World Trail Pty Ltd

Great Ocean Road Coastal Trail

Coastal Hazard Vulnerability Assessment: Smythe Creek to Skenes Creek Section

December 2022

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Great Ocean Road Coastal Trail
Coastal Hazard Vulnerability Assessment: Smythe Creek to Skenes Creek Section

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WSP acknowledges that every project we work on takes place on First Peoples lands.
We recognise Aboriginal and Torres Strait Islander Peoples as the first scientists and engineers and pay our respects to Elders past and present.

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1 Introduction

1.1 Purpose of Document

Golder Associates Pty Ltd (Golder) has been engaged by World Trail Pty Ltd (World Trail) to undertake geotechnical hazard and risk assessment for the proposed Great Ocean Road Coastal Trail between Fairhaven and Skenes Creek along the coastline of south west Victoria.

Part of the project scope is for Golder to prepare of a Coastal Hazard Vulnerability Assessment (CHVA) for the portion of the proposed trail between Smythe Creek and Skenes Creek Beach. This work has been undertaken by WSP Australia, noting that Golder is a member of the WSP group of companies.

This report sets out the findings of the CHVA.

2 Project background

2.1 Proposed Trail

The Department of Environment, Land, Water and Planning (DELWP) is seeking to prepare a master plan for a new walking trail between Fairhaven and Skenes Creek, near the iconic Great Ocean Road. A feasibility study for the proposed trail was undertaken in 2019, the results of which are presented in a report prepared by Ernst and Young[1]. The feasibility study includes a conceptual trail alignment (Concept Route 1) which is replicated in Figure 2.1.

Figure 2.1 Concept Route 1 Trail Alignment (World Trail, 2019)

Subsequent to issue of the alignment shown in Figure 2.1, World Trail has further developed this alignment, producing a ground truthed alignment (Ground Truthed Route 2) provided to Golder on 21 July 2021. However, for the portion of the proposed trail between Smythe Creek to Skenes Creek Beach covered by the CHVA, the Concept Route 1 route is unchanged. The Smythe Creek to Skenes Creek Beach portion is shown in Figure 2.2.

Figure 2.2: Portion of the proposed trail between Smythe Creek and Skenes Creek

2.2 Objectives of the CVHA

The CHVA has been undertaken in accordance with the guidelines for CHVA as set out in the Victorian Coastal Hazard Guide (VCHG), and in particular Section 8 of the guide, which sets out an approach for assessing and evaluating risks associated with coastal hazards. In line with this, the objectives of the CHVA are to:

- Identify and characterise coastal risks to the proposed track
- Qualitatively estimate the risks
- Evaluate the estimated risks
- Provide recommendations for risk management, if required.

3 The Proposed Development

3.1 Overview of the Trail

The portion of the Great Ocean Road Coastal Trail covered by this CVHA is length of the trail between Smythe Creek and Skenes Creek. The trail over this section generally parallels the Great Ocean Road and we understand will be constructed on the southern (seaward) side of the road. However, at two locations the trail leaves the road and descends to the back of the coastal beach or rock platform.

3.2 Delineation of the coastline

The coastline along which the trail is located can be subdivided into four separate compartments according to the shoreline conditions adjacent to the track, accounting for the geology and geomorphology along the alignment. These segments are:

- Section 1: Smythe Creek to Petticoat Creek
- Section 2: Biddles Beach
- Section 3: Biddles Beach to Skenes Creek Beach
- Section 4: Skenes Creek Beach

Each of these segments is discussed in the following sections

3.2.1 Section 1: Smythe Creek to Petticoat Creek

This section of the trail that extends from Smythe Creek at the eastern end to Petticoat Creek at the western end and is shown in Figure 3.1. At the eastern end the proposed trail runs along the eastern side of Smythe Creek and crosses to the southern side of the Great Ocean Road. The path has four sub-sections as identified in Figure 3.1.

Table 3-1: Section 1 Smythe Creek to Petticoat Creek path segments

Sub-sections	Trail Description
1a	The trail generally follows the southern side of the Great Ocean Road for the first 1200 m before descending down to the back of the narrow sandy beach landward of the rocky shore platform
1b	The trail extends for some 775 m along the back of the narrow beach
1c	The path ascends back to the road over a length of 280 m
1d	Heading west the trail runs along the southern side of the Great Ocean Road for a further 1180 m to Petticoat Creek.

As outlined in the Geotechnical Hazard Assessment, the coastline in this section is a hard shoreline characterised by rocky shore platforms with a narrow beach zone behind. There is a steep bank between the beach and the road.

Figure 3.1: Section of trail from Smythe Creek to Petticoat Creek

3.2.2 Section 2: Biddles Beach

The section of the trail that covers the section of beach foreshore at Biddles Beach is shown in Figure 3.2 and identified in Table 3-2.

Table 3-2: Section 2 Biddles Beach Path

Sections	Trail Description
2	The trail in this area runs along the back of the sandy beach, shoreward of the vegetated dune.

Figure 3.2: Section of track at Biddles Beach

The beach can be considered to be a pocket beach contained between rocky headlands to the east and west.

3.2.3 *Section 3: Biddles Beach to Skenes Creek Beach*

This section of the trail that extends from Biddles Beach at the northern end to Skenes Creek at the southern end is shown in Figure 3.3 and the trail has the following two sub-sections identified in Table 3-3.

Table 3-3: Section 3 Biddles Beach to Skenes Creek Beach Path Segments

Sub-sections	Trail Description
3a	From the south end of Biddles Beach the trail crosses through the vegetated area behind the rocky foreshore over a length of around 830 m
3b	The trail traverses some 335 m to the north end of Skenes Creek Beach

Figure 3.3: Section of trail from Biddles Beach to Skenes Creek Beach

3.2.4 Section 4: Skenes Creek Beach

The section of the trail that covers the section of beach foreshore at Skenes Beach is shown in Figure 3.4 and Table 3-4.

Table 3-4: Section 4 Skenes Creek Beach Trail

Sections	Trail Description
4	The trail in this area runs along the side of the road, at the back of the Skenes Creek Foreshore Caravan Park, and is some 50 m from the back from the sandy beach at this location.

Figure 3.4: Section of trail at Skenes Beach

3.3 Trail Exposure Types

The foregoing sections have delineated the trail into nine sections based the on the trail location and coastline morphology. Using these classifications for the trail and for further assessment of coastal hazard and risks, the sections can be grouped into four trail exposure types as set out in Table 3-5.

Table 3-5: Description of trail types

Trail Type	Trail Location Description	Track Sections
A	Trail located adjacent to road, above a hard coastal embankment.	1a, 1c,1d, 3a, 3b
B	Trail located at rear of beach	2
C	Trail located adjacent to road behind vegetated dune at rear of beach	4
D	Trail located at rear of coastal rock platform	1b

4 Risk Assessment

4.1 Risk Assessment Process

The process for risk assessment set out in the VCHG is based on Australian Standard for Risk Management[1]. Figure 4.1 is an extract from the VCHG setting out the steps that apply to the risk management process.

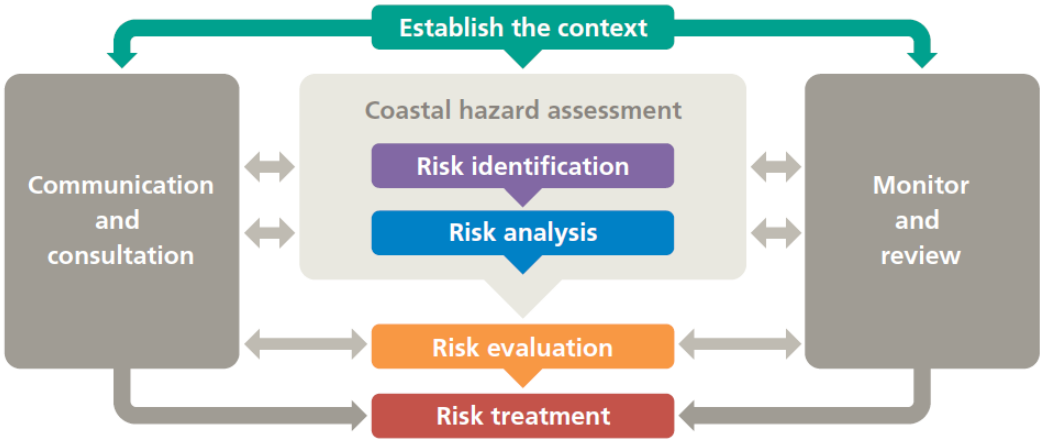

Figure 4.1: Risk Assessment Process, VCHG, 2012

Each of the steps in the centre of the flow chart have been followed in the risk assessment undertaken for the trail and are covered separately in the following sections.

4.2 Context

The coastline considered in the assessment is the shoreline between Smythe Creek and Skenes Creek Beach as indicated in Figure 2.2.

The coastline is generally comprised of colluvial and terrace slopes, overlying the Eumeralla Formation with gently sloping terrain. The coast is formed from rocky shore platforms with occasional beaches and occasional low coastal foredunes[2].

The planning period utilised for the assessment is to 2100, with conditions established for current conditions and 2040, 2070 and 2100 climate change predictions.

4.3 Risk identification

This section of coast is subject to the following processes:

- Mean sea level rise,
- Astronomic tides,

[1] Australian Standards (2008) ISO/SA/NZS 31000: Risk Management – Principles and Guidelines, Standards Australia, Sydney.

[2] Golder Geotechnical Risk Assessment "Great Ocean Road Coastal Trail, Geotechnical Hazard Assessment", 2022

- Storm tides
- Waves and wave run-up
- Coastal erosion

For this section of coast, the estimates of the various processes for Apollo Bay, located some 5 km to 10 km from the stretch of coastline covered by the length of trail being assessed have been utilised as appropriate.

4.3.1 Mean sea level rise

Estimates of anticipated sea level rise for the Victorian open coast are provided in the VCHG. Estimated sea level rise for the area of the trail has been taken from VCHG for Apollo Bay. The sea level rise predictions are given in Table 4-1.

Table 4-1: Estimates of sea level rise

Time horizon	2030	2070	2100
Men sea level rise	0.15 m	0.47 m	0.82 m

4.3.2 Astronomic tides

Tidal plane information from Apollo Bay has been taken from VCHG. Heights are given for highest astronomical tide (HAT), mean high water springs (MHWS) and mean high water neaps (MHWN). At stations marked by an asterisk, tides are generally diurnal and so the average value of the high tides is given by the mean higher high water (MHHW) and mean lower high water (MLHW).

Table 4-2 Existing tide levels

Location	HAT (m AHD)	MHWS/MHHW (m AHD)	MHWN/MLHW (m AHD)
Apollo Bay	1.09	0.83	0.13

4.3.3 Storm tides

The “storm tide level” is the combined effect of astronomical tide and storm surge and is the effective “storm level” during an extreme event. The meteorological component of the storm tide is commonly referred to as storm surge and includes the variation in water levels due to falling atmospheric pressure and severe winds during storms.

Storm tide values for Apollo Bay are described in the VCHG. The values presented in the VCHG for different scenarios are set out in Table 4-3. These levels are for the 1 in 100-year storm tide return period under current climate conditions and with two future scenarios.

1. Scenario One considered the AR4 A1F1 scenario for mean sea level rise over the 21st century (i.e., 0.15 m, 0.47 m and 0.82 m for 2030, 2070 and 2100 respectively).
2. Scenario Two combines the AR4 A1Fl scenario with the equivalent high annual averaged wind speed change averaged over Bass Strait calculated by CSIRO and the Australian Bureau of Meteorology

Table 4-3: Estimates of storm tide

Current Climate	2030		2070		2100	
	1	2	1	2	1	2
1.4 m	1.6 m	1.6 m	1.9 m	2.0 m	2.2	2.5

The estimated inundation extents from the 1% AEP storm tides for the current climate and for Scenario 2 for each of 2030, 2070 and 2100 are shown in Figure 4.2 through to Figure 4.5.

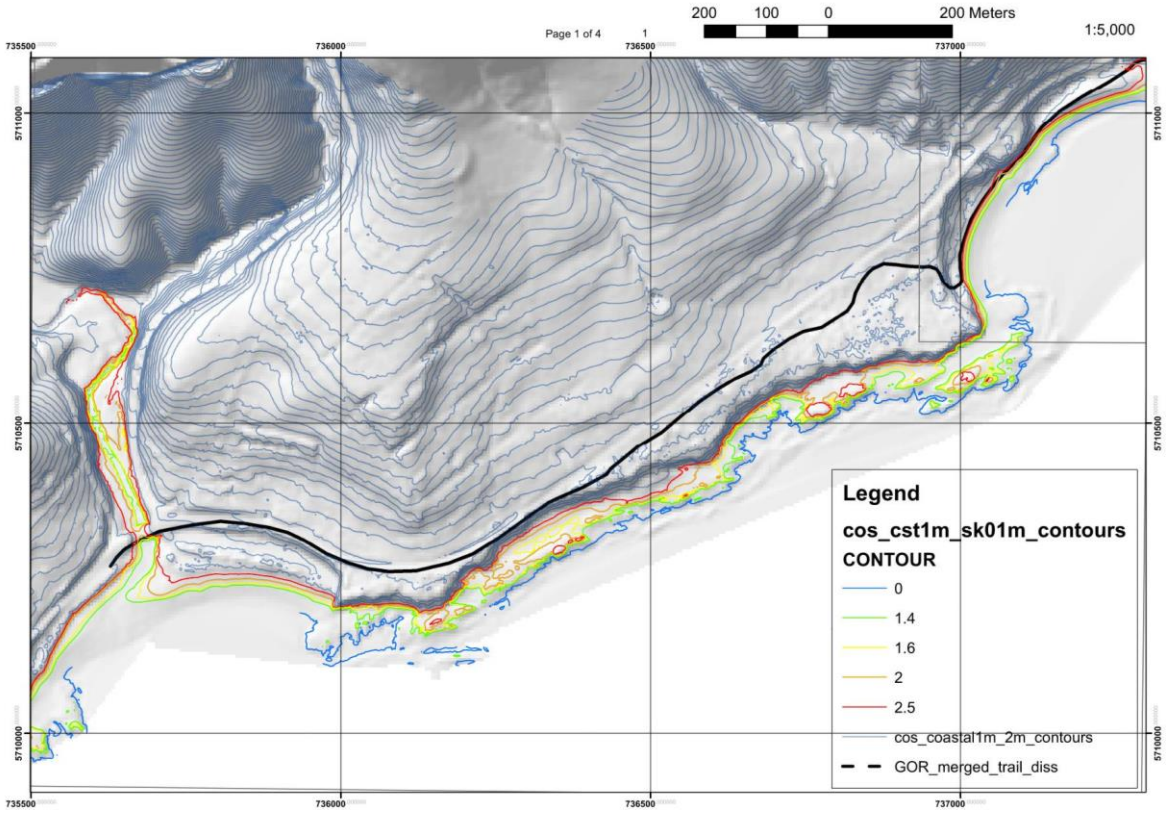

Figure 4.2: 1% AEP Storm tide levels plan (01) – current = 1.4 m, 2030 = 1.6 m, 2070 = 2 m, 2100 = 2.5 m

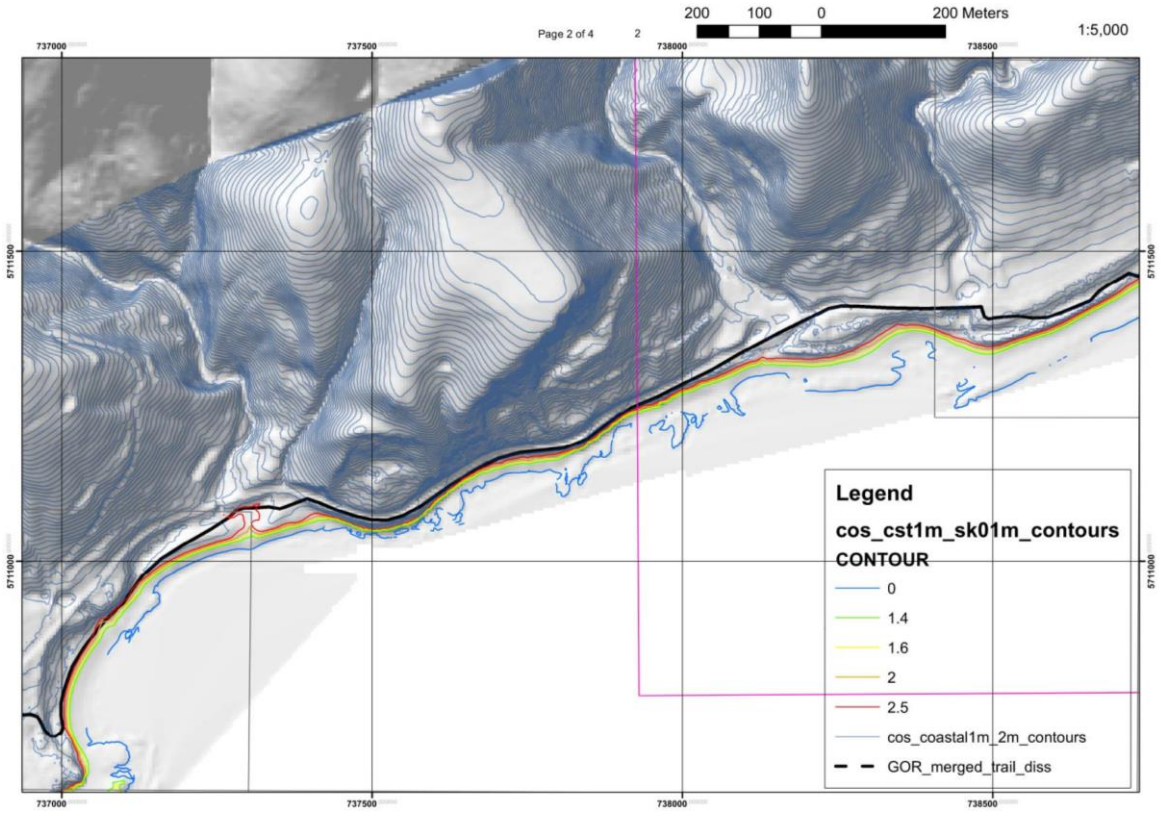

Figure 4.3: 1% AEP Storm tide levels plan (02) – current = 1.4 m, 2030 = 1.6 m, 2070 = 2 m, 2100 = 2.5 m

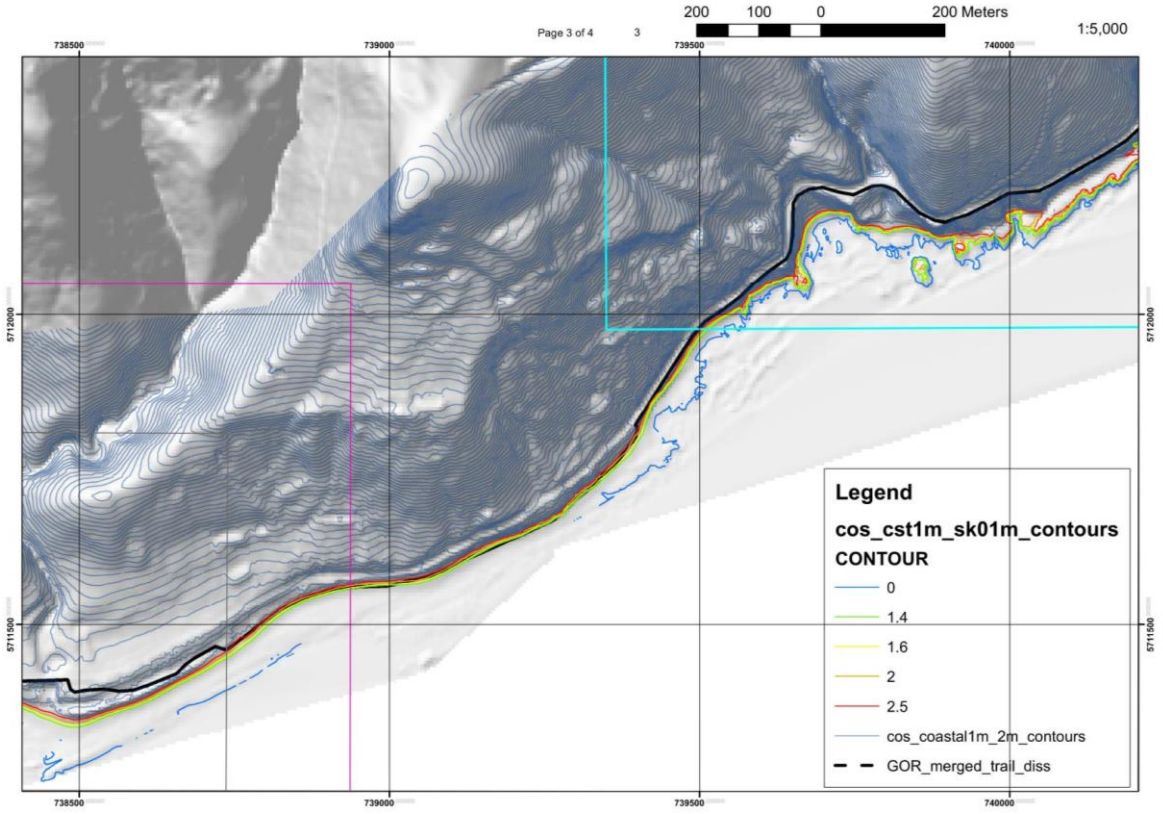

Figure 4.4: 1% AEP Storm tide levels plan (03) – current = 1.4 m, 2030 = 1.6 m, 2070 = 2 m, 2100 = 2.5 m

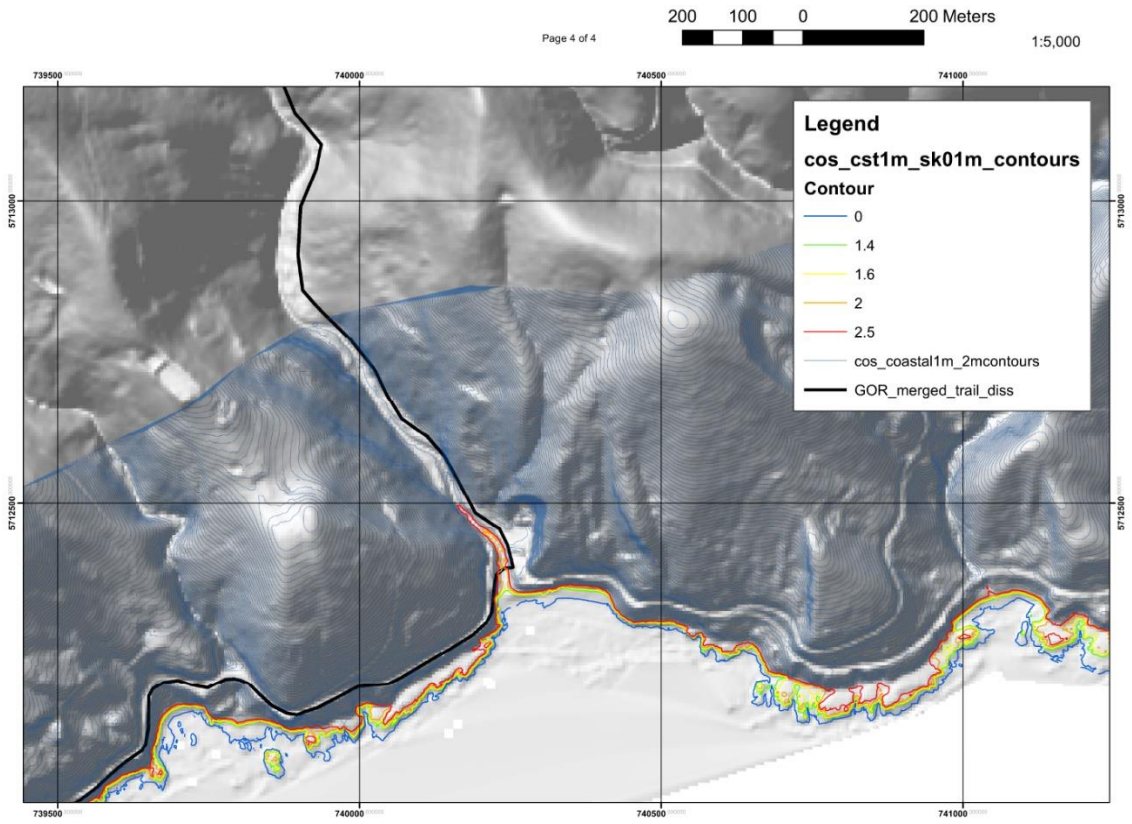

Figure 4.5: 1% AEP Storm tide levels plan (04) – current = 1.4 m, 2030 = 1.6 m, 2070 = 2 m, 2100 = 2.5 m

4.3.4 Waves and wave run-up

The main source of wave energy at the site is south-westerly Southern Ocean swell waves, as well as shorter period swell and local sea waves generated within Bass Strait as shown in Figure 4.6.

GHD (2018)[2] showed that south-westerly waves are the dominant wave direction in the area with waves propagating from this direction around 94% of the time. South-easterly and easterly waves are less frequent and occur around 5% of the time. More than 70% of the waves are long period swell waves with a period of 16 to 20 seconds.

Figure 4.6: Wave sources and directions affecting the Victorian coastline

GHD (2018)[3] assessed the offshore wave climate near the study area at Apollo Bay and determined significant wave heights for a range of exceedance probabilities. These values are presented in Table 4-4.

Table 4-4: Estimates of offshore significant wave heights

AEP (ARI)	Hs (m)
63% (1 year)	5.2
10% (10 years)	6.3
5% (20 years)	6.6
2% (50 years)	7.0
1% (100 years)	7.2

[3] Water Technology, *Coastal Hazard Vulnerability Assessment, Apollo Bay*, Australian Tourism Investments No. 5 Pty Ltd (March 2019)

The sections of trail that would be impacted by the wave effects are those sections located at the back of beaches. At other locations, where the trails are located on top of embankments and adjacent the road, the trail is not expected to be directly impacted by wave effects.

Trail Types B and D would be impacted by wave effects as follows:

- Trail Type B: the trail along Section 2 located at the back of Biddles beach is more exposed and experiences a high energy wave environment leading to significant wave set up and run up.
- Trail Type D: the trail along Section 1b located at the rear of the rock shelf and below the road embankment would also be impacted by wave effects.

Wave height scenarios considered for the assessment of wave run-up are 5 m (unlikely) and 8 m (rare). Estimates of runup due to these extreme events and the estimated run-up is presented in Table 4-5.

Table 4-5: Estimated wave run-up hazard for the different levels of likelihood

Likelihood	Scenario	Significant run-up (m AHD)	Maximum run-up (m AHD)
Likely	1% AEP Storm Tide + Hs = 5m, Tp=14s	1.4	1.8
Unlikely	1% AEP Storm Tide + Hs = 8m, Tp=14s	1.9	2.6

The analysis also includes future wave run-up levels under the adopted storm tide sea level rise scenarios. The resultant wave run-up water levels are presented for significant wave run up Table 4-6 and maximum wave run up Table 4-7. For the purpose of the risk assessment, a more conservative estimate of the maximum wave run up has been adopted.

Table 4-6: Significant Wave Run-up

Likelihood	Scenario	Existing (m AHD)	2030 High (m AHD)	2070 High (m AHD)	2100 High (m AHD)
Likely	1% AEP Storm Tide + Hs = 5m, Tp=14s	2.8	3.0	3.4	3.9
Unlikely	1% AEP Storm Tide + Hs = 8m, Tp=14s	3.2	3.4	3.8	4.3

Table 4-7: Maximum Wave Run up

Likelihood	Scenario	Existing (m AHD)	2030 High (m AHD)	2070 High (m AHD)	2100 High (m AHD)
Likely	1% AEP Storm Tide + Hs = 5m, Tp=14s	3.3	3.5	3.9	4.4
Unlikely	1% AEP Storm Tide + Hs = 8m, Tp=14s	4.0	4.2	4.6	5.1

The extent of inundation of maximum wave run-up for the likely event under existing conditions and accounting for future sea level rises for 2030, 2070 and 2100 are shown in Figure 4.7 (Trail Type B - Section 2) and Figure 4.8 (Trail Type D - Section 1b). For both trail types the trail is substantially inundated during the wave events for the existing condition and all future scenarios.

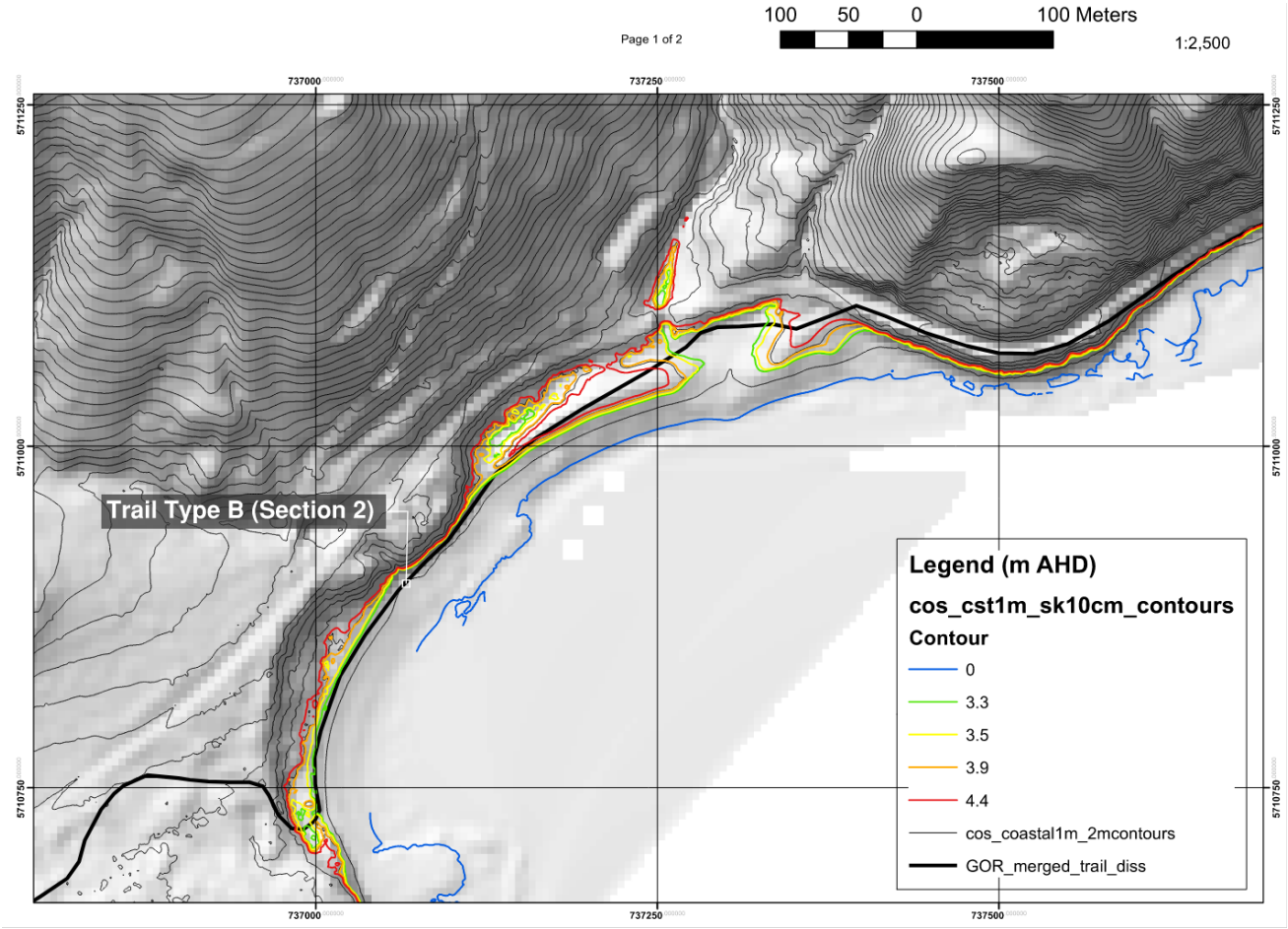

Figure 4.7: Trail Type B - Section 2 trail impacted by wave run up for the Likely scenario.

current = 3.3 m, 2030 = 3.5 m, 2070 = 3.9 m, 2100 = 4.4 m

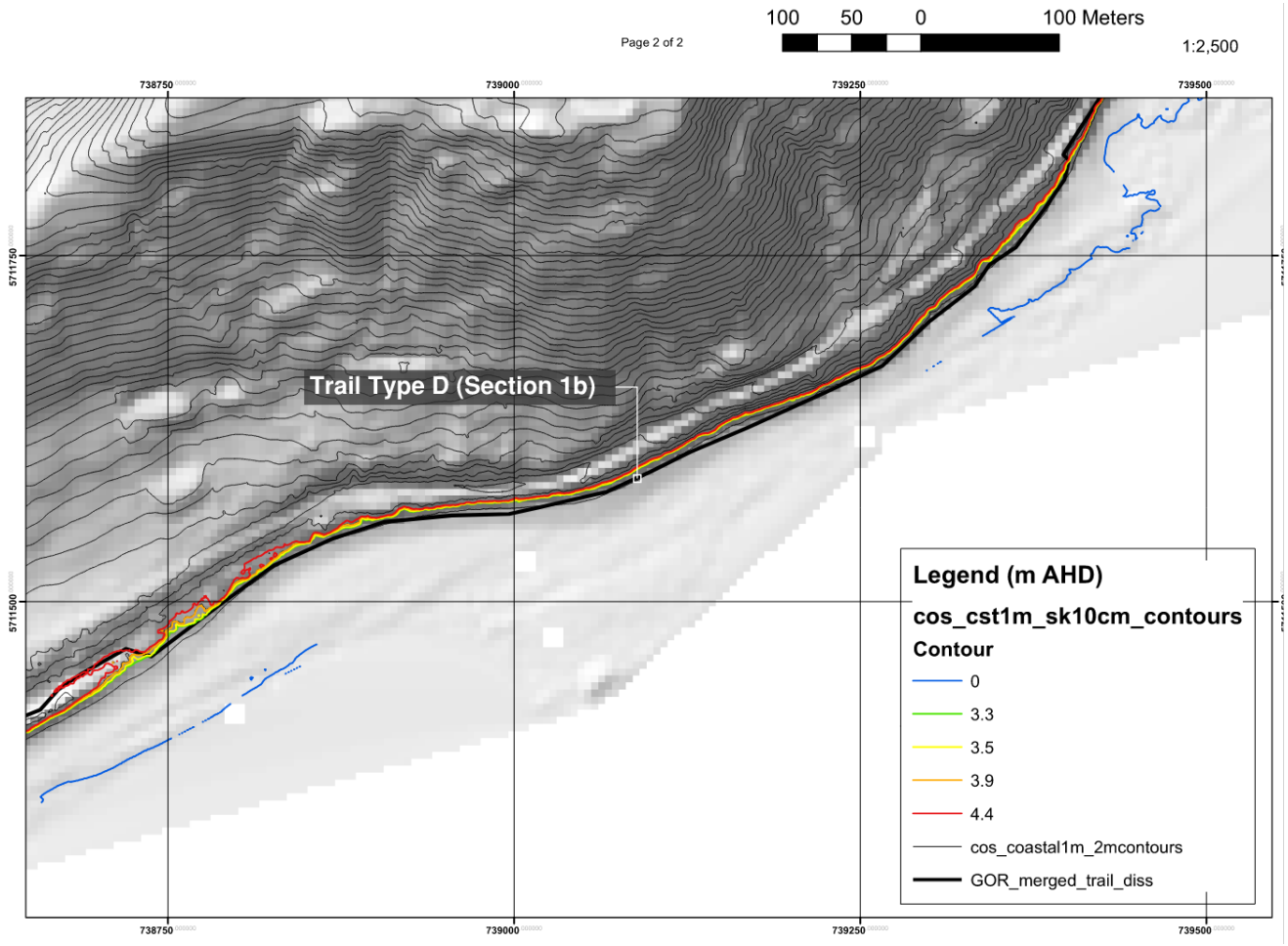

Figure 4.8: Trail Type D - Section 1b trail portion impacted by wave run up for the Likely scenario current = 3.3 m, 2030 = 3.5 m, 2070 = 3.9 m, 2100 = 4.4 m

4.3.5 Coastal Erosion

The Golder Report[4] outlines that except for a small section of the beach at Skenes Creek west of the Great Ocean Road bridge over Skenes Creek (approx. 120 m length), the coastline has been assessed by ASMG and ESG as having a low to very low vulnerability for soft coast erosion and has not been identified as susceptible to soft coast erosion hazards.

Where the trail is within an area susceptible to progressive erosion (i.e. at beach locations), the ground on which the trail is located could be affected by erosion, possibly removed above sea level. These areas are dynamic, and whilst there is potential for the trail to be removed by erosion there is also potential for sand to accrete and for the ground on which the trail is located to be reinstated.

The paths along the Biddles Beach (Trail Type B) and the rear of the coastal rock platform (Trail Type D) are assessed as potentially having a high vulnerability to coastal erosion. As noted in Section 3.2.2, Biddles Beach is pocket beach contained between rocky headlands to the east and west. Additionally, the beach has a rocky seabed offshore of the beach. Trail Type D, which is located behind the rock platform at a level of around +3m AHD, is not considered to be at risk of erosion.

The Bruun rule is widely used to estimate beach recession due to sea level rise, however the simplicity of the rule means it does not account for many of the variables that impact on the beach.

Trail Type B is substantially influenced by the presence of rock shelves and estimation of erosion needs to take this into account. The Komar [5] Geometric Model of Foredune Erosion was used to estimate the erosion. This model was developed for determining storm erosion during periods of elevated water level, however the model is often quoted for assessing longer term shoreline response due to sea level rise. The equation essentially reduces to the Bruun rule except that the beach face slope is adopted rather than the slope to profile closure.

Costal erosion distances calculated using the Komar equation for Trail Type B are shown in Table 4-8.

Table 4-8: Recession due to sea level rise

Recession (m)	**Scenarios and Year**		
Active Profile	2030	2070	2100
Trail Type B - Biddles Beach	3	8	14
Trail Type D – Rear of coastal rock platform	3	10	17

A graphical representation of the coastal erosion distances for Trail Type B are shown in Figure 4.9, Figure 4.10 and Figure 4.11.

In recognition of the potential for inaccuracies in the calculation of erosion distances, sensitivity checks will be made for increased erosion distances equal to twice the values calculated in Table 4-8. These scenarios have the Suffix “A” in the Risk Scenarios assessed in the following sections.

[4] Golder Associates Pty Ltd, “Great Ocean Road Coastal Trail, Geotechnical Hazard Assessment”, (April 2022)

[5] Komar, P. D., McDougal, W.G., Mara, W.J., and Ruggiero P. (1997), “The Rational Analysis of Setback Distances: Application to the Oregon Coast” Shore and Beach Vol.67 (1), pp1-49

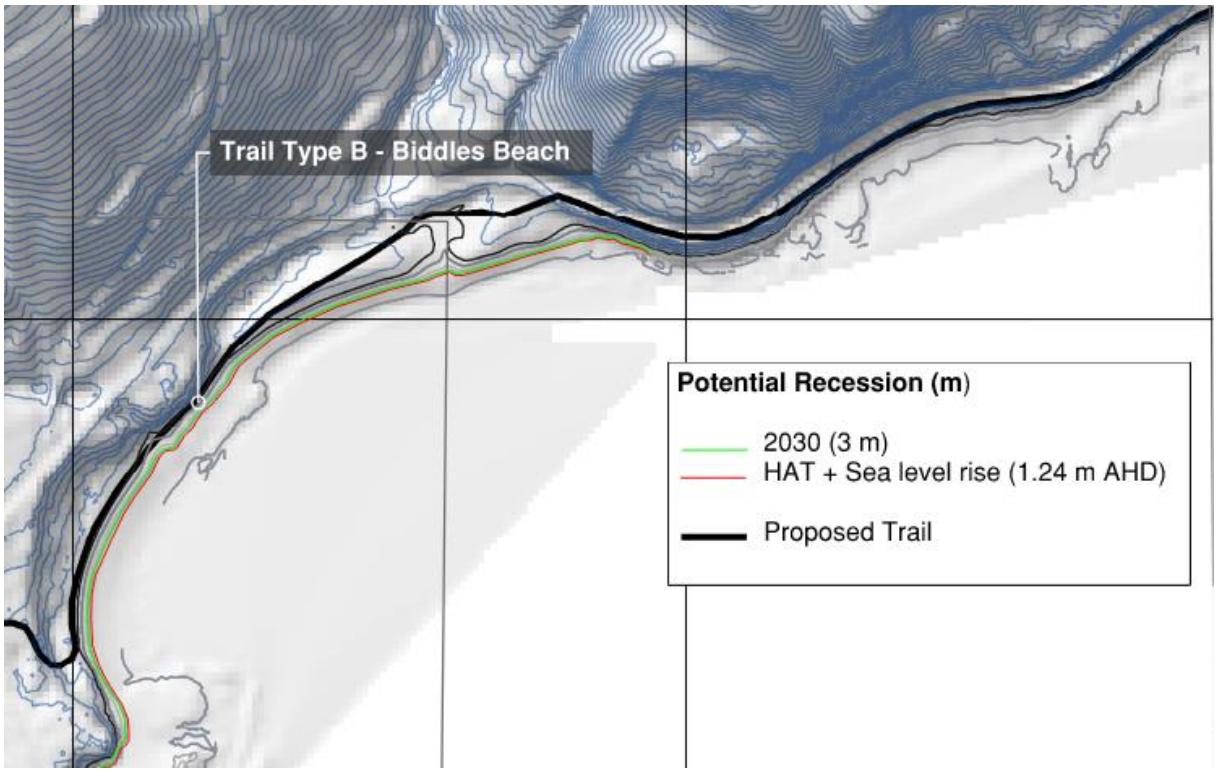

Figure 4.9 Potential future shoreline recession for Trail Type B in 2030

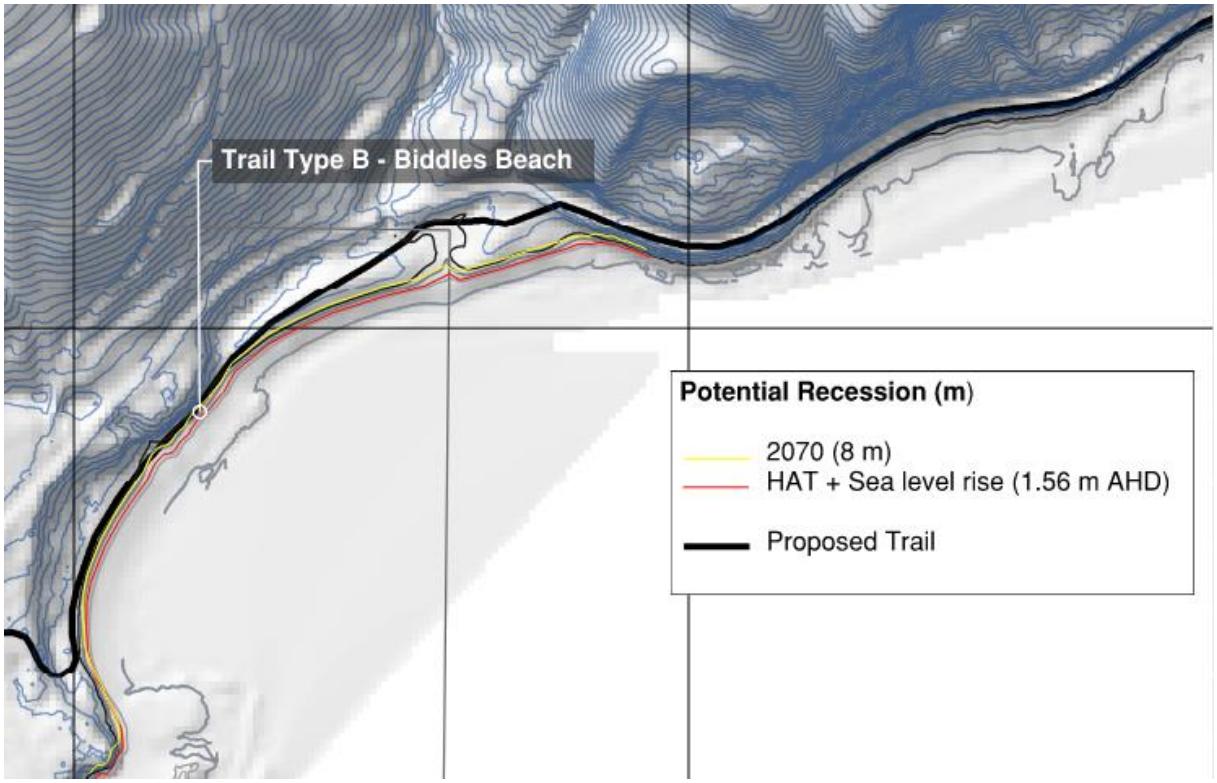

Figure 4.10 Potential future shoreline recession for Trail Type B in 2070

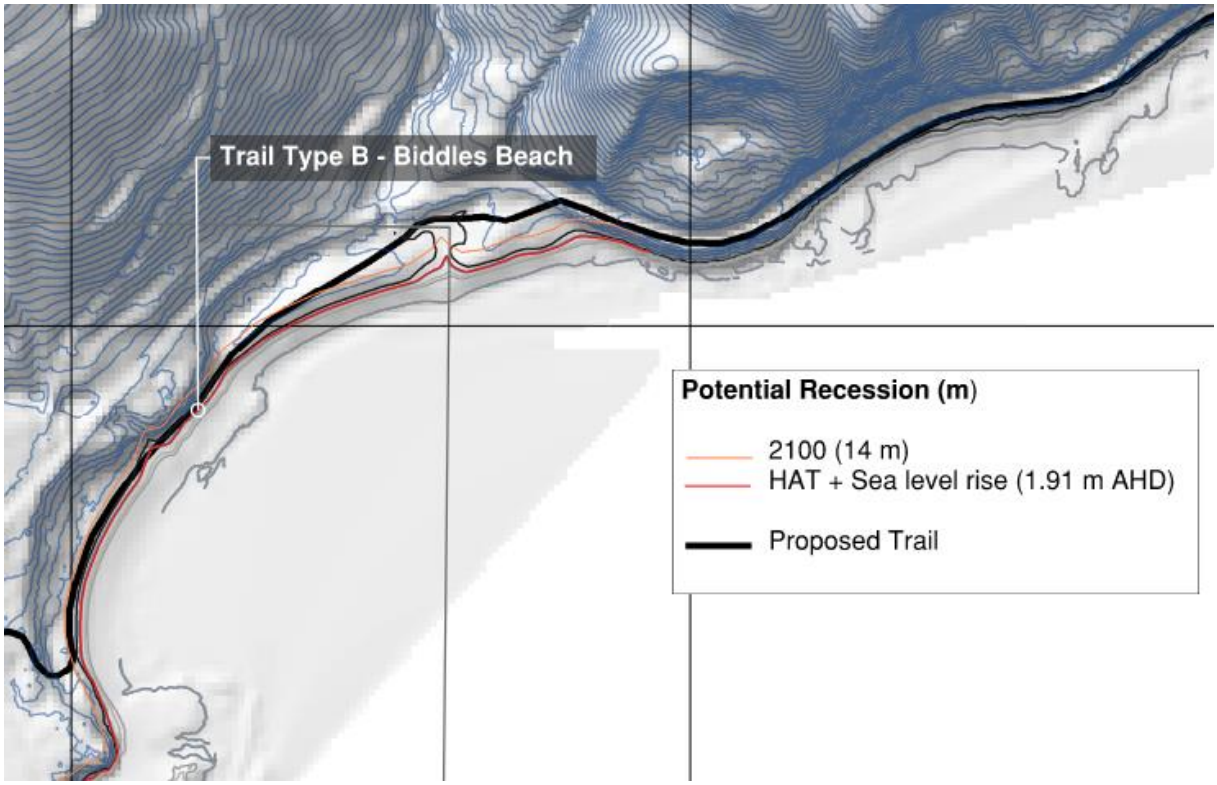

Figure 4.11 Potential future shoreline recession Trail Type B in 2100

4.3.6 Risk Scenarios

A number of different scenarios have been assessed as set out in Table 4-9.

Table 4-9: Scenarios for which risk is assessed

Year	Trail Type	Sea Level Rise (m)	1 in 100-yr storm tide level (m)	Wave run-up (m)	Coastal Morphology	Scenario Number
Present Day	A	Present Day	1.4		Present day	1
Present Day	B	Present Day	1.4		Present day	2
Present Day	C	Present Day	1.4		Present day	3
Present Day	D	Present Day	1.4		Present day	4
Present Day	B	Present Day	1.4	3.3	Present day	5
Present Day	D	Present Day	1.4	3.3	Present day	6
2030	A	Present Day +0.2	1.6			7
2030	B	Present Day +0.2	1.6			8
2030	C	Present Day +0.2	1.6			9
2030	D	Present Day +0.2	1.6			10
2030	B	Present Day	1.6	3.3		11
2030	B	Present Day +0.2	1.6		Erosion of foredune 3 m inland from present day	12
2030	B	Present Day +0.2	1.6		Erosion of foredune 6 m inland from present day	12A
2030	B	Present Day +0.2	1.6	3.5	Erosion of foredune 3 m inland from present day	13
2030	B	Present Day +0.2	1.6	3.5	Erosion of foredune 6 m inland from present day	13A
2030	D	Present Day	1.6	3.3		14
2070	A	Present Day +0.47	1.9-20			15
2070	B	Present Day +0.47	1.9-20			16
2070	C	Present Day +0.47	1.9-20			17
2070	D	Present Day +0.47	1.9-20			18
2070	B	Present Day +0.2	1.9-20	3.5		19
2070	B	Present Day +0.47	1.9-20		Erosion of foredune 8 m inland from present day	20

Year	Trail Type	Sea Level Rise (m)	1 in 100-yr storm tide level (m)	Wave run-up (m)	Coastal Morphology	Scenario Number
2070	B	Present Day +0.47	1.9-20		Erosion of foredune 16 m inland from present day	20A
2070	B	Present Day +0.47	1.9-20	3.9	Erosion of foredune 8 m inland from present day	21
2070	B	Present Day +0.47	1.9-20	3.9	Erosion of foredune 16 m inland from present day	21A
2070	D	Present Day +0.2	1.9-20	3.5		22
2100	A	Present Day +0.82	2.2-2.5			23
2100	B	Present Day +0.82	2.2-2.5			24
2100	C	Present Day +0.82	2.2-2.5			25
2100	D	Present Day +0.82	2.2-2.5			26
2100	B	Present Day +0.5	2.2-2.5	3.9		27
2100	B	Present Day +0.82	2.2-2.5		Erosion of foredune 14 m inland from present day	28
2100	B	Present Day +0.82	2.2-2.5		Erosion of foredune 28 m inland from present day	28A
2100	B	Present Day +0.82	2.2-2.5	4.4	Erosion of foredune 14 m inland from present day	29
2100	B	Present Day +0.82	2.2-2.5	4.4	Erosion of foredune 28 m inland from present day	29A
2100	D	Present Day +0.5	2.2-2.5	3.9		30

4.4 Risk Analysis

Risk analysis involves assessment of the likelihood and consequences of the hazard scenarios and associated risks. This allows a level of risk to be assessed which in turn guides decisions around whether risk mitigation measures are required and the form these measures should take. The VCHG provides examples of criteria to assess likelihood and consequence, and these have been adopted here. The following describes the basis of the likelihood and consequences estimated for this assessment.

4.4.1 Likelihood

The likelihood of each of the hazard scenarios shown in Table 4-11 has been estimated qualitatively using Table 8-3 from the VCHG. Table 8-3 has been reproduced in Table 4-10 for reference.

Table 4-10: Table 8-3 from VCHG

Time period (year)				
Present	**2040**	**2070**	**2100**	**Combination of events to assess coastal hazards**
Likely	Virtually certain			1% AEP storm tide and wave height with 10% AEP catchment flows
Unlikely	About as likely as not	Likely	Virtually certain	0.2 m of sea-level rise plus 1% AEP storm tide and wave height with 10% AEP catchment flows
Very unlikely	Unlikely	About as likely as not	Likely	0.5 m of sea level rise plus 1% AEP storm tide and wave height with 10% AEP catchment flows
		Very unlikely	About as likely as not	0.8 m of sea level rise plus 1% AEP storm tide and wave height with 10% AEP catchment flows
			Unlikely	1.1 m of sea level rise plus 1% AEP storm tide and wave height with 10% AEP catchment flows
			Very unlikely	1.4 m of sea level rise plus 1% AEP storm tide and wave height with 10% AEP catchment flows

Table 4-11: Summary of estimated likelihood of storm tide for each hazard scenario assessed.

Scenario Number	Year	Event	Estimated Likelihood
1	Present Day	1 in 100 (1%) AEP storm tide wave height.	Likely
2			
3			
4			
5		1 in 100 (1%) AEP storm tide wave height and wave run up 3.3 m	Likely
6			
7	2030	0.2 m sea level rise plus 1 in 100 (1%) AEP storm tide	About as likely as not
8			
9			
10			
11		No SLR, 1 in 100 (1%) AEP storm tide and wave run up 3.5m	Virtually certain
12		0.2 m sea level rise with 3 m recession	Likely
12A		0.2 m sea level rise with 6 m recession	Likely
13		0.2 m sea level rise plus 1 in 100 (1%) AEP storm tide and wave run up 3.5m	About as likely as not
13A		0.2 m sea level rise plus 1 in 100 (1%) AEP storm tide and wave run up 3.5m	About as likely as not
14		No SLR, 1 in 100 (1%) AEP storm tide and wave run up 3.5m	Virtually certain
15	2070	0.47 m sea level rise plus 1 in 100 (1%) AEP storm tide	About as likely as not
16			
17			
18			
19		0.2 m sea level rise plus 1 in 100 (1%) AEP storm tide and wave run up 3.9m	Likely
20		0.47 m sea level rise with 8 m recession	Likely
20A		0.47 m sea level rise with 16 m recession	Likely
21		0.47 m sea level rise plus 1 in 100 (1%) AEP storm tide and wave run up 3.9m with 8m recession	About as likely as not
21A		0.47 m sea level rise plus 1 in 100 (1%) AEP storm tide and wave run up 3.9m with 16m recession	About as likely as not
22		0.2 m sea level rise plus 1 in 100 (1%) AEP storm tide and wave run up 3.9 m	Likely
23	2100	0.82 m sea level rise plus 1 in 100 (1%) AEP storm tide	

Scenario Number	Year	Event	Estimated Likelihood
24			About as likely as not
25		0.82 m sea level rise plus 1 in 100 (1%) AEP storm tide	About as likely as not
26			
27		0.5 m sea level rise plus 1 in 100 (1%) AEP storm tide and wave run up 3.9m	Likely
28		0.82 m sea level rise with 14 m recession	Likely
28A		0.82 m sea level rise with 28 m recession	Likely
29		0.82 m sea level rise plus 1 in 100 (1%) AEP storm tide and wave run up 4.4m with 14 m recession	About as likely as not
29A		0.82 m sea level rise plus 1 in 100 (1%) AEP storm tide and wave run up 4.4m with 28 m recession	About as likely as not
30		0.5 m sea level rise plus 1 in 100 (1%) AEP storm tide and wave run up 3.9m	Likely

4.4.2 Consequence

The VCHG sets out an example for the assessment of consequence in Table 8-2 which is reproduced in Table 4-12.

Table 4-12: Table 8-2 from VCHG providing examples of consequence categories

Scale of impact	Description of consequences			
	Health & safety	Social	Economic	Environmental
Major	Multiple fatalities, or significant irreversible effects to > 50 persons	Ongoing serious social issues. Significant damage to structures and items of cultural significance	Severe, i.e. over $10 million or more than 50% of assets	Severe long-term environmental impairment of ecosystem functions
Severe	Single fatalities and/or severe permanent disability (>30%) to one or more persons	Ongoing serious social issues. Significant damage to structures and items of cultural significance	Major, i.e. between $1M and $10M or 10 to 50% of assets	Very serious long-term environmental impairment of ecosystem functions
Moderate	Moderate irreversible disability or impairment (< 30%) to one or more persons	Ongoing social issues, permanent damage to buildings and items of cultural significance	Moderate, i.e. between $100,000 and $1M or 10% of assets	Moderate short term effects but not affecting ecosystem functions
Minor	Reversible injury possibly requiring hospitalisation	Ongoing social issues, temporary damage to buildings and items of cultural significance Medium- term social issues, minor damage to dwellings	Minor, i.e. between $10,000 and $100,000 or 1% of assets	Minor effects on physical environment
Negligible	Minor first aid or no medical treatment required	Negligible short-term social impacts on local population, mostly repairable	Small, i.e. less than $10,000 or 0.1% of assets	Insignificant effects on physical environment

Based on the descriptions in

Table 4-12, the consequences to the proposed development for each of the hazard scenarios has been assessed as shown in Table 4-13. In making this assessment it has been assumed the cost to repair or reroute the damaged section of trail would be in the range $10,000 to $100,000 (minor impact). This is based on there being no actual trail construction proposed as the intent is for walkers to walk along the beach. If there is no trail construction, the only damage would be to wayfinding and interpretive signage.

Table 4-13: Summary of estimated consequences or hazard scenarios assessed

Scenario Number	Trail Type	Year	Description	Consequences
1	A	Present Day	Under present day conditions, with a trend of sand accumulation, the foredune is not expected to be breached and the probability that site is impacted by coastal processes is negligible.	Negligible/Insignificant
2	B	Present Day	Under this scenario, the trail located at rear of the beach can be partially inundated in an extreme storm tide event. If the trail is partially inundated, some erosion of the of the trail could occur.	Minor
3	C	Present Day	Under present day conditions, with a trend of sand accumulation, the foredune is not expected to be breached and the probability that site is impacted by coastal processes is negligible.	Negligible/Insignificant
4	D	Present Day	Under this scenario, the trail located at rear of the beach can be partially inundated in an extreme storm tide event. If the trail is partially inundated, some erosion of the of the trail could occur.	Minor
5	B	Present Day	Under this scenario, the trail located at rear of the beach can be substantially inundated in an extreme storm tide event. If the trail is substantially inundated, significant erosion of the of the trail could occur.	Minor
6	D	Present Day	Under this scenario, the trail located at rear of the beach can be substantially inundated in an extreme storm tide event. If the trail is substantially inundated, significant erosion of the of the trail could occur.	Minor
7	A	2030	Under this scenario the proposed trail is not expected to be inundated by elevated storm tide and elevated water levels.	Negligible/Insignificant
8	B	2030	Under this scenario, the trail located at rear of the beach can be partially inundated in an extreme storm tide event. If the trail is partially inundated, some erosion of the of the trail could occur.	Minor
9	C	2030	Under this scenario the proposed trail is not expected to be Inundated by elevated storm tide and elevated water levels.	Negligible/Insignificant

Scenario Number	Trail Type	Year	Description	Consequences
10	D	2030	Under this scenario, the trail located at rear of the beach can be partially inundated in an extreme storm tide event. If the trail is partially inundated, some erosion of the of the trail could occur.	Minor
11	B	2030	Under this scenario, the trail located at rear of the beach can be substantially inundated in an extreme storm tide event. If the trail is partially inundated, some erosion of the of the trail could occur.	Minor
12	B	2030	Under this scenario the proposed trail is not expected to be inundated by elevated water levels.	Negligible/Insignificant
12A	B	2030	Under this scenario the proposed trail is not expected to be inundated by elevated water levels.	Negligible/Insignificant
13	B	2030	Under this scenario, the trail located at rear of the beach can be substantially inundated in an extreme storm tide event. If the trail is substantially inundated, significant erosion of the of the trail could occur.	Minor
13A	B	2030	Under this scenario, the trail located at rear of the beach can be substantially inundated in an extreme storm tide event. If the trail is substantially inundated, significant erosion of the of the trail could occur.	Minor
14	D	2030	Under this scenario, the trail located at rear of the beach can be substantially inundated in an extreme storm tide event. If the trail is partially inundated, some erosion of the of the trail could occur.	Minor
15	A	2070	Under this scenario the proposed trail is not expected to be inundated by elevated storm tide and elevated water levels.	Negligible/Insignificant
16	B	2070	Under this scenario, the trail located at rear of the beach can be partially inundated in an extreme storm tide event. If the trail is partially inundated, some erosion of the of the trail could occur.	Minor
17	C	2070	Under this scenario the proposed trail is not expected to be inundated by elevated storm tide and elevated water levels.	Negligible/Insignificant
18	D	2070	Under this scenario, the trail located at rear of the beach can be partially inundated in an extreme storm tide event. If the trail is partially inundated, some erosion of the of the trail could occur.	Minor

Scenario Number	Trail Type	Year	Description	Consequences
19	B	2070	Under this scenario, the trail located at rear of the beach can be substantially inundated in an extreme storm tide event. If the trail is substantially inundated, significant erosion of the of the trail could occur.	Minor
20	B	2070	Under this scenario the proposed trail is not expected to be inundated by elevated water levels.	Negligible/Insignificant
20A	B	2070	Under this scenario the proposed trail is not expected to be inundated by elevated water levels.	Negligible/Insignificant
21	B	2070	Under this scenario, the trail located at rear of the beach can be substantially inundated in an extreme storm tide event. If the trail is substantially inundated, significant erosion of the of the trail could occur.	Minor
21A	B	2070	Under this scenario, the trail located at rear of the beach can be substantially inundated in an extreme storm tide event. If the trail is substantially inundated, significant erosion of the of the trail could occur.	Minor
22	D	2070	Under this scenario, the trail located at rear of the beach can be substantially inundated in an extreme storm tide event. If the trail is substantially inundated, significant erosion of the of the trail could occur.	Minor
23	A	2100	Under this scenario the proposed trail is not expected to be inundated by elevated storm tide and elevated water levels.	Negligible/Insignificant
24	B	2100	Under this scenario, the trail located at rear of the beach can be partially inundated in an extreme storm tide event. If the trail is partially inundated, some erosion of the of the trail could occur.	Minor
25	C	2100	Under this scenario the proposed trail is not expected to be inundated by elevated storm tide and elevated water levels.	Negligible/Insignificant
26	D	2100	Under this scenario, the trail located at rear of the beach can be partially inundated in an extreme storm tide event. If the trail is partially inundated, some erosion of the of the trail could occur.	Minor
27	B	2100	Under this scenario, the trail located at rear of the beach can be substantially inundated in an extreme storm tide event. If the trail is substantially inundated, significant erosion of the of the trail could occur.	Minor
28	B	2100	Under this scenario the proposed trail is not expected to be inundated by elevated water levels.	Negligible/Insignificant

Scenario Number	Trail Type	Year	Description	Consequences
28A	B	2100	Under this scenario the proposed trail is not expected to be inundated by elevated water levels.	Negligible/Insignificant
29	B	2100	Under this scenario, the trail located at rear of the beach can be substantially inundated in an extreme storm tide event. If the trail is substantially inundated, significant erosion of the of the trail could occur.	Minor
29A	B	2100	Under this scenario, the trail located at rear of the beach can be substantially inundated in an extreme storm tide event. If the trail is substantially inundated, significant erosion of the of the trail could occur.	Minor
30	D	2100	Under this scenario, the trail located at rear of the beach can be substantially inundated in an extreme storm tide event. If the trail is substantially inundated, significant erosion of the of the trail could occur.	Minor

4.4.3 Risk evaluation

The VCHG provides a matrix in Table 8-4 can be used to qualitatively assess risk. This matrix is reproduced in Table 4-14.

Table 4-14: Risk matrix, extract from VCHG, Table 8-4

		Consequence				
		Insignificant	Minor	Moderate	Major	Extreme
Likelihood	Virtually certain	Medium	High	High	Extreme	Extreme
	Likely	Medium	Medium	High	High	Extreme
	About as likely as not	Low	Medium	Medium	High	High
	Unlikely	Low	Low	Medium	Medium	High
	Very unlikely	Low	Low	Low	Medium	Medium

Using the matrix in Table 4-14 the risk for each hazard scenario has been assessed. The results of this assessment are presented in Table 4-15.

Table 4-15: Risk estimate for hazard scenarios assessed

Scenario Number	Trail Type	Estimated Likelihood	Consequences	Risk
1	A	Likely	Negligible/Insignificant	Medium
2	B	Likely	Minor	Medium
3	C	Likely	Negligible/Insignificant	Medium
4	D	Likely	Minor	Medium
5	B	Likely	Minor	Medium
6	D	Likely	Minor	Medium
7	A	About as likely as not	Negligible/Insignificant	Low
8	B	About as likely as not	Minor	Medium
9	C	About as likely as not	Negligible/Insignificant	Low
10	D	About as likely as not	Minor	Medium
11	B	Virtually certain	Minor	High
12	B	Likely	Negligible/Insignificant	Medium
12A	B	Likely	Negligible/Insignificant	Medium
13	B	About as likely as not	Minor	Medium
13A	B	About as likely as not	Minor	Medium
14	D	Virtually certain	Minor	High
15	A	About as likely as not	Negligible/Insignificant	Low

Scenario Number	Trail Type	Estimated Likelihood	Consequences	Risk
16	B	About as likely as not	Minor	Medium
17	C	About as likely as not	Negligible/Insignificant	Low
18	D	About as likely as not	Minor	Medium
19	B	Likely	Minor	Medium
20	B	Likely	Negligible/Insignificant	Medium
20A	B	Likely	Negligible/Insignificant	Medium
21	B	About as likely as not	Minor	Medium
21A	B	About as likely as not	Minor	Medium
22	D	Likely	Minor	Medium
23	A	About as likely as not	Negligible/Insignificant	Low
24	B	About as likely as not	Minor	Medium
25	C	About as likely as not	Negligible/Insignificant	Low
26	D	About as likely as not	Minor	Medium
27	B	Likely	Minor	Medium
28	B	Likely	Negligible/Insignificant	Medium
28A	B	Likely	Negligible/Insignificant	Medium
29	B	About as likely as not	Minor	Medium
29A	B	About as likely as not	Minor	Medium
30	D	Likely	Minor	Medium

4.5 Risk Evaluation

The VCHG does not provide a direct indication of whether risks assessed using the matrix presented in Table 4-14 can be tolerated or require risk mitigation.

However, we note that a Low Risk would usually be one that is acceptable and does not require special treatment or risk mitigation. This applies for Trail Types A and C for all future scenarios.

For the present day, for Trail Types A and C, a Medium Risk scenario has been estimated.

For future scenarios in 2030, 2070 and 2100, with the sea level rise estimates taken from VCHG, the risk level for Trail Types B & D is Medium. Additional scenarios with reduced amounts of sea level rise (11, 14, 19, 22, 27 and 30) were also assessed. For these scenarios the risk evaluation was found to be High in 2030 and Medium for 2070 and 2100 future scenarios.

The increased risk for scenarios 11 and 14 results from the increased likelihood for the scenario. The risk matrix (Table 4-14) defines the level of risk for a particular combination of consequence and likelihood. If the likelihood of an event increases (eg reduced future SLR compared to forecast SLR) the level of risk for that future scenario increases compared to the present day scenario.

4.6 Risk Treatment

Based on the assessed risks, the Trail Types A and C do not require any treatment.

Trail Types B and D, the portions at Biddles Beach (Section 2) and at the rear of the rock platform (Section 1B) have been estimated to be exposed to a Medium Risk of damage in the present day and in future scenarios. In scenarios 11 and 14, with reduced estimates of sea level rise for 2030, a High Risk is estimated.

The trail, located at the rear of the beach, is expected to be impacted with signage potentially damaged by storm events. If this minor damage is considered acceptable, then additional treatment is not required. Alternatively, consideration can be given to placing the signs on higher ground.

If the sediments on which the trail is located are removed, the trail could be reinstated on underlying rock or the trail relocated along the road. Provision could also be made to develop an alternative route, for example along the Great Ocean Road to be used in the event that the trails on the beach and shore platform are impacted and become impassable.

5 Conclusions

The risk to the prosed trail from coastal hazards has been assessed, considering sea level rise and a 1 in 100-year storm tide under present day as well as forecast conditions in 2030, 2070 and 2100. This assessment indicates:

In carrying out this assessment the trail was subdivided into four trail types as follows:

- Trail Type A: Trail located adjacent to road, at the crest of an embankment constructed on a rocky, hard coast.
- Trail Type B: Trail located at rear of a sandy beach
- Trail Type C: Trail located adjacent to road behind vegetated dune at rear of beach
- Trail Type D: Trail located at the rear of coastal rock platform

For all future scenarios for Trail Types A and C a Low Risk has been estimated and no special treatment or risk mitigations are advised at this time.

Trail types B and D, both located behind an active beach zone, are at Medium Risk of damage in the present day and Medium Risk for all future scenarios, taking account of the future sea level rise taken from the VCHG. For reduced sea level estimates the risk level increases to High Risk in 2030.

If deemed to be required, risk treatment could include:

- If the minor damage to signage is considered acceptable, then additional treatment is not required, alternatively, consideration can be given to placing the signs on higher ground.
- Making provision to reinstate or realign the trail in the event it is damaged in a storm event.
- Providing an alternative route that could be adopted in the event the trail is lost damaged or destroyed. The shoulder of the Great Ocean Road may be a candidate alternative alignment.

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