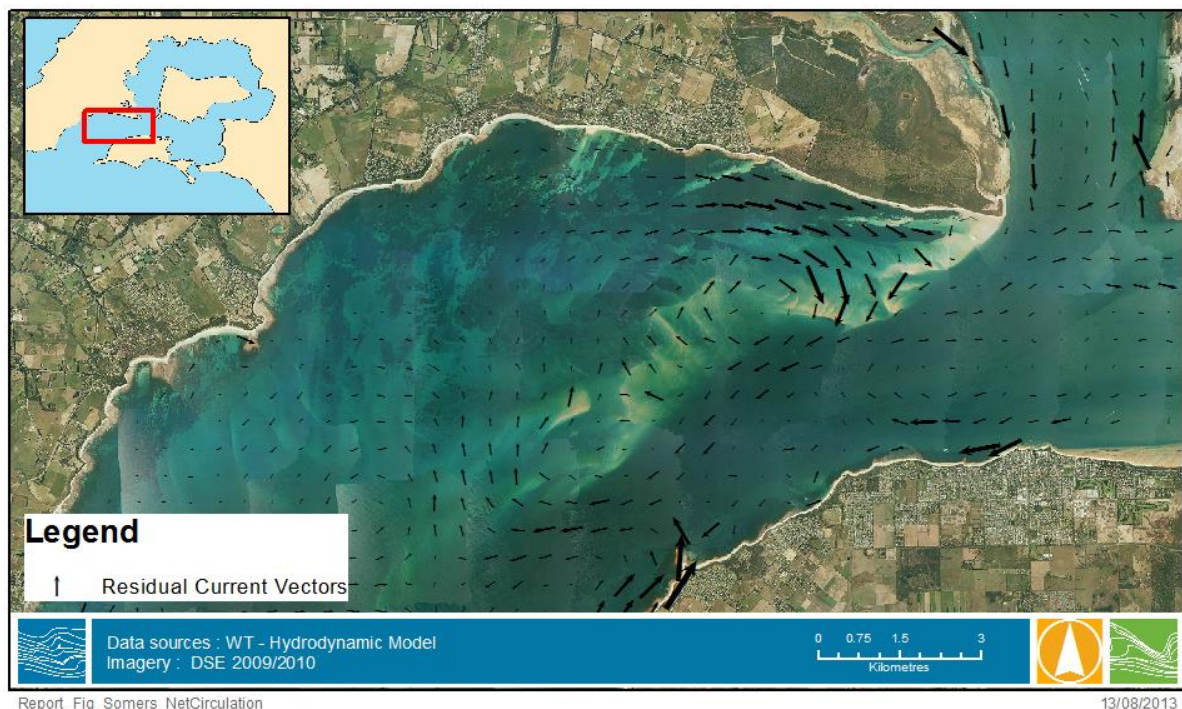
It is evident from close analysis of the wave climate that wave conditions at Somers are modulated by ebb and flood tide current flows through the Western Entrance. During ebb tide conditions, a combination of wave-current blocking and wave-current refraction tends to reduce wave heights compared to flood tide conditions.



**Figure 2-7 Wave Roses – Summer (2003), and Winter (2003)**

**Tidal and Wind Driven Currents**

Variations in the bathymetry of the Western Entrance, the asymmetry in the flood and ebb tide flows into and out of Western Port, and the coriolis effect contribute to a significant net eastward current drift along the shoreline of the study area. Figure 2-8 displays the predicted net current speeds and directions through the Western Entrance from a representative 12 month simulation in the hydrodynamic and spectral wave model (see Report 4 – Appendix B for more detail) and clearly show the strong eastward residual current drift in this region of Western Port.



**Figure 2-8 Residual Tidal and Wave Current Vector Plot**

**2.1.4 Sediment Movements**

These tidal currents and circulation patterns drive the movement of sediment throughout the bay. This zone from the Western Entrance to just beyond Sandy Spit, is the most dynamic of Western Port, exposed to strong tidal currents and varying degrees of wave activity. Channel sediment,



offshore banks and coastal deposits are almost entirely sand. The combination of net flow and wave induced transport make it a zone of strong inward movement of sand, providing a supply to offshore sand bars and the beaches along Balnarring/Somers and along the northern shore of Phillip Island.

### 2.1.5 Coastal Structures

Significant lengths of the study area shoreline have been modified by the construction of coastal structures in an effort to protect development from the highly variable nature of the shoreline that is observed within this study area. The existing coastal structures as defined by the DEPI coastal asset database are shown in Figure 2-9.



**Figure 2-9 Extent of the Coastal Structures in the Balnarring-Somers Study Area**

#### ***Balnarring Beach Revetment and Groynes***

The shore protection structures at Balnarring Beach consist of a series of timber groynes and a rock revetment, shown in Figure 2-10 and Figure 2-11.

The groyne field consists of 4 timber groynes located perpendicular to the shoreline at Point Sumner. The structural condition of the groynes within the study area is generally poor with the majority of the pile and slats displaying signs of significant deterioration. At the time of this study the majority of groynes were exposed to varying depths over significant sections of their length.

The purpose of groynes is to capture the long shore sediment transport resulting in accretion of sand on the updrift side of the groynes. The groyne field may be providing a potentially important function in limiting the level that the beach can lower directly in front of the rock revetment at their rear during periods of low sand supply and or storm conditions. Loss of sand from the footings of the rock revetment is a common failure mechanism of these types of structures.

The rock revetment is located along the dune line to the rear of the timber groynes. It consists of dumped rock of a range of sizes and the surface is currently uneven and eroded in a number of locations. The revetment provides protection to the dune line against the impact of waves and associated shoreline erosion.



**Figure 2-10 Timber Groynes at Balnarring Beach**



**Figure 2-11 Rock Revetment at Balnarring Beach**



### ***Merricks Creek***

In the late 1960s construction of timber training walls was undertaken to constrain the location of the entrance of Merricks Creek. The extent of the original coastal engineering works also included a number of additional components:

- An eastern and western timber training wall at the Merricks Creek entrance.
- Lateral spur dykes constructed on the eastern training wall to deflect flows away from the wall and prevent scour and undermining of the timber wall pile foundations.
- A timber seawall connected to the western training wall that was constructed to mitigate shoreline recession west of the entrance.
- Timber groynes constructed perpendicular to the seawall to trap sand and mitigate shoreline recession.

Currently the entrance training walls consist of the western timber training wall and an extensive rock training wall along the eastern side of the entrance, extending for some distance upstream, as shown in Figure 2-12.



**Figure 2-12 Merricks Creek Entrance Structures**

### ***Somers Sea Wall***

A large rock sea wall has been constructed along the shoreline at Somers. This wall extends from in front of the Somers yacht club for a distance of approximately 300m. The main section of the wall in front of the yacht club appears well constructed and in good condition.

Further west along the beach are sections of private sea wall, which have been outflanked previously by erosion, Figure 2-14.



Looking West

Looking East

**Figure 2-13 Sea Wall at Somers in front of the Yacht Club**



**Figure 2-14 Sections of Private Sea Wall at Somers**



### 2.1.6 Historic Shoreline Change

A series of seven geo-referenced historical aerial photographs of Somers beach covering the period from 1957 to 2009 were provided by DEPI for this project. An additional four historical aerial photographs (1966-1989) of Merricks Creek were also available from previous studies of the area undertaken by Water Technology.

Analysis of historic shoreline change in the study area was undertaken by digitising the inferred stable vegetation line for each aerial photograph. The digitised shorelines were then overlaid, allowing for trends in shoreline position to be identified. Figure 2-15 displays the historical shoreline analysis for Somers Beach. Figure 2-16 displays the historical shoreline analysis for Merricks Creek.

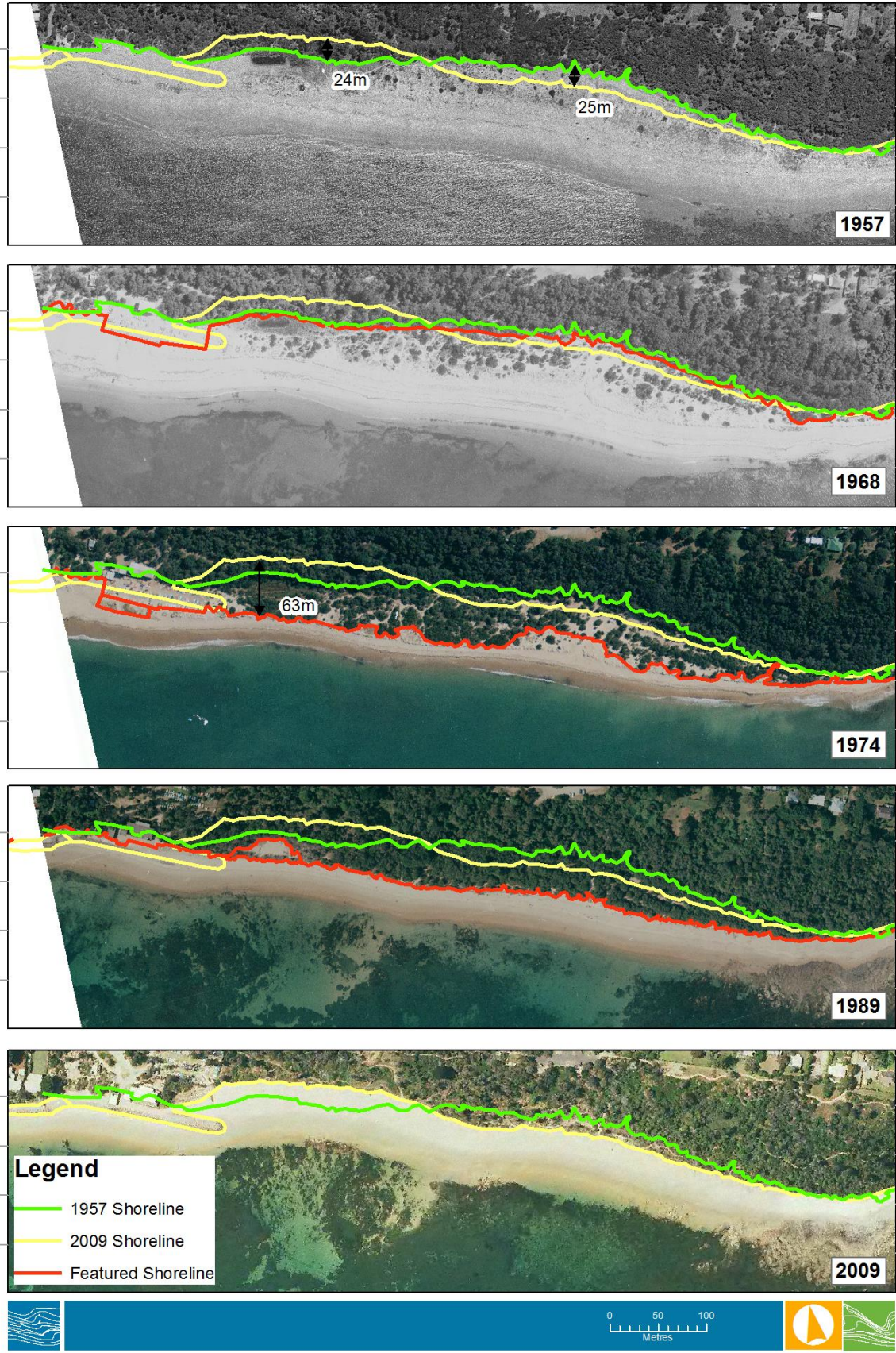
The historical aerial photography of the shorelines displayed in Figure 2-15 and Figure 2-16 highlight the extent of underlying variability in the shoreline position at this location. The following relevant changes to the shoreline position are discussed below:

#### ***Somers Beach (Figure 2-15)***

- Between 1957 and approximately 1974, the shoreline consistently advanced seaward as a broad lobe of sand migrated eastward past this location. The advancing shoreline enabled the Somers Yacht Club and other development to be built at locations that had historically been part of the active beach.
- As the broad sand lobe slowly migrated eastward in the 1980s, these locations were impacted by shoreline recession and a rock revetment was progressively extended eastward, to protect residential development and the Somers Yacht Club. However, despite extensive erosion around the eastern end of the rock revetment, the shoreline immediately eastward is still approximately 24 m more landward of its position in 1957. Further to the west, the shoreline is however currently approximately 25 m seaward of its position in 1957.
- From 1974 to 2009, terminal erosion scour east of the rock revetment protecting the Somers Yacht Club has resulted in a localised maximum recession of approximately 63 m.

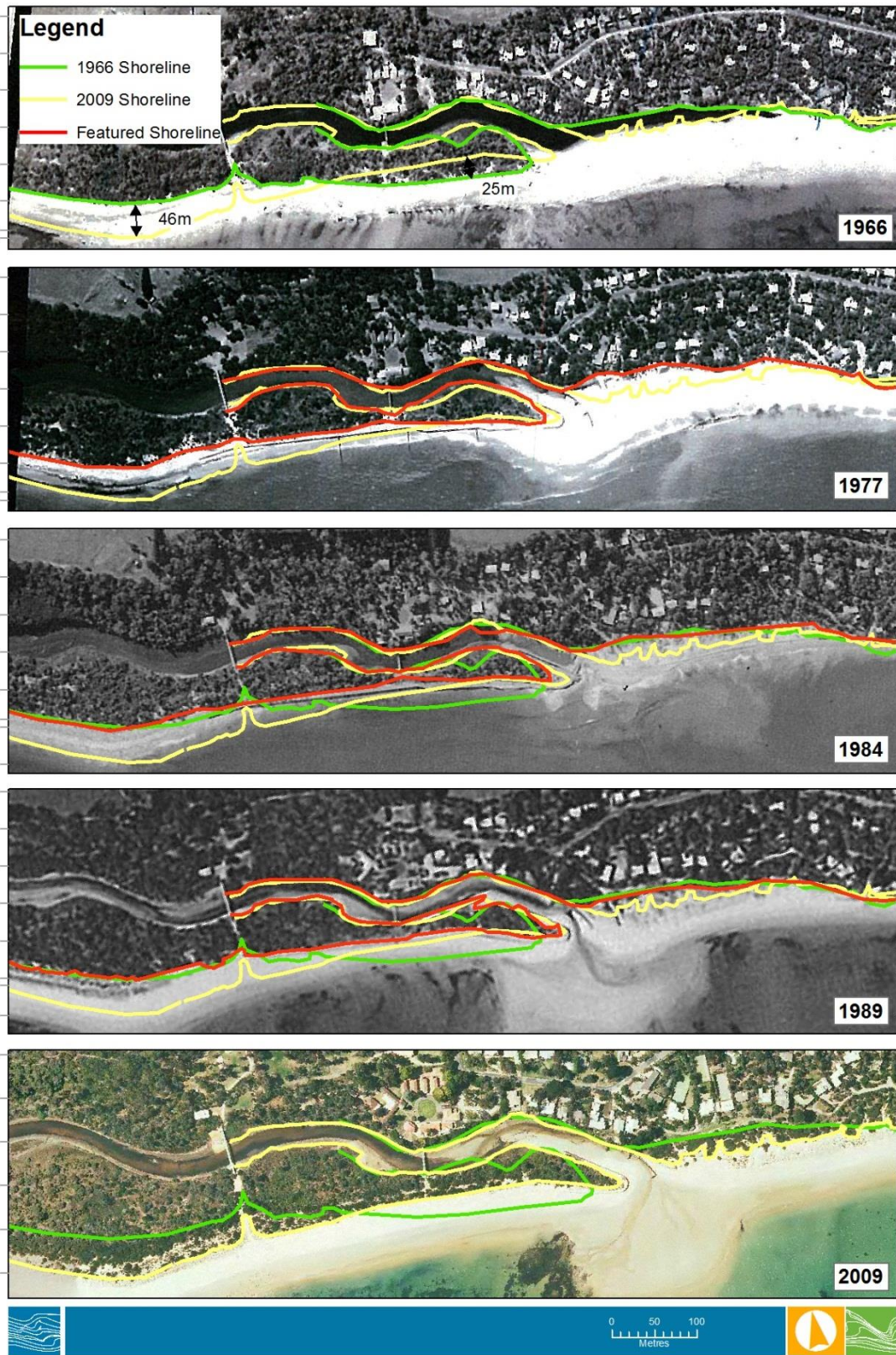
#### ***Merricks Creek (Figure 2-16)***

- Prior to the training of the Merricks Creek entrance during the 1970s, the entrance in 1966 was approximately 350 m eastward of its present location.
- Following the training of the Merricks Creek entrance, the shoreline to the east gradually prograded through to 2013.
- Between 1966 and 1977, the shoreline west of Merricks Creek receded significantly, exposing a timber sea wall and groyne field that were previously buried.
- By 1989, a broad lobe of sand began to migrate into the frame and shoreline to the west of Merricks Creek, and this section of shoreline prograded by almost 50 m between 1989 and 2013. The timber wall and groynes evident in the 1989 photo in this area are now completely buried by sand.



**Figure 2-15 Analysis of Historical Shoreline Variability at Somers Beach**





**Figure 2-16 Analysis of Historical Shoreline Variability at Merricks Creek**

## 2.2 Local Hazard Assessment

The sources of potential hazards and the extent of uncertainty relating to the assessment of the impact of sea level rise on these hazards in the study area are analysed and discussed in the following sections. The sources of potential hazards have been grouped under the broad categories of erosion and inundation hazards for ease of understanding and for the purposes of mapping hazard extents.

### 2.2.1 Erosion Hazards

This section details the key erosion hazard mechanisms and interactions relevant to this representative location. Further background definitions and conceptual models of the different erosion hazard mechanisms described in this section are detailed in the accompanying Part A report (Report 5).

#### ***Backshore Sand Lobe Migration***

As has been identified from the review of historical aerial photography, the eastward longshore drifting of sand along the Somers shoreline primarily takes the form of the migration of backshore sand lobes, which introduces considerable variability in the shoreline position and therefore the potential extent of coastal hazards.

The most detailed analysis of sediment transport rates associated with migrating sand lobes known to exist in this region is that undertaken by Bird (1993). Bird (1993) compared gains and losses of sediment over a ten year period (1975-1985) between Somers and Sandy Point by means of repeated surveys along a series of 24 fixed transect points in the dunes and out to the low spring tide line. The area of investigation was to the immediate east of the present representative location; however the processes and rates of sediment transport are expected to be very similar.

Between 1975 and 1985 sections of the shoreline were observed to recede by distances of up to 21 m and accrete seaward by distances of up to 55 m, although Bird (1993) did not state what these distances were measured relative to. The total erosion and accretion volumes along the shoreline were relatively closely balanced at approximately 90,000 m<sup>3</sup>. Average rates of net sediment accretion or erosion along individual transects over the ten year period were as high as 1,000 – 2,000 m<sup>3</sup>/yr/m.

The genesis of the sandy lobes observed at Somers and further to the east along Sandy Point, is not considered to be well understood. Bird (1993) speculated that the lobes may originate from the interaction of drifting sand past the intermittently open and closed mouth of Merricks Creek. It is however, clear from the historical aerial photography that the sand lobes occur well to the west of the Merricks Creek entrance and other processes must also be responsible for the introduction of sand lobes to this shoreline.

Bird (1993) does however also note that patterns of erosion and accretion over periods of several decades in the southern part of Western Port are possibly related to weather and tide associations and cycles of sand movement on the sea floor in the Western Entrance. It is considered plausible that the dynamics of the sediment transport processes across Middle Bank are contributing to the formation of sand lobes and subsequent shoreline variability observed along the Somers shoreline. The sediment transport dynamics of Middle Bank could result in the episodic injection of sediment to the shoreline from offshore or through variations to the wave refraction patterns across Middle Bank and subsequent distribution of wave energy along these shorelines. These processes may be modulated by climatic factors including the frequency of strong winds and waves that may increase the rates of sediment transport and bedform variations across Middle Bank.

From the review of the historical aerial photography and detailed historical survey analysis undertaken by Bird (1993), it is clear that the characteristics of the sediment transport processes at



this location are contributing to significant underlying shoreline variability. Both the historical aerial photography analysis and survey analysis show that underlying variation of approximately 50 m in the shoreline position has been observed at multiple locations along this study area over the last approximately 50 years. This extent of historical shoreline variability cannot necessarily be taken as evidence of an upper limit of future change over 100 year future timeframes and it is considered conceivable and appropriate to plan for underlying variability in the shoreline position at this location that includes additional factors of safety.

In addition, analysis of the potential impact of sea level rise on the wave climate at this location provides estimates of increases in cumulative annual wave energy of approximately 50% by 2100 at this location. The increase in wave energy is largely attributed to increased depths across Middle Bank which reduces the frictional losses of waves propagating across the area. This magnitude of increase in wave energy is considered potentially quite significant to the rates of sediment transport along this shoreline and this may potentially increase the magnitude of the underlying shoreline variability.

For these reasons, an additional factor of safety of 2 times the maximum observed underlying historical (~50 year) variability of 50 m is considered appropriate at this location. This provides a hazard extent of 100 m due to underlying backshore sand lobe driven shoreline variability to 2100 along the sandy shorelines. The hazard extents for the interim timeframes have been scaled relative to the 2100 hazard extent.

#### ***Equilibrium Profile Recession***

As identified in the Part A assessment, the particular characteristics of the sandy spit shoreline type classes in Western Port are problematic for the application of the Bruun model (Bruun, 1962) for estimating equilibrium profile recession distances.

The wide and shallow offshore region of Middle Bank is a dynamic environment where sediment is actively being transported and mobilised and is likely to be intermittently supplying the shoreline with sediment. It is therefore not possible to identify a depth of sediment closure for these shorelines. The complex offshore geometry and dynamic sediment transport processes at this location are considered relatively unique and the subsequent process and magnitude by which the sandy shorelines are likely to respond to increases in mean sea level are possibly not well defined by conventional, equilibrium profile models.

Adjustment of the shoreline profiles with sea level rise could however be expected to occur to some extent, as wave action progressively impacts the upper beach face and berm, and sediment is redistributed across the profile. The seaward extent of this profile adjustment cannot however be defined with any level of confidence.

From close inspection of the shoreline profiles and considering the broader geomorphic setting of the sandy shorelines at this location, it is considered possible that the profile response to sea level rise may be largely limited to the beach face and immediate near shore zone on these shorelines, which would reduce the Bruun factor compared to that typically expected on conventional sandy shore profiles. Table 2-1 displays estimates of equilibrium profile recession based on the near-shore and beach face slopes of the Balnarring and Somers Beach profiles displayed in Figure 2-5.

From Table 2-1 it can be seen that consideration of the active slopes from these profiles provides relatively low Bruun Factors and subsequent recession distances with sea level rise. Given the level of uncertainty that exists in the potential process and magnitude of response of these shorelines due to sea level rise, it is considered more appropriate to plan for conventional rates of recession on these shorelines. An assumed Bruun Factor of 30 has been adopted, recognising that the particular characteristics of the sandy shorelines at this location may result in relatively lower rates of sea level rise driven profile recession than would be expected on more conventional sandy shoreline profiles.

**Table 2-1 Equilibrium Profile Recession Estimates of Balnarring to Somers Sandy Shorelines**

Profile	Active Slope (degree)	Bruun Factor	Equilibrium Profile Recession for each Sea Level Rise Scenario		
			+0.2m (2040)	+0.5m (2070)	+0.8m (2100)
Somers Beach	4.2	14	3	7	11
	Adopted	<b>30</b>	<b>6</b>	<b>15</b>	<b>24</b>
Balnarring Beach	3.7	15	3	8	12
	Adopted	<b>30</b>	<b>6</b>	<b>15</b>	<b>24</b>

**Bluff Reactivation**

Shore platforms of variable elevation are exposed at low tide below marginal bluffs and narrow platform beaches at Point Sumner and Balnarring Beach foreland, and also from Somers to South Beach. The shore platforms are gently sloping ( $\sim 0.4^\circ$ ) and can be up to 200 m wide at low tide. The shore platforms are composed of fresh to weathered basalts. The bluffs are composed of fresh to weathered basalts and are overlaid by Baxter Formation Ferruginous Sandstone (Figure 2-17).



**Figure 2-17 Baxter Formation Ferruginous Sandstone overlying Weathered Basalt, Sumner Point (Photo: Neville Rosengren, 7 June 2013)**

The width of the platform beaches in front of the bluffs at these locations is relatively short and the bluffs are therefore considered potentially vulnerable to slope failures initiated by destabilisation of the base of the bluff due to sea level rise.

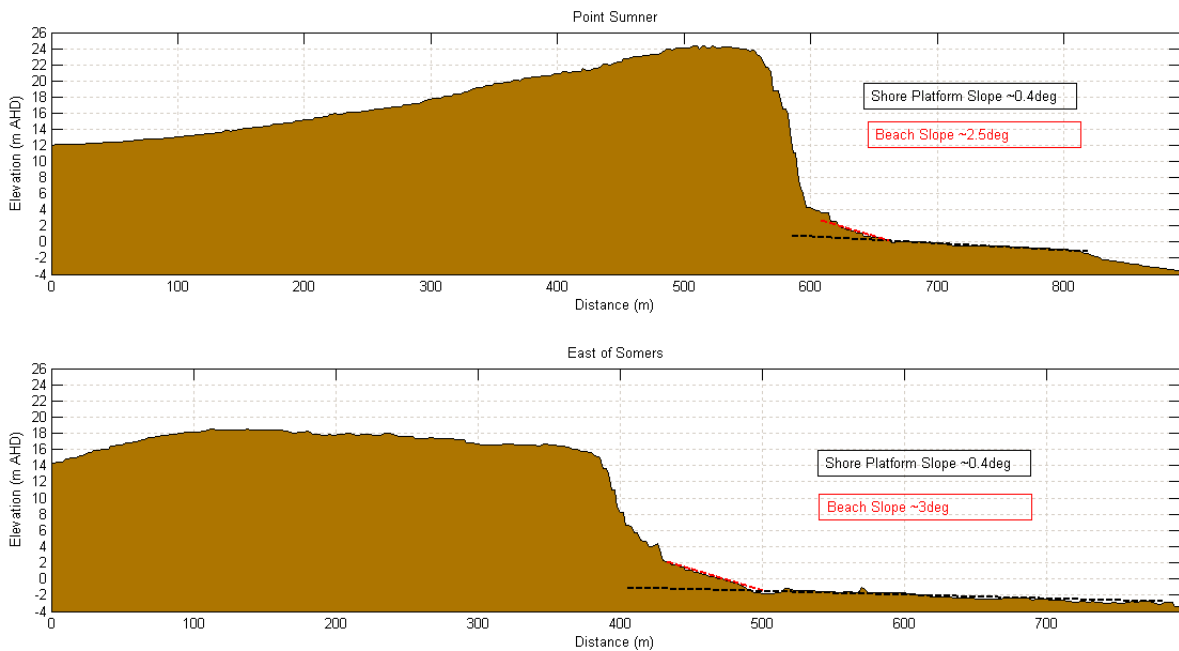
Figure 2-18 displays two representative cross sections through the platform beach and bluff shorelines at Point Sumner and East of Somers. From Figure 2-18 it can be seen that the slope of the

shore platforms is approximately  $0.4^{\circ}$ , and beach face slopes are approximately  $2.5-3.0^{\circ}$ . The platform beaches are generally less than 50 m wide. The geometric translation of the platform beach along the shore platform slopes at these locations provides estimated equilibrium recession distances displayed in Table 2-2. From Table 2-2 it can be seen that due to the existing relatively narrow width of the platform beaches in this study area, translation of the platform beaches due to sea level rise would potentially result in significant marine influences interacting with the base of the bluffs for sea level rise scenarios between +0.2 m (2040) to +0.5 m (2050). The risk of significant slope failures occurring along the bluff are a possible consequence of the base of the bluffs being destabilised by marine processes.

The potential slope failure mechanisms and their extent along the reactivated bluffs in this study area due to sea level rise cannot be predicted with any level of certainty. The weathered basalts and Baxter Formation sandstones comprising the bluffs could be expected to have relatively weak rock mass strengths and would be vulnerable to mass movements when slopes of this material are oversteepened by wave action or at the interface between these two lithologies. A major slope failure in cliffs of similar material has occurred historically at San Remo.

Given the historical precedent of major slope failures in cliffs of similar geology in Western Port and the fact that slope failures can occur with little to no warning, a conservative hazard zone for slope failures along the bluffs in this study area is considered appropriate.

The hazard extent has therefore been considered to extend landward from the base of the bluff by a factor of 5 times the height of the bluff along these shorelines. This results in a final failure slope of approximately  $11^{\circ}$  along these bluffs where they are likely to be reactivated by sea level rise.



**Figure 2-18 Platform Beach and Bluff Slope Analysis**

**Table 2-2 Summary of Predicted Future Rates of Platform Beach Recession**

Shore Platform Slope (degree)	Sea Level Rise Scenario		
	+0.2m (2040)	+0.5m (2070)	+0.8m (2100)
0.4	29 m	72 m	115 m



## 2.2.2 Inundation Hazards

### ***Merricks Creek ICOLL Response***

Climate change is expected to impact both rainfall (streamflows) and coastal processes (wind, waves and sea level) and ICOLL's such as Merricks Creek could therefore be subject to a range of potential impacts.

However the most significant change to coastal hazards associated with ICOLL's such as Merricks Creek is considered to be the expected increase in the average berm height that will be observed as sea level rise results in a landward and upward translation of the shoreline at the creek's entrance. The increase in the entrance berm height will result in water levels in the Merricks Creek lagoon reaching a higher level before a natural break out can occur across the entrance. This could be expected to result in semi-permanently inundated areas expanding laterally along the margins of the Merricks Creek lagoon.

### ***Storm Tide Inundation***

Due to the slope of the backshore areas, storm tide inundation associated with the design events modelled in the various sea level rise scenarios do not indicate significant storm tide inundation extents within this location.

This is also the case within Merrick's Creek, where the storm tide is contained within the vegetated estuary corridor due to the terrain in this area. This is shown in Figure 2-19, where the peak storm tide elevation at the Merricks Creek entrance has been mapped throughout the estuary.

### ***Catchment Inflows***

The 10% AEP catchment flows have been generated for Merricks Creek and modelled for each sea level rise scenario. A summary of the analysis used to determine the 10% AEP flows is provided in Appendix B. The resultant inundation extents for each scenario are shown in Figure 2-20 and show virtually no difference in inundation extent for each sea level rise condition. This is because the entrance condition of the creek is the dominant control of the water levels upstream.



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**Figure 2-19 Storm Tide Inundation of Merricks Creek (1% AEP Storm Tide under Existing Mean Sea Level)**





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**Figure 2-20 Catchment Inflows and Sea Level Rise Inundation Extents, Merricks Creek**



### **2.2.3 Evaluation of Sources of Uncertainty**

The sources and significance of uncertainty associated with the assessment of the potential future extent of inundation and erosion hazards in the study area are discussed below:

#### ***Backshore Sand Lobe Migration***

Aspects of the genesis and processes that transport sediment as large longshore migrating sand lobes along these shorelines remain poorly understood. Their significance to the contemporary processes and variability that is observed on these shorelines cannot be understated and their influence could be expected to contribute to future coastal hazard extents along these shorelines, regardless of projected sea level rise this century.

Sea level rise may also cause significant changes to the amount of wave energy that impacts these shorelines due to greater depths across Middle Bank and this may increase the underlying variability of the sediment transport processes on these shorelines.

The extent of historical shoreline variability observed over the last approximate 50 years cannot therefore be taken as evidence of an upper limit of future changes over 100 year timeframes and a conservative approach to managing this uncertainty is therefore considered appropriate.

#### ***Bluff Reactivation***

The potential mechanism and extent of slope failures that may occur due to reactivation of the bluffs by sea level rise cannot be predicted with any level of certainty. Erosion of the beach areas seawards of the bluff or regular wave impacts at the base of the bluff would indicate increased susceptibility to failure but should these changes occur it does not necessarily mean that failure would result or that failure could only occur under these conditions, due to the influence of the underlying local geology. However, significant slope failures in similar geology have occurred historically in Western Port with little to no warning and as such a conservative hazard zone for slope failures is considered appropriate.

The potential for slope failures to occur along reactivated bluffs in the study area will also be significantly influenced by human activities associated with development along the bluffs. Construction of new buildings, swimming pools, changes to drainage and vegetation may all contribute to future slope instability.

#### ***Coastal Protection Structures***

Coastal protection works identified within the DEPI coastal asset database which lie within the study area influence the shoreline erosion susceptibility and the processes operating on them under existing conditions. Due to the broad scale of the coastal processes affecting shoreline erosion along the extent of this representative location, the localised effects each structure has on the shoreline, and the localised impact they would have on the hazard assessment approach they have not been explicitly included within the hazard assessment. A comment is provided on their impact or response to future conditions in the following table.

It is recommended that a monitoring program be developed to record the conditions of the structures and document any failures or stability issues. Further more detailed design assessments of each structure would be required to determine likely failure conditions and design requirement under future sea level rise conditions. This is considered beyond the scope of the current assessment.

**Table 2-3 Summary of Coastal Protection Structures (Balnarring to Somers)**

Structure	Likely Impact or Effect of Future Conditions
Timber Groynes and Rock Revetment at Balnarring Beach	<p>Increased wave action as a result of sea level rise conditions will likely result in continued deterioration of the groyne structures.</p> <p>The rock revetment located on the dune to the rear of the groynes provides some protection against erosion of the dune locally; however broader coastal processes in the area such as the migration of sand lobes and increased wave action as a result of sea level rise are likely to affect its effectiveness to provide erosion protection in the future. Increased wave action and wave run-up with each increment of sea level rise will affect the stability of the rocks and monitoring of the structure stability is recommended.</p>
Merricks Creek Entrance structures	<p>The training of the Merricks Creek entrance has prevented the entrance's natural eastward migration and the shoreline to the immediate east of the training walls has prograded seaward in response. The stability of the shoreline to the immediate east of the Merricks Creek training walls is reliant on the ongoing maintenance of the Merricks Creek training walls.</p> <p>Sea level rise is likely to impact these structures through increased wave action at their base which will potentially affect their stability.</p> <p>It has been assumed for the inundation modelling that the current location of the creek entrance is maintained by these structures, as there is currently no method for predicting possible future locations of the entrance should the entrance structures fail.</p> <p>Both the timber training wall and the rock wall will require on-going monitoring to assess any potential instability associated with sea level rise.</p>
Somers Sea Wall	<p>It is considered likely that without the development of the rock sea wall at Somers, a small number of dwellings, including the Somers Yacht Club, would have been severely impacted by erosion as a broad sand lobe migrated away from this area during the 1980s. The future extent of erosion and inundation hazards at this location will be strongly determined by the maintenance and adaptation of this structure to future sea level rise.</p>

## 2.3 Local Coastal Hazard Mapping

The local models and assessments of future shoreline change/hazards developed in the previous sections have been applied to refine the erosion and inundation hazard extents developed in Part A of this project, within the Balnarring to Somers representative location.

Table 2-4 documents the final erosion mapping method adopted and/or hazard extent that was mapped. The inundation hazard extent was mapped based on the outputs from the hydrodynamic modelling which has been smoothed to match in with the local elevation model. As per Part A, all hazard extents are relative to a shoreline delineated relative to the MHWS tidal plane and subsequent water level variation across Western Port.

Figure 2-21 displays the erosion hazard extents for the Balnarring to Somers representative location, while Figure 2-22 displays the inundation hazard extents.

**Table 2-4 Summary of Erosion Hazard Mapping Method/Extent for Balnarring to Somers Representative Location**

Shoreline Class	Hazard Type	Timeframe		
		2040	2070	2100
<b>Platform Beach and Bluff</b>	Bluff Reactivation	Initial coastal hazard extent estimate based on platform beach narrowing across shore platform. Hazard extent buffered based on estimates provided in Table 2-2 and displayed below		
		29 m	72 m	115 m
		Where the translation of the platform beach intersected steeper backshore terrain associated with the bluff, the hazard extent was truncated along this interface. The interface between the platform beach and base of the bluff was approximated by the 3.0m AHD contour. Where the hazard extent intersected the base of the bluff, the hazard extent was buffered landward as a function of the height of the top of the bluff/ $\tan(11^\circ)$ as a provision for slope failures (Landward hazard distance effectively 5 times the cliff/bluff height).		
<b>Sandy and Sandy Spit</b>	Backshore Sand Lobe Migration	Maximum hazard extent of 100m due to underlying backshore sand lobe driven shoreline variability to 2100. The hazard extents for the interim timeframes have been scaled relative to the 2100 hazard extent below.		
		40 m	70 m	100 m
	Equilibrium Profile Recession	Additional hazard extent equivalent to a Bruun Factor of 30 as per below.		
		6 m	15 m	24 m
	(Total)	(46 m)	(85 m)	(124 m)

## 2.4 Summary and Recommendations

A summary of the coastal hazards identified within the Balnarring to Somers representative location along with a description of any associated uncertainty is provided in Table 2-5.

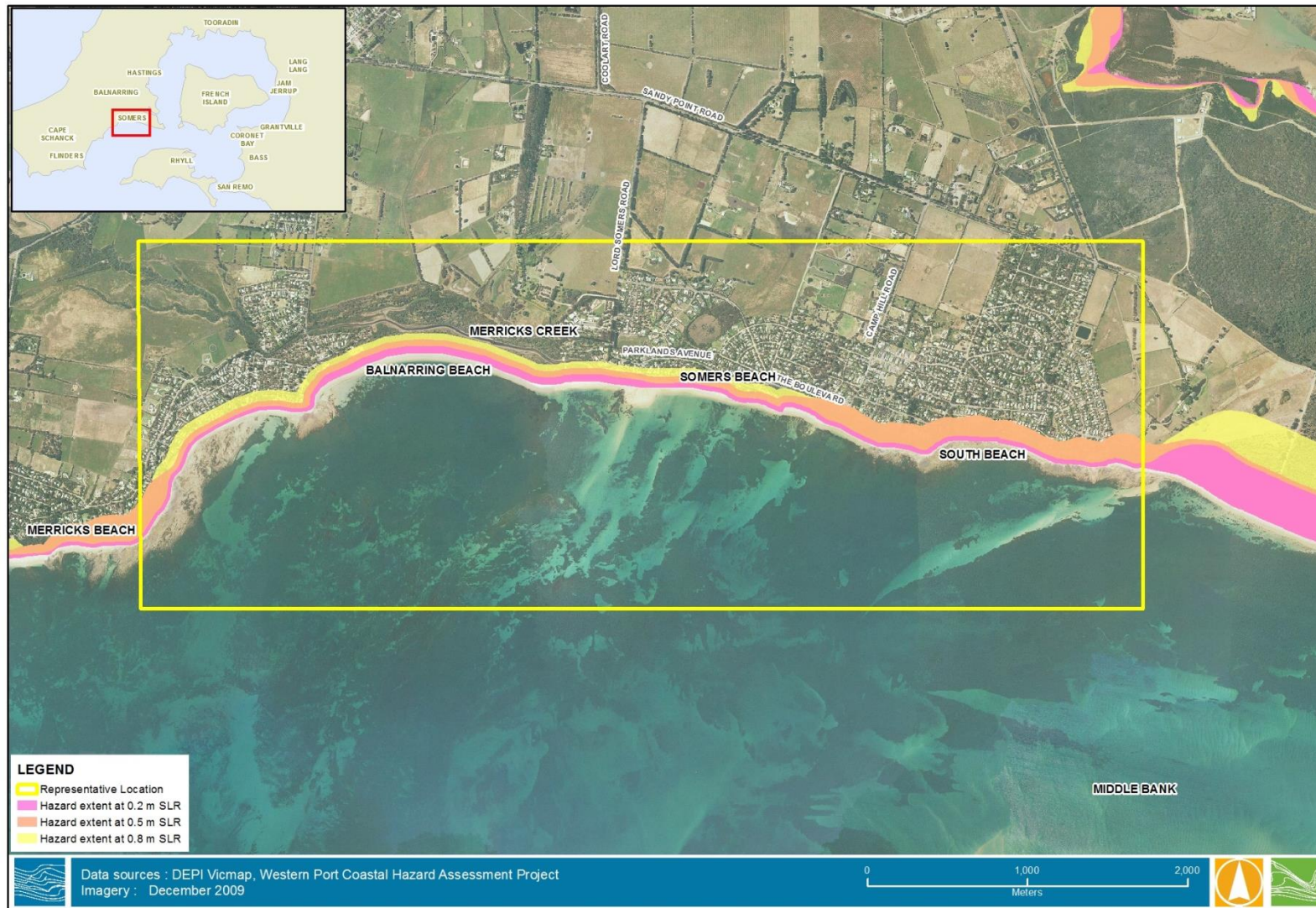
The following recommendations are provided from the results of the local coastal hazard assessment of the Balnarring to Somers representative location:

- There remains a high degree of uncertainty in relation to the extent of potential coastal erosion hazard impacts due to sea level rise in this location as the full extent of the underlying shoreline variability remains uncertain and cannot be predicted with a high level of confidence due to the inherent uncertainty in the key physical processes.
- Further data collection and studies into the sediment transport dynamics in this region of Western Port could potentially enable the evolution of, along with the temporal and spatial scales of the shoreline variability to be better understood although there is no guarantee that further data or existing analysis techniques would be able to fully capture the dynamic variability of this sandy shore. If the variability of the key physical processes can be better



understood then it would be possible to further refine the extent of coastal erosion hazards over the timeframes relevant to this assessment.

- Long term monitoring of the condition and stability of the coastal structures could be implemented and further detailed assessment of design conditions including their effectiveness in managing coastal erosion hazards undertaken prior to future adaption works.
- The complexity of the coastal processes and associated level of variability are however likely to remain such that a strategic and precautionary approach to managing coastal hazard risks should be adopted in this location.
- Measures to manage the identified coastal hazard due to sea level rise could include the following:
  - Development of a strategic approach to the management and future adaptation of the existing shoreline protection works;
  - Initiation of planning measures to minimise the risks within the hazard overlays;
  - Referring requests for additional development along the bluff backed shorelines located within the erosion hazard overlays for specialist geotechnical assessment.

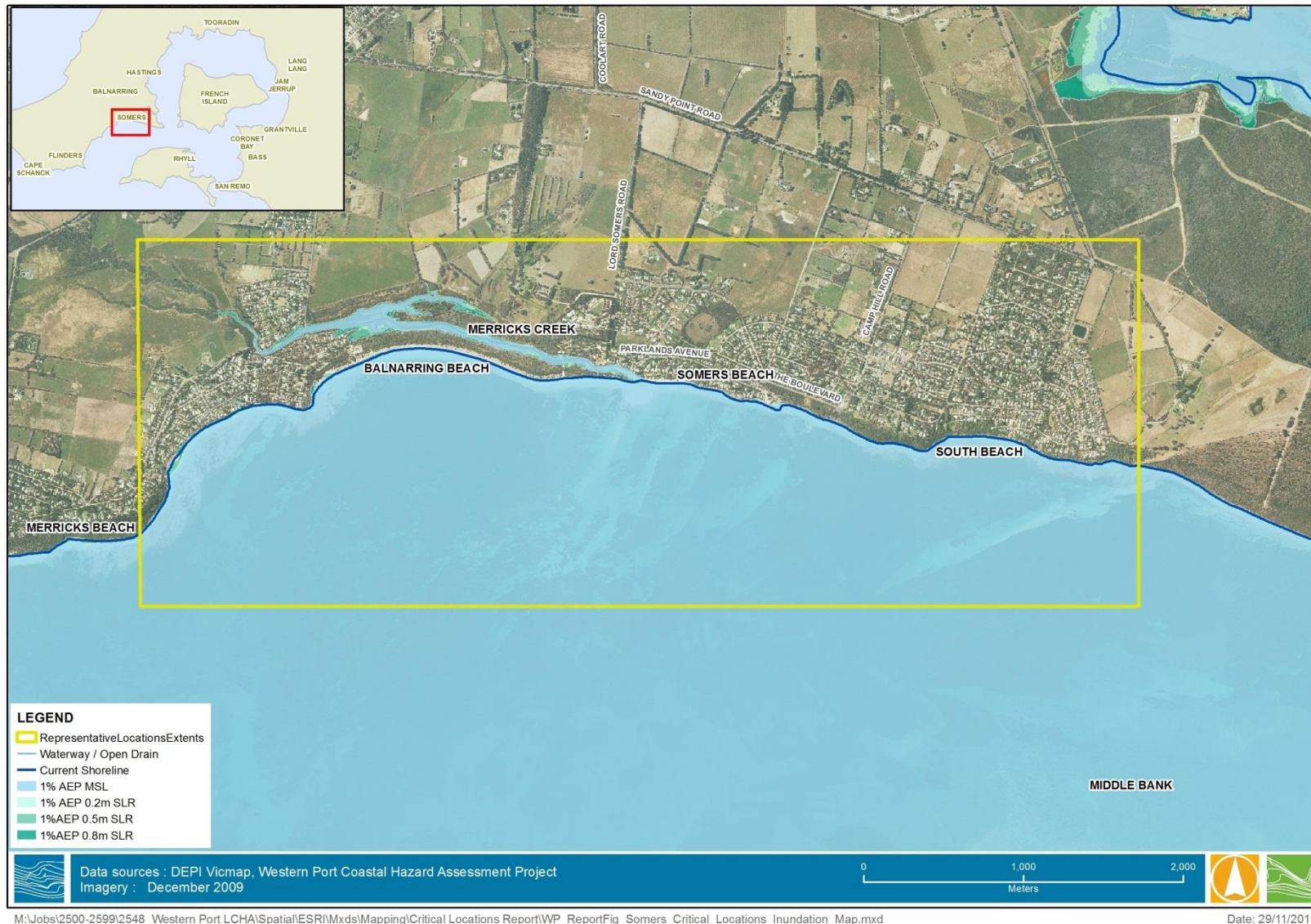


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**Figure 2-21 Erosion Hazard Extents for the Balnarring to Somers Representative Location**





**Figure 2-22 Inundation Hazard Extents for the Balnarring to Somers Representative Location**



**Table 2-5 Summary of Coastal Hazard Analysis and Uncertainties for the Balnarring to Somers Representative Location**

Hazard Category	Specific Hazard	Timeline	Likelihood	Uncertainty	Comments
Coastal Erosion	Backshore Sand Lobe Migration	Present	Likely	<b>High</b>	Ongoing significant shoreline variability due to this process should be expected to 2100 and may exceed that observed in the historical photographic record. Sea level rise may potentially increase variability of this process due to changes in wave energy on the shoreline. Scale of impact due to this hazard could be severe within this location towards the end of the century.  High level of uncertainty exists due to complexity of the contributing processes and stochastic nature of the hazard within the study area. Decision making in response to this hazard is only considered appropriate at the landform/settlement scale.
		2040	Likely		
		2070	Likely		
		2100	Likely		
	Equilibrium Profile Recession	Present	Very Unlikely	<b>Moderate</b>	Profile recession due to sea level rise is increasingly likely towards the end of the century. The scale of impact is likely to be moderate within this location by the end of the century.  A moderate level of uncertainty is associated with the estimates of equilibrium profile recession due to limitations of available assessment methods.
		2040	Unlikely		
		2070	Likely		
		2100	Likely		
	Marginal Bluff Reactivation	Present	Very Unlikely	<b>Moderate</b>	The likelihood of major slope instabilities developing towards 2100 is only considered possible; however the consequence of such failures in terms of the scale of impact is potentially severe due to the likely rapid rate of change and limited warning times associated with this hazard.  A moderate level of uncertainty exists due to limited information or understanding of the underlying geology and potential hazard processes. Site specific data and specialist geotechnical assessments are required to improve confidence at lot/parcel scale.
		2040	Unlikely		
		2070	About as Likely as Not		
		2100	About as Likely as Not		
Inundation	Storm Tide Inundation	Present	Very Unlikely	<b>Low</b>	There are generally limited impacts from storm tide inundation due to the elevations and/or steep slope of the backshore areas.
		2040	Unlikely		
		2070	Unlikely		
		2100	About as Likely as Not		

### 3. TOORADIN AND COASTAL VILLAGES

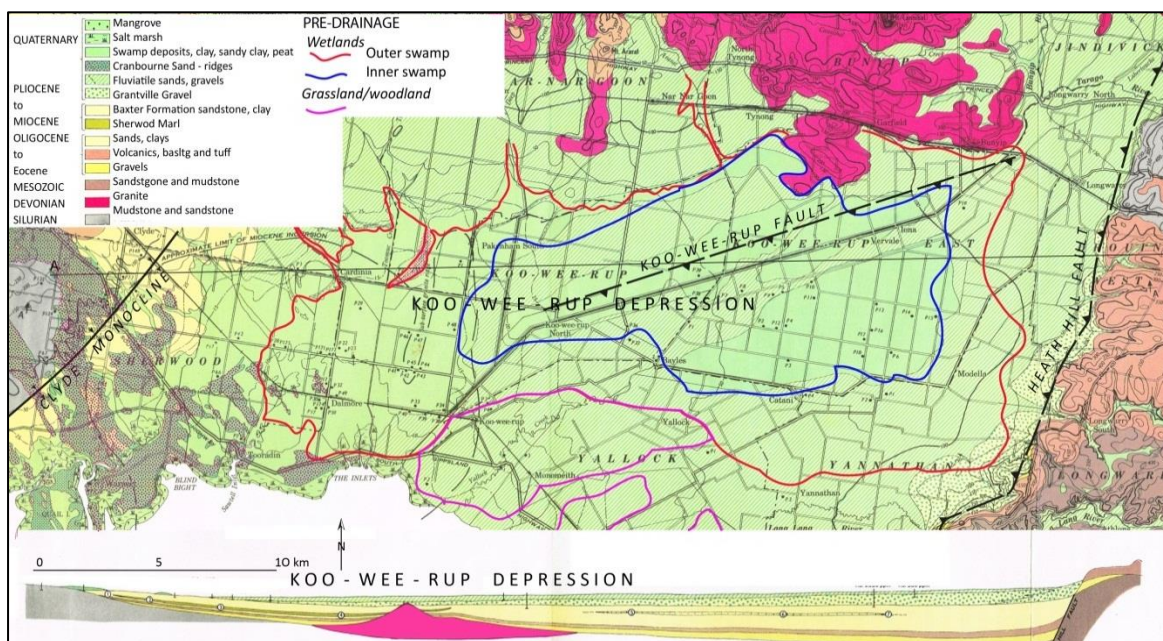
#### 3.1 Overview

The Tooradin and Coastal Villages representative location shoreline extends from Rutherford Inlet to the Main Drain as displayed in Figure 3-2. The study area includes the coastal villages of Warneet, Cannons Creek, Blind Bight and Tooradin, and is comprised of the coastal wetland fringed shoreline and estuary shoreline classes identified in the Part A assessment, Report 5.

The characteristics and susceptibility of this shoreline to coastal hazards is integrally related to the nature and variations in geology, geomorphology, coastal vegetation and the hydrodynamic setting. The following sections provide a broad overview of the nature and variability of the physical environment of the Tooradin and Coastal Villages area as a basis for understanding the potential type, extent and susceptibility of the shoreline to coastal hazards.

##### 3.1.1 Geology

This study area straddles the southern margin of the Koo-wee-rup Depression at the nadir of the Western Port Sunland and is a low relief coastline backed by a flat hinterland. There are no hard rock materials apart from irregular occurrence of weakly cemented ferruginous sand in the inland sand dunes. The hinterland, shore and nearshore is developed on late Cainozoic sediments including extensive lateral and vertical sequences of swamp deposits overlain in places by wind-blown sand (Figure 3-1).

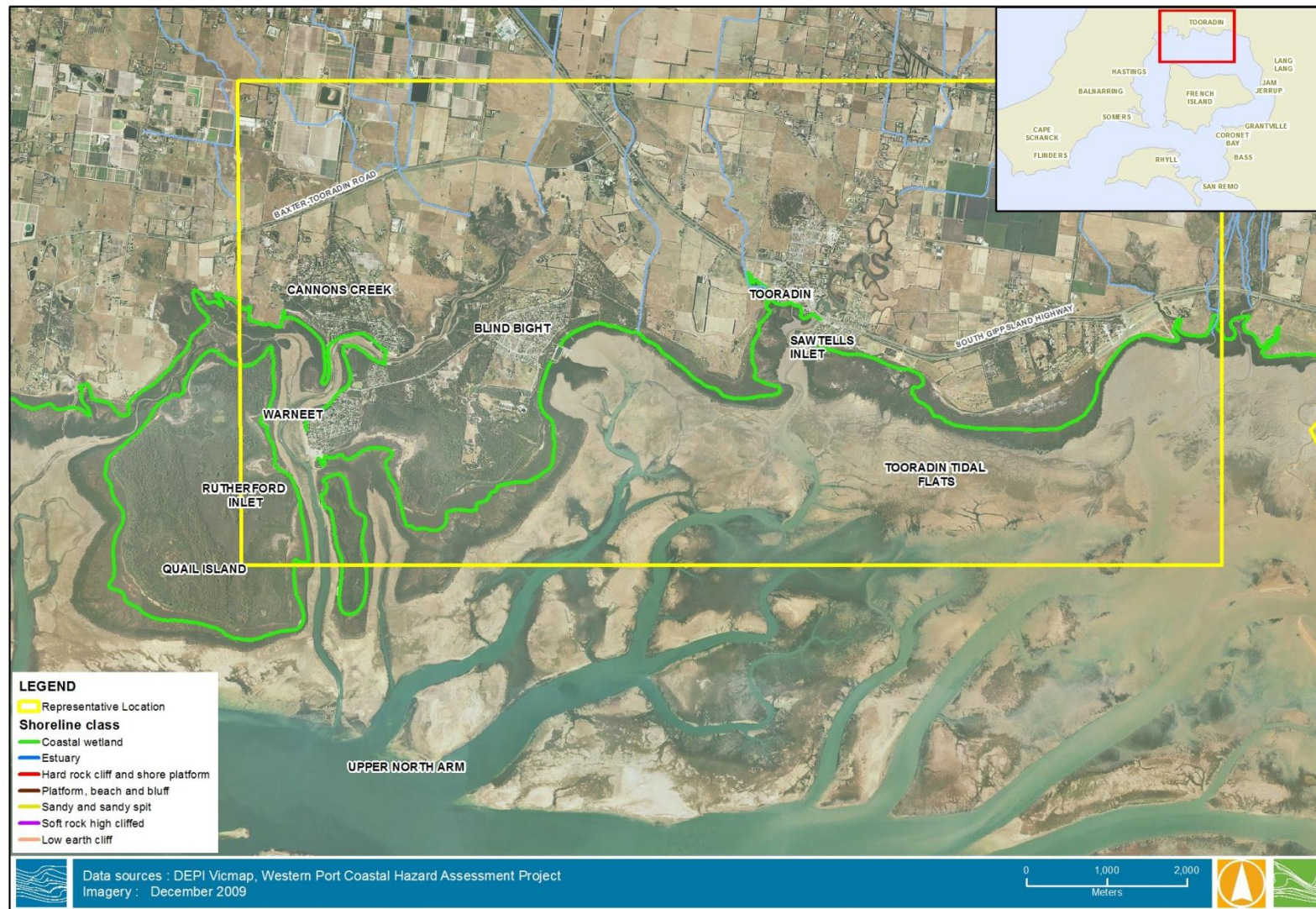


**Figure 3-1 Surficial Geology of Northern Western Port (Map after Jenkin 1962; swamp outlines after Yugovic and Mitchell, 2005)**

##### *Cranbourne Sand & Coastal Sand*

Deposits of wind-blown sand are extensive in the western part of the study area, notable as low relief sand sheets and higher north-west-south-east trending dune ridges. The sands are clear, colourless or slightly stained medium to coarse quartz (Jenkin 1962) and have a well-developed soil profile with bleached strongly acidic (pH 5.0 – 5.4) upper horizons and very dark brown often cemented “coffee-rock” sub-soils with only traces of clay (Sargeant and Imhof 1996).





**Figure 3-2 Tooradin and Coastal Villages Study Area Locality Plan**



### ***Drained Swamp Deposits***

East of Tooradin is a broad zone of drained former wetlands that comprised the Cardinia, Dalmore and Koo-Wee-Rup swamps. The swamp deposits are predominantly clay with variable organic components ranging from only traces through to thick layers of peat. Along the coast of this sector, swamp deposits are overlain either by sandy beach ridges of reworked Cranbourne Sand or by Holocene mangrove and saltmarsh deposits.

### ***Coastal and Nearshore Sediment***

The nearshore sediments are integrally related to processes associated with coastal wetland vegetation.

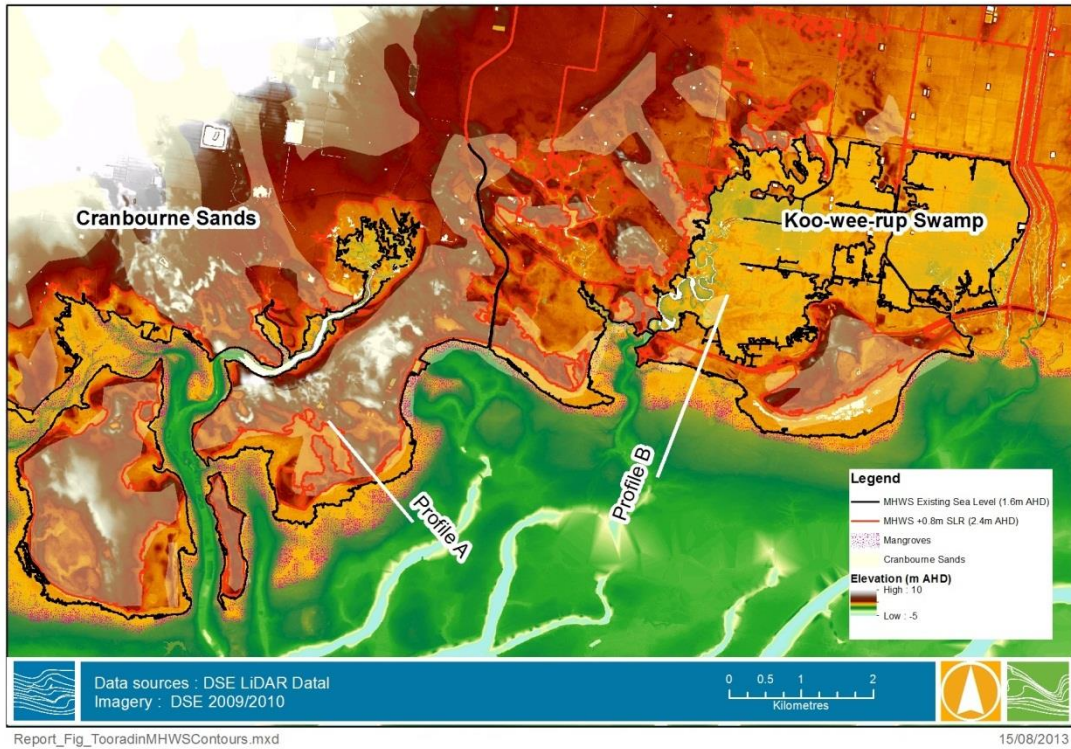
The innermost zone is saltmarsh and only fully inundated on rare occasions. It has a flat to very gently sloping surface of varied sediment types from sand to clay and includes local accumulations of saltmarsh peat. The surface is cut by a shallow and often intricate network of tidal channels. Storm derived debris including sand, broken shell and seagrass wrack accumulates towards the inner (landward) margins of the marsh.

Further seaward, the floor of the mangrove zone is muddy with thin accumulations of sand and organic litter and sediment, trapped by the close network of trunks and pneumatophores. The mangroves are spreading onto the nearshore sands, a persistent feature of the middle to high intertidal zone that fringes the mangrove zone along this study area. This is a relatively grass-free zone up to 300 metres wide with variable proportions of mud (the “Inshore Sandy Marginal Zone” of Marsden and Mallett, 1974). It slopes gently seaward and has a complex surface of ripples and well-defined reticulate tidal drainage channels.

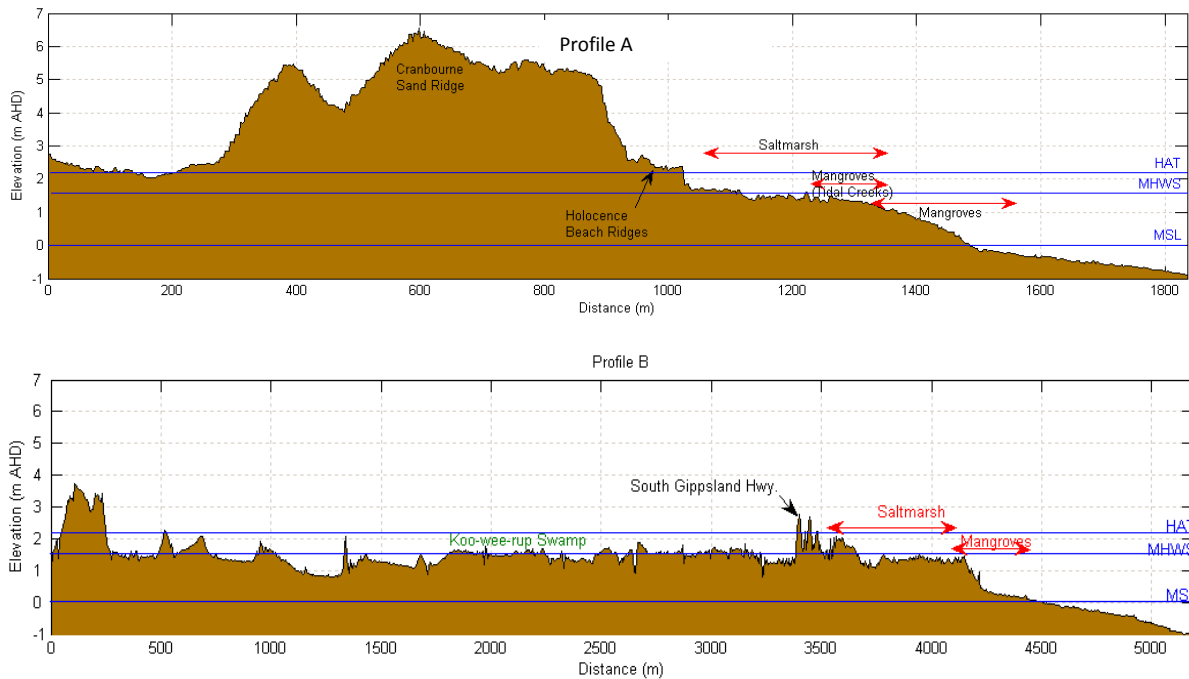
### **3.1.2 Coastal Geomorphology**

The coastal geomorphology of the western section of the study area (west of Tooradin) is strongly influenced by the hinterland of remnant Cranbourne Sands. These broad, low sand sheets and ridges gradually give way to the Koo-Wee-Rup swamp to the east around Tooradin.

The main relevant components of the coastal geomorphology of the study area are displayed below in Figure 3-3 and described in more detail in the following sections.



**Figure 3-3 Coastal Geomorphology of Tooradin and Coastal Villages Study Area**



**Figure 3-4 Representative Profiles of the Tooradin and Coastal Villages Study Area**

***Cranbourne Sands***

The hinterland terrain west of Tooradin is elongated ridges trending northwest-southeast, and broad low sheets of Cranbourne Sand with an outlier of this landscape 2 km east of Tooradin near the Tooradin Airport. Inland from Cannons Creek the ridges rise to 12m giving local relief of 5 to 7 m above the intervening swales.

These sands form an almost continuous zone behind the highest high water mark from Warneet east to The Inlets (Figure 3-3), with ridges 7 m to 12 m high at Cannons Creek. East of Tooradin the ridges are subdued and do not extend east of The Inlets. The seaward margin of the Cranbourne Sands has been reworked at higher sea-levels and deposited as curving parallel and sub-parallel ridges to 3 m high inland of the saltmarsh zone and beyond the reach of present mean high water spring tide..

### ***Coastal Wetlands***

A continuous mangrove zone backed by saltmarsh extends from Watson Inlet to the Bunyip River (Main Drain). The mangrove and saltmarsh zone is usually between 200 m to 400 m wide, but is over 800 m wide on the west of Quail Island and south of Warneet. Saltmarsh can comprise 80% of that width in some locations. The saltmarsh surface terrain slopes at a very low angle eg. <0.1%. The surface slope steepens abruptly across the mangrove fringe from >0.5% to over 1% (Figure 3-4).

The zone is crossed by a close-spaced, co-ordinated branching network of tidal creeks that in places are incised over 1 m into the substratum of the saltmarsh zone and continue across part of the mangrove zone. There is no clear topographical variation across the saltmarsh zone apart from creek incisions and shallow enclosed depressions, usually at the rear of the zone but in places central in the marsh. Some marshes display sets of sub-parallel vegetation zones in the central and rear areas that are a reflection of micro-topographical variation – ridges and swales with amplitudes of 0.2 m to 0.4 m. These are chenier ridges of sand, shell and wrack deposited during storms and swash-built beach ridges deposited before a broad, continuous mangrove community established.



**Figure 3-5 Pools and Bare Ground at the Rear of Saltmarsh and Low Chenier Ridges – West of Tooradin Airport (Photo: Neville Rosengren, 20 March 2013)**

### ***Koo-Wee-Rup Swamp***

The extensive hinterland wetlands of northern Western Port formed in the middle and lower reaches of Clyde Creek, Cardinia Creek, Toomuc Creek, Bunyip River and Yallock Creek. They were progressively drained between 1876 and 1897 (Figure 3-6) and since then maintenance, extension and flood protection work has continued (Roberts 1985). Sawtells Inlet and The Inlets are coastal embayments located at the lowest and westernmost part of the Koo-Wee-Rup Depression. They are drained wetlands now less than two metres above sea-level. The inner margin of both embayments is defined by the 2.5 m AHD contour which marks a distinct rise in elevation. The lowland of the embayments in part may be a result of land subsidence post-drainage but may also be a degraded escarpment from a brief episode of higher Holocene sea-level.



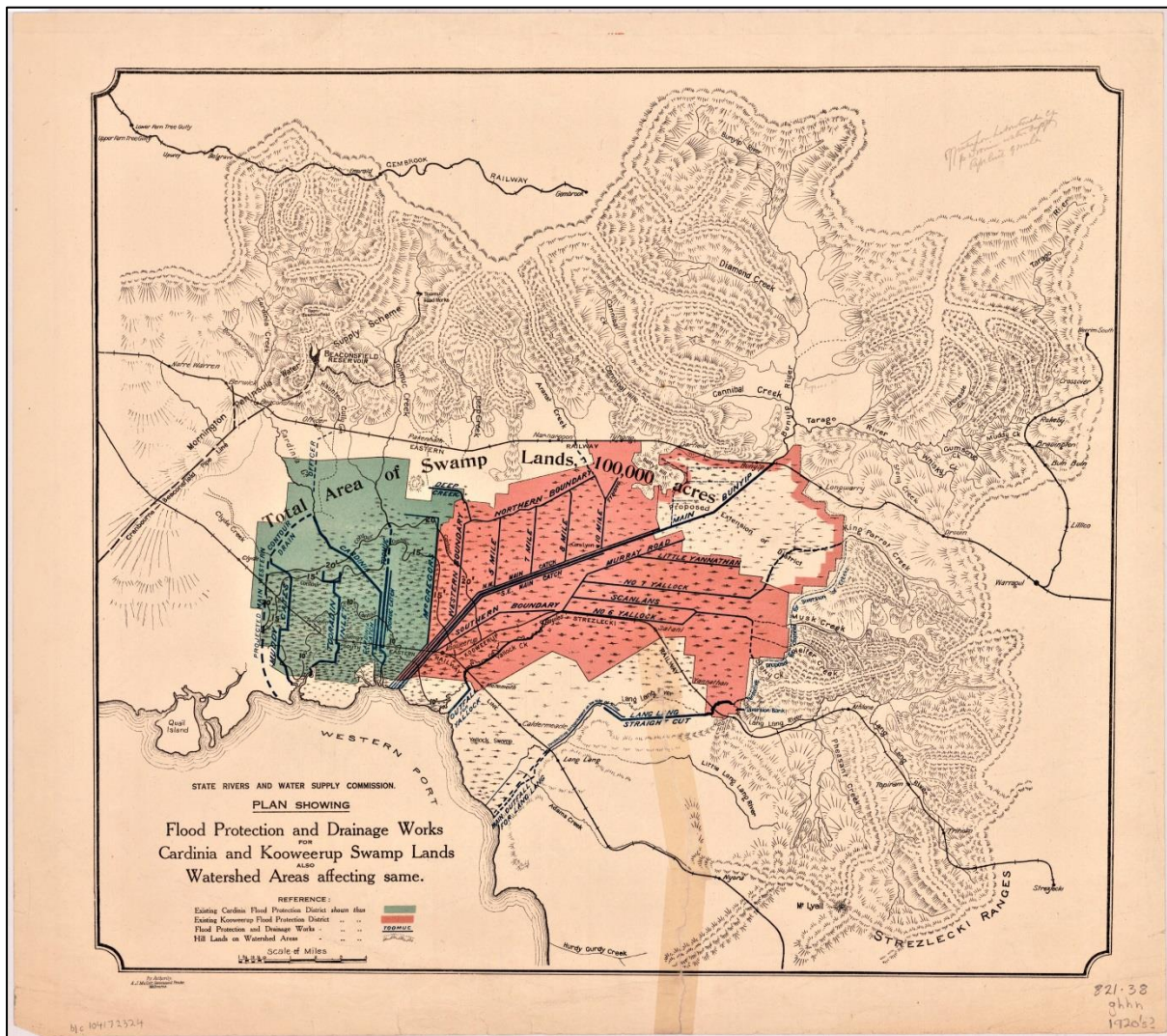
Other local evidence of this higher sea-level are the branching remnants of former tidal channels west of The Inlets and at the head of Cannons Creek and Watson Inlet, the large amplitude former tidal meanders of Sawtell Inlet and similar abandoned meanders of Yallock Creek.

**South Gippsland Highway and Hydraulic Structures**

The South Gippsland Highway and associated causeway represent an important morphological feature in the landscape east of Tooradin. The elevated causeway forms a significant barrier between Western Port and the Koo-Wee-Rup Swamp and limits the extent of coastal inundation even under existing sea levels (Figure 3-4).

Hydraulic connections between Western Port and Koo-Wee-Rup Swamp do however occur via numerous small bridge and culvert structures that currently exist through the South Gippsland Highway causeway and provide conduits for tidal and coastally driven water levels to propagate into the southern parts of the Swamp.

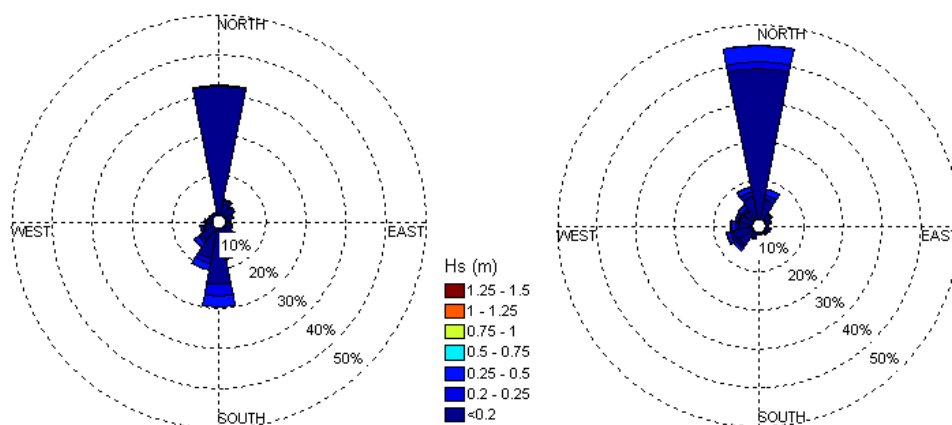
Adaptation responses to the impacts of existing coastal water level variations in Koo-Wee-Rup Swamp already exist in the form of the tidal gate structure at Sawtells Inlet (Tooradin). This structure throttles the volume of tidal water that can flow upstream north of the South Gippsland Highway along Sawtell Inlet and into the Koo-Wee-Rup Swamp.



**Figure 3-6 Flood Protection and Drainage Map of Koo Wee Rup Swamps – circa 1920 (State Library of Victoria).**

### 3.1.3 Hydrodynamic Setting

Waves along the study area are generated locally within the northern and western arms of Western Port. The confined fetches and shallow depths in this region of Western Port result in relatively small waves, generally less than 0.5m (Figure 3-7). Due to the large tidal range and low profiles, the amount of wave energy that impacts the shorelines is very strongly modulated by the phase of the tide.



**Figure 3-7 Wave Roses Summer (2003) & Winter (2003)**

### 3.1.4 Sediment Movements

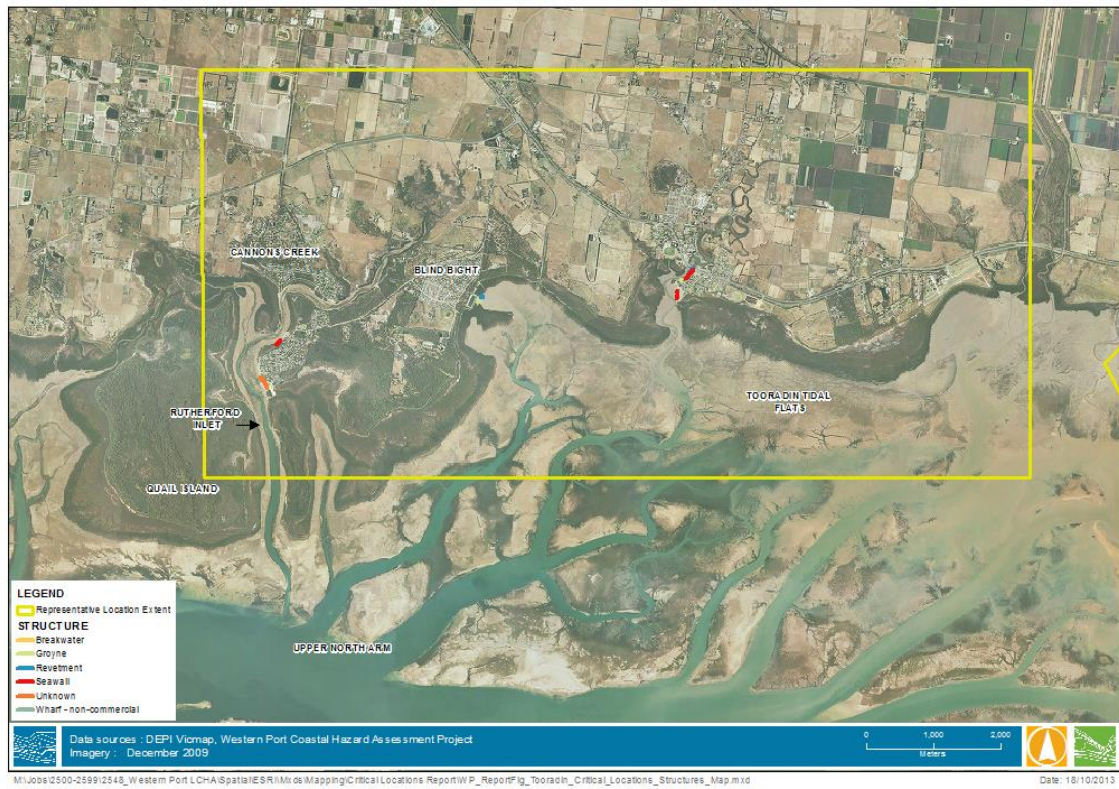
This northern section of Western Port contains an extensive intertidal flat system containing a web of minor channels. Intertidal sedimentation processes associated with the channels dominate, resulting in significant deposition of suspended mud. Catchment sediment inputs have affected this area although volumes appear to be reducing (S. Brizga & Associates, 2001). Significant volumes of muddy sediments are being introduced to the system by the continued erosion of the eastern shoreline.

### 3.1.5 Coastal Structures

There are few lengths of the study area shoreline which have been modified by the formal construction of coastal structures. The existing coastal structures as defined by the DEPI coastal asset database are shown in Figure 3-8.

These structures comprise the Sawtells Inlet tidal gates and adjacent sea wall and the rock revetment at the Tooradin boat ramp, as shown in Figure 3-9 and Figure 3-10. The remaining structures located are associated with boat ramps or boating/recreational facilities and are shown in Appendix C.





**Figure 3-8** Extent of the Coastal Structures in the Tooradin & Coastal Villages Study Area



**Figure 3-9** Sawtells Inlet Tidal Gates





**Figure 3-10** Rock Revetment Structure at Tooradin adjacent to Boat Ramp

## **3.2 Local Hazard Assessment**

The sources of potential hazards and the extent of uncertainty relating to the assessment of the impact of sea level rise on these hazards in the study area are analysed and discussed in the following sections. The sources of potential hazards have been grouped under the broad categories of erosion and inundation hazards for ease of understanding and for the purposes of mapping hazard extents.

### **3.2.1 Erosion Hazards**

This section details the key erosion hazard mechanisms and interactions relevant to this representative location. Further background definitions and conceptual models of the different erosion hazard mechanisms described in this section are detailed in the accompanying Part A report (Report 5).

#### ***Loss of Coastal Wetlands***

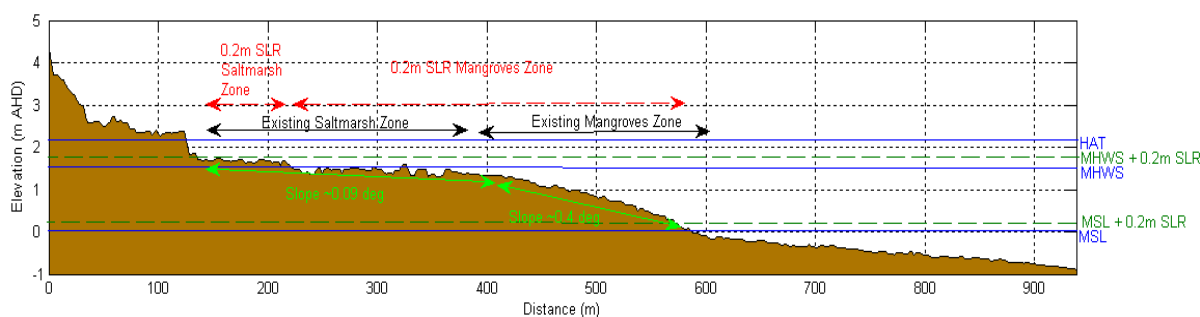
As identified in the Part A assessment, the primary impact of rises in relative sea levels on coastal wetlands and other types of peripheral vegetation is expected to be associated with changes in inundation regimes and depths.

Analysis of the existing cross section profiles across the coastal wetland fringed shorelines in this study area provide the opportunity to evaluate how sensitive the coastal wetland vegetation is likely to be to future changes in sea level. Figure 3-11 displays a typical cross section through the coastal wetland fringed shorelines in the study area relative to key tidal planes and the existing distribution of salt marsh and mangrove vegetation. Figure 3-11 also displays the intersection of key tidal planes through the cross section profile including +0.2m of sea level rise and the inferred extent of

saltmarsh and mangrove vegetation due to the subsequent change in the tidal inundation regime across the profile.

The following observations relating to the sensitivity of coastal wetland fringed shorelines to sea level rise are provided based on the analysis displayed in Figure 3-11.

- Due to the very low gradient of the saltmarsh terrace zone, sea level rise scenarios of as little as +0.2 m would cause dramatic changes to the frequency of tidal inundation across the existing salt marsh zone. The frequency of inundation that would be generated across this zone would be considered generally unsuitable for saltmarsh.
- The tidal inundation regime across the profile would potentially remain within the range favourable for mangroves for sea level rise scenarios of +0.2 m (2040) and potentially up to +0.8 m (2100). This suggests that, setting aside major changes to wave climates and sediment transport processes on these shorelines, a fringe of mangroves may potentially persist to some extent on these shorelines.



**Figure 3-11 Analysis of Sensitivity of Coastal Wetland Shoreline Profile to Sea Level Rise**

This is a simplified analysis of coastal wetland sensitivity to sea level rise in the study area and neglects significant uncertainties associated with contributing factors, including:

- Potential increases in sediment elevations associated with sedimentation processes and below ground productivity;
- Predicted significant changes to wave energy and rates of sediment transport due to sea level rise; and
- Climatic changes such as higher mean temperatures and reduced frequency of frosts that are likely to be favourable to mangrove productivity.

It is important to note that despite the range of uncertainties relating to the trajectory of response and potential rates of change that may be observed on the coastal wetland fringed shorelines in the study area, the consequence of this uncertainty on the potential extent of erosion hazards is considered relatively minor. This is because nearly all the coastal wetland fringed shorelines in this study area are backed by relatively elevated backshore hinterland associated with the Cranbourne Sands. The potential extent of erosion hazards is therefore considered to be significantly controlled by the interface between the coastal wetland depositional terraces and the elevated topography of Cranbourne Sands. Within this critical location, this interface generally marks the location of earlier mid-Holocene sandy shorelines that developed from the reworking of these Cranbourne Sands by wave action.

For these reasons, the extent of the potential coastal erosion hazards associated with changes in vegetation communities on these shorelines has remained the same as the extents developed in the Western Port Part A assessment. The erosion hazard extent therefore represents the intersection of the MHWS tidal plane extents, including sea level rise, along the coastal wetland fringed shorelines

in this critical location. Where MHWS tidal planes extend completely across the depositional terrace and intersect backshore sandy landforms, it is expected that erosion hazards may evolve along this interface due to the combination of the loss/decline of coastal wetland vegetation, frequent tidal inundation and significantly increased wave action.

### **Backshore Tidal Inundation**

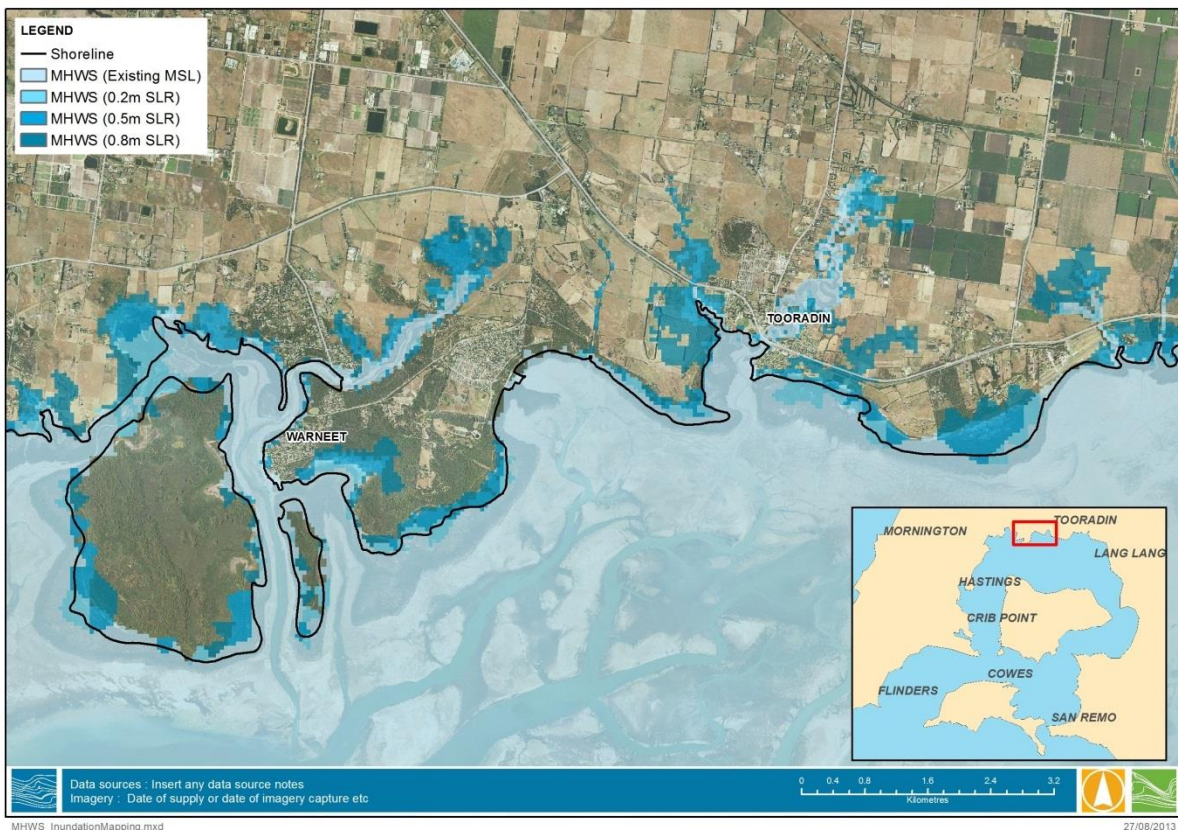
Much of the Koo-Wee-Rup Swamp is currently located at elevations at or below the existing MHWS tidal plane in this region of Western Port. Extensive tidal inundation of the Koo-Wee-Rup Swamp is currently prevented by the presence of the South Gippsland Highway causeway and the small and limited number of hydraulic connections through the causeway linking Western Port to the swamp.

Increases in sea level could, however, be expected to increase the duration and volume of the tidal flows into Koo-Wee-Rup Swamp through the existing hydraulic connections on the South Gippsland Highway.

Areas that in future experience more frequent tidal inundation due to sea level rise could be expected to evolve into muddy intertidal zones which would be fringed by proto shorelines that may include saltmarsh and mangroves.

Reasonable predictions of the extent of Koo-Wee-Rup Swamp that may potentially be tidally engaged through the connection with the existing hydraulic structures on the South Gippsland Highway due to sea level rise are possible through the use of the hydrodynamic model to integrate the time varying tidal water levels and propagation through these structures.

Figure 3-12 displays the predicted extent of tidal inundation under MHWS for each of the sea level rise scenarios.



**Figure 3-12 MHWS Tidal Plane for Each of the SLR Scenarios**



### **3.2.2 Inundation Hazards**

#### ***Storm Tide Inundation***

Extreme storm tide conditions may generate more extensive coastal inundation within the study area, particularly along shorelines that are not backed by Cranbourne Sands such as within the Koo-Wee-Rup Swamp.

To further refine the predicted inundation extents detailed in Report 4 of Part A, for the 1% AEP storm tide scenarios in this local study area, the hydrodynamic model mesh was further refined to capture additional small scale topographic details associated with the many raised features, such as levees or embankments, and channel features within the study area.

Figure 3-14 displays the predicted extent of inundation under the 1% AEP design storm tide for each sea level rise scenario following the local refinement of the hydrodynamic model mesh.

It is critical to understand that the extent of storm tide inundation due to sea level rise in this study area, and the Koo-Wee-Rup Swamp in particular, will be fundamentally limited by the time varying-duration characteristics of storm tides and hydrodynamic interactions with key topographic features and hydraulic structures that currently exist in this region. The predicted maximum extents of inundation are therefore significantly less than would be inferred by intersecting the peak storm tide level with the topography in this region as per the 'bathtub' assessment method.

From Figure 3-14 it can be seen that in general, the western section of the study area, which is largely backed by Cranbourne Sands, is only predicted to experience relatively minor and incremental increases in storm tide inundation extents up to the +0.8 m sea level rise scenario.

The eastern section of the study area in the Koo-Wee-Rup Swamp is, however, expected to experience very significant increases in storm tide inundation extents. Significant overtopping of the South Gippsland Highway is predicted to commence east of Tooradin during a 1% AEP storm tide with +0.5m sea level rise (2070 time scale, Scenario 2). By 2100, assuming +0.8 m of sea level rise; extensive overtopping of the South Gippsland Highway is predicted at multiple locations both west and east of Tooradin. The extent of overtopping of the South Gippsland Highway is predicted to generate quite extensive inundation of the southern section of the Koo-Wee-Rup Swamp.

### **3.2.3 Evaluation of Sources of Uncertainty**

The sources and significance of uncertainty associated with the assessment of the potential future extent of inundation and erosion hazards in the study area are discussed below:

#### ***Coastal Wetlands***

While significant uncertainties exist in relation to the details of the likely trajectory of response and potential rates of change that may be observed on the coastal wetland fringed shorelines, the potential extent of erosion hazards is expected to be largely limited to the interface between the coastal wetland depositional terraces and the elevated topography associated with the Cranbourne Sands. This therefore provides a significant control on the potential upper extent of coastal erosion hazards on these shorelines.

#### ***South Gippsland Highway Causeway***

Progressively more frequent inundation of the South Gippsland Highway by storm tides could be expected to be met by actions to either raise the causeway or realign the highway. The extent of coastal inundation in the low lying backshore areas of the Koo-Wee-Rup Swamp will be sensitive to any structural adaptive responses, for example, increases in the elevation of the highway causeway, its alignment, or the number and/or size of hydraulic structures through it.

### ***Tidal Gates***

It is expected that as sea level rise progressively increases the frequency and extent of tidal inundation generated through the unregulated hydraulic structures on the South Gippsland causeway into the Koo-Wee-Rup Swamp, adaptation of the structures to regulate these flows could occur.

The future management and adaptation of the unregulated hydraulic structures on the South Gippsland Highway will significantly influence both the extent of coastal inundation, as well as the extent to which frequent backshore tidal inundation of the Koo-Wee-Rup Swamp results in the evolution of muddy intertidal regions and shorelines in these areas.

### ***Stormwater***

Interactions between elevated coastal water levels and the stormwater networks in the coastal villages within the study area may result in additional inundation impacts either through direct surcharging of the stormwater pipe and pit networks by large storm tides and/or by limiting the egress of locally generated runoff due to reduced hydraulic grades through the stormwater network. Prediction of these additional inundation impacts requires very fine scale hydraulic analysis incorporating the stormwater pipe network, which was beyond the scope of this assessment.

### ***Coastal Structures***

Except for the tidal gates and rock wall at Sawtells Inlet (discussed above) coastal structures located within this study area are localised rock walls or revetments associated with boating or recreational infrastructure. These structures have been included within the erosion hazard zone delineation as it is assumed they will be maintained into the future. For further details see Appendix C.

For all coastal structures within the study area, it is recommended that a monitoring program be developed to record the conditions of the structures and document any failures or stability issues arising in the future. Further more detailed design assessments of each structure would be required to determine likely failure conditions and design requirement under future sea level rise conditions. This is considered beyond the scope of the current assessment.

## **3.3 Local Coastal Hazard Mapping**

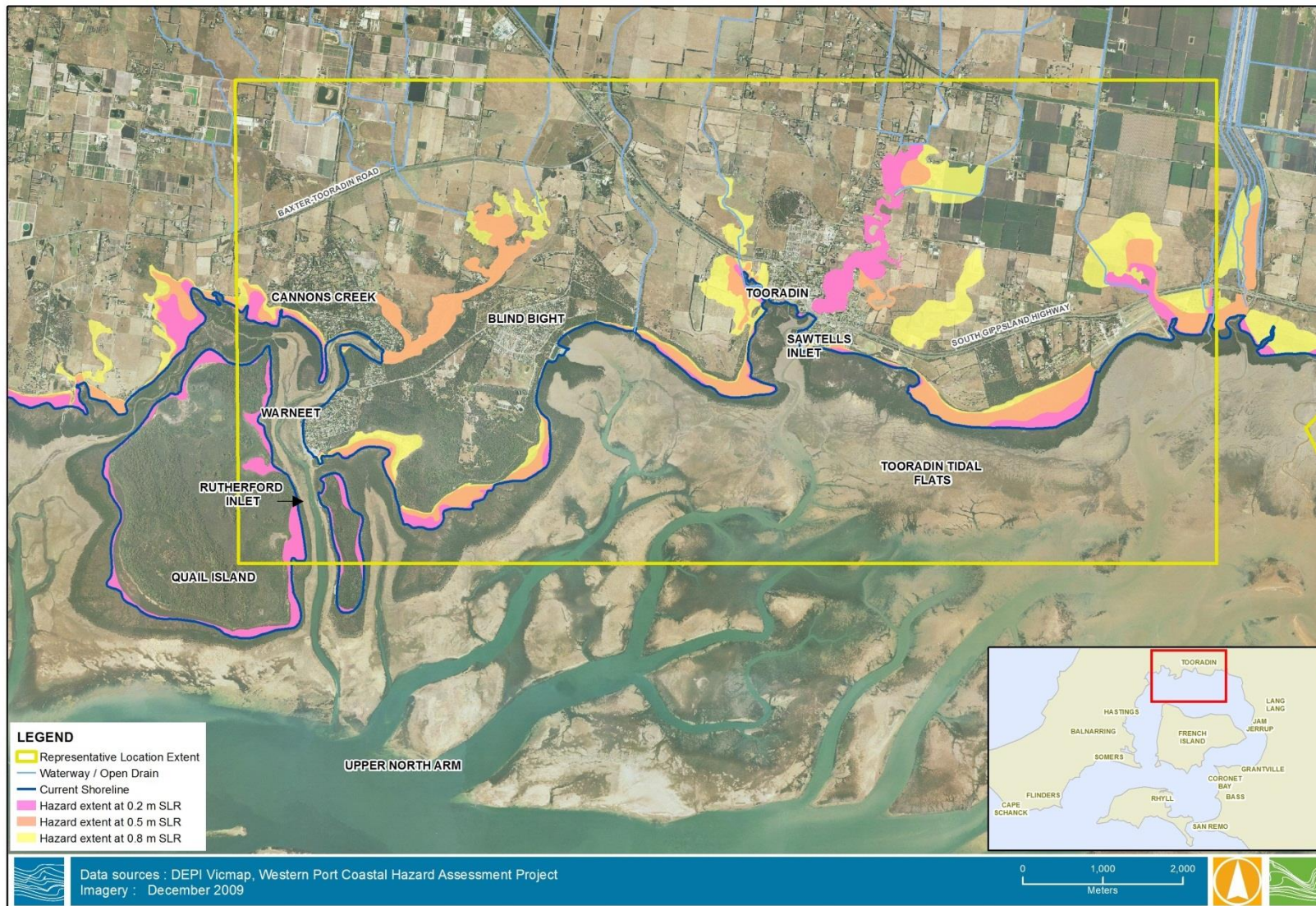
The local models and assessments of future shoreline change/hazards developed in the previous sections have been applied to refine the erosion and inundation hazard extents within the Tooradin and Coastal Villages representative location. Table 3-2 documents the final erosion mapping method adopted and/or the hazard extent that was mapped for the Tooradin and Coastal Villages representative location. The inundation hazard extent was mapped based on the outputs from the hydrodynamic modelling which has been smoothed to match in with the local elevation model. As per Part A, all hazard extents are relative to a shoreline delineated relative to the MHWS tidal plane and subsequent variation in water level across Western Port.

Figure 3-13 displays the erosion hazard extents for the Tooradin and Coastal Village representative location, while Figure 3-14 displays the inundation hazard extents.

**Table 3-1 Summary of Erosion Hazard Mapping Method/Extent for Tooradin and Coastal Villages Representative Location**

Shoreline Class	Hazard Type	Timeframe		
		2040	2070	2100
Coastal Wetlands	Loss of Coastal Wetlands	<p>The hazard zone was determined by intersection of the modelled MHWS tidal plane extent for each sea level rise scenario with the digital terrain model (DTM) to estimate the landward extent of the mangrove fringe.</p> <p>Where the predicted MHWS tidal plane intersected steeper backshore terrain landward of the saltmarsh-mangrove depositional terrace, the hazard extent was truncated along this interface.</p> <p>The interface between the saltmarsh-mangrove depositional terrace and backshore landforms was delineated from analysis of the LiDAR survey, aerial photography and geological mapping data.</p>		
	Backshore Tidal Inundation	<p>The hazard extent was mapped from changes to the MHWS tidal limit of inundation predicted by the hydrodynamic model for each sea level rise scenario.</p>		

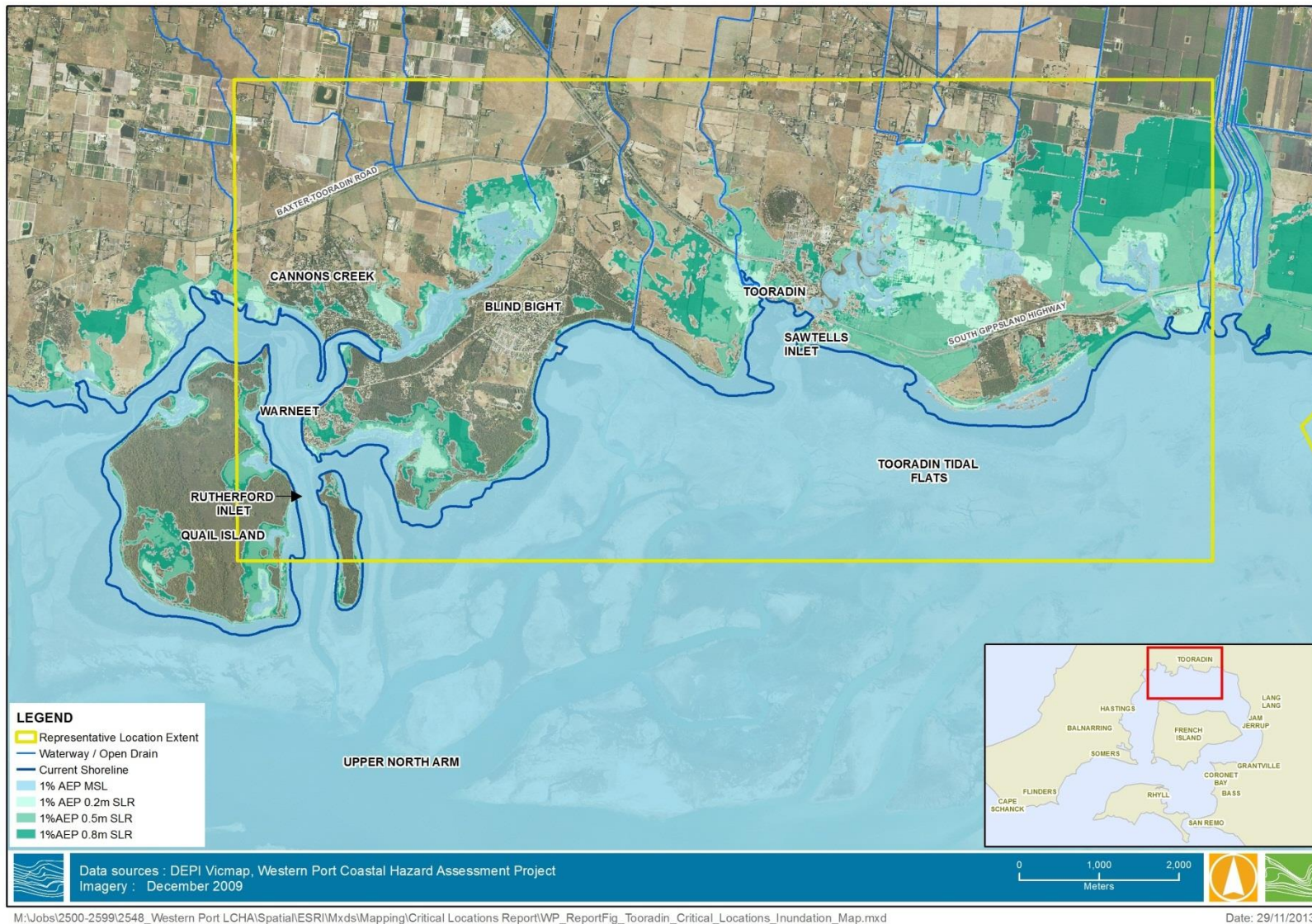




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**Figure 3-13 Erosion Hazard Extents for the Tooradin and Coastal Villages Representative Location**





**Figure 3-14 Inundation Hazard Extents for the Tooradin and Coastal Villages Representative Location**

### 3.4 Summary and Recommendations

A summary of the coastal hazards identified within the Tooradin and Coastal Villages representative location along with a description of any associated uncertainty is provided Table 3-2.

The following recommendations are provided from the results of the local coastal hazard assessment of the Tooradin and Coastal Villages representative location:

- The level of uncertainty in the potential erosion and inundation hazard extents within this critical location is considered low to moderate. Major loss of coastal wetlands could be expected by the end of the century and an upper limit on the subsequent extent of erosion hazards can be reasonably defined based on underlying geomorphic considerations. The extent of inundation hazards within the critical location can be predicted relatively reliably using the available modelling tool, but will ultimately be impacted by the extent of the adaptive responses to these hazards towards the end of the century.
- Measures to manage the identified coastal hazards due to sea level rise in this location could include the following:
  - Further monitoring programs to understand the long term trends in surface elevations within coastal wetlands in Western Port would assist in refining the likely trajectory and rates of change to the vegetation communities along these shorelines;
  - Development of a strategic approach towards providing adaptation space for the landward migration of saltmarsh and mangrove fringed shorelines into the Koo-Wee-Rup Swamp;
  - A strategic approach to the management and future adaptation responses for the South Gippsland Highway and the hydraulic structures connecting Western Port to the Koo-Wee-Rup Swamp, as these assets will increasingly influence the extent of inundation hazards in this region;
  - Long term monitoring of the condition and stability of the coastal structures could be implemented, however apart from the tidal gates these structures only provide very localised protection against inundation or erosion hazards.
  - Initiation of planning measures to minimise the risks within the hazard overlays; and
  - Additional detailed hydraulic analysis of the potential interactions between elevated coastal water levels and the stormwater networks in the coastal villages in order to understand the potential significance on inundation hazards.



**Table 3-2 Summary of Coastal Hazards and Uncertainties for the Tooradin and Coastal Villages Representative Location**

Hazard Category	Specific Hazard	Timeline	Likelihood	Uncertainty	Comments
Coastal Erosion	Loss of Coastal Wetlands	Present	Unlikely	<b>Moderate/</b> <b>Low</b>	The likelihood of a significant loss of coastal wetlands is high.  The level of uncertainty is low to moderate; the adaptive capabilities of vegetation communities may limit the impact of modest amounts of sea level rise but relatively major loss of coastal wetlands could be expected by the end of the century. An upper limit on the probable extent of erosion hazards can be reasonably defined.
		2040	About as Likely as Not		
		2070	Likely		
		2100	Likely		
	Backshore Tidal Inundation	Present	Unlikely	<b>Low/</b> <b>Moderate</b>	Significant backshore tidal inundation increasingly likely towards the end of the century within the Koo-Wee-Rup Swamp.  The level of uncertainty is considered low-moderate. Hazard impact can be predicted relatively confidently based on existing conditions, however future adaptive responses to levee/embankments and South Gippsland Highway will likely influence the hazard extent towards the end of the century.
		2040	Unlikely		
		2070	Likely		
		2100	Virtually Certain		
Coastal Inundation	Storm Tide Inundation	Present	Unlikely	<b>Low/</b> <b>Moderate</b>	The level of uncertainty is considered low-moderate. Hazard impacts can be predicted relatively confidently based on existing conditions, however future adaptive responses to levee/embankments and South Gippsland Highway will likely influence the hazard extent towards the end of the century.
		2040	About as Likely as Not		
		2070	Likely		
		2100	Virtually Certain		

## 4. LANG LANG (MAIN DRAIN TO JAM JERRUP)

### 4.1 Overview

The Lang Lang representative location shoreline extends from the mouth of the Yallock Creek drain to the southern end of Lang Lang Beach as displayed in Figure 4-2. This study area is exclusively comprised of the low earth-cliffed shoreline classes identified in the Part A assessment.

The characteristics and susceptibility of this shoreline to coastal hazard impacts is integrally related to the nature and variations in geology, geomorphology, and hydrodynamic setting. The following sections provide a broad overview of the nature and variability of the physical environment of the Lang Lang location as a basis for understanding the potential type, extent and susceptibility of the shoreline to coastal hazards.

#### 4.1.1 Geology

The Lang Lang study area is comprised almost entirely of unnamed swamp, lake and alluvial deposits associated with the former Tobin Yallock swamps (Figure 4-1). Towards the southern limit of the study area are the Haunted Hills ferruginous sands, gravels and silt outcrop at Jam Jerrup.

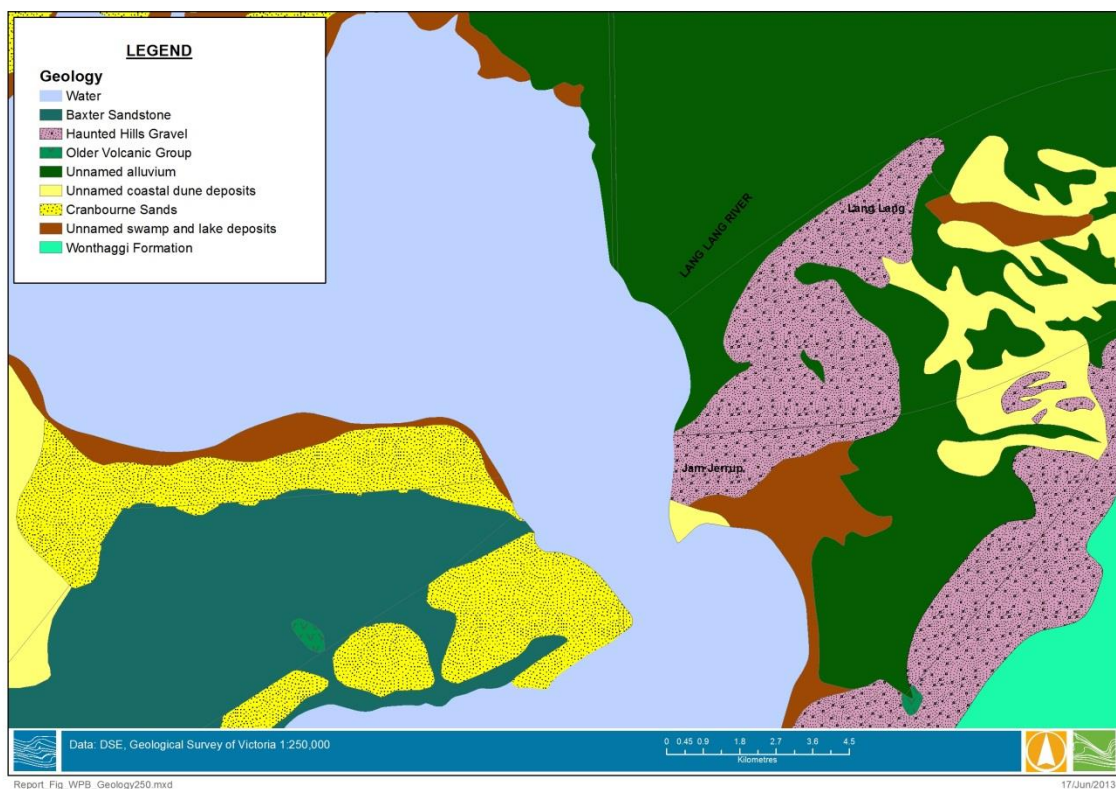


Figure 4-1 Geology of Lang Lang Representative Location



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Date: 18/10/2013

**Figure 4-2 Lang Lang Study Area Locality Plan**