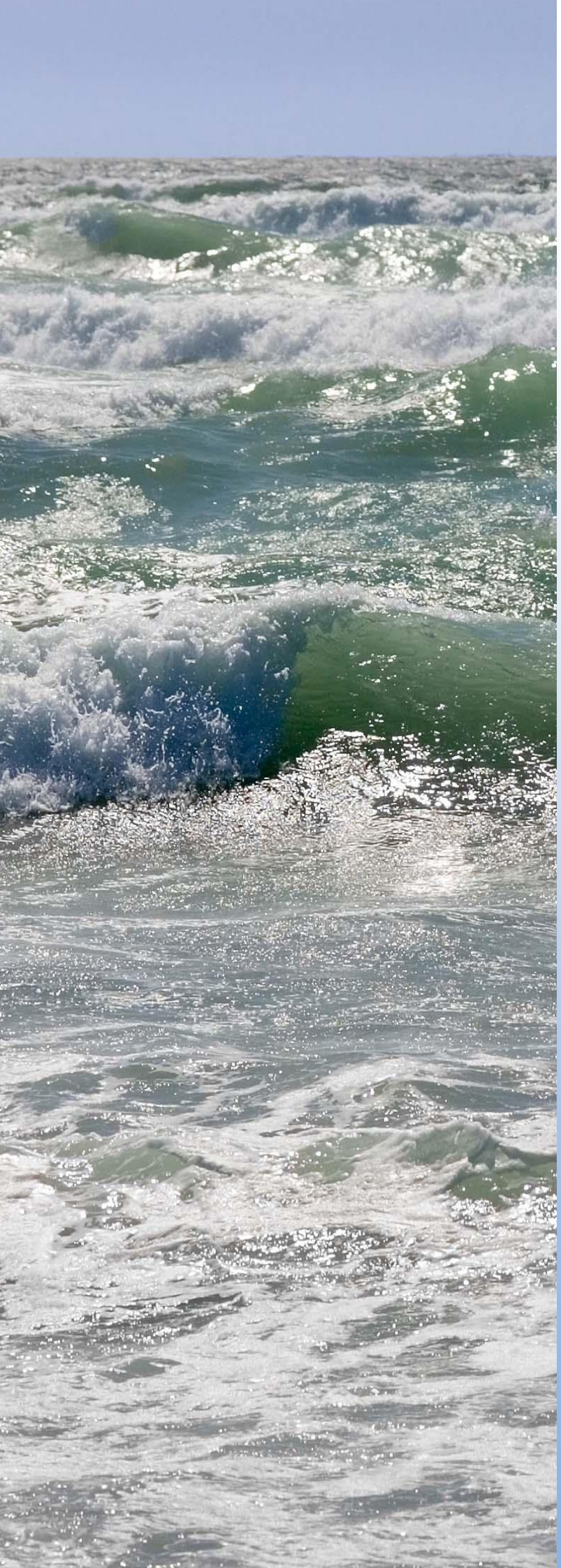

COASTAL ENGINEERING SOLUTIONS

92 ELIZABETH AVENUE ROSEBUD WEST

COASTAL HAZARD VULNERABILITY ASSESSMENT

prepared for

Watermark Village Pty Ltd

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SUMMARY

- The property at 92 Elizabeth Avenue, Rosebud West is the subject of a proposed planning application to create a 99 lot subdivision. In accordance with the *Victorian Coastal Strategy 2008*, this Coastal Hazard Vulnerability Assessment (CHVA) has been completed for the site.
- 92 Elizabeth Street is set back some 1125 metres from the natural shoreline of Port Phillip Bay. Existing dwellings, and a 60 metre wide vegetated dune constitute all of this foreshore buffer. Consideration of existing and likely future coastal processes indicate that the proposed development is beyond the effects of any shoreline erosion in the period leading up to and including 2100.
- Land levels across the proposed area of land to be sub-divided for residential purpose will be set at +3.5m AHD or greater. These levels are above the influences of present-day 100 year return period storm tide events; consequently the property is currently not at risk of storm tide inundation.
- By 2040, the combined effects of future climate change (including predicted sea level rise and increased "storminess") mean that the occurrence of a 100 year return period storm at that time will be such that there will be no inundation of the sub-divided allotment area according to either CSIRO or Melbourne Water – even allowing for 600mm freeboard as nominated by Melbourne Water. Since this is an in-fill development, the controlling climate change scenario is the Year 2040 case.
- For the predicted climate change scenario in the year 2100, the ground levels over the proposed sub-divided area are at +3.5m or greater which means there is still a freeboard above Melbourne Water's requirements of 0.5 metres.
- It is reasonable to assume that the habitable areas of the dwellings in development will be set at +3.5m (AHD) or greater – the minimum fill level over the sub-divided area.

1 INTRODUCTION

1.1 General

A 99 lot subdivision is proposed on the property at 92 Elizabeth Avenue Rosebud West. Survey for the subdivision has been prepared by Cranbourne Land Pty Ltd as part of the planning approvals process. The applicant has requested that a Coastal Hazard Vulnerability Assessment (CHVA) for the subject site be prepared in accordance with the requirements of the *Victorian Coastal Strategy 2008* and the *Victorian Coastal Hazard Guide 2012*. Flooding criteria introduced by Melbourne Water in 2012 for Westernport and Port Phillip bays will be the dominant criteria in terms of inundation. Melbourne Water has also provided advice to Neil M Craigie Pty Ltd in relation to local flood levels and this advice is included in this CHVA.

This Coastal Hazard Vulnerability Assessment includes:

- A description of the relevant sea level, storm and foreshore characteristics.
- Shoreline and site vulnerability to a storm having a 100 year return period for the present-day climate scenario.
- Corresponding shoreline and site vulnerability (including future climate change influences) over a planning period that extends to the year 2040.
- Shoreline and site vulnerability (including future climate change influences) over a planning period to 2100.
- The vulnerability of the site to coastal hazards over these various timeframes include the effects of future sea level rise (and other associated increases in storm parameters) as nominated in the *Victorian Coastal Strategy 2008* and flood levels as nominated in Melbourne Water, 2012 and to Neil M Craigie Pty Ltd.

1.2 Location and Property Characteristics

The location of 92 Elizabeth Avenue in relation to Port Phillip Bay and its shoreline is shown conceptually on Figure 1 and Figure 2. The northern boundary of the property is set back some 1125 metres from the natural shoreline of Port Phillip Bay. The land between 92 Elizabeth Avenue and the shoreline is fully developed in terms of residential land and associated infrastructure.

The subject land that is to be sub-divided off the overall land area at 92 Elizabeth Avenue varies in height from about 1.7 metres at the southern boundary of the subdivision into residential lots to levels of over 4 metres near the northern boundary and abutting land that has already been built up with residential lots. The land to be subdivided is less than 70% of the total land area at 92 Elizabeth Avenue. The balance of the land lies to the south of the sub-division and is reserved for environmental and flood mitigation purposes. See Figure 3.

The land area that is to be sub-divided into residential allotments will be filled to a minimum level of +3.5m AHD.

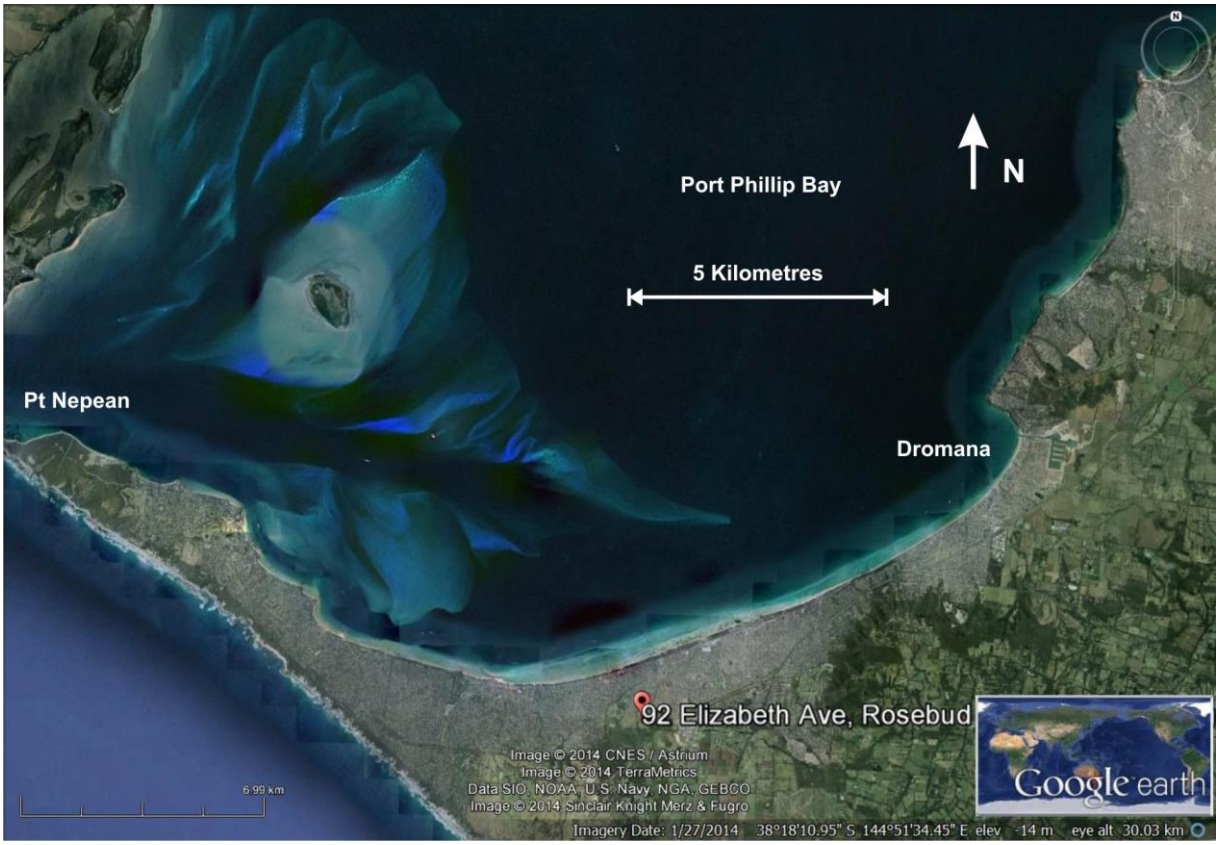

Figure 1 : Overall Location of 92 Elizabeth Ave in relation to Port Phillip Bay

Figure 2 : Location of 92 Elizabeth Ave relative to shoreline

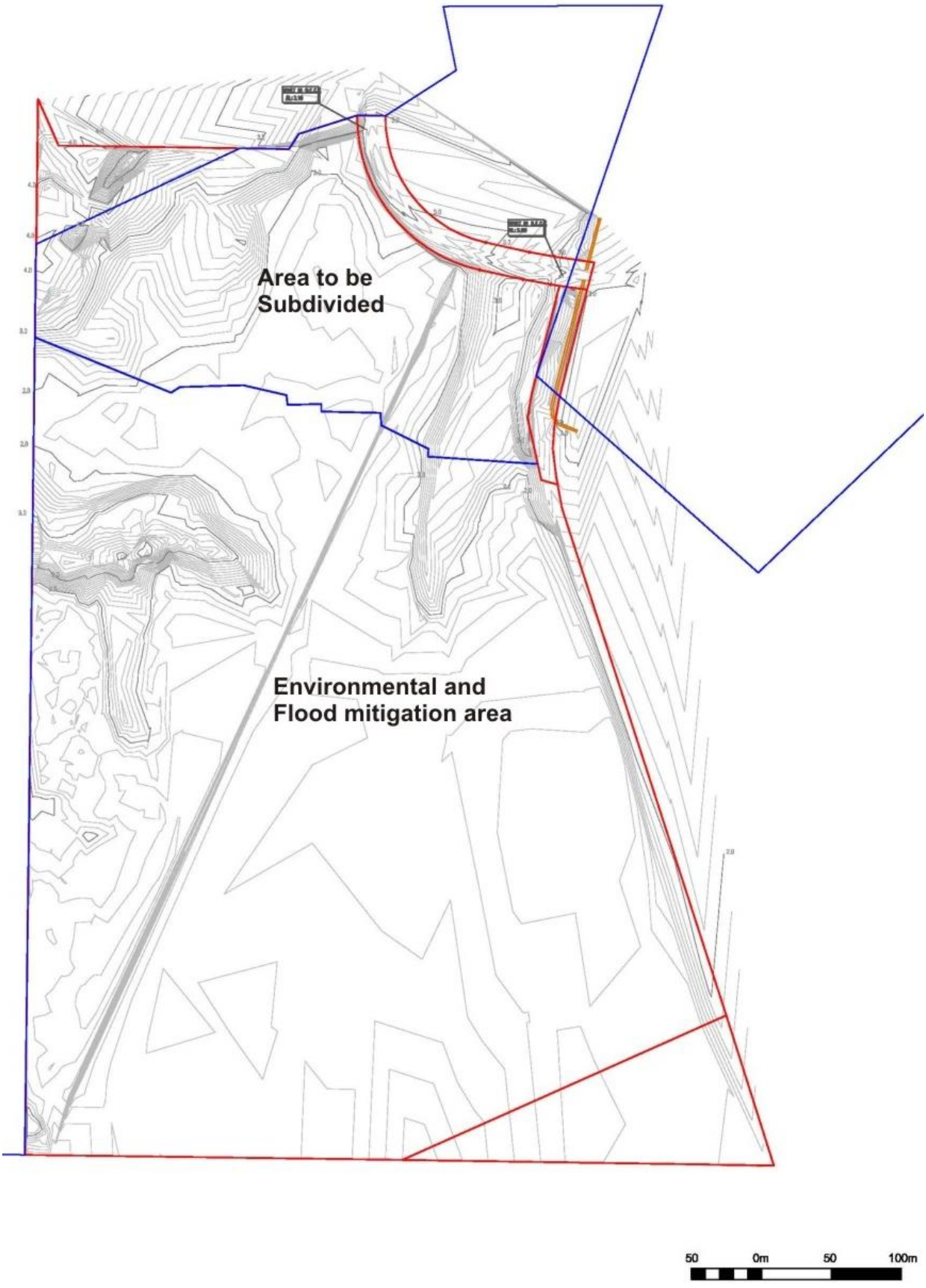

Figure 3 : Land contours

2 ASSESSMENT PARAMETERS

2.1 Overview

The *Victorian Coastal Strategy 2008* includes a policy to plan for a rise above present-day sea levels of not less than 0.8m by the year 2100. In June 2009 the Victorian State Government appointed a *Coastal Climate Change Advisory Committee* (CCCAC) to consider and recommend appropriate planning responses to the implications of future climate change to the state's coastal regions.

The CCCAC's Final Report was released by the Minister for Planning on the 5th June 2012. A number of recommendations have been accepted by the Government - including the following amendments to the *State Planning Policy Framework* which have particular relevance to the proposed development:

- *In planning for possible sea level rise, an increase of 0.2 metres over current 1 in 100 year flood levels by 2040 may be used for new development in close proximity to existing development (urban infill).*
- *Plan for possible sea level rise of 0.8 metres by 2100, and allow for the combined effects of tides, storm surges, coastal processes and local conditions such as topography and geology when assessing risks and coastal impacts associated with climate change.*

In conjunction with predicted sea level rise, there are other climate change influences that need to be addressed - primarily as a consequence of increased "storminess" and the associated increase in storm tide levels along Victoria's shoreline.

These various additional factors have been addressed in the comprehensive CSIRO report " *The Effect of Climate Change on Extreme Sea Levels in Port Phillip Bay*" (McInnes et al, 2009). Consequently when undertaking this CHVA, parameters associated with increased storminess have been adopted from the CSIRO reports, as well as the direct implications of future sea level rise.

Independently, Melbourne Water has made its own assessment of storm tide inundation and has made recommendations for the required freeboard of habitable floor levels *"Planning for sea level rise, 2012"* In its assessment, Melbourne Water stipulate that its levels are generally higher than those of CSIRO and will used in Melbourne Water's assessment of planning applications in the coastal zone.

2.2 Storm Tide and Surge

Figure 4 illustrates the primary water level components of a storm tide event. Any increase in ocean water levels as a consequence of future climate change would be in addition to these various natural phenomena. A brief discussion of these components is offered below.

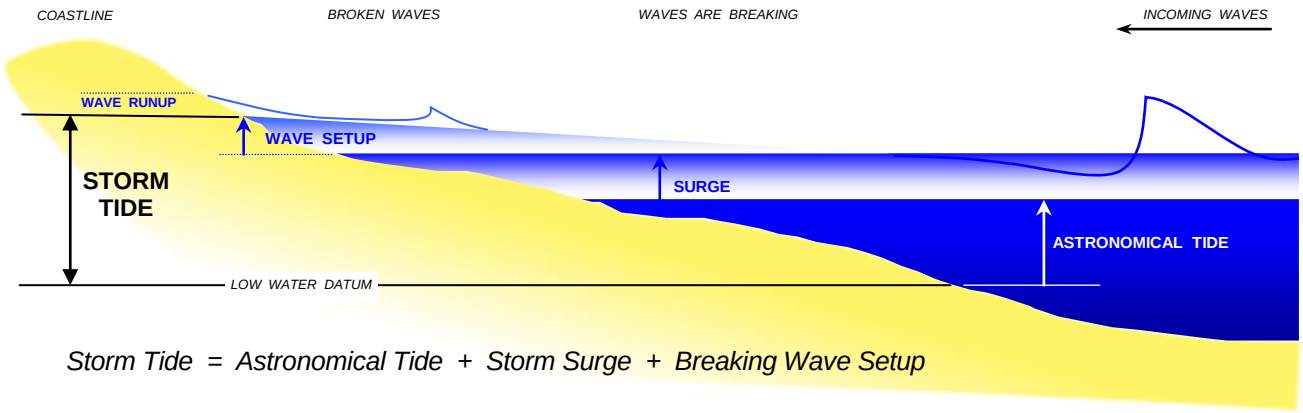

Figure 4 : Components of a Storm Tide Event

- *Astronomical Tide:* The astronomical tide is the normal day-to-day rising and falling of ocean waters in response to the gravitational influences of the sun and the moon. The astronomical tide can be predicted with considerable accuracy. Astronomical tide is an important component of the overall storm tide because if the peak of a severe storm were to coincide with a high spring tide for instance, severe flooding of low lying coastal areas can occur and the upper sections of coastal structures can be subjected to severe wave action.

- *Storm Surge :* This increase in ocean water levels is caused by meteorological effects during severe storms. Strong winds blowing over the surface of the ocean forces water against the coast at a greater rate that it can flow back to sea. Furthermore sea levels can rise locally when a low pressure system occurs over the sea - resulting in what is termed an “inverted barometer” effect. A 10mb drop in atmospheric pressure results in an approximate 10 cm rise in sea level. In order to predict the height of storm surges, these various influences and their complex interaction are typically replicated by numerical modelling techniques using computers - such as has been done for the CSIRO study for Victoria’s coast (McInnes et al, 2008, 2009).

- *Breaking Wave Setup:* As storm waves propagate into shallower coastal waters, they begin to shoal and will break as they encounter the nearshore region. The dissipation of wave energy during the wave breaking process induces a localised increase in the ocean water level shoreward of the breaking point which is called breaking wave setup. Through the continued action of many breaking waves, the setup experienced on a foreshore during a severe wave event can be sustained for a significant timeframe and needs to be considered as an important component of the overall storm tide on a foreshore.

- *Wave Runup:* Wave runup is the vertical height above the local water level up to which incoming waves will rush when they encounter the land/sea interface. The level to which waves will run up a structure or natural foreshore depends significantly on the nature, slope and extent of the land boundary, as well as the characteristics of the incident waves.

Future climate change scenarios indicate there will be increases in the magnitude of storm surges due to changed meteorological conditions. The CSIRO reports determines the combined effects of future sea level rise and storm tide for a 100 year return period under such

conditions as "*Scenario 2*" – IPCC 2007 A1FI scenario in combination with 'high' wind speed scenario. It is the Scenario 2 conditions that are applied in this report.

Reference to these results shows that the ocean water levels summarised in Table 1 can be used as predictions for 100 year return period storm tide levels at Rosebud under future climate change scenarios to the Year 2100.

It is pertinent to note that the predicted storm tide level of +1.42m (AHD) in the year 2040 for Cowes is 0.33 metres above the predicted present-day level; and differs from the 0.2 metres stated in the *State Planning Policy Framework*. This is because by necessity it also includes the effects of climate change on meteorological conditions; and therefore on future storm surges - not just a 0.2 metre sea level rise.

Location	Current Climate	2040	2100
Rosebud	+1.09	+1.42	+2.22

Table 1 : CSIRO :Predicted (interpolated for 2040) 100 year Return Period Storm Tide Levels at Rosebud
(metres above AHD)

However, Melbourne Water's assessment of flood levels for areas affected by predicted sea level rise results in higher levels as indicated in below in Table 2. These levels apply to all of Port Phillip Bay, rather than being specific to the Rosebud area.

Location	Current Climate	2040	2100
Westernport Bay	+1.6	+1.8	+2.4

Table 2 : Melbourne Water : Predicted 100 year Return Period Flood Levels (for Port Phillip Bay)
(metres above AHD)

2.3 Coastal Processes

The term "*coastal processes*" is used to classify the naturally prevailing conditions of waves and currents that shape and control the stability of foreshores. In this instance, the property at 92 Elizabeth Avenue is located some 1125 metres inland from the natural shoreline that exists along Port Phillip Bay to the north of the subject land. This wide developed land area together with the naturally vegetated dune area, with a width of in excess of 60 metres, seaward of the developed land provides a substantial physical buffer between the property and the waters of the Bay.

2.3.1 Overview

The coastal processes on the Bay's shoreline between Rye and Dromana have been identified as part of earlier coastal studies undertaken by Coastal Engineering Solutions. Those studies (Coastal Engineering Solutions, 1996, 2004, 2008, 2009 and 2010) were mostly commissioned by state government departments supported MPSC.

Those studies concluded that there is a small net movement of sand from west to east at Rosebud, less than 1,000 cubic metres per year, and at Anthony's Nose there was a zero net movement of sand. The implication is that Rosebud is a net sand deposition area where the beach has tended to grow seaward and the dunes are building, albeit slowly.

Also based on the condition of the vegetated dunes on the foreshore north of 92 Elizabeth Avenue, it appears that this section of Port Phillip Bay's shoreline is stable and not undergoing any long-term erosion under present day sea levels and climate conditions.

2.3.2 Waves and Sediment Movement

The mechanism for sand movement along the shoreline at Rosebud is by wave action. The height of waves reaching shore is limited by the depth of water on the nearshore seabed approach slopes, as well as the fetch characteristics across which the winds generating the waves can blow. Fetches lengths are around 15kms to 50kms ; and are within the sector of west-north-west (through north) to north-east.

Waves generated from the northern sector occur mainly in winter; whereas waves from the west predominantly occur in summer. These waves move sediment at the Rosebud foreshore in two quite distinct modes:

- ***Longshore sediment transport*** whereby sand is moved along the coast, the direction of sand movement being dependent on the direction at which waves arrive at the shoreline relative to the shore alignment. Figure 5 illustrates this mechanism. Longshore sediment transport will occur whenever there are waves arriving at the beach at an angle that is not perpendicular to the beach.
- ***Offshore/onshore sediment transport*** whereby sand is moved off the beach face during storms and placed in offshore bars. During milder wave conditions the sand is returned to the beach – this is onshore sediment transport.

There is almost a balance in the annual movement of sand along the coast at Rosebud. During winter approximately 2,000 to 3,000 cubic metres of sand moves westward - whereas up to about 1,000 cubic metres more moves eastward during summer. This results in a net easterly transport of up to 1,000 cubic metres each year, which is supplied by the foreshores of Port Phillip Bay further to the west.

Nevertheless, sand can be eroded from the beach during storms. Beaches can recover naturally following such severe events, however the short-term erosion can potentially threaten foreshore infrastructure.

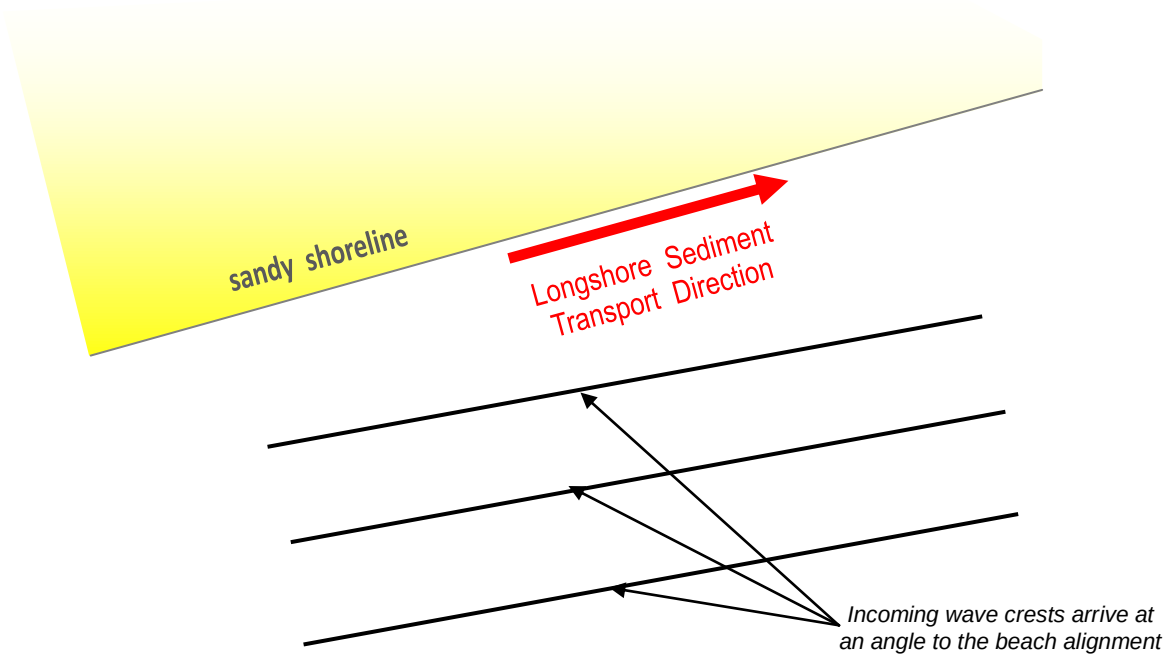

Figure 5 : Sand movement along a beach caused by waves

Coastal Engineering Solutions (2009) estimated that the extent of foreshore erosion during the severe storm event of 1st July 2008 was around 6 metres at the Rye Yacht Club.

The beach fronting north of 92 Elizabeth Avenue has a higher dune height than at Rye yacht Club for which it is estimated that the erosion is 2/3rd, say to 4 metres. During a more severe event with a return period of 100 years it is estimated that the width of erosion would still be significantly less than 10 metres at present day sea levels

However this is a transient eroded beach condition. Storm waves and the elevated level of Bay waters during storms attack the upper parts of the beach and the dunes, removing sand and depositing it in offshore sand bars. During subsequent milder sea conditions, this sand is transported back onto the beach; and the upper beach profile is restored by onshore winds blowing beach sand into the dunes.

In other words, the Rosebud foreshore is currently stable (even accreting) in the long-term. There are nevertheless short-term erosion events of varying severity caused by storms, but the beach profile tends to re-establish its pre-storm condition during subsequent periods of milder sea and weather conditions. The preceding **Figure 2** provides a general appreciation of the local setting and nature of the land between 92 Elizabeth Avenue and the Bay.

The predicted sea level rise and the increased wave energy associated with climate change effects will invariably alter the position of the shoreline in future years. It is estimated that the natural intertidal area will evolve so as to have a shoreline position some 0-5 metres further inshore by the year 2040; and some 10-15 metres by 2100.

3 PRESENT-DAY VULNERABILITY

3.1 Vulnerability to the 100 year Return Period Storm Event

3.1.1 Existing Inundation Risk

Land levels on the land to be subdivided at 92 Elizabeth Avenue vary between approximately +1.7 metres (AHD) at the southern perimeter to over 4 metres (AHD). Over 70% of the land, the southern portion, is low-lying and will not be subdivided. It is reserved for flood mitigation and environmental purposes.

As noted previously in Table 1, the predicted ocean water level currently associated with a 100 year return period event is +1.09m (AHD) along local foreshores as defined by CSIRO (2009). However, the current climate flood level according to Melbourne Water is +1.6m (AHD). This latter level is the dominant criteria because of the distance of the land from the coast. This inundation level is some 1.9 metres below the lowest land level (after filling) within the subdivided land at 92 Elizabeth Avenue. The property is therefore currently unaffected by storm tides or floods initiated by a 100 year return period event. However, Melbourne Water require a 600mm freeboard above its nominated level to allow for local waves. This is also accommodated for present day sea levels with the nominated minimum fill level of +3.5m AHD.

3.1.2 Existing Coastal Erosion Risk

The property at 92 Elizabeth Avenue is located some 1125 metres inland and will therefore be well beyond the effects of any storm erosion.

3.2 Mitigation

No mitigation is required because it is assumed that all finished floor levels for habitable building areas will be set at +3.5m AHD which is 1.3 metres above Melbourne Water's freeboard requirements.

4 VULNERABILITY OVER A PLANNING PERIOD TO 2040

4.1 Storm Parameters

The CSIRO study of future climate change effects throughout Victorian coastal areas (McInnes et al, 2009) predicts an increase in the strength of winds during storms by the year 2040. This increased "storminess" in conjunction with predicted sea level rise at 2040 results in an estimated 100 year return period storm tide level of +1.42 metres (AHD) - refer to Table 1.

However, the flood level nominated by Melbourne Water for 2040 is +1.8 metres (AHD). This is the controlling parameter for assessing vulnerability to inundation.

4.2 Vulnerability to the 100 year Return Period Storm Event

4.2.1 Inundation Risk in 2040

As stated previously, land levels on the land to be subdivided at 92 Elizabeth Avenue vary between approximately +1.7 metres (AHD) at the southern perimeter to over 4 metres (AHD). Over 70% of the land, the southern portion, is low-lying and will not be subdivided. It is reserved for flood mitigation and environmental purposes.

As noted previously in Table 1, the predicted ocean water level associated with a 100 year return period event is +1.42m (AHD) along local foreshores as defined by CSIRO (2009). However, the flood level according to Melbourne Water is +1.8m (AHD). This latter level is the dominant criteria because of the distance of the land from the coast. This inundation level is some 1.7 metres below the lowest land level (after filling) within the subdivided land at 92 Elizabeth Avenue. The property is therefore currently unaffected by storm tides or floods initiated by a 100 year return period event. However, Melbourne Water also requires a 600mm freeboard above its nominated level to allow for local waves. This is also accommodated for the year 2040 sea levels with the nominated minimum fill level of +3.5m AHD.

4.2.2 Coastal Erosion Risk in 2040

As stated previously, the property at 92 Elizabeth Avenue is located some 1125 metres inland and will therefore be well beyond the effects of any storm erosion and will therefore be well beyond the effects of any storm erosion to the Year 2040.

4.3 Mitigation

No mitigation is required because it is assumed that all finished floor levels for habitable building areas will be set at +3.5m AHD which is 1.1 metres above Melbourne Water's freeboard requirements.

5 VULNERABILITY OVER A PLANNING PERIOD TO 2100

5.1 Storm Parameters

The *Victorian Coastal Strategy* requires consideration of a 0.8 metre rise in sea levels by the year 2100. The CSIRO study of future climate change effects (McInnes et al, 2009) predicts a 19% increase in the strength of winds during storms by the year 2100. This increased "storminess" in conjunction with 0.8 metre sea level rise results in a 100 year return period storm tide level of +2.22 metres (AHD) by the year 2100 - refer to Table 1.

However, the flood level nominated by Melbourne Water for 2100 is +2.4 metres (AHD). This is the controlling parameter for assessing vulnerability to inundation.

5.2 Vulnerability to the 100 year Return Period Storm Event

5.2.1 Inundation Risk in 2100

As stated previously, land levels on the land to be subdivided at 92 Elizabeth Avenue vary between approximately +1.7 metres (AHD) at the southern perimeter to over 4 metres (AHD). Over 70% of the land, the southern portion, is low-lying and will not be subdivided. It is reserved for flood mitigation and environmental purposes.

As noted previously in Table 1, the predicted ocean water level associated with a 100 year return period event is +2.22m (AHD) along local foreshores as defined by CSIRO (2009). However, the flood level according to Melbourne Water is +2.4m (AHD). This latter level is the dominant criteria because of the distance of the land from the coast. This inundation level is some 1.1 metres below the lowest land level (after filling) within the subdivided land at 92 Elizabeth Avenue. The property is therefore currently unaffected by storm tides or floods initiated by a 100 year return period event. However, Melbourne Water also requires a 600mm freeboard above its nominated level to allow for local waves. This is also accommodated for the year 2100 sea levels with the nominated minimum fill level of +3.5m AHD.

5.2.2 Coastal Erosion Risk in 2100

As stated previously, the property at 92 Elizabeth Avenue is located some 1125 metres inland and will therefore be well beyond the effects of any storm erosion and will therefore be well beyond the effects of any storm erosion to the Year 2100.

5.3 Mitigation

No mitigation is required because it is assumed that all finished floor levels for habitable building areas will be set at +3.5m AHD which is 0.5 metres above Melbourne Water's freeboard requirements.

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