2019 | OMCN Consulting

COASTAL RISK ASSESSMENT

79 Harbour View, Sandy Point

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02/10/2019

Dear Anne & Phil,

Congratulations on getting ahead of the market and deciding to become informed on your property's coastal vulnerability to sea level rise. This OMCN Coastal Risk Assessment provides a summary of your property's flood and erosion risk from storm surge, tides and sea level rise over the next 20, 50 and 80 years. If you have any questions regarding this assessment please don't hesitate to contact us and we would be more than happy to discuss them with you.

Warm regards,

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Coastal Risk Profile

Risk has been calculated within this report by comparing the likelihood of occurrence with the associated consequences for 79 Harbour View, Sandy Point. The coastal flooding and coastal erosion risk has been assigned a score of either; very low, low, moderate, high or very high based of the analysis presented within Appendix A. It is recommended that if a risk score above low is recorded that further action should be undertaken to reduce the risk to a reasonable level.

Coastal Flood Risk

The future 1 in 100 year coastal flooding levels for 79 Harbour View have been mapped across a range of sea level rise (SLR) scenarios for the next 20, 50 and 80 years (2040, 2070 and 2100) within Figure 1 (see Appendix A for details on the analysis).

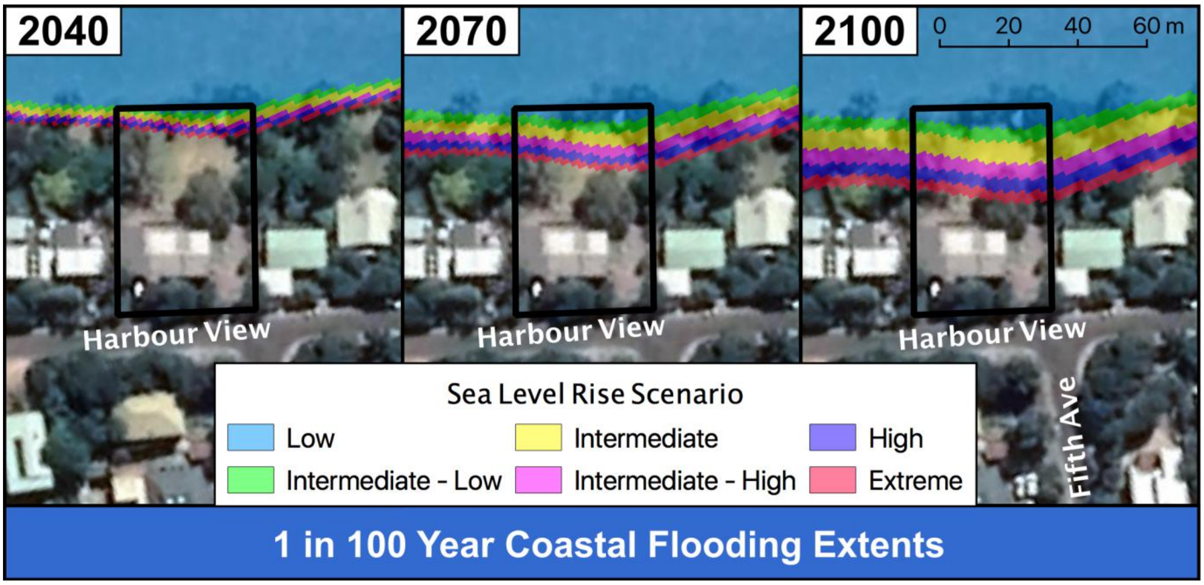

Figure 1 - The 1 in 100 year coastal flooding extents under various sea level rise scenarios.

The future coastal flood risk of 79 Harbour View for 2040, 2070 and 2100 is detailed within Table 2, the main rationale used to assign the risk scores can be found below:

- In **2040**, the 1 in 100yr coastal flood levels associated with the low to extreme SLR scenarios encroach onto the lower section of the property by roughly 2-7m, leaving a buffer of between 23-18m to the house.
- In **2070**, the 1 in 100yr coastal flooding levels associated with the low to extreme SLR scenarios encroach onto the lower section of the property by roughly 4-13m, leaving a buffer of between 21-13m to the house.
- In **2100**, the 1 in 100yr coastal flooding levels associated with the low to extreme SLR scenarios encroach onto the lower section of the property by roughly 5-20m, leaving a buffer of between 20-5m to the house.
- None of the 1 in 100yr flood levels assessed are likely to impact the house in 2040, 2070 or 2100.

Table 2 - Coastal flood risk

Year	Likelihood	Consequence	Risk Score
2040	Unlikely	Insignificant	**Very Low**
2070	Possible	Insignificant	**Low**
2100	Possible	Minor	**Moderate**

Coastal Erosion Risk

Coastal erosion is predominantly driven by waves and wave driven currents. As 79 Harbour View is located inside Shallow Inlet the property's erosion risk along its north eastern boundary is negligible due to the low wave energy environment found at this location. As such, this report has assessed the coastal erosion risk of 79 Harbour View from recession of Waratah Beach. Future coastal erosion estimates for a number of different sea level rise scenarios have been mapped across the next 20, 50 and 80 years (2040, 2070 and 2100) and are presented below within Figure 2 (see Appendix A for details on the analysis).

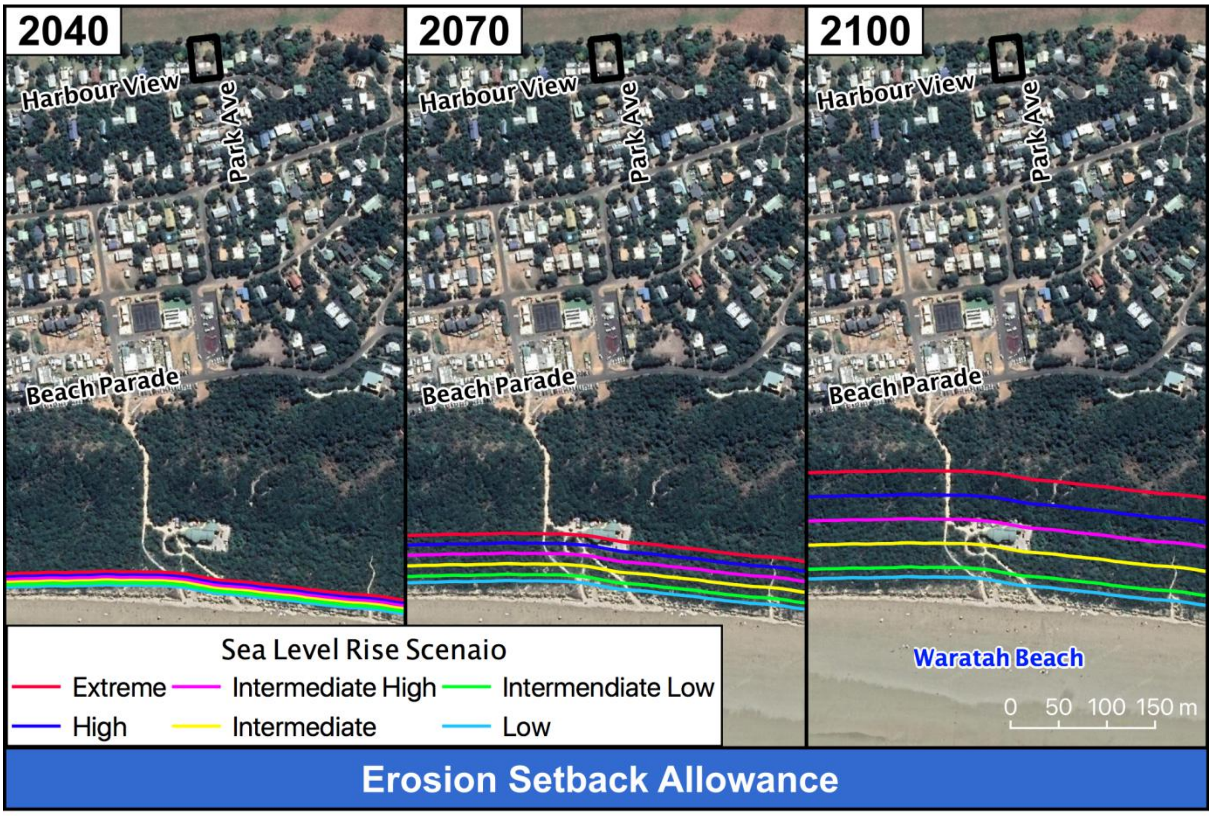

Figure 2 - Coastal erosion estimates for various sea level rise scenarios

The future coastal erosion risk for 79 Harbour View across the 2040, 2070 and 2100 time horizons is detailed within Table 3, the main rationale used to assigned the risk scores can be found below:

- There is a buffer of over 400m between the property and the coastal erosion estimates for all years assessed (2040, 2070 and 2100).

Table 3 - Coastal erosion risk

Year	Likelihood	Consequence	Risk Score
2040	Rare	Insignificant	**Very Low**
2070	Rare	Insignificant	**Very Low**
2100	Rare	Insignificant	**Very Low**

Risk Summary

79 Harbour View has a very low risk of coastal erosion over the next 20, 50 or 80 years. The coastal flooding risk is also classified as very low for 2040, however the risk increases to low in 2070 and moderate in 2100. This risk analysis has been undertaken with the assumption that the protection offered by the Shallow Inlet levee system is minimal. This assumption has been made due to the uncertainty surrounding the maintenance of the levee system and the upgrades required to protect it against sea level rise.

Recommendations

The risks outlined above show that the property has a low vulnerability to sea level rise within the short term. In the long term, 2070 and beyond, the property does become susceptible to coastal flooding. The following actions are recommended to help mange your risk level:

Track Sea Level Rise Projections

Though the risks detailed above are relatively low it is recommended that the you should stay up to date with sea level rise projections. These projections are currently available from the following organisations: Commonwealth Scientific and Industrial Research Organisation (CSIRO), National Oceanic and Atmospheric Administration (NOAA) and the Intergovernmental Panel on Climate Change (IPCC).

Contact your Local Council

Get in touch with your local council and request any relevant documentation which outlines their commitment to protecting the coastline from coastal hazards. Some councils are planing to adapt by building coastal protective structures such as seawalls, groynes and breakwaters. However, others are adopting "planned retreat" policies which essentially involves letting the sea move landward unabated whilst banning or limiting development in vulnerable areas. If planned retreat is adopted there are substantial financial implications for the property market in the area. It is recommend that the South Gippsland Shire Council be contacted to clarify who, if anybody, is legally responsible if the levee system within Shallow Inlet fails.

Mitigation Options

Actions which you can take on your own to manage your risk include:

- Increasing the floor level of your house to ensure that flood waters would not inundate the house under the projected sea level rise scenarios.
- Similarity you could build a small levee to control the flow of water across your property away from your building footprint.

Insurance

The risks associated with storm surge, coastal erosion and gradual sea level rise are excluded by many general insurance policies. You should check with your home insurance provider weather you are covered from damages as a result of these coastal hazards.

APPENDIX A - Coastal Risk Analysis

Glossary

Term	Definition
Annual Exceedance Probability (AEP)	Annual exceedance probabilities (AEPs) refer to the probability of a given event occurring within a single year. For example a 1 in 100 year storm has a 1% annual exceedance probability, which implies that there is a 1% chance of a 1 in 100 year storm occurring in a given year.
Australian Height Datum (AHD)	The Australian Height Datum (AHD) is a vertical datum in Australia. Zero metres AHD is equal to the mean sea level of Australia between 1966 - 1968.
Bathtub Model	A coastal modelling tool which assumes that all areas with an elevation below that of the flood level will be flooded. This does not take into account the time it takes for flood waters to enter the flooded area.
Bruun Rule	The “Bruun Rule” is a formula that describes the relationship between shoreline retreat and sea level rise. It was proposed by Per Bruun in 1962 and is the most commonly used model to predict sea level rise recession distances on sandy coastlines. The “Bruun Rule” states that a typical concave beach will undergo erosion on the upper beach profile and deposition will occur offshore in order to maintain a constant water depth.
Climate Change	The change in global weather patterns and temperatures attributed to human activity. The global warming associated with climate change leads to an increase in sea levels due to ice sheet melt and thermal expansion of the oceans.
Coastal Erosion	The displacement of sand associated with coastal processes such as waves, currents and wind.
Coastal Flooding	Coastal flooding is the natural process by which land is inundated by water from the ocean. There are a number of causes of coastal flooding which include; storm surge, tides, tsunamis and sea level rise.
Coastal Recession	Erosion of the beach resulting in the landward movement of the shoreline.
Erosion	Displacement of material by natural processes including waves, winds, runoff, currents and rain.
Erosion due to sea level rise	Erosion associated with the increased water depths experienced as the sea level increases. These greater depths allow more wave energy to penetrate to the upper beach face which typically results in the offshore movement of sediment (erosion).
Freeboard	Freeboard refers to the height of a point above the water line.
Greenhouse Effect	The greenhouse effect is a natural process that warms the Earth’s surface. As solar radiation reaches the Earth’s atmosphere, a portion is reflected back to space and the rest is absorbed and re-radiated by greenhouse gases. As the volume of green house gasses in the atmosphere increases the green house gas effect is enhanced, increasing global warming.
Intergovernmental Panel on Climate Change (IPCC)	The Intergovernmental Panel on Climate Change (IPCC) is an intergovernmental body of the United Nations dedicated to providing the world with an objective, scientific view of climate change.
Long Term Erosion Trend	The historic trend of shoreline position which can either be stable, accreting (moving oceanward) or receding (moving landward). The long term erosion trend is usually measured by comparing historic aerial imagery and noting the change in position of the shoreline over time.
Light Detection and Ranging (LiDAR).	LiDAR, is a remote sensing method that uses a laser to measure the distance to the Earth from a drone or plane.
National Oceanic and Atmospheric	The National Oceanic and Atmospheric Administration is an American scientific agency within the United States Department of Commerce that

Administration (NOAA)	focuses on the conditions of the oceans, major waterways, and the atmosphere.
Sea Level Rise (SLR)	The increase in the global mean sea level due to mechanisms associated with an increase in global temperature. Localised sea level rise associated with tectonic movement and subsidence is not addressed within this report.
Storm Erosion	Erosion experienced during a storm event. The increase in wave energy and water levels associated with a storm results in the offshore movement of sediment.
Storm Surge	Increased water levels associated with storm activity due to waves, wind and changes in atmospheric pressure.
Tide	Natural fluctuations in ocean water levels due to the gravitational pull of the sun and the moon.
Vegetation Line	The vegetation line represents the boundary between the established vegetation and the sandy beach which is constantly under flux due to exposure to waves, tides, storms and wind.

1. Sea Level Rise

Climate change is a contentious topic in today's society, however over 97% of scientist agree that human activity is accelerating the rate of global warming (NASA[1], 2019). The degree to which global warming progresses into the future is significant for the coastal zone since a byproduct of increasing temperatures is sea level rise. The two main mechanisms by which this occurs are outlined below:

- As land ice melts due to warmer temperatures the runoff makes its way to the world's oceans, which results in an increase in their volume.
- As the oceans increase in temperature, the water molecules expand due to a phenomenon known as thermal expansion. This leads to an increase in the volume of the world's oceans as the warmer water molecules take up more space than they did previously.

Recent Sea Level Rise

Global mean sea level (GMSL) has increased by about 21-24 cm since 1880, and has increase by 9.38cm since 1993 (NASA[2], 2019).

Future Sea Level Rise

The increasing temperatures which will drive future sea level rise can be attributed to the greenhouse gas effect. The more greenhouse gasses that are emitted into our atmosphere the greater the warming effect will become. The uncertainty surrounding the future of greenhouse gas emissions and the complex physics surrounding the melt of ice sheets means that it is very hard to predict future sea level rise accurately. To allow for this uncertainty global climate models are run with different scenarios which aim to cover the widely accepted range of possible future emissions and ice melt scenarios. There are various emission scenarios which cover anything from a swift reduction in global fossil fuel use, to scenarios where their use grows unabated. Similarly there are various ice sheet scenarios comprised of different ice sheet melt rates for the Antarctic and Greenland ice sheets. The most recent and notable sea level rise projections were published by the National Oceanic and Atmospheric Administration of America (NOAA) in 2017 (NOAA, 2017). These projections build on previous work published by the Intergovernmental Panel on Climate Change (IPPC) in 2013 (Church et al., 2013a) and Parris et al in 2012. The 2017 sea level rise projections can be seen in Figure 3 and are broken down into various scenarios (low - extreme) which reflect the relative amount of sea level rise associated with each scenario.

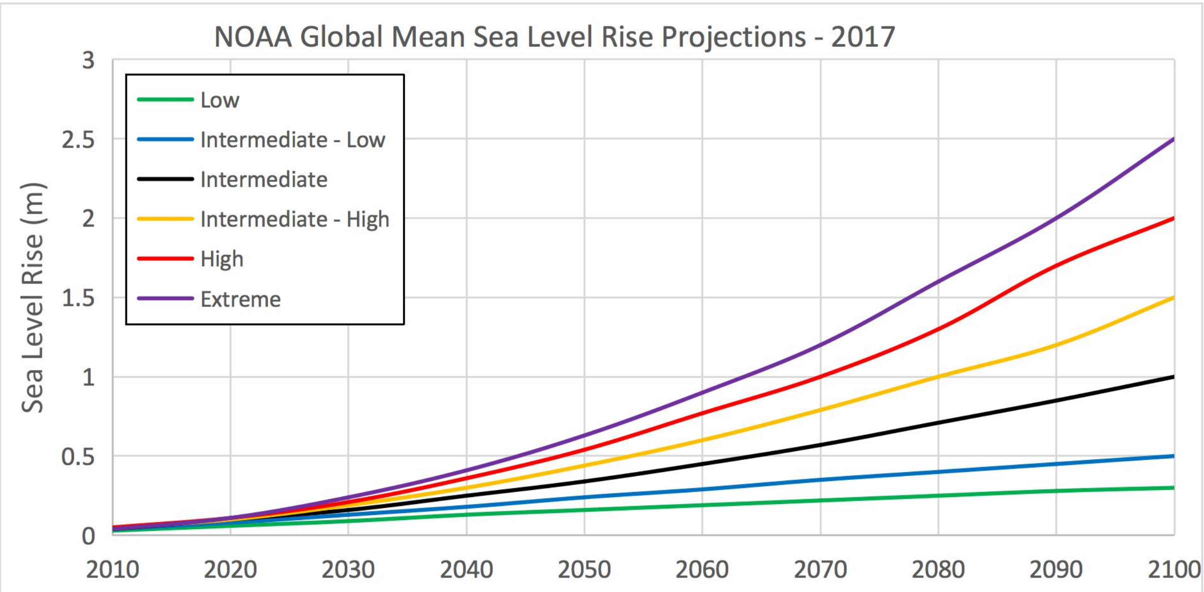

Figure 3 - NOAA sea level rise projections (NOAA, 2017)

2. Coastal Flooding

Coastal flooding is the natural process by which land is inundated by water from the ocean. There are a number of causes of coastal flooding which include; storm surge, tides, tsunamis and sea level rise. The following factors are addressed within this report:

- **Storm Surge** - Increased water levels associated with storm activity due to waves, wind and changes in atmospheric pressure.
- **Tides** - Natural fluctuations in water levels due to gravitational pull of the sun and the moon. These become significant when higher tidal water levels coincide with a storm surge event.
- **Sea Level Rise -** The increase in the global mean sea level predominantly due to global warming.

Coastal flooding levels are measured using annual exceedance probabilities (AEPs) which refer to the probability of a water level occurring within a given year. The storm surge and tidal component of the coastal flooding levels, referred to as the "storm tide", for Walkerville was calculated by the CSIRO as part of their investigation into extreme water levels along the Victorian coastline (McInness at al, 2009). As Walkerville is located 10km west of Sandy Point these levels are considered representative of those at Sandy Point and have been adopted for this study (see Table 4).

Table 4 - Storm tide levels at Walkerville (McInnes at al, 2009).

AEP(%)	Annual Recurrence Interval (ARI)	Extreme Water Level (mAHD)
10	1 in 10 years	1.57
5	1 in 20 years	1.73
2	1 in 50 years	1.89
1	1 in 100 years	1.98

These values do not include an allowance for elevated water levels associated with waves such as wave set up or wave run up. As the property is located within Shallow Inlet it is protected from the open coast and therefore any increase in flooding levels due to wave action is considered negligible. Consequently no wave allowance has been included within the following coastal flooding assessment.

In Victoria the 1% AEP flood event is used to regulate new developments and construction standards across the state. Local Government Areas (LGAs) are responsible for ensuring that their planning schemes include the 1% AEP flooding levels. Also in Victoria sellers are obligated to make available the "due diligence checklist" to potential buyers which includes links to this 1% AEP flooding information (Consumer Affairs Victoria, 2016).

In coastal regions an allowance for sea level rise in the year 2100 which is based on the 2013 IPPC sea level rise projections is added to the current 1% AEP levels in line with the Victorian Coastal Strategy (2014). Within the South Gippsland Shire this allowance is 0.8m and the Land Subject to Inundation Overlay (LSIO) for the region was updated to include this value in March 2016 (Planning Panels Victoria, 2016). The Sandy Point LSIO can be found within Appendix B and currently runs along the north eastern boundary of 79 Harbour View.

The IPCC has recently (September 2019) come out and revised their 2013 sea level rise projections, increasing them by 0.1m. The issue facing both government and property owners is the uncertainty surrounding sea level rise projections. As more data becomes available and the science is updated it is likely that these values will be continually revised upwards leading to more changes in the 1% AEP flood levels and the LSIO in the future.

In order to capture uncertainty attributed to sea level rise in the the 1% AEP, coastal flooding levels for 79 Harbour View have been calculated for 2040, 2070 and 2100 across all sea level rise scenarios presented within Section 1 of Appendix A (see Table 5).

Table 5 - Coastal flooding levels(m AHD) at 79 Harbour view for all NOAA sea level rise scenarios.

NOAA - Sea Level Rise Scenario	2040	2070	2100
Low	1.7	1.79	1.87
Intermediate - Low	1.75	1.92	2.07
Intermediate	1.82	2.14	2.57
Intermediate - High	1.87	2.36	3.07
High	1.93	2.57	3.57
Extreme	1.98	2.77	4.07

The resultant 1% AEP coastal flooding levels have been mapped using bathtub modeling for 79 Harbour View and are presented below within Figure 4. The elevation data used is from the Geosciences Australasia Digital Elevation Model (DEM) of Australia, derived from a 5m LiDAR grid (Geosciences Australasia, 2015).

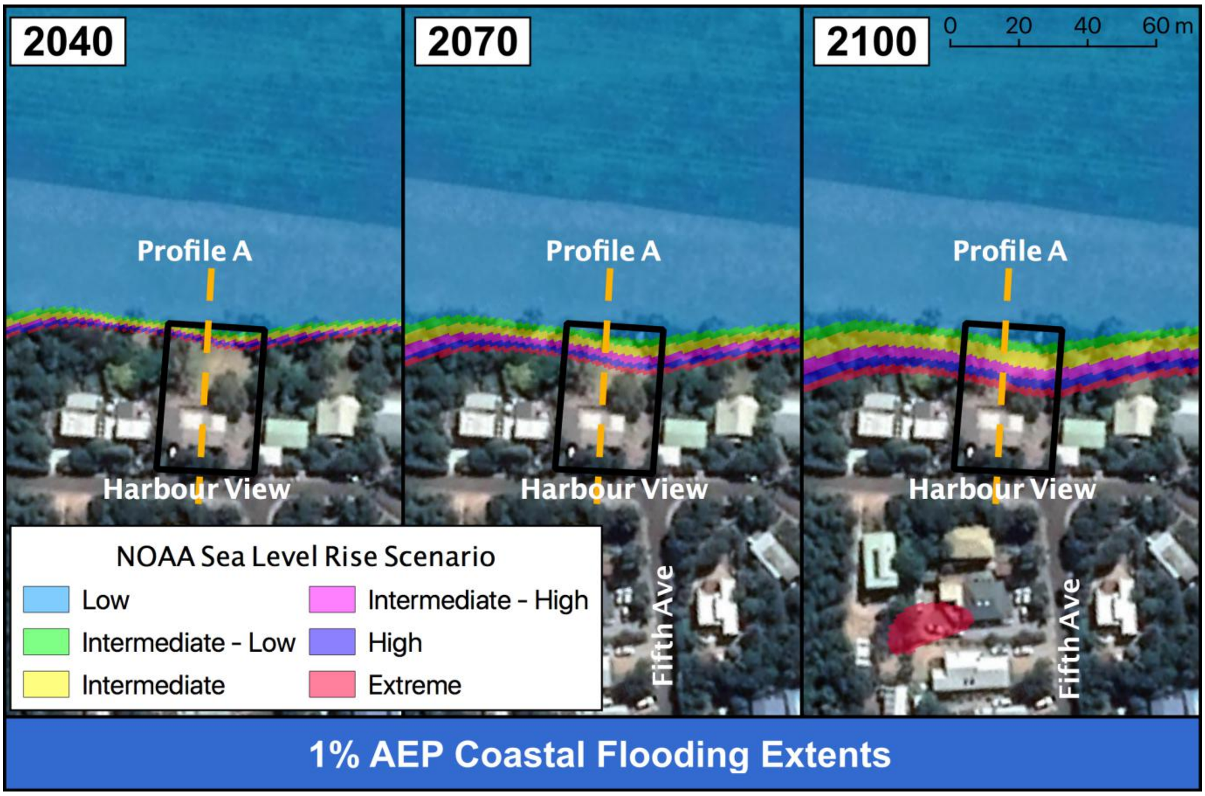

Figure 4 - 1% AEP Coastal Flooding Extents for all NOAA sea level rise projections.

The steep hill on which 79 Harbour View is situated results in a relatively small spatial variation between the different SLR scenarios and restricts the flooding to the north eastern half of the property. The implication of these flood levels on the property is summarised below:

- In **2040**, the 1% AEP coastal flood levels associated with the low to extreme SLR scenarios encroach onto the lower section of the property by roughly 2-7m, leaving a buffer of between 23-18m to the house.
- In **2070**, the 1% AEP coastal flooding levels associated with the low to extreme SLR scenarios encroach onto the lower section of the property by roughly 4-13m, leaving a buffer of between 21-13m to the house.
- In **2100**, the 1% AEP coastal flooding levels associated with the low to extreme SLR scenarios encroach onto the lower section of the property by roughly 5-20m, leaving a buffer of between 20-5m to the house.

A cross section of Profile 1 (see Figure 4) showing the coastal flooding levels for all SLR scenarios in 2100 can be seen below in *Figure 5.* This figure illustrates that the house's freeboard for the extreme sea level rise scenario is over 1.5m.

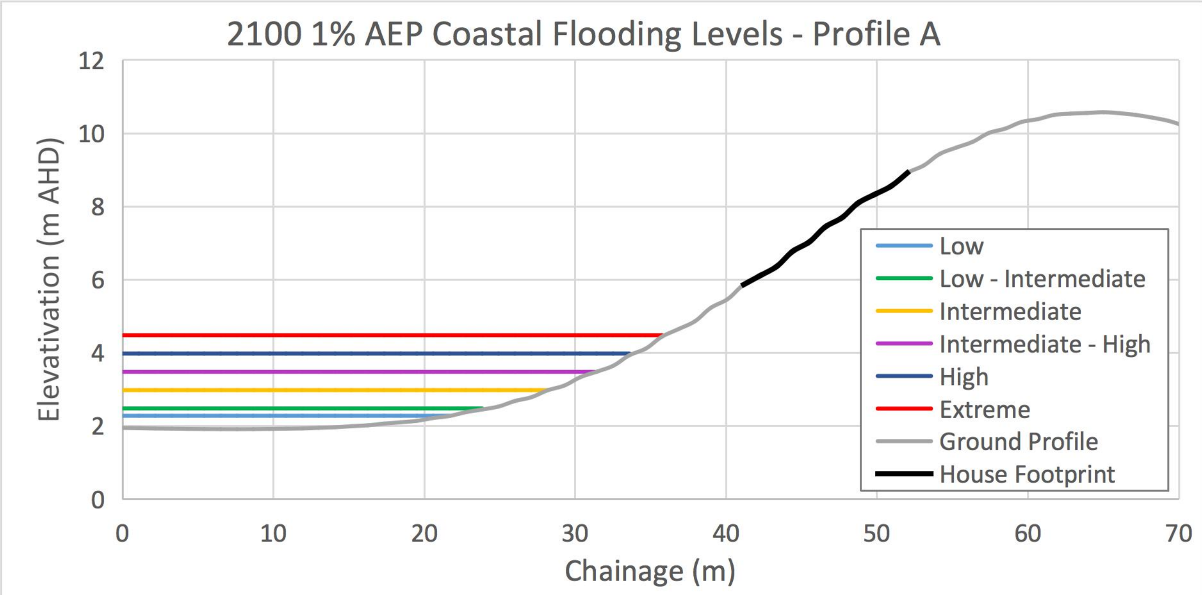

Figure 5 - 2100 1% AEP coastal flooding levels along Profile A.

3. Coastal Erosion

As 79 Harbour View is located inside Shallow Inlet the property's risk profile is more exposed to coastal flooding than coastal erosion due to the low wave energy environment found at this location. Coastal erosion is predominantly driven by waves and wave driven currents. As such, this report has assessed the coastal erosion risk of 79 Harbour View from recession of Waratah Beach. The distance between the Waratah Beach shoreline and 79 Habour view is roughly 540m, which can be classed as substantial. It is noted however, that if the levee system is abandoned erosion may occur on the north eastern side of the property, due to small wind waves or boat wake generated within shallow inlet. When developing an understanding of the coastal erosion risk there are five key factors which need to be assessed (Mariani et al, , 2012), these are detailed below:

- **Storm Erosion (S1)** - Erosion experienced during a a storm event.
- **Long Term Erosion Trend (S2)** - The historic trend of shoreline position which can either be stable, accreting (moving oceanward) or receding (moving landward). The long term erosion trend is usually measured by comparing historic aerial imagery and noting the change in position of the shoreline over time.
- **Erosion due to Sea Level Rise (S3)** - Shoreline erosion which is driven by the offshore movement of sediment associated with increases in sea level.
- **Beach Rotation (S4)** - An allowance for any cyclical or one way change in dune orientation due to changes in the wave environment.
- **Dune Stability (S5)** - The geotechnical stability of the dune system which is related to the substrate of the dune (E.g sand, sandstone, basalt, calcarenite).

Total Erosion Allowance = S1 + S2 +S3 +S4 +S5

In 2012 the Antarctic Climate and Ecosystems Cooperative Research Centre (ACECRC) undertook a widespread study of erosion along the Australian coastline. Within this study they developed generic distances for storm erosion (S1) and erosion due to sea level rise (S3) across substantial sections of Australia's coastline (Mariani et al, , 2012). These values are designed to be used as part of a first pass assessment of coastal erosion risk with more detailed site specific investigations recommended if any vulnerability arises. The ACECRC values for S1 and S3 specified for the coastline from South Gippsland to the Mornington Peninsula have been adopted for this study.

3.1 Storm Erosion (S1)

This type of erosion is charecterised by the offshore transport of sand from the dune system during a storm event (see Figure 6). The amount of erosion observed typically depends on the storm surge level, the tidal level and the wave energy associated with the storm event. Significant erosion events occur when high wave energy storms occur in conjunction with a large storm surge and a high tidal level.

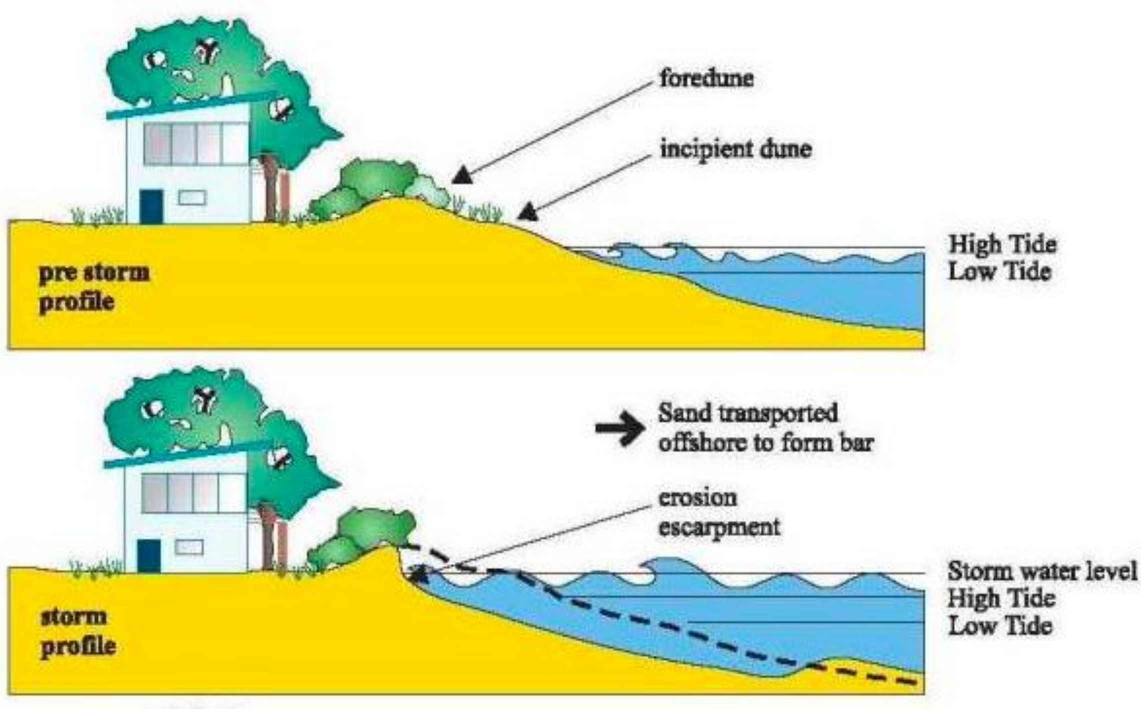

Figure 6 - Impact of storm erosion on the beach profile (DLWC 2001).

As specified above a generic storm erosion allowance was calculated by ACECRC for the South Gippsland to Mornington Peninsula coastline. This value has been adopted for this study and can be found below in Table 6. This value is based off the estimated volume of sediment being moved from two consecutive 1 in 100 year storm events (200m^3).

Table 6 - Storm erosion allowance (S1) (Mariani et al, , 2012)

Location	Storm Erosion - S1 (m)
Waratah Main Beach	20

3.2 Long Term Erosion Trend (S2)

The long term erosion trend for Sandy Point has been assessed by comparing the shoreline position of Waratah Beach on historic aerial imagery for the last 9 years: 2019, 2015, 2011, and 2010. The shoreline position has been mapped using the coastal vegetation line. This line represents the boundary between the established vegetation and the sandy beach which is constantly under flux due to exposure to waves, tides, storms and wind. The results of the analysis are presented below within Figure 7.

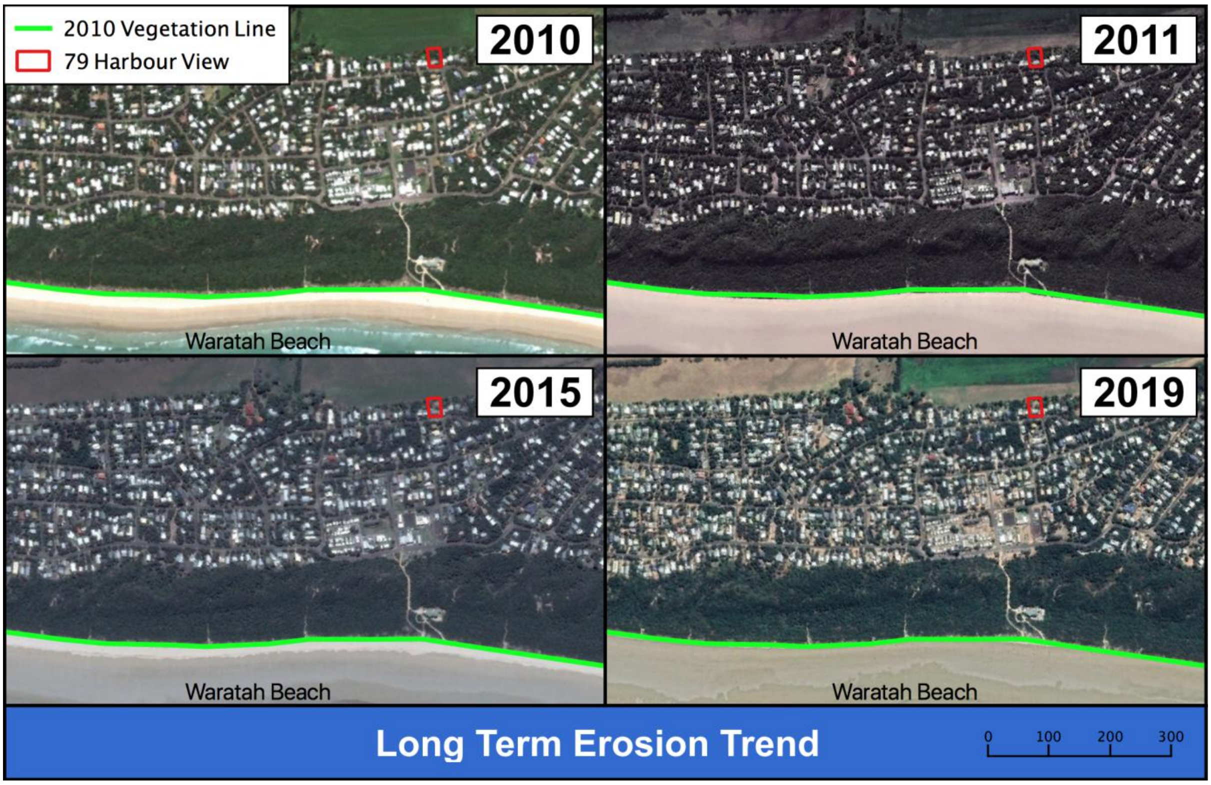

Figure 7 - Historic shoreline position of Waratah Beach.

From the analysis it can be seen that the shoreline has been stable over the last 9 years with no significant change in the vegetation line observed between 2010-2019. Therefore, the long term erosion allowance (S2) component of the total erosion is set to 0m/year which reflects the stability of the shoreline.

3.3 Erosion due to Sea Level Rise (S3)

The main mechanism which leads to erosion as sea levels rise is the change in depths associated with increases in water level. As the sea level rises the depths across the beach profile increase, this allows more wave energy to penetrate shore-ward. This results in increased erosion near the shoreline and the offshore movement of sand. This sand is then deposited on the lower sections of the beach profile increasing the bed level until the depths are equal to those that existed prior to the sea level rise. This result is the landward migration of the shoreline which is commonly referred to as shoreline or coastal retreat. An illustration of this erosion concept can be seen below within Figure 8.

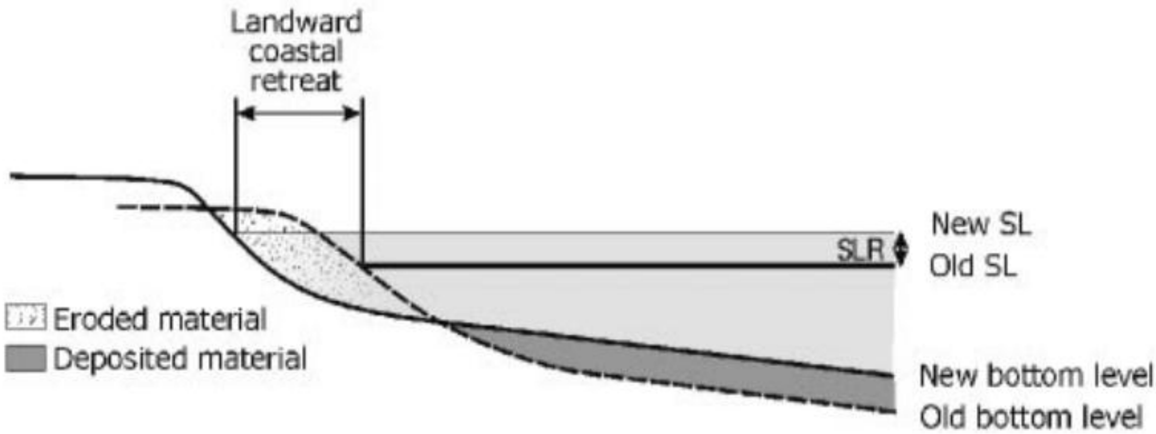

Figure 8 - Beach response to sea level (SL) rise (Davidson-Arnott, 2005).

The response of the coast to sea level rise can be in the order of 100 times the level of sea level rise, this multiplying factor is referred to as a Bruun Factor, the scientific basis of which is derived within the Bruun Rule. The Bruun Rule is a formula for the relationship between shoreline retreat and sea level rise and is the most common model used to predict sea level rise recession distances on sandy coastlines.

The Bruun Factor along the South Gippsland to Mornington Peninsula coastline as specified by ACECRC is 50 (Mariani et al, , 2012). This implies that for every 1m of sea level rise a provision for 50m of landward recession should be made. This Bruun Factor has been used to calculate the shoreline recession rates associated with sea level rise at Waratah Beach. The amount of sea level rise significantly impacts the recession observed when applying a Bruun Factor. As such, the Bruun Factor has been applied to all sea level rise projections presented within Section 1 of Appendix A. This will aid in capturing the uncertainty associated with future emission scenarios and ice sheet melt. The erosion distances for 2040, 2070 and 2100 have been calculated and are presented within Table 7.

Table 7 - Erosion due to sea level rise (S3) in meters.

NOAA Sea Leve Rise Scenario	2040	2070	2100
Low	6.5	11.00	15
Intermediate Low	9	17.50	25
Intermediate	12.5	28.50	50
Intermediate High	15	39.50	75
High	18	50.00	100
Extreme	20.5	60.00	125

3.4 Beach Rotation (S4)

No beach rotation is observed along the Waratah Beach shoreline as is seen by the stable vegetation line observed in *Figure 5.* Therefore, there will be no allowance for beach rotation included within the total erosion allowance.

3.5 Dune Stability (S5)

As this report is a first pass coastal risk assessment a geotechnical assessment of the dune system is considered unnecessary. As such, no allowance has been made for dune stability and a completely sandy dune system is assumed.

3.6 Total Erosion Allowance

The total erosion allowance as specified above has been calculated along the Waratah Bay shoreline for 2040, 2070 and 2100 and is presented below within Table 8.

Table 8 - Total erosion allowance in metres.

NOAA Sea Leve Rise Scenario	2040	2070	2100
Low	26.5	31	35
Intermediate Low	29	37.5	45
Intermediate	32.5	48.5	70
Intermediate High	35	59.5	95
High	38	70	120
Extreme	40.5	80	145

The total erosion allowances for 2040, 2070 and 2100 have been mapped from a horizontal setback datum (HSD) of 1.98m AHD, which is equal to the water level associated with a 1% AEP storm event. This line represents the upper portion of the beach which is at risk of erosion under a 1% AEP storm event. The total erosion allowances for Waratah Beach can be seen below within Figure 9.

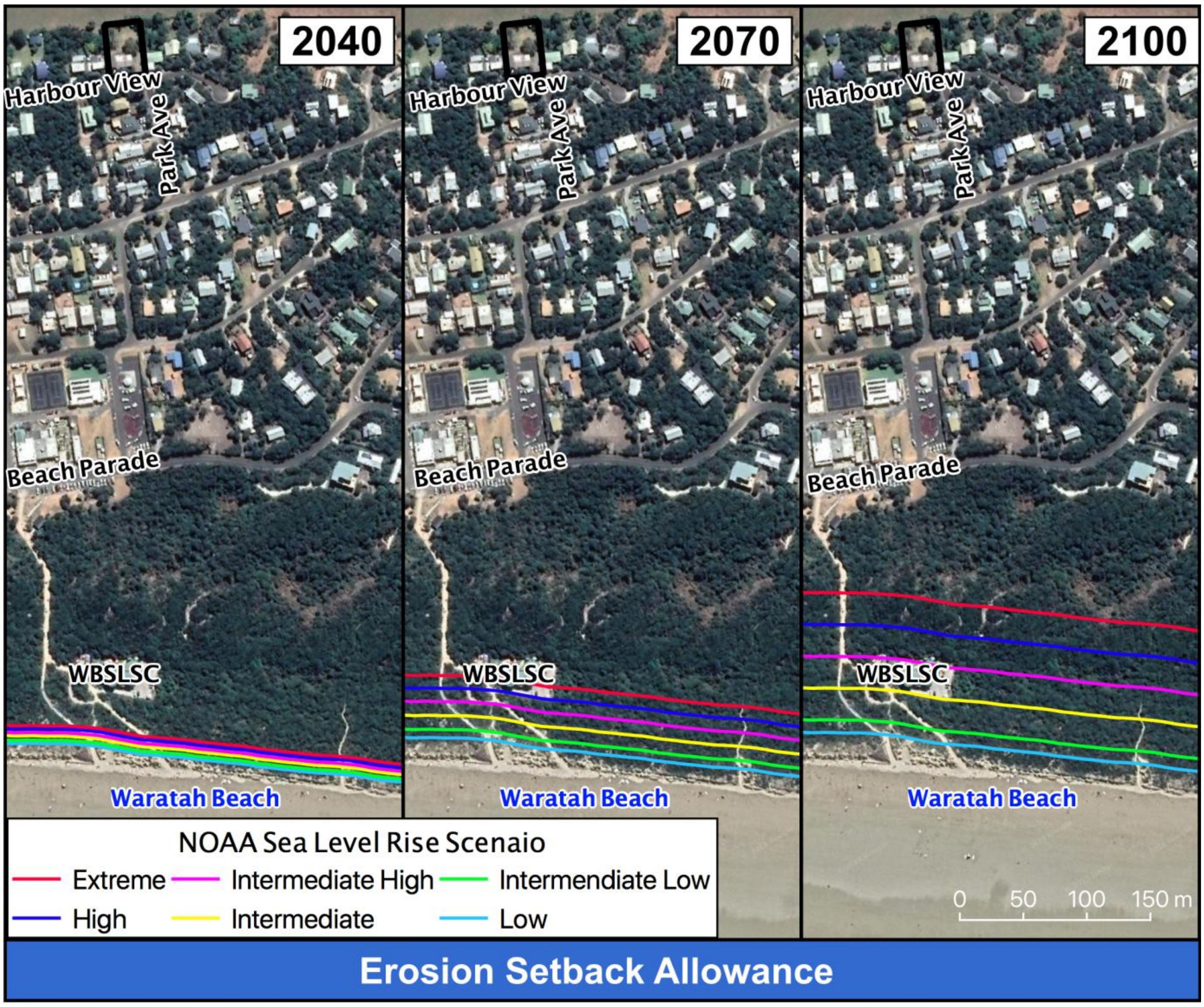

Figure 9- Total coastal erosion risk associated with NOAA SLR scenarios.

The main component contributing to the erosion observed within Figure 9 is the impact of sea level rise on shoreline erosion (S3). However, under all the projected sea level scenarios for 2040, 2070 and 2100 the probability of coastal erosion undermining the property at 79 Harbour View is insignificant.

5. References

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Davidson-Arnott, R. G. (2005). Conceptual model of the effects of sea level rise on sandy coasts. Journal of Coastal Research, 1166-1172.

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Mariani A, Shand TD, Carley JT, Goodwin ID, Splinter K, Davey EK, Flocard F and Turner IL 2012, Generic Design Coastal Erosion Volumes and Setbacks for Australia, Antarctic Climate & Ecosystems Cooperative Research Centre, Hobart, Tasmania.

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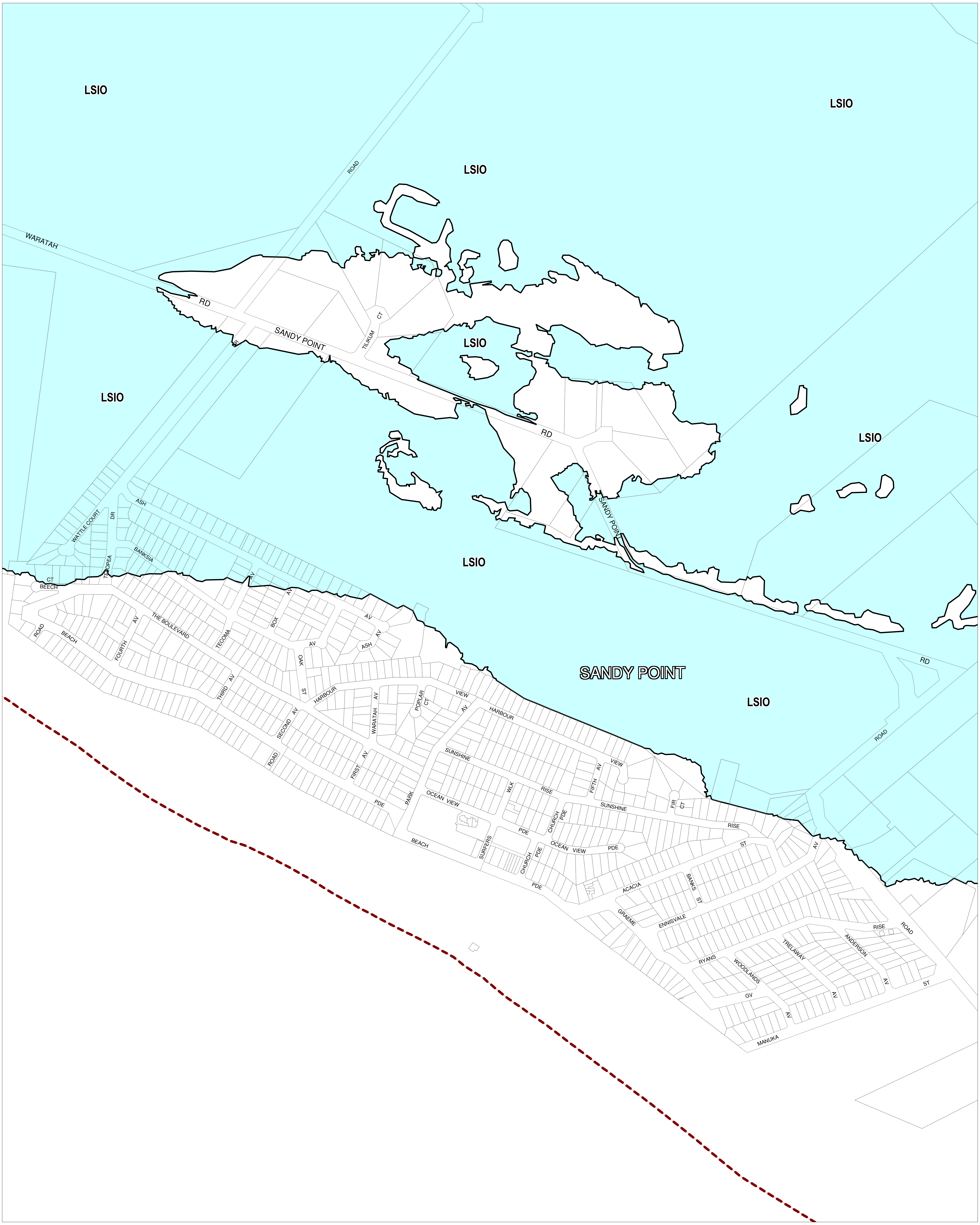
APPENDIX B - Sandy Point LSIO

SOUTH GIPPSLAND PLANNING SCHEME - LOCAL PROVISION



This map should be read in conjunction with additional Planning Overlay Maps (if applicable) as indicated on the INDEX TO MAPS.

Overlays

LSIO Land Subject To Inundation Overlay

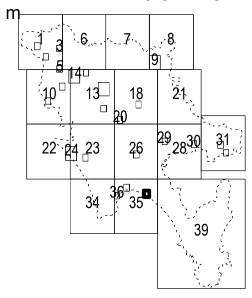
100 0 100 200 300 400 500 m

AUSTRALIAN MAP GRID ZONE 55

N

State Government Victoria

INDEX TO ADJOINING METRIC SERIES MAP



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AMENDMENT C81

LAND SUBJECT TO INUNDATION OVERLAY

MAP No 38LSIO