World Trail

Great Ocean Road Trail

Geotechnical Risk Mitigation

May 2024

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Great Ocean Road Trail
Geotechnical Risk Mitigation

World Trail

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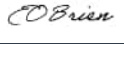
Prepared by:	Emma O'Brien	21 May 2024	
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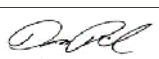
Approved by:	Darren Paul	21 May 2024	

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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Executive summary

The proposed Great Ocean Road Coastal Trail (GORCT) is a new walking trail to be constructed between Fairhaven and Skeens Creek, near the iconic Great Ocean Road. WSP Pty Ltd (WSP) has previously undertaken a geotechnical hazard assessment and a geotechnical risk assessment for the proposed GORCT. The hazard assessment identified areas along the proposed route that are exposed to geotechnical hazards to allow route selection to consider those hazards as part of trail set out and alignment.

The quantitative geotechnical risk assessment sets out the risk to loss of life and property associated with the previously identified geotechnical hazards along the proposed trail. The assessment identified a number of areas of elevated geotechnical risk where risk mitigation should be considered if the trail is to pass through the exposed area. Several lengths of the trail were identified as being potentially suitable for the provision of risk mitigation measures to reduce the overall geotechnical risk within their respective trail segments. These selected trail segments are set out in Table ES.1.

Table ES.1 Sections of the GORCT identified for geotechnical risk mitigation.

Trail Segment	Chainage	Location	Hazard	Length
Fairhaven to North Lorne (FL)	CH17820 - CH18440	Big Hill	Cut Batter	620 m
North Lorne to South Lorne (L)	CH25620 - CH27320	Lorne Foreshore	Fill Batter	1700 m
	CH28920 - CH29150	Shipwreck Trail	Fill Batter	230 m
South Lorne to Cumberland River (LC)	CH30330 - CH31310	Old Tramway	Cut Batter	980 m
Cumberland River to Wye River (CW)	CH41900 – CH42050	Cumberland Campground	Rockfall	150 m
	CH42520 – CH 42620	Cumberland River	Rockfall	100 m
	CH43350-CH43450	Cumberland Hill	Rockfall	100 m
	CH50920 - CH51370	Jaimeson Creek Campground	Cut Batter	450 m
	CH52350 - CH52420	Godfrey Track	Cut Batter	70 m
	CH53990 - CH56280	East of Separation Creek	Cut Batter	2290 m
	CH56770 - CH57200	Paddy’s Path	Cut Batter	430 m
Total trail length for mitigation review				7120 m

The hazards identified for mitigation were assessed in the field to allow concepts for mitigation measures to be developed. Soft engineering mitigation measures are favoured over hard engineering mitigation measures due to economic feasibility and preserving the amenity of the trail. The following hazards along the GORCT were identified suitable for the practical provision of risk mitigation measures:

- Rockfall
- Soil detachment from cut batters onto track.
- Rock detachment from cut batters onto track.
- Fill embankment failure onto the track.

Risk mitigation measures for these hazards at discrete locations along the trail have been identified. The mitigation measures should be constructed under geotechnical supervision and should include:

- Micro-routing of the trail to avoid rockfall hazards.
- Providing an alternative route to reduce the number of walkers exposed to the hazard.
- Scaling, trimming and selected vegetation removal to stabilise cut batters and to reduce the probability of detachment.
- Construction of minor structures to reduce the probability of detached material reaching the track e.g. rock ditches and non-engineered rock fences.

A summary of the mitigation measures recommended for each trail segment is set out in Table 1.1. The geotechnical assessment required for each mitigation measure is also described. Pre-construction geotechnical assessment is required to identify specific remediation measures, for example, which blocks need to be scaled or where slopes are over-steepened and should be trimmed. Post-construction geotechnical supervision is required to assess the residual risk following the works and to advise if further mitigations are needed. The mitigation measures are also presented in the drawing set included in Appendix A-1.

The risk to life for each mitigated hazard, as well as the combined risk to life for all hazards along the trail segment, was estimated. Each mitigated trail segment shows a decrease in risk to life arising from the mitigated hazards, as well as the combined risk to life for all hazards within each trail segment. The most notable risk reduction being the Cumberland River to Wye River trail segment which was originally assessed as having an unacceptable combined risk to life which decreased to tolerable on the basis of the mitigation measures implemented.

The combined risk to life for the other mitigated trail segments (Fairhaven to Lorne, North Lorne to South Lorne, and Lorne to Cumberland River) was initially assessed as being tolerable. However, with mitigation measures in place the combined risk to life for these three segments reduced, plotting further away from the not acceptable-tolerable boundary on the F-N plots.

Given the effective risk reduction afforded by the mitigation measures described, and the relatively low economic impact of those measures compared to hard engineering alternatives, it is recommended the mitigation measures suggested are implemented in an effort to reduce the risk to life for the walking trail as far as reasonably practical.

Table 1.1 Summary of mitigation measures recommended for each trail segment. The required geotechnical assessment pre- and post-construction is described.

Trail No.[#]	Sector[#]	Location Coordinates (Start/End)[#]	Trail Segment	Chainage	Location	Hazard	Length	Drawing Sheet	Mitigation Measures	Geotechnical Input/Assessment	
										Pre-construction	Post-construction
Trail 34	2. Spout Creek to Lily Pond Reserve	-38.492615, 144.009969 -38.496739, 144.008672	Fairhaven to North Lorne (FL)	CH17820 - CH18440	Big Hill	Cut Batter	620 m	1	Rock scaling, local trimming where slope angles are vertical or overhanging, selected vegetation removal, construction of a rock catch ditch.	Yes. Geotechnical engineer to identify select rocks to be scaled, select areas of slope to be trimmed and select vegetation to be removed.	Yes. Inspection of completed works to ensure risk has been reduced.
Trail 45 & 46a	3. Lily Pond Reserve to Cumberland River	-38.520939, 143.988454 -38.533361, 143.977768	North Lorne to South Lorne (L)	CH25620 - CH27320	Lorne Foreshore	Fill Batter	1700 m	2	Hazard removed if high-tide route is utilised. Provide signage to warn walkers of the hazard during low tide.	No	No
Trail 46c	3. Lily Pond Reserve to Cumberland River	-38.544929, 143.981346 -38.546247, 143.983374	North Lorne to South Lorne (L)	CH28920 - CH29150	Shipwreck Trail	Fill Batter	230 m	3	Development of alternative inland route out of Lorne reduces the number of walkers exposed to hazard.	No	No
Trail 47	3. Lily Pond Reserve to Cumberland River	-38.553765, 143.982204 -38.551961, 143.973836	South Lorne to Cumberland River (LC)	CH30330 - CH31310	Old Tramway	Cut Batter	980 m	4	1) Scaling of loose rock from cut face. 2) Development of alternative inland route out of Lorne reduces the number of walkers exposed to hazard. 3) Micro-rerouting to avoid a section of the geotechnical hazard. 4) Rock netting. Options 1 and 2 combined reduce risk to a tolerable range. If preferred, the risk may be further reduced by implementing options 3 and 4.	1) Yes. Geotechnical engineer to identify select rocks to be scaled. 2) No. 3) Yes. Geotechnical engineer to ensure hazard is avoided. 4) N/A detailed design required.	1) Yes. Inspection of completed works to ensure risk has been reduced. 2) No. 3) Yes. Inspection of completed works to ensure risk has been reduced. 4) N/A detailed design required.
Trail 55	4. Cumberland River to Jamieson Creek	-38.572787, 143.946772 -38.572133, 143.945399	Cumberland River to Wye River (CW)	CH41900 - CH42050	Cumberland Campground	Rockfall	150 m	5	Micro-rerouting of trail to avoid geotechnical hazard.	Yes. Geotechnical engineer to ensure adequate setback distance from hazard.	Yes. Inspection of completed works to ensure risk has been reduced.
Trail 55	4. Cumberland River to Jamieson Creek	-38.568752, 143.945377 -38.568299, 143.944616	Cumberland River to Wye River (CW)	CH42520 - CH42620	Cumberland River	Rockfall	100 m	5	Provide signage to warn walkers of the hazard. Signage alone does not reduce risk of hazard, but the overall trail segment risk is decreased from mitigation measures at other hazards.	No	No
Trail 56	4. Cumberland River to Jamieson Creek	-38.566829, 143.942263 -38.567345, 143.9417	Cumberland River to Wye River (CW)	CH43350 - CH43450	Cumberland Hill	Rockfall	100 m	5	Scaling of loose rock from the slope above the track. Placing natural protection, such as existing fallen trees, to catch rock.	Yes. Geotechnical engineer to identify areas where loose rocks should be removed and advice where to locate natural protection.	Yes. Inspection of completed works to ensure risk has been reduced.
Trail 66	4. Cumberland River to Jamieson Creek	-38.597584, 143.918781 -38.601273, 143.918652	Cumberland River to Wye River (CW)	CH50920 - CH51370	Jaimeson Creek Campground	Cut Batter	450 m	6	Delineation of pedestrian pathway on far side of road to avoid walking under cut. Rock scaling, local trimming where slope angles are vertical or overhanging, selected vegetation removal.	Yes. Geotechnical engineer to identify select rocks to be scaled, select areas of slope to be trimmed, select vegetation to be removed.	Yes. Inspection of completed works to ensure risk has been reduced.
Trail 67a	5. Jamieson Creek to Wye River	-38.606929, 143.916371 -38.607318, 143.916961	Cumberland River to Wye River (CW)	CH52350 - CH52420	Godfrey Track	Cut Batter	70 m	7	Rock scaling, local trimming where slope angles are vertical or overhanging, selected vegetation removal, construction of a rock catch ditch.	Yes. Geotechnical engineer to identify select rocks to be scaled, select areas of slope to be trimmed, select vegetation to be removed.	Yes. Inspection of completed works to ensure risk has been reduced.
Trail 67a	5. Jamieson Creek to Wye River	-38.616217, 143.913348 -38.628933, 143.900645	Cumberland River to Wye River (CW)	CH53990 - CH56280	East of Separation Creek	Cut Batter	2290 m	8	Rock scaling, local trimming where slope angles are vertical or overhanging, selected vegetation removal, construction of a rock catch ditch.	Yes. Geotechnical engineer to identify select rocks to be scaled, select areas of slope to be trimmed, select vegetation to be removed.	Yes. Inspection of completed works to ensure risk has been reduced.
Trail 67c	5. Jamieson Creek to Wye River	-38.631095, 143.89748 -38.633761, 143.891107	Cumberland River to Wye River (CW)	CH56770 - CH57200	Paddy's Path	Cut Batter	430 m	9	Rock scaling and local trimming where slope angles are vertical or overhanging. Construction of a one-metre-high rock fence at the base of the cut.	Yes. Geotechnical engineer to identify select rocks to be scaled and to ensure adequate coverage of hazard is achieved by fence.	Yes. Inspection of completed works to ensure risk has been reduced.

[#]Informaton provided by World Trail

1 Engagement

The proposed Great Ocean Road Coastal Trail (GORCT) is a new walking trail to be constructed between Fairhaven and Skeens Creek, near the iconic Great Ocean Road. WSP Pty Ltd (WSP) had been engaged by World Trail Pty Ltd (World Trail) to provide mitigation advice for sections of the trail that have been identified as having an elevated geotechnical risk from landslides, debris flow, rockfall and erosion.

WSP has previously undertaken a geotechnical hazard assessment and a geotechnical risk assessment for the proposed GORCT to inform the master plan currently being developed by the Department of Energy, Environment and Climate Action (DEECA, formerly DELWP). The hazard assessment identified areas along the proposed route that are exposed to geotechnical hazards to allow route selection to consider those hazards as part of trail set out and alignment. Hazard maps were produced in conjunction with a ground truthing exercise across the project area. The hazard assessment was completed in April 2022 with the findings set out in the Great Ocean Road Coastal Trail Geotechnical Hazard Assessment (REF: 21468192-001-R-Rev0).

The geotechnical risk assessment was completed in December 2022 with the findings set out in the Great Ocean Road Coastal Trail Geotechnical Risk Assessment (REF: 21468192-002-R-Rev1). The quantitative geotechnical risk assessment, completed as part of the master plan development, sets out the risk to loss of life and property associated with the previously identified geotechnical hazards along the proposed trail. The assessment identified a number of areas of elevated geotechnical risk where risk mitigation should be considered if the trail is to pass through the exposed area. Several lengths of the trail were identified as being potentially suitable for the provision of risk mitigation measures to reduce the overall geotechnical risk within their respective trail segments.

This report describes mitigation measures for those sections of trail assessed to have an elevated geotechnical risk. The study has been undertaken in general accordance with the WSP proposal PP210421-WSP-MEL-GEO-LTR-001 dated 17 November 2023. Authorization to undertake the geotechnical investigation was provided by World Trail via the execution of a contract between WSP and World Trail dated 8 February 2024.

2 Project Background

2.1 Trail Development

A preferred alignment for the GORCT has been developed and ground truthed by World Trail as presented in Figure 2.1. Based on the information provided, we understand the following about the proposed alignment:

- The trail passes through a number of coastal villages, including Fairhaven, Moggs Creek, Big Hill, Lorne, Cumberland River, Wye River, Kennett River, Grey River, and Skenes Creek.
- The trail passes through varied terrain, including beaches, shore platforms and forested coastal ranges.
- The trail is proposed to be typically 1 m wide, but the width could range between 0.5 m and 1.5 m. It crosses the Great Ocean Road at several locations.
- A number of facilities will be incorporated into the trail, including lookouts, car parking, and amenities including public toilets.
- Suspension bridges are proposed to be incorporated into the proposed alignment at key water crossing points.

Figure 2.1 Overview of the proposed Great Ocean Road Coastal Trail alignment.

As part of the geotechnical risk assessment, the proposed trail was divided into segments to facilitate the assessment of each segment independently. A chainage was established along the main trail, commencing in Fairhaven (at chainage =

0) and concluding in Skenes Creek (at chainage = 90290) for reference purposes. The trail was nominally split into seven segments defined by key trail milestones. Along the proposed trail, several alternate loops, dead-end branches, and bridges have also been proposed. The trail segments and chainages are described in Table 2.1. Each trail segment has been assigned an ID to assist with the analysis.

Table 2.1 Segments assessed along proposed along the Great Ocean Road Coastal Trail

Type	ID	Position	From	To	Chainage From	Chainage To	Distance (m)
Main Trail	FL		Fairhaven	North Lorne	0	25640	25640
Main Trail	L		North Lorne	South Lorne	25640	30000	4360
Main Trail	LC		South Lorne	Cumberland River	30000	41490	11490
Main Trail	CW		Cumberland River	Wye River	41490	57580	16090
Main Trail	WK		Wye River	Kennett River	57580	63080	5500
Main Trail	KSm		Kennett River	Smythe Creek	63080	84600	21520
Main Trail	KSk		Smythe Creek	Skenes Creek	84600	90290	5690
Loop	Loop1	Off Main Trail LC	LC_CH31385	LC_CH33615	0	2027	2027
Loop	Loop2	Off Main Trail LC	LC_CH35910	LC_CH39760	0	1948	1948
Loop	Loop3	Off Main Trail FL-L	FL_CH25580	L_CH26460	0	934	934
Loop	Loop4	Off Main Trail CW	CW_CH41550	CW_CH49070	0	4646	4646
Loop	Loop5	Connects Bridge4 to Loop4	Bridge4_CH1260	Loop4_CH2100	0	1090	1090
Loop	Loop6	Off Main Trail KSm	KSm_CH63080	KSm_CH65860	0	2540	2540
Loop	Loop7	Off Main Trail CW	CW_CH44290	CW_CH46305	0	1454	1284
Branch	Branch1	Off Loop1	Loop1_CH1265	End of branch	0	1017	1017
Branch	Branch2	Off Main Trail LC	LC_CH38345	End of branch	0	95	95
Branch	Branch3	Off Main Trail LC	LC_CH40480	End of branch	0	43	43
Branch	Branch4	Off Main Trail CW	CW_CH44195	End of branch	0	108	108
Branch	Branch5	Off Main Trail FL	FL_CH7475	End of branch	0	50	50
Branch	Branch6	Off Main Trail FL	FL_CH19487	End of branch	0	37	37
Branch	Branch7	Off Main Trail KSm	KSm_CH66720	Grey River	0	1635	1635

Type	ID	Position	From	To	Chainage From	Chainage To	Distance (m)
Bridge	Bridge0	Off Main Trail FL	FL_CH14193	FL_CH14810	0	176	176
Bridge	Bridge1	Off Main Trail FL	FL_CH18263	FL_CH18685	0	204	204
Bridge	Bridge2	Off Main Trail FL	FL_CH21270	FL_CH21645	0	107	107
Bridge	Bridge4	Within Loop 7	Loop7_CH240	Loop7_CH410	0	170	170

2.2 Hazard Analysis

Assessment of whether a hazard could impact public using the trail was informed by the outcomes of the geotechnical hazard assessment. This included the assessment of run out distances, the size of debris that could impact the trail and the frequency at which landslides or rockfalls could occur. The following hazards are considered to present a risk to life and were assessed as part of the quantitative risk assessment:

- Shallow soil landslide causing the track to be undermined or impacted by debris.
- Rockfall causing impact to the track or walkers on the track.
- Debris flow impacting the track where it crosses gullies.
- Deep seated rock landslide causing the track to be undermined.
- Fill material falling on to trail, where the track is below fill embankments, for example below the fill embankment of the Great Ocean Road.
- Failure of a fill embankment where it undermines the trail.
- Rock or soil falling onto the trail from an existing cutting.
- Soil falling onto trail from an existing cutting.
- Undermining of the trail due to the failure of a cutting in rock or soil, for example where the trail is near the crest of a road cutting.

2.3 Risk Assessment

The geotechnical risk assessment was undertaken in accordance with the methods set out in the New South Wales National Parks and Wildlife Service Guidelines for Quantitative Risk to Life Calculations for Landslides (NSW NPWS 2020). These guidelines have been developed specifically for the assessment of risks to visitors in national parks and include specific methods for assessing risk to people on walking trails and lookouts.

To assess the risk to loss of life, the following variables are considered:

- The type of hazard; e.g. rock fall, natural shallow landslide, etc.
- The likelihood of the hazard occurring, AND of it reaching an asset or location where a person could be located, being the product of the probability of the event occurring and the probability of debris reaching a person or asset (likelihood).
- The annual probability that a person is present when the hazard occurs (temporal probability).
- The probability that a person is killed if impact occurs (vulnerability).

– The number of people that could be impacted by the hazard (exposed population).

These methods involve consideration of risk to the individual most at risk - the individual who has the greatest exposure to the hazard (usually the person exposed over the greatest time). Additionally, the societal risk was considered which takes into account the fact that many different people, in this case tens of thousands, will be exposed to the hazards affecting the trail each year. The assessment of societal risk involves the calculation of an 'F-N Pair', providing a single point based on the probability of an impact occurring and the estimated number of people killed if impact occurs. The guidelines also consider the potential for people to be exposed to multiple hazards on a single traverse along a walking trail, producing a cumulative risk from the individual hazards.

To evaluate the risk to loss of life for the individual most at risk, the criteria set out in the Colac Otway Shire Erosion Management Overlay (EMO) was used. For risk to life associated with new development, the annual probability of loss of life of the individual most at risk must not exceed 10^{-5} / annum. This criteria is generally always met when assessing the risk to an individual using a walking trail.

Evaluation of the societal risk was undertaken using a different method as there are no criteria for evaluating societal risk, included in the Colac Otway planning scheme. The societal risk was assessed using the Australian National Committee on Large Dams Guidelines on Risk Assessment (ANCOLD 2003), which has been adopted by the NSW NPWS as the criteria against which rockfall risks in national parks are evaluated. The calculated F and N are combined to create an F-N pair which is shown on an F-N plot and compared to set limits of acceptance. This results in a categorisation of risk(s) as Acceptable, Tolerable or Not Acceptable.

2.4 Risk Mitigation

As an outcome of the geotechnical risk assessment, several lengths of the trail were identified as being potentially suitable for the provision of risk mitigation measures to reduce the overall geotechnical risk within their respective trail segments. These selected sections are set out in Table 2.2.

Table 2.2 Sections of the GORCT identified for geotechnical risk mitigation.

Trail Segment	Chainage	Location	Hazard	Length
Fairhaven to North Lorne (FL)	CH17820 - CH18440	Big Hill	Cut Batter	620 m
North Lorne to South Lorne (L)	CH25620 - CH27320	Lorne Foreshore	Fill Batter	1700 m
	CH28920 - CH29150	Shipwreck Trail	Fill Batter	230 m
South Lorne to Cumberland River (LC)	CH30330 - CH31310	Old Tramway	Cut Batter	980 m
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	CH42520 – CH 42620	Cumberland River	Rockfall	100 m
	CH43350-CH43450	Cumberland Hill	Rockfall	100 m
	CH50920 - CH51370	Jaimeson Creek Campground	Cut Batter	450 m
	CH52350 - CH52420	Godfrey Track	Cut Batter	70 m
	CH53990 - CH56280	East of Separation Creek	Cut Batter	2290 m
	CH56770 - CH57200	Paddy's Path	Cut Batter	430 m
Total trail length for mitigation review				7120 m

3 Aims and methodology of assessment

3.1 Aims of Assessment

The aims of the geotechnical risk mitigation assessment are as follows:

- To identify specific geotechnical hazards suitable for the provision of risk mitigation.
- To provide mitigation solutions for the identified hazards to reduce the geotechnical risk.
- To re-assess the overall geotechnical risk for each trail segment assuming implementation of the proposed mitigation solutions.

3.2 Methodology

The methodology of the geotechnical risk mitigation assessment is as follows:

- Site visits were undertaken to each identified segment of the trail to make geotechnical observations of the hazard and to assess suitable mitigation concepts.
- To re-assess the geotechnical risk for each trail segment following the implementation of the proposed mitigation solutions.
- Where realignment/micro-routing of the trail is identified as a suitable option for mitigation, the identification of a suitable realignment option.
- Where “soft engineering” mitigation solutions are recommended, conceptual mitigation advice and design has been developed and presented.
- Where “hard engineering” mitigation solutions are recommended, a detailed design will be provided as an additional scope.

The method of assessing the risk associated with each hazard is set out in the WSP Geotechnical Risk Assessment Report (2022), it follows the general framework for landslide risk management as set out in AGS 2007[1]. We have used the same general framework in order to assess the reduced risk following the implementation of the proposed mitigation solutions.

[1] Australian Geomechanics Society, Guidelines for Landslide Risk Management, Australian Geomechanics, Vol 42, No. 1, March 2007.

4 Fieldwork

Fieldwork was undertaken between 26 and 28 February 2024 by a WSP senior engineering geologist accompanied by a World Trail representative. Field observations for each geotechnical hazard location are presented below.

4.1 Fairhaven to Lorne

4.1.1 Big Hill Cut

The Big Hill cut is a continuous cut that extends for approximately 620 m between CH17820 and CH18440 (Figure 4.1). The cut is typically 1 m to 2.5 m in height with slope angles ranging between 50° and 80°, with local areas of vertical or over-hanging slope. The cut exposes a mixture of soil and weathered rock. Orthogonal defects are persistent in the rock mass and appear to have contributed to the full and partial detachment of blocks of rock from the cut face. Some blocks have not travelled all the way to the toe of the cut, and some have come to rest on the cut. Evidence of rockfall was observed approximately half-way across the walking trail, up to 1.5 m from the base of the cut. The trail at this location is 2 m to 3 m wide, the outer 0.5 m is not suitable to be used as a walking track as it is comprised of placed fill.

Between CH18300 and CH18350, the cut height increases to 4 m over an approximately 50 m length (Figure 4.2). The bottom 3 m of the cut is comprised of cobbles and boulders of up to 1.5 m in diameter within a soil matrix with a slope angle of 60º to 70º. The top 1 m is comprised of soil with a slope angle of 80º to 90º. Detached rock (rockfall) was observed on the track of up to 200 mm in diameter, and located up to 1.5 m from the base of the cut (Figure 4.3).

Figure 4.1 Left: 1.25 m high cut, slope angle 80°. Right: 2 m high cut, slope angle 60°, rockfall observed at base of cut.

Figure 4.2 Four metre high cut, slope angle 60° to 80°.

Figure 4.3 Left: 4 m high cut with boulders up to 1.5 m diameter in the slope face. Right: rockfall observed at base of cut up to 200 mm in diameter.

4.2 North Lorne to South Lorne

4.2.1 Lorne Foreshore and Shipwreck Trail Fill Batter

The fill batter hazard along the Lorne foreshore and Shipwreck Trail is associated with the Great Ocean Road fill batter which has been constructed directly above the beach and trail. Between CH25600 and CH26400, the proposed walking trail alignment is along a section of North Lorne beach where a medium to high hazard associated with collapse of the upslope road fill batter (Figure 4.4) has been identified. The fill batter along this section is typically 4 m to 5 m in height with a slope angle of between 45º and 70°. The batter face is well vegetated with very few areas of exposed soil. Based on the field observations, it is expected that the fill batter hazard would only affect the 10 m to the rear of the beach. People walking along the lower reaches of the beach are not exposed to the hazard.

The site visit was undertaken during low to mid-tide, it was observed that all beach walkers were walking along the nearshore to avoid the soft sand closer to the fill batter. Following the site visit, a review of aerial imagery was used to determine the tidal range at North Lorne beach. As presented in Figure 4.5, at high tide the width of passable beach is 0 m to 10 metres at the base of the fill batter.

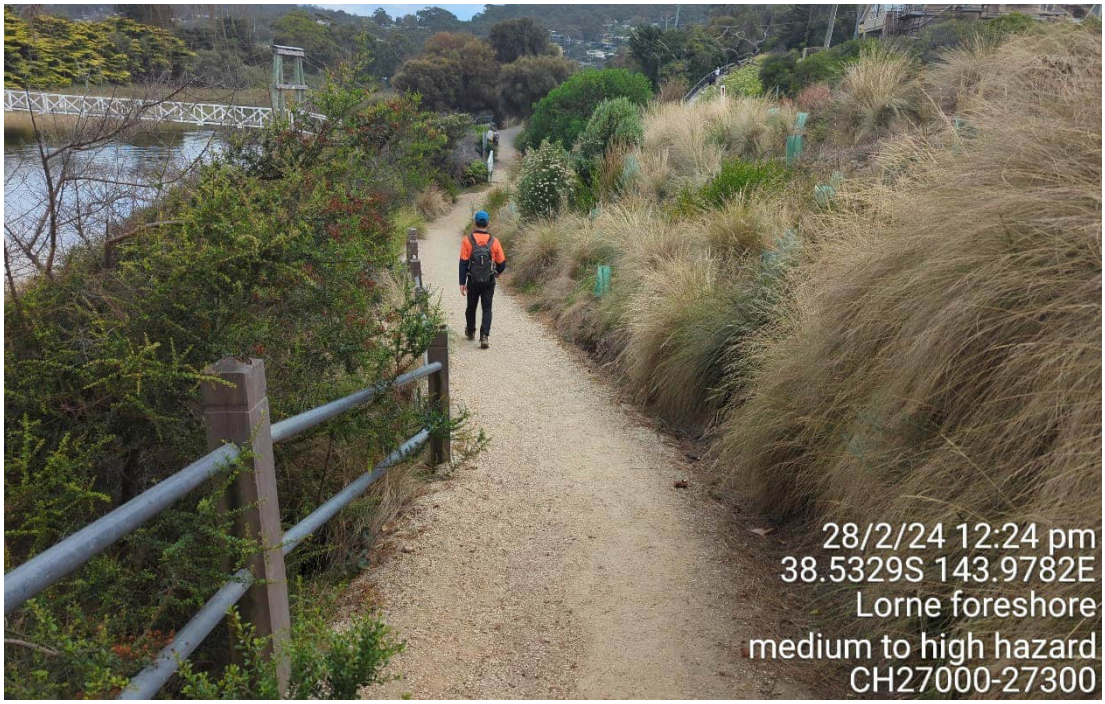
Figure 4.4 Fill batter along North Lorne beach.

Figure 4.5 High tide mark as observed in aerial imagery, indicating high tides comes within 0 m to 10 m of the fill batter toe. Image sourced from Near Maps.

From CH26400 onwards, the proposed alignment joins exiting trails (The Bert Alsop Track and Shipwreck Trail), along which the fill batter is assessed to present a medium to high hazard. The fill batter along these sections of trail is 1.5 m to 4 m in height with an average slope angle of 45º and localised over-steepened slopes of up to 80°. The trail width along these sections is relatively narrow, typically 1 m to 1.5 m wide. The fill batter is vegetated, however, there are localised areas of exposed soil. The batter is comprised of soil with cobbles and boulders, some of which are loosely placed on the batter face.

Figure 4.6 Four metre high fill batter along Bert Alsop Track, with cobbles and boulders on bater face.

Figure 4.7 Four metre high fill batter along Bert Alsop Track, with a one-metre-high vertical cut into the fill batter toe to accommodate walking trail.



4.3 Lorne to Cumberland River

4.3.1 Old Tramway Cut

The old tramway cut can be separated into two distinct segments, the lower old tramway cut between CH31000 and CH31380, and the upper old tramway cut between CH30330 and CH30750.

The lower old tramway cut ranges in height between 2 m and 5 m. The cuts are typically comprised of near vertical rock (slope angles between 70° and 80°) with persistent defects resulting in fractured blocks of rock sitting loosely on the cut face or fallen to the ground (Figure 4.8, Figure 4.9). Fresh rockfall up to 200 mm in diameter was observed on the outer edge of the 1 m wide track. At some locations, there is a soil layer up to 1.5 m thick mantling the rock within the cut face. Evidence of previous slumping was observed in the soil (Figure 4.10).

The upper old tramway cut ranges between 1 m and 4 m in height with slope angles of between 60° and 80º (Figure 4.11). The majority of the cut is comprised of rock with localised regions of soil with boulders. A mixture of historic rockfall and fresher rockfall was observed on the trail. It is unknown whether the rockfall has fallen out of the cut face or the large near-vertical bluff above the cut (Figure 4.12).

Figure 4.8 Lower old tramway cut. Left 4 m high, 80º slope angle with overhang. Right: 4 m high, 70º slope angle.

Figure 4.9 Lower old tramway cut. Left: Loose blocks sitting on slope. Right: Fresh rockfall on walking trail.

Figure 4.10 Lower old tramway cut. Soil cut with evidence of previous slumping.

Figure 4.11 Upper old tramway cut. Left: 2 m high soil and boulder cut, 55º slope angle. Right: 4 m high rock cut, 70º slope angle.

Figure 4.12 Upper old tramway cut: Left: Sandstone bluff above cut possibly contributing to rockfall on walking track. Right: Historic and newer rockfall on walking track.

4.4 Cumberland River to Wye River

4.4.1 Cumberland Campground Rockfall

The high rockfall hazard at Cumberland Campground is associated with a near vertical 6 m high cliff, the result of the Cumberland River cutting down over geological time (Figure 4.13). The cliff is comprised of bedded sandstone with orthogonal jointing. Significant overhangs were observed on the cliff face, caused by blocks of sandstone falling out of the cliff face and river erosion at the base of the cliff. Detached rock blocks of up to 750 mm in diameter were observed on the grassy riverbank up to 5 m away from the base of the cliff, distinguishable from the river cobbles due to their angular shape (Figure 4.14). It is likely the blocks originally fell onto the walking trail but have been relocated as part of trail maintenance activities.

The walking trail at this location is 1.5 m to 2.5 wide, positioned directly at the base of the cliff. On the outer edge of the trail is a 3.5 m to 6.5 m wide shoulder between the walking trail and the river.

Figure 4.13 Five-metre-high cliff with orthogonal jointing and significant overhangs.

Figure 4.14 Left: Orthogonal jointing and undercutting resulting in rockfall hazard. Right: Angular piece of rockfall, inferred to have been moved off the walking trail during maintenance.

4.4.2 Cumberland River Rockfall

The rockfall hazard between CH42520 and CH42620 is associated with a 5 m to 10 m high near vertical cliff directly above the walking trail. A relatively fresh rockfall block up to 900 mm in diameter was observed on the outer edge of the

walking trail (Figure 4.15). The rockfall scarp was approximately 5 m high and visible in the cliff face above the trail. The exposed rock was observed to be fresh indicating thew rockfall was likely a relatively recent event. The walking trail at this location is less than 1 m wide and is bound by the river, consequently, shifting the trail away from the cliff is not possible without crossing the river.

Figure 4.15 Left: Rockfall scarp exposed in cliff face about 5 m above the ground. Right: Detached block between the river and walking trail.

4.4.3 *Cumberland Hill Rockfall*

The rockfall between CH43350 and CH43500 is associated with a 5 m high bluff of sandstone that outcrops along a ridgeline. The outcrop is near vertical and has significant over-hangs. Orthogonal jointing and spheroidal weathering have made this outcrop susceptible to rockfall. Historical and more recent rockfall was observed up to 50 m downhill from the bluff, many of the detached rocks are now sitting loosely on the 35º slope.

Figure 4.16 Left: Sandstone outcrop at ridgeline. Right: Rockfall on slope observed up to 50 m downslope of the sandstone outcrop.

4.4.4 *Jaimeson Creek Campground Cut*

The Jaimeson Creek Campground cut is a 1 m to 2.5 m high cut that leads up to and beyond the campground from the Great Ocean Road. The cut is comprised of soil with cobbles and ranges in slope angle between 45º and 80º (Figure 4.17). Evidence for minor slumping and erosion was observed in the cut face. Locally, large trees within the cut face appear to be contributing to instability via loading and root jacking. The walking trail at this location also serves as an access road to the campground and is about 3 m wide.

Figure 4.17 Left: 1.5 m high soil cut, 80º slope angle. Right: 2.5m high soil cut, 70º slope angle, minor instability and slumping observed.

4.4.5 *Godfrey Track Cut*

The cut between CH52350 and CH52420 along Godfrey Track is up to 2 m in height with an average slope angle of 55°. The cut is comprised of soil with some cobbles and boulders. Localised instability and slumping were observed although there was no evidence this had impacted the trail. In some locations, trees near the cut face are likely causing further instability due to root jacking.

Figure 4.18 Left: Cut face showing minor instability in the soil. Right: 2 m high soil cut, 55° slope angle.

4.4.6 East of Separation Creek Various Cuts

Between CH53990 and CH56280, east of Separation Creek, there are multiple cuts along the walking trail identified as low to moderate cut-soil hazards and cut-rock hazards. This section of the trail was assessed to understand the characteristics of the cuts. The cuts along this segment of trail were observed to be between 0.5 m and 3 m high, with slope angles varying between 40° and 85° (Figure 4.20, Figure 4.21). The cuts are typically comprised of soil with minimal rock observed in the cut faces. The cuts that presented the more significant hazards appeared to be more recently constructed and are typically over 1.5 m in height, with slope angles greater than 70º (Figure 4.22). Evidence for erosion of the cut face was observed on some of these steeper cuts. The walking trail was 1 m to 1.5 m in width along this segment of track.

Figure 4.19 Various cuts east of Separation Creek. Left: 2 m high cut, 40º slope angle. Right: 1.5 m high cut, 70º slope angle.

Figure 4.20 Various cuts east of Separation Creek. Left: 1 m high cut, 80º slope angle. Right: 1.8 m high cut, 50º slope angle.

Figure 4.21 Overstepped cut east of Separation Creek, 1.5 m high cut, 85º slope angle, erosion of cut face observed.

4.4.7 Paddy's Path Cut

Between CH56770 and CH57000 the cut is comprised of soil with some boulders and is about 1 in high with slope angles of 40° to 60° (Figure 4.22). Between CH57000 and CH57200, the cut is comprised of highly fractured rock with soil and is up to 2 m high with slope angles of between 50° and 80°. Above the cut is a relatively steep (60°), well vegetated natural slope. The highly fractured rock is dipping unfavourably out of the cut face which makes it susceptible to rockfall. The walking track along this section is about 1 m wide and is bound on its outer edge by the rock netting for the Great Ocean Road cut below, constraining options to relocate the trail away from the base of the cut.

Figure 4.22 Left: 1 m high soil cut between CH56770-CH57000. Right: Up to 2-m high fractured rock cut between CH57000-CH57200.

5 Proposed Mitigation and Risk Assessment

Based on observations made in the field, practical mitigation measures for each hazard are subsequently described. Soft engineering mitigation measures, such as minor earthworks and minor re-routing have been favoured over hard engineering mitigation measures, such as retaining structures. The mitigated societal risk (the reduced risk following the implementation of the recommended mitigation measures) for each trail segment have been calculated using the methods set out in NSW NPWS (2020). F-N plots showing mitigated risks have been developed to evaluate the risk against the criteria set out in ANCOLD (2003).

5.1 Fairhaven to Lorne

5.1.1 Big Hill Cut

To reduce the risk to loss of life associated with the cut hazard at Big Hill, the following mitigation concepts are recommended and conceptualised in Figure 5.1. The mitigation measures should be constructed under geotechnical supervision:

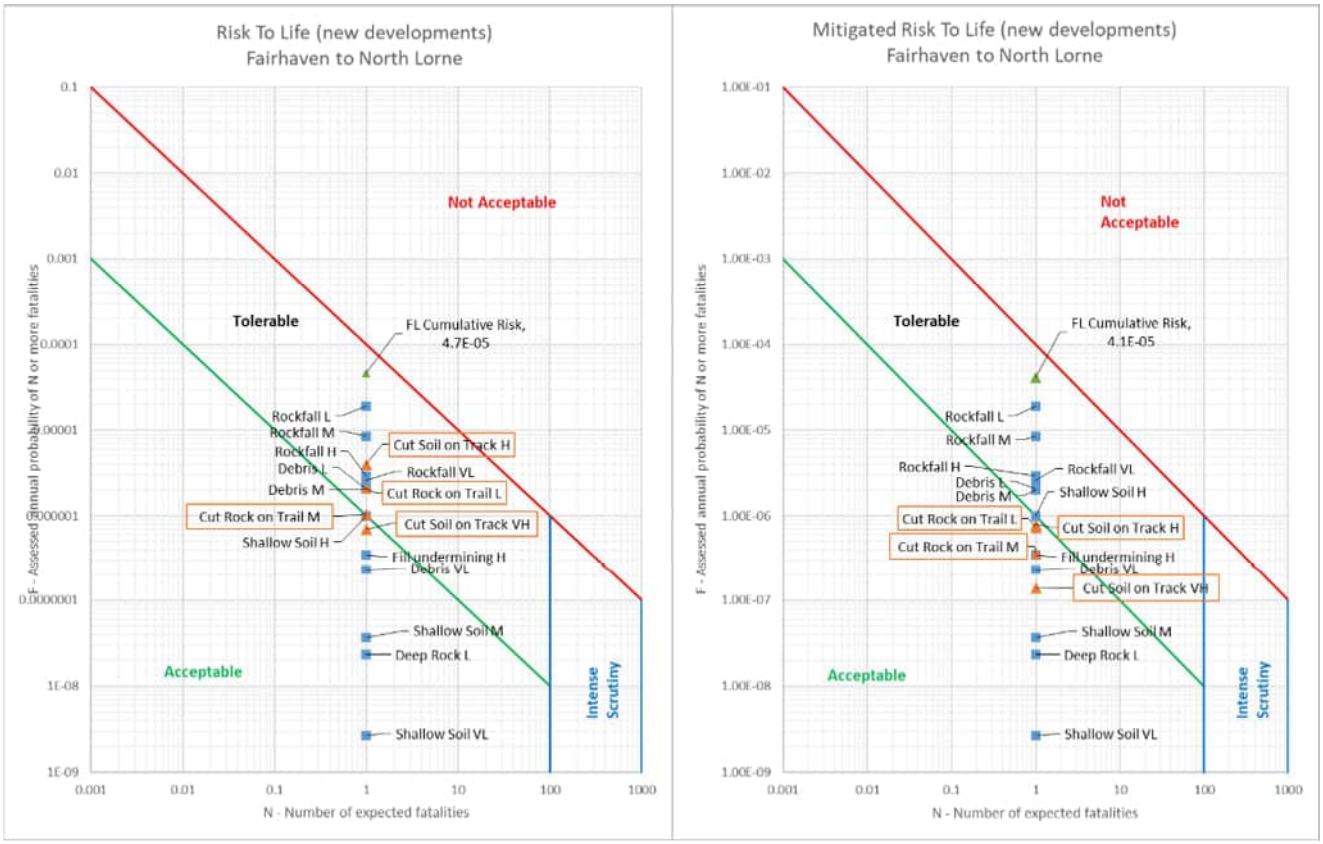
- Scaling of loose rock blocks from the cut face.
- Local trimming of the cut face where slope angles are vertical or overhanging.
- Select vegetation removal where root jacking is contributing to cut instability.
- Construction of a 0.3 m wide, 0.3 m deep rock catch ditch at the base of the cut.

Figure 5.1 Big Hill cut mitigation example. Left: Scaling of loose blocks on slope, trimming of local overhang, rock ditch along base of cut. Right: Selected vegetation removal where root jacking is occurring.

5.1.2 *Fairhaven to Lorne Mitigated Risk*

The mitigated risk to life associated with the cut hazards for the section of trail between Fairhaven and North Lorne has been estimated and is presented in Figure 5.2 The F-N plots show a clear reduction in the estimated risk to life following the implementation of mitigation measures. Left unmitigated, the societal risk associated with cut failures for this section of trail are primarily tolerable. However, with mitigation measures in place, all cut hazards become acceptable. The combined societal risk to life for all hazard along the trail segment also decreases when the mitigation measures are implemented.

Figure 5.2 F-N Plots for all hazards within the Fairhaven to North Lorne trail segment, cut hazards are displayed in orange. Left: Unmitigated cut hazards. Right: Mitigated cut hazards.



5.2 North Lorne to South Lorne

5.2.1 *Lorne Foreshore and Shipwreck Trail Fill Batter*

Based on site observations, the fill instability hazard along North Lorne beach is only applicable during high tides when walkers are forced to come within 10 m of the fill batter toe. During low-tide and mid-tide, it is assumed walkers will favour the hard sand and the nearshore and consequently walk at a point greater than 10 m from the toe of the fill batter. We understand that World Trail have developed a high-tide alternative route that avoids the beach, this route was included in the original Master Plan. Based on this information, the fill hazard between CH25600 and CH26400 (where the walking trail is along the beach) can be eliminated based on the following assumptions:

1 During low-tide and mid-tide walkers will stay greater than 10 m away from the toe of the fill batter as they favour walking on the hard sand at the nearshore.

2 During high-tide when there is less than 10 m between space at the toe of the fill batter and the water edge, walkers will take the alternative high-tide route which avoids the fill batter.

Where the trail joins the Bert Alsop Track (CH26400 - CH27300), fill batter remediation is not practical due to the proximity of the Great Ocean Road. An alternative mitigation measure is to keep walkers on the beach until the fill batter is no longer a hazard at CH27400, where they can rejoin the trail. This option would eliminate the fill batter hazard during low-tide and mid-tide under the same assumption that walkers favour the hard sand on the lower reaches of the beach. During high-tide, walkers will need to use the Bert Alsop Track and cannot avoid the fill batter hazard. However, the estimated risk to life for this section of trail will be reduced as the hazard is only applicable during high tide, about 25% of the time. Consequently, the numbers of walker exposed to this hazard will be 25% of the expected annual number of walkers, 11,057 out of 44,229 walkers per year.

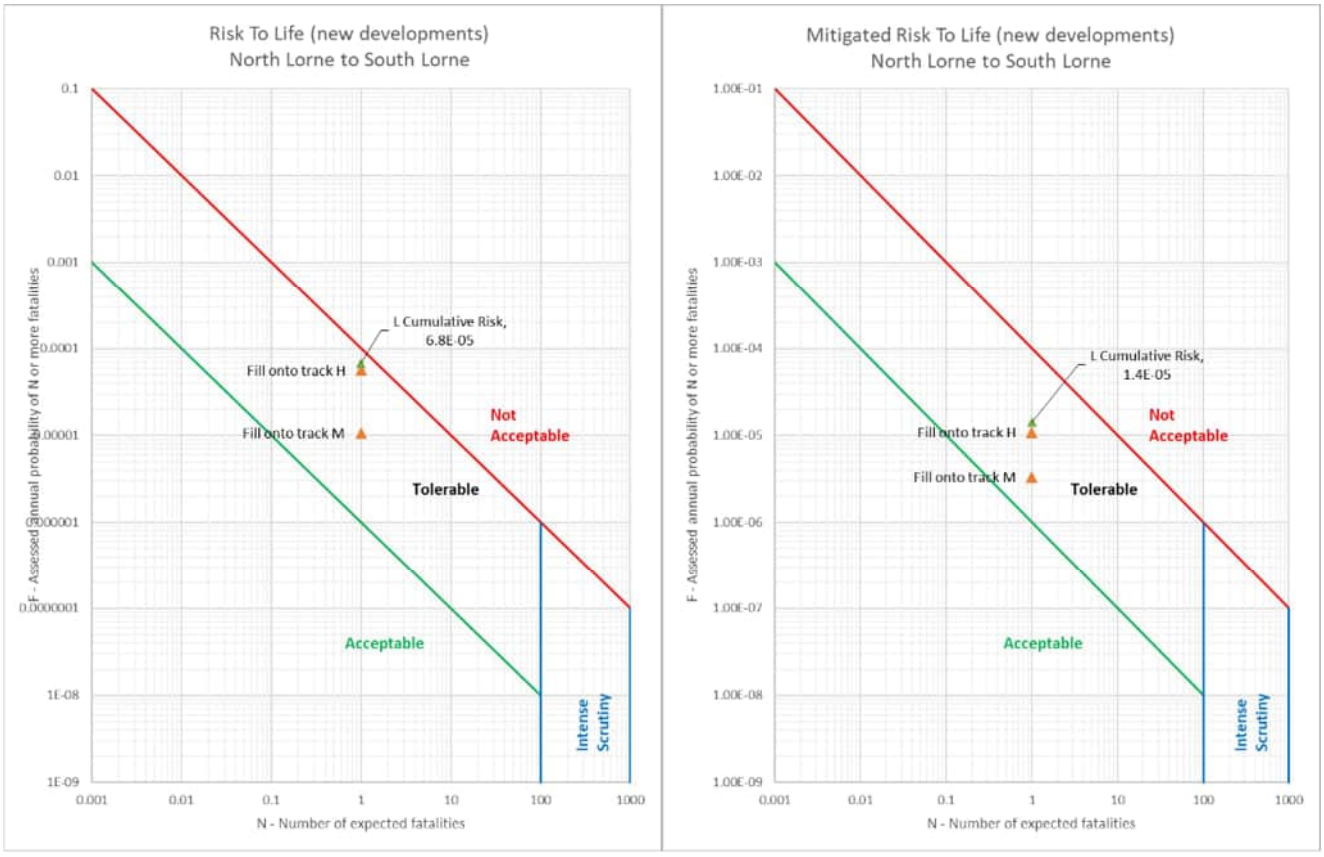
To encourage walkers to stay more than 10 m away from the fill batter toe, it is recommended that consideration be given to providing signage along the beach warning walkers of the fill batter hazard and not to walk at the base of the fill batter.

The section of Shipwreck Trail with the fill batter hazard (CH28920 - CH29150) will be mitigated as part of the Old Tramway Cut mitigation. As described in Section 5.3.1, an alternative route out of Lorne will reduce the annual number of walkers using this section of the Shipwreck Trail by 50%, from 44,229 to 22,114 walkers per year.

5.2.2 North Lorne to South Lorne Mitigated Risk

The mitigated risk to life associated with the fill batter hazards for the section of trail between North Lorne to South Lorne has been estimated and is presented in Figure 5.3. The mitigation measures lower the societal risk associated with the fill batter hazard as far as practically possible. However, the hazards still fall within the tolerable category.

Figure 5.3 F-N Plots for all hazards within the North Lorne to South Lorne trail segment. Left: Unmitigated fill batter hazards. Right: Mitigated fill batter hazards.



5.3 Lorne to Cumberland River

5.3.1 Old Tramway Cut

Based on site observations along the lower old tramway track, the estimated hazard along the 40 m of trail (between CH31050-CH31090) was increased from a low hazard to a medium hazard. The increase in hazard level is the result of site observations undertaken during the recent site visit such as recent rockfall on the trail, loose fractured blocks exposed on the cut face, and overhangs.

The following mitigation concepts are recommended in order of assumed practicality:

1. Scaling of loose rock blocks from the cut face, local trimming of the cut face where slope angles are vertical or overhanging, selected vegetation removal where root jacking is assessed to be contributing to cut instability. Scaling works should be carried out under geotechnical supervision.
2. Reduce annual walker numbers by providing an alternative route that avoids the old tramway cut. World Trail has provided a conceptual alternative route presented in Figure 5.4. This route is aligned to the back (inland side) of Lorne taking walkers inland to rejoin the main trail at CH33600. This alignment avoids the old tramway cut completely. The risk from geotechnical hazards along this route were previously assessed and are referred to as Branch1 and Loop1 in the WSP Geotechnical Risk Assessment (2022). Based on advice from World Trail, it is estimated that approximately half of the walkers (22,114 out of 44,229) will take the alternative route.
3. Micro-rerouting to avoid a hazardous section of the cut (between CH31050-CH31090). A conceptual micro-routing option is presented in Figure 5.5.
4. Hard engineering options, such as rock netting. This would require submission of a detailed design package, separate to the scope of this report.

Figure 5.4 Alternative route (in green) to avoid the old tramway cut. Alternative route travels out the inland side of Lorne, rejoining the main trail (in yellow) at CH33600.

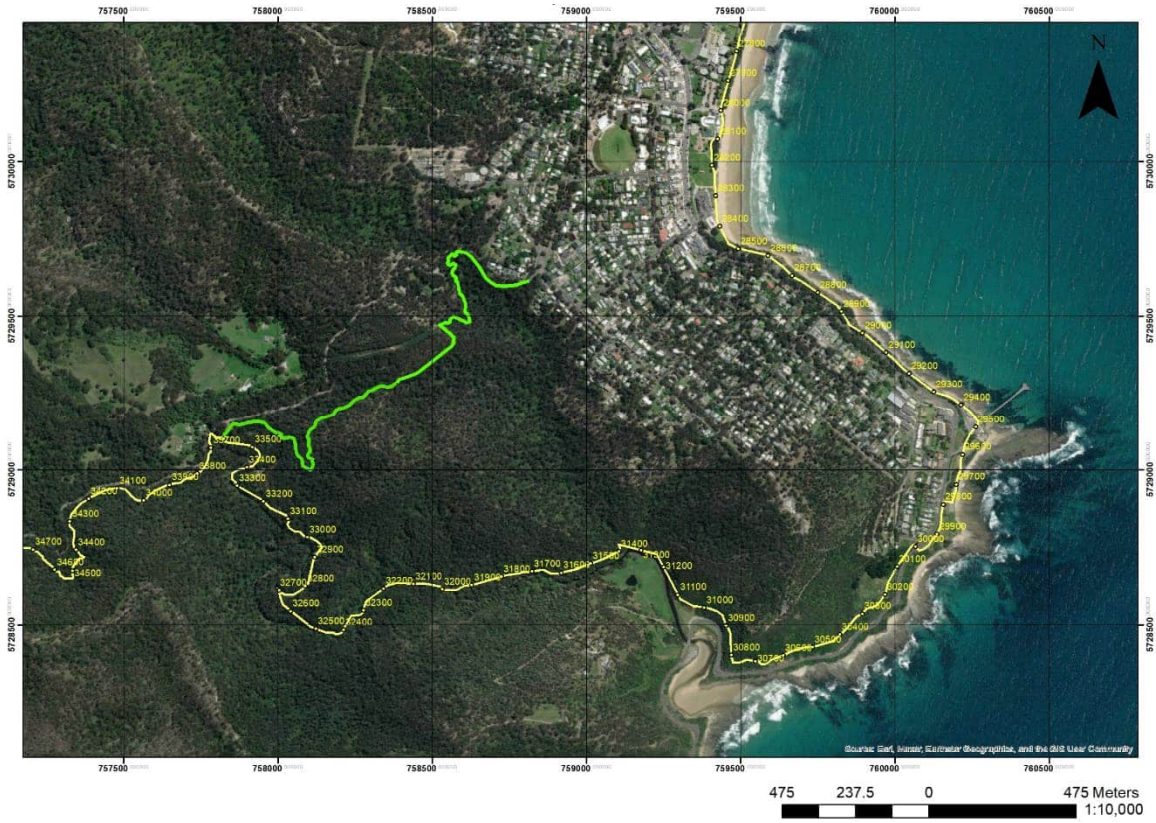
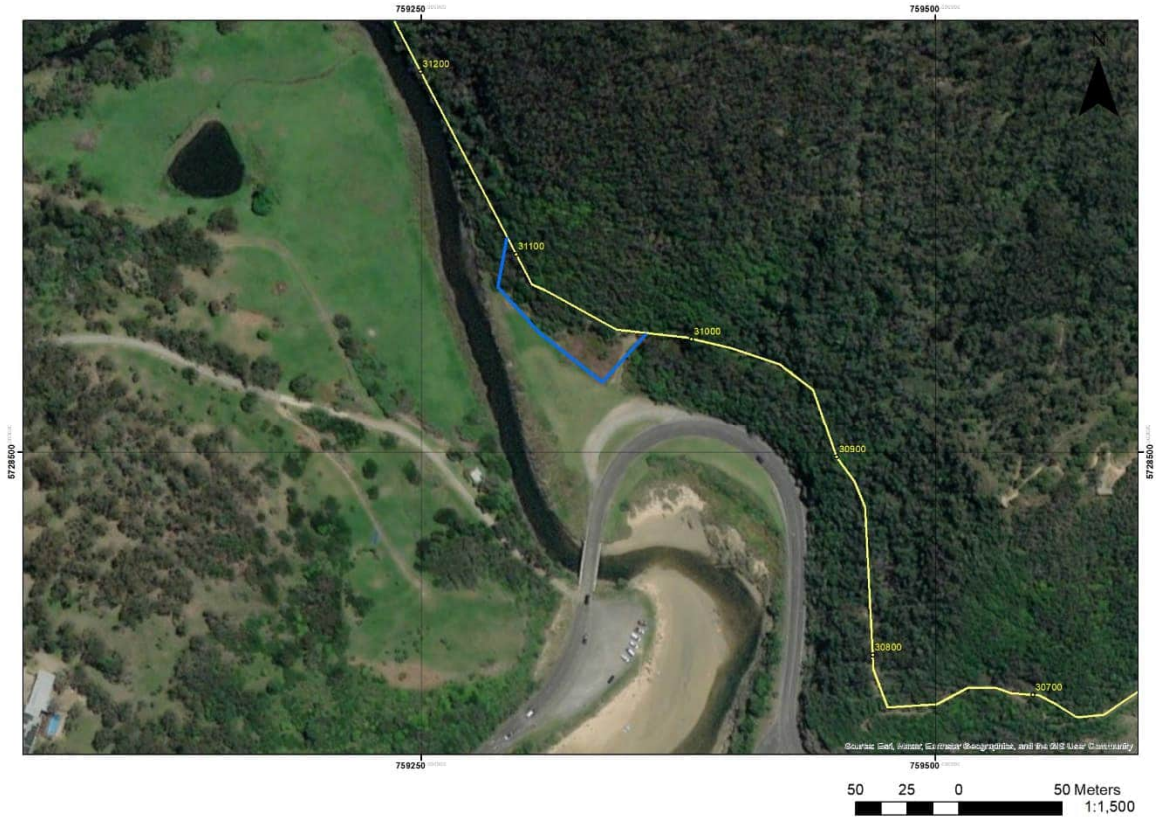


Figure 5.5 Micro-rerouting option (in blue) to avoid 100 m of old tramway cut hazard.



5.3.2 Lorne to Cumberland River Mitigated Risk

The F-N plots for the mitigated risk to life for the soft engineering mitigation options (options one, two and three) are presented in Figure 5.6. To reduce the cumulative risk to life as far as practically possible (the risk arising from all hazards to which a person is exposed), all three mitigation options can be used in combination.

However, the most effective singular mitigation option is option two, reducing the annual number of walkers by providing an alternative route. The risk reduction achieved by doing this is shown in the bottom left graph in Figure 5.6, where the cumulative risk to life decreases the most significantly out of the three soft engineering options. Mitigation option two reduces the risk associated with the old tramway cut. However, it also reduces the risk for all other hazards identified along the section of trail (including rockfall, shallow landslide, debris flow etc.). We note that the combined risk to life for the alternative route out of Lorne was assessed in the WSP Geotechnical Risk Assessment (2022) using estimated total number of expected walkers (44,229), which was determined to be acceptable. Consequently, this route has been reassessed using half the number of walkers (22,114).

Mitigation option two has been combined with mitigation option one as this is the easiest mitigation measure to achieve and, at the very least, should be implemented. Implementing mitigation options one and two combined reduces the risk to life off the boundary of tolerable-to-not-acceptable and into the tolerable range. If preferred, the risk may be further reduced by implementing mitigation measures three and four.

Option four considers a hard engineering alternative, such as rock netting, as a mitigation measure for the old tramway cut. The F-N plot for mitigation option four is presented in Figure 5.7. The implementation of rock netting is the most effective at reducing the risk associated with the old tramway cut, as well as significantly lowering the combined risk. However, we note that a lower combined risk was achieved by combining the soft mitigations options one and two, and certainly the combination of all three soft mitigation options.

Figure 5.6 F-N Plots for all hazards within the Lorne to Cumberland trail segment with the old tramway cut hazards displayed in orange. Top left: Unmitigated hazards. Top right: Mitigation Option 1. Bottom left: Mitigation Options 1 & 2. Bottom Right: Mitigation Options 1, 2 & 3.

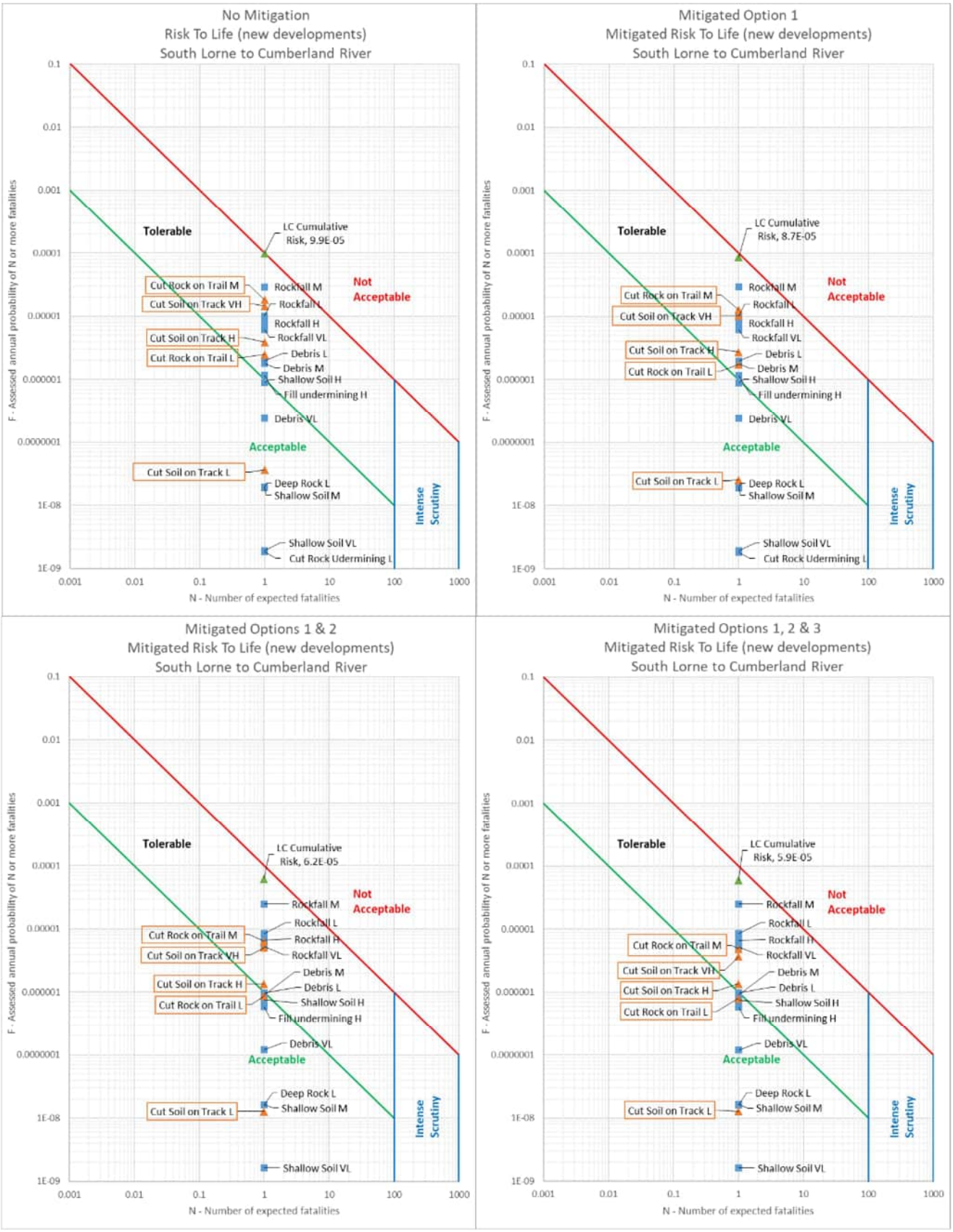
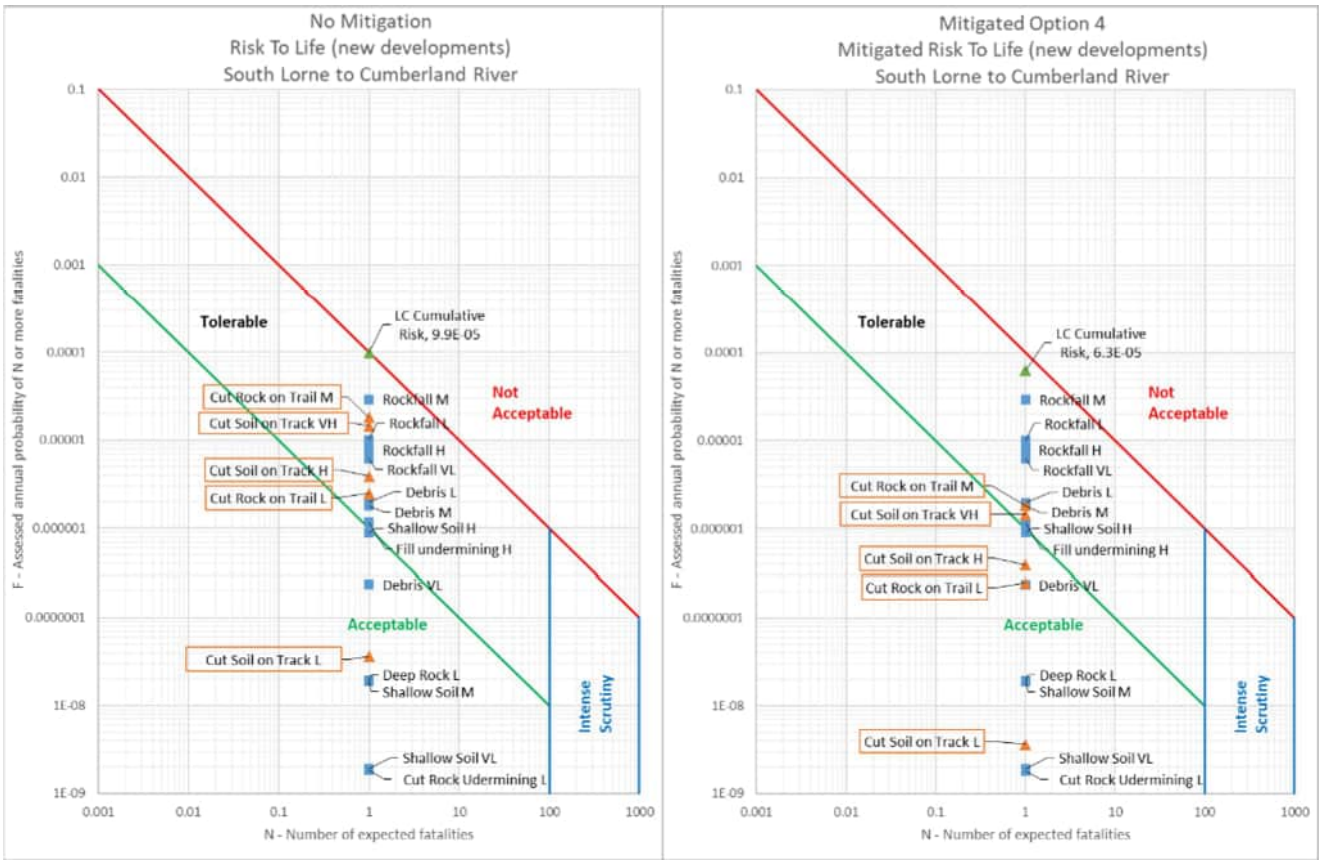


Figure 5.7 F-N Plots for all hazards within the Lorne to Cumberland trail segment with the old tramway cut hazards displayed in orange. Left: Unmitigated hazards. Right: Mitigation Option 4.



5.4 Cumberland River to Wye River

5.4.1 Cumberland Campground Rockfall

To reduce the risk of loss of life associated with the rockfall hazard at Cumberland Campground, micro-rerouting of the alignment to relocate the track away from the toe of the cliff face is recommended. Based on field observations, there is an approximately 3.5 m to 6.5 m width of riverbank between the outer edge of the existing walking trail and the Cumberland River. The trail should be relocated on to the riverbank as far as practically possible away from the toe of the cliff. A conceptual alignment is presented in Figure 5.8, Figure 5.9, and Figure 5.10. We expect a minimum distance of 3 m between the inner edge of the proposed trail and cliff toe should be achievable, with some sections of the trail having a width of up to 5 m where the riverbank location permits. The existing walking trail could be revegetated to discourage walkers from using it.

Figure 5.8 Proposed micro-rerouting in blue to avoid the rockfall hazard between CH41900 and CH42050 immediately south of Cumberland River Campground.

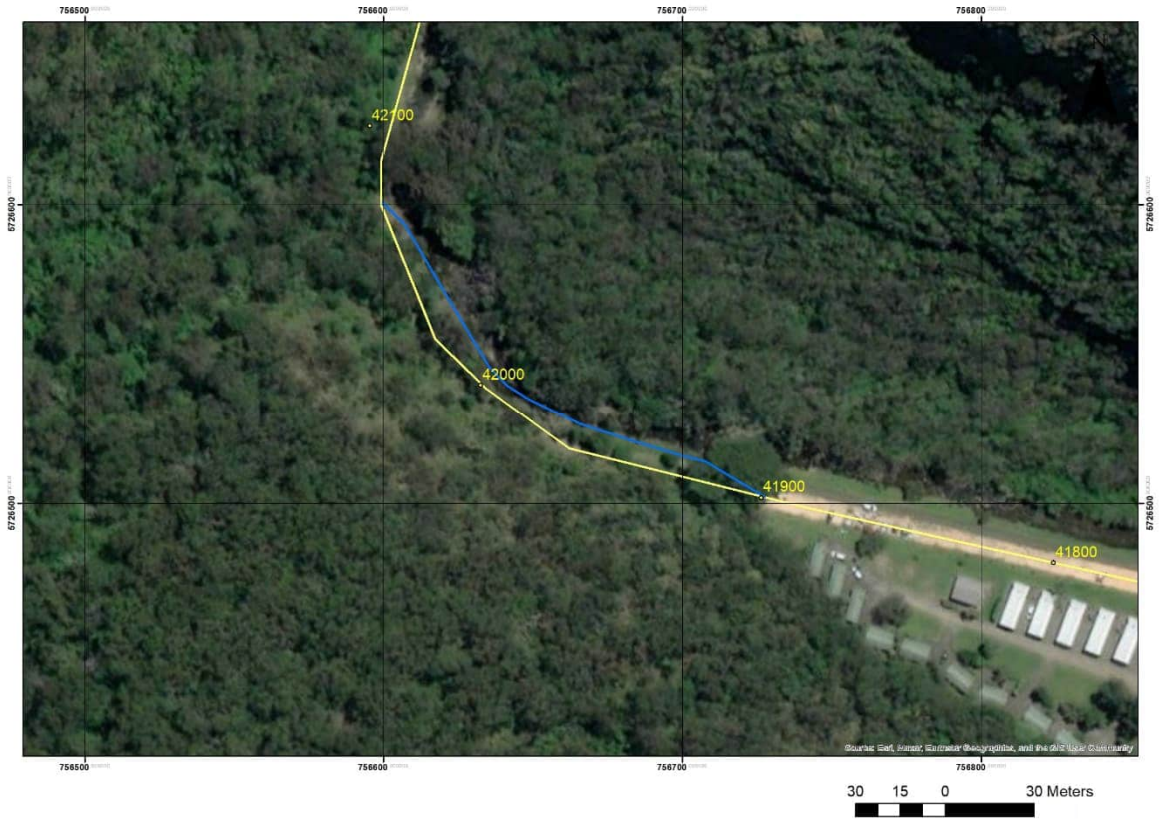


Figure 5.9 Proposed micro-rerouting in blue in relation to rockfall hazard mapping.

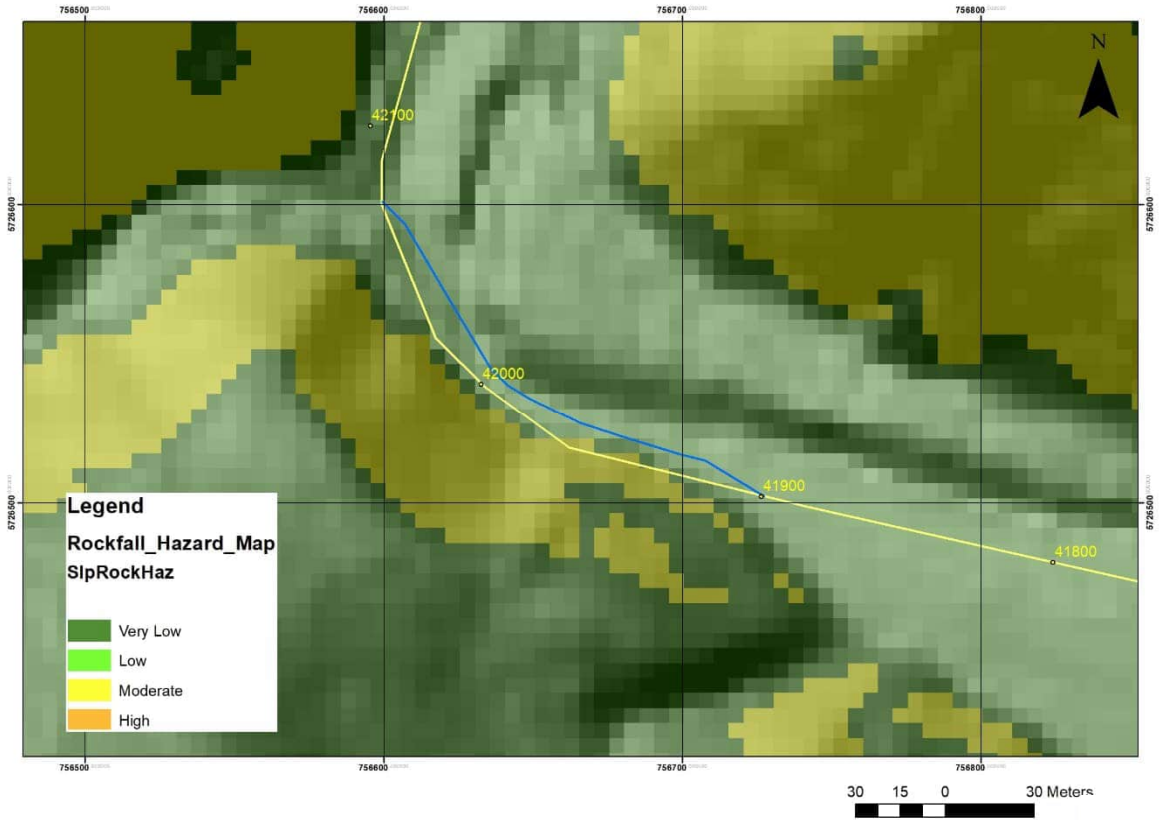


Figure 5.10 Conceptualised micro-rerouting to avoid rockfall hazard between CH41900 and CH42050 immediately south of Cumberland River Campground.

5.4.2 Cumberland River Rockfall

This section of trail is not suitable for soft engineering mitigation concepts. The trail cannot be re-routed to avoid the rockfall risk without adding an additional two river crossings to the alignment, nor is there sufficient space available to shift the trail away from the base of the cliff. Hard engineering mitigation measures, such as rock netting or canopies, could be implemented, however are unlikely to be economically feasible. It is recommended that signage is implemented alerting the walkers to the rockfall hazard and advising them to move quickly through this section of trail. Based on the rockfall mitigation measures recommended for the Cumberland River Campground and Cumberland Hill rockfall hazards, the cumulative rockfall risk for this broader section of trail has adequately reduced without the need to provide further mitigation measures to address the Cumberland River rockfall hazard, as presented in Figure 5.15.

5.4.3 Cumberland Hill Rockfall

Based on field observations, such as the large volume of historic and recent rockfall on the slope, an additional 200 m of moderate rockfall hazard was added to the section of trail. The following mitigation measures are recommended:

- Scaling of the loose rock from the slope below the sandstone outcrop. Note, we do not recommend scaling rock from the face of the sandstone outcrop due to the geotechnical risk this could pose to workers.
- Natural protection, such as existing fallen trees, to slow down or catch a proportion of the rockfall that travels down the slope. Natural protection should be placed upslope of the trail and perpendicular to the slope direction.

5.4.4 Jaimeson Creek Campground Cut

The cut-rock hazard has been removed for the cuts observed near the Jaimeson Creek Campground based on the composition of the cuts identified during the ground truthing exercise. Additionally, 25 m of high rockfall hazard has been reduced to low rockfall hazard as it was associated with the cut rather than rock detachment originating further

upslope. The following mitigation measures are recommended which would need to be constructed under geotechnical supervision:

- Scaling of loose rock blocks from the cut face.
- Local trimming of the cut face where slope angles are vertical or overhanging (Figure 5.11).
- Selected vegetation removal where root jacking is contributing to cut instability (Figure 5.11).
- Encourage walkers to use the outer edge of the trail along the campground access road e.g. mark out a pedestrian walkway on the outer edge (Figure 5.12).

Figure 5.11 Left: Trim over steepened soil. Right: removal of vegetation causing root jacking.

Figure 5.12 Delineation of pedestrian walkway on outer edge of access road.

5.4.5 *Godfrey Track Cut*

The following mitigation measures are recommended which will require construction under geotechnical supervision:

- Scaling of loose rock blocks from the cut face.
- Local trimming of the cut face where slope angles are vertical or overhanging (Figure 5.13).
- Selected vegetation removal where root jacking is contributing to cut instability (Figure 5.13).
- Construction of a rock ditch at the base of the cut where space permits.

Figure 5.13 Left: Trimming of over steepened soil. Right: removal of vegetation causing root jacking.

5.4.6 East of Separation Creek, Various Cuts

The hazard associated with rock detachment from the cut has been removed for eleven out of thirteen of the cuts assessed based on the composition of the cut identified during the ground truthing exercise. The hazard associated with the detachment of soil from the cuts was not modified for any of the cuts. Additionally, a 15 m length of track previously assessed as being subject to high rockfall hazard has been reassessed as low rockfall hazard based on site assessment and the recognition that the hazard is associated with a cut. The following mitigation measures are recommended for the cuts between CH53990 and CH56280 which should be constructed under geotechnical supervision:

- Scaling of loose rock blocks from the cut face.
- Local trimming of the cut face where slope angles are vertical or overhanging.
- Selected vegetation removal where root jacking is contributing to cut instability.
- Construction of a rock ditch at the base of the cut where space permits.

5.4.7 Paddy's Path Cut

Between CH56770 and CH57000 the hazard associated with the detachment of soil from cuts has been reduced from 'Very High' to 'High' and the hazard associated with the detachment of rock has been reduced from 'Medium' to 'Low' based on the average slope angle and cut composition identified during the ground truthing exercise. As a mitigation measure, local trimming of the soil cut is recommended where slope angles are near vertical or over-hanging, as well as scaling of loose cobbles and boulders from within the soil matrix.

Between CH57000 and CH57200, the rock-cut hazard has been increased from 'Low' to 'Medium' based on the average slope angle and unfavourable defect orientation identified during the ground truthing exercise. Rock scaling should not be undertaken at this location due to the unfavourable defect orientation and potential for scaling activities to trigger larger rock detachment. Alternatively, a one-metre-high rock fence could be installed at the base of the cut where rockfall hazards from the cut have been identified (Figure 5.14). Engineering design of the fence is not required due to the low energy with which it would be impacted. A typical fence, such as a post and panel or chain-mesh fence that can withstand

low energy rockfall load is likely to be suitable. The fence should be constructed under geotechnical supervision to ensure adequate coverage of the hazard is achieved.

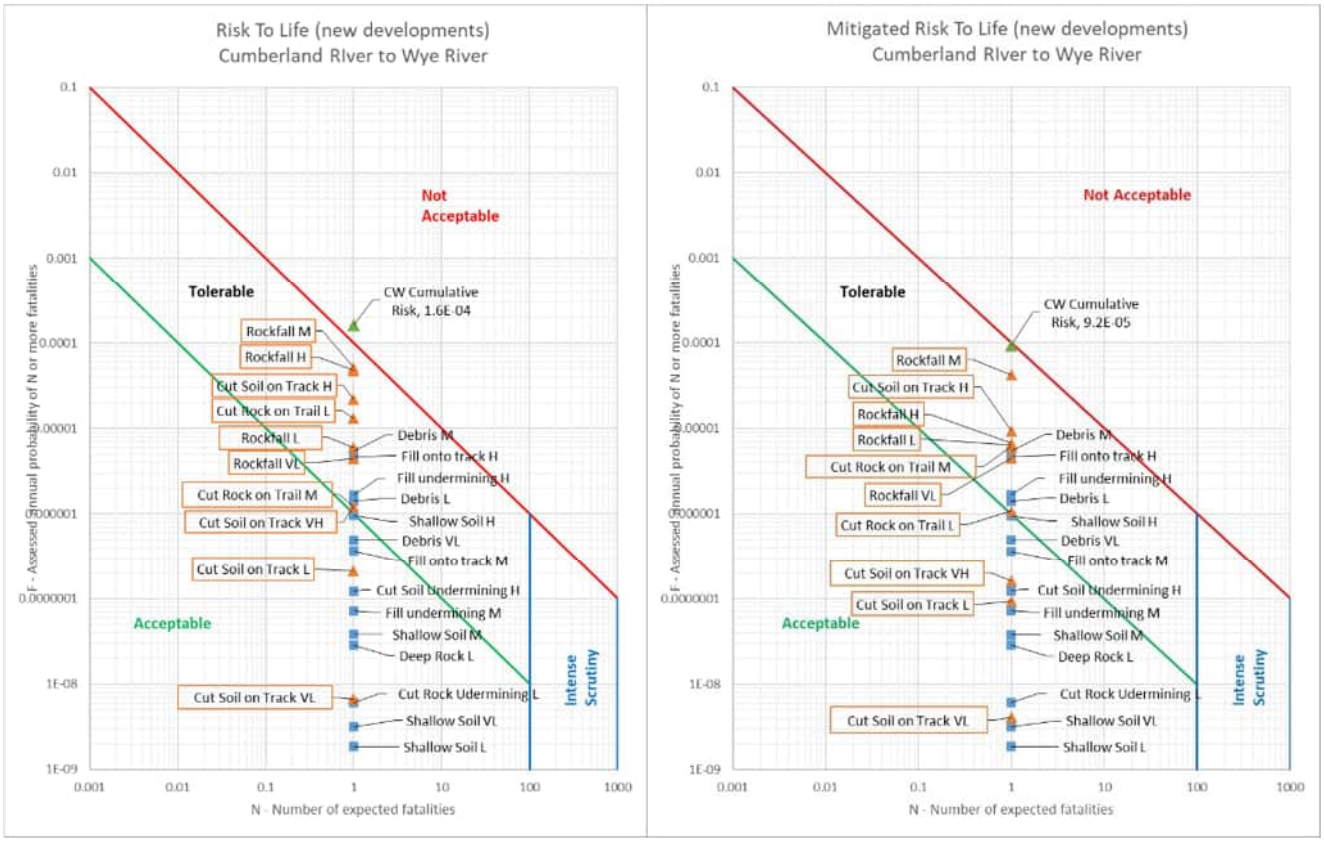
We note that hazard along a 200 m length of the track associated with rock and soil detachment from the cut has been removed from the risk assessment just beyond Paddy's Path, between CH57290-CH57490. World Trail has confirmed this alignment does not go through the area exposed to this hazard as was assumed in the initial assessment.

Figure 5.14 Conceptual 1 m high rock fence at the base of the rock cut.

5.4.8 *Cumberland River to Wye River Mitigated Risk*

Assuming all the mitigation measures recommended in Section 5.4 are implemented, the mitigated risk to life for the Cumberland River to Wye River section of the trail is presented in Figure 5.15. Most mitigated hazards show a significant decrease in risk arising from the implementation of risk mitigation, with the exception of the hazard associated with rock detachment from the cut which has increased due to the moderate rockfill hazard assessed during the ground truthing exercise at Cumberland Hill. Notably, the combined risk to life decreases from not acceptable to tolerable with the implementation of the mitigation measures.

Figure 5.15 F-N Plots for all hazards within the Cumberland River to Wye River trail segment, cut hazards and rockfall hazard are displayed in orange. Left: Unmitigated cut and rockfall hazards. Right: Mitigated cut and rockfall hazards.



6 Conclusions

A geotechnical risk assessment was completed for the proposed GORCT in 2022. An outcome of this assessment was that several hazardous lengths of the trail are potentially suitable for the provision of risk mitigation measures to reduce the overall geotechnical risk within their respective trail segments. The hazards identified for mitigation were assessed in the field to determine which mitigation measures were suitable to implement. Soft engineering mitigation measures were favoured over hard engineering mitigation measures due to economic feasibility. The following hazards along the GORCT were identified suitable for the practical provision of risk mitigation measures:

- Rockfall
- Soil detachment from cut batter onto track.
- Rock detachment from cut batter onto track.
- Fill embankment failure onto track.

Risk mitigation measures for these hazards at discrete locations along the trail have been identified. The mitigation measures should be constructed under geotechnical supervision and include:

- Micro-rerouting of the trail to avoid rockfall hazards.
- Providing an alternative route to reduce the number of walkers exposed to the hazard.
- Scaling, trimming and selected vegetation removal to stabilise cut batters and reduce the probability of detachment.
- Construction of minor structures to reduce the probability of detached material reaching the track e.g. rock ditches and non-engineered rock fences.

A summary of the mitigation measures recommended for each trail segment is presented in Table 6.2. The geotechnical assessment required for each mitigation measure is also described. Pre-construction geotechnical assessment is required at some locations to identify specific remedial measures, for example, which blocks need to be scaled or where slopes are over-steepened and should be trimmed. Post-construction geotechnical supervision is required to assess the residual risk following the works and to advise if any further mitigations are needed. The mitigation measures are also presented in the drawing set included in Appendix A-1.

The risk to life for each mitigated hazard, as well as the combined risk to life for all hazards along the trail segment, was estimated and presented on an F-N plot. The plots indicate a decrease in risk arising from the mitigated hazards, as well as the combined risk to life for all hazards within each trail segment. The most notable risk reduction being the Cumberland River to Wye River trail segment which was originally assessed as having an unacceptable combined risk to life which decreased to tolerable on the basis of the mitigation measures implemented.

The combined risk to life for the other mitigated trail segments (Fairhaven to Lorne, North Lorne to South Lorne, and Lorne to Cumberland River) was initially assessed as being tolerable. However, with mitigation measures in place the combined risk to life for these three segments reduced, plotting further away from the not acceptable-tolerable boundary on the F-N plots and into the tolerable zone. The societal risk reduction for the four mitigated trail segments is presented in Figure 6.1.

The acceptable, tolerable and unacceptable zones are based on the guidelines adopted by ANCOLD (2003) and NSW NPWS (2020) and are provided as a guide only. The level of risk acceptance must be confirmed by the regulator, however it is noted that the risk criteria adopted, based on cumulative probability of societal risk is analogous to the individual risk criteria based on the probability of loss of life to an individual adopted in the Colac Otway planning scheme.

Given the effectiveness of the mitigation measures presented, and the relatively low economic impact in comparison to hard engineering alternatives, the mitigation measures should be implemented in an effort to reduce the risk to life for the walking trail as far as reasonably practical. The mitigation measures recommended are summarised in Table 6.1.

Figure 6.1 F-N Plots for the combined societal risk for each trail segment, segments with proposed mitigation measures are displayed in orange. Left: Unmitigated hazards. Right: Mitigated hazards.

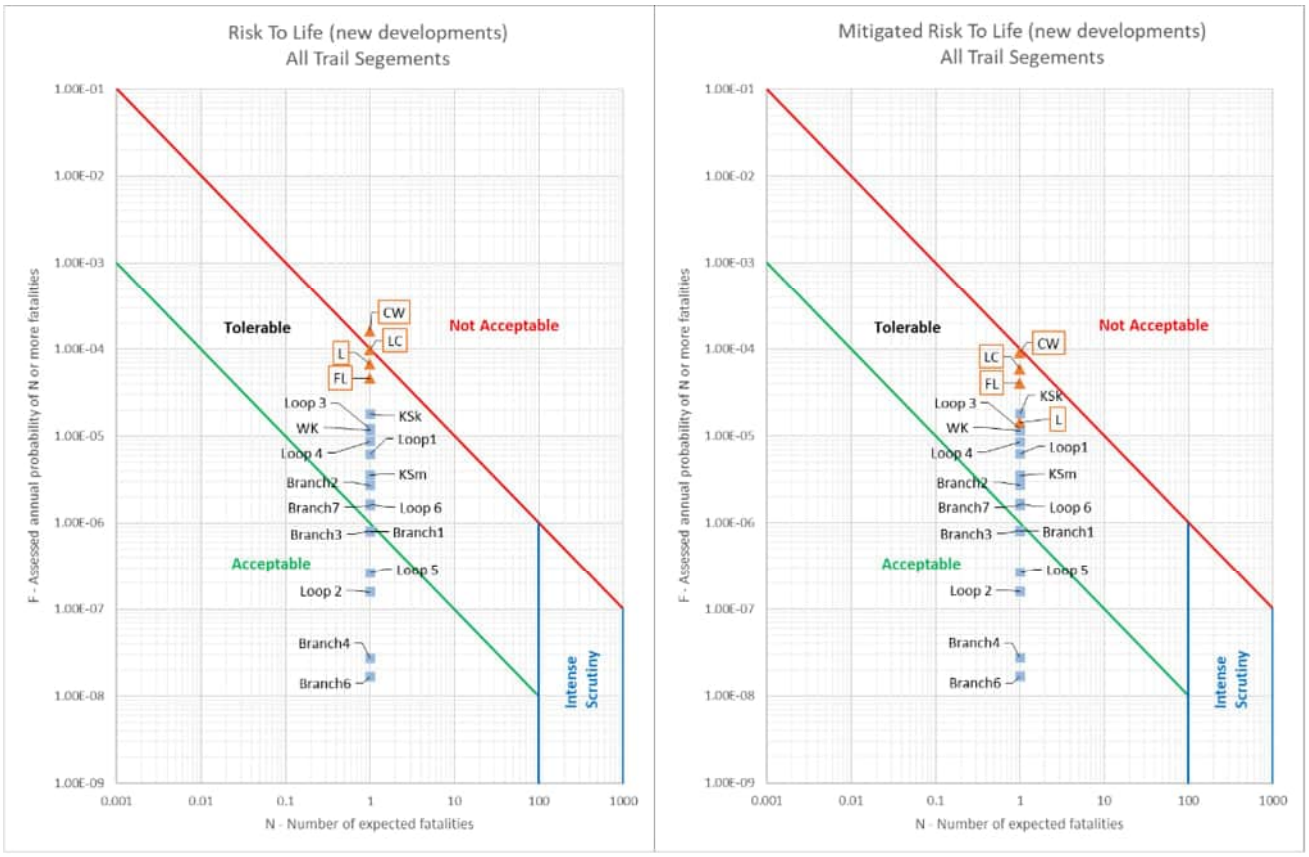


Table 6.1 Summary of mitigation measures recommended. Pre-construction geotechnical assessment is required to identify specific remediation measures, for example which blocks need to be scaled. Post-construction geotechnical supervision is required to assess the residual risk following the works and to advise if any further mitigations are needed.

Table 6.2 Summary of mitigation measures recommended for each trail segment. The required geotechnical assessment pre- and post-construction is described.

Trail No.[#]	Sector[#]	Location Coordinates (Start/End)[#]	Trail Segment	Chainage	Location	Hazard	Length	Drawing Sheet	Mitigation Measures	Geotechnical Input/Assessment	
										Pre-construction	Post-construction
Trail 34	2. Spout Creek to Lily Pond Reserve	-38.492615, 144.009969 -38.496739, 144.008672	Fairhaven to North Lorne (FL)	CH17820 - CH18440	Big Hill	Cut Batter	620 m	1	Rock scaling, local trimming where slope angles are vertical or overhanging, selected vegetation removal, construction of a rock catch ditch.	Yes. Geotechnical engineer to identify select rocks to be scaled, select areas of slope to be trimmed and select vegetation to be removed.	Yes. Inspection of completed works to ensure risk has been reduced.
Trail 45 & 46a	3. Lily Pond Reserve to Cumberland River	-38.520939, 143.988454 -38.533361, 143.977768	North Lorne to South Lorne (L)	CH25620 - CH27320	Lorne Foreshore	Fill Batter	1700 m	2	Hazard removed if high-tide route is utilised. Provide signage to warn walkers of the hazard during low tide.	No	No
Trail 46c	3. Lily Pond Reserve to Cumberland River	-38.544929, 143.981346 -38.546247, 143.983374	North Lorne to South Lorne (L)	CH28920 - CH29150	Shipwreck Trail	Fill Batter	230 m	3	Development of alternative inland route out of Lorne reduces the number of walkers exposed to hazard.	No	No
Trail 47	3. Lily Pond Reserve to Cumberland River	-38.553765, 143.982204 -38.551961, 143.973836	South Lorne to Cumberland River (LC)	CH30330 - CH31310	Old Tramway	Cut Batter	980 m	4	1) Scaling of loose rock from cut face. 2) Development of alternative inland route out of Lorne reduces the number of walkers exposed to hazard. 3) Micro-rerouting to avoid a section of the geotechnical hazard. 4) Rock netting. Options 1 and 2 combined reduce risk to a tolerable range. If preferred, the risk may be further reduced by implementing options 3 and 4.	1) Yes. Geotechnical engineer to identify select rocks to be scaled. 2) No. 3) Yes. Geotechnical engineer to ensure hazard is avoided. 4) N/A detailed design required.	1) Yes. Inspection of completed works to ensure risk has been reduced. 2) No. 3) Yes. Inspection of completed works to ensure risk has been reduced. 4) N/A detailed design required.
Trail 55	4. Cumberland River to Jamieson Creek	-38.572787, 143.946772 -38.572133, 143.945399	Cumberland River to Wye River (CW)	CH41900 - CH42050	Cumberland Campground	Rockfall	150 m	5	Micro-rerouting of trail to avoid geotechnical hazard.	Yes. Geotechnical engineer to ensure adequate setback distance from hazard.	Yes. Inspection of completed works to ensure risk has been reduced.
Trail 55	4. Cumberland River to Jamieson Creek	-38.568752, 143.945377 -38.568299, 143.944616	Cumberland River to Wye River (CW)	CH42520 - CH42620	Cumberland River	Rockfall	100 m	5	Provide signage to warn walkers of the hazard. Signage alone does not reduce risk of hazard, but the overall trail segment risk is decreased from mitigation measures at other hazards.	No	No
Trail 56	4. Cumberland River to Jamieson Creek	-38.566829, 143.942263 -38.567345, 143.9417	Cumberland River to Wye River (CW)	CH43350 - CH43450	Cumberland Hill	Rockfall	100 m	5	Scaling of loose rock from the slope above the track. Placing natural protection, such as existing fallen trees, to catch rock.	Yes. Geotechnical engineer to identify areas where loose rocks should be removed and advice where to locate natural protection.	Yes. Inspection of completed works to ensure risk has been reduced.
Trail 66	4. Cumberland River to Jamieson Creek	-38.597584, 143.918781 -38.601273, 143.918652	Cumberland River to Wye River (CW)	CH50920 - CH51370	Jaimeson Creek Campground	Cut Batter	450 m	6	Delineation of pedestrian pathway on far side of road to avoid walking under cut. Rock scaling, local trimming where slope angles are vertical or overhanging, selected vegetation removal.	Yes. Geotechnical engineer to identify select rocks to be scaled, select areas of slope to be trimmed, select vegetation to be removed.	Yes. Inspection of completed works to ensure risk has been reduced.
Trail 67a	5. Jamieson Creek to Wye River	-38.606929, 143.916371 -38.607318, 143.916961	Cumberland River to Wye River (CW)	CH52350 - CH52420	Godfrey Track	Cut Batter	70 m	7	Rock scaling, local trimming where slope angles are vertical or overhanging, selected vegetation removal, construction of a rock catch ditch.	Yes. Geotechnical engineer to identify select rocks to be scaled, select areas of slope to be trimmed, select vegetation to be removed.	Yes. Inspection of completed works to ensure risk has been reduced.
Trail 67a	5. Jamieson Creek to Wye River	-38.616217, 143.913348 -38.628933, 143.900645	Cumberland River to Wye River (CW)	CH53990 - CH56280	East of Separation Creek	Cut Batter	2290 m	8	Rock scaling, local trimming where slope angles are vertical or overhanging, selected vegetation removal, construction of a rock catch ditch.	Yes. Geotechnical engineer to identify select rocks to be scaled, select areas of slope to be trimmed, select vegetation to be removed.	Yes. Inspection of completed works to ensure risk has been reduced.
Trail 67c	5. Jamieson Creek to Wye River	-38.631095, 143.89748 -38.633761, 143.891107	Cumberland River to Wye River (CW)	CH56770 - CH57200	Paddy's Path	Cut Batter	430 m	9	Rock scaling and local trimming where slope angles are vertical or overhanging. Construction of a one-metre-high rock fence at the base of the cut.	Yes. Geotechnical engineer to identify select rocks to be scaled and to ensure adequate coverage of hazard is achieved by fence.	Yes. Inspection of completed works to ensure risk has been reduced.

[#] Information provided by World Trail

7 Limitations

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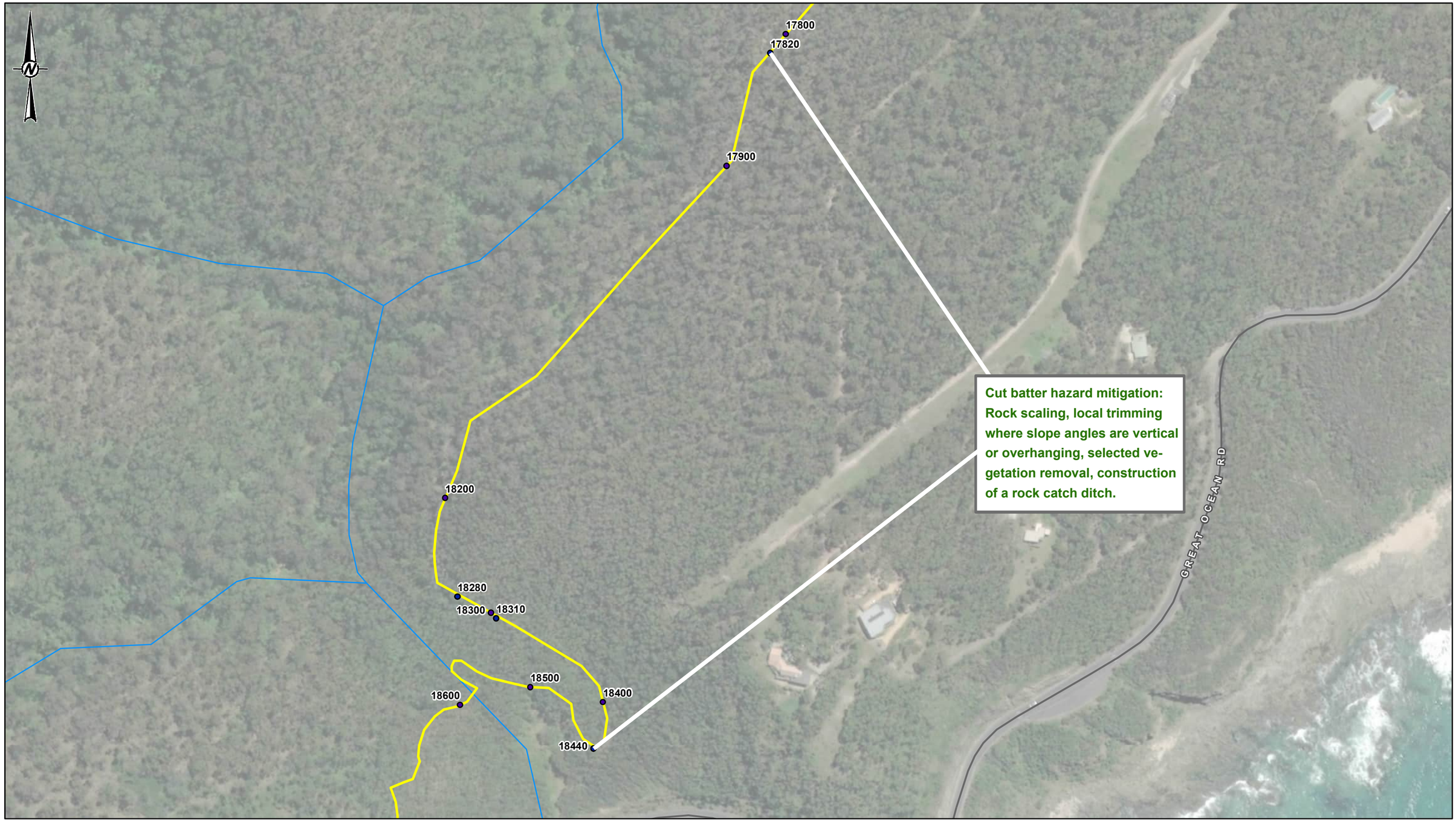
References

- Australian Geomechanics Society, ‘Practice Note Guidelines for Landslide Risk Management 2007,’ Journal and News of the Australian Geomechanics Society, Vol. 42, No. 1, March 2007 (AGS 2007c)
- Australian Geomechanics Society, ‘Commentary on Practice Note Guidelines for Landslide Risk Management 2007,’ Journal and News of the Australian Geomechanics Society, Vol. 42, No. 1, March 2007 (AGS 2007d)
- New South Wales National Parks and Wildlife Services, ‘Guidelines for Quantitative Risk to Life Calculations for Landslides,’ 16 January 2020 (NSW NPWS 2020)

APPENDIX A-1
Great Ocean Road Coastal Trail Mitigation Measures – Drawing Set



LEGEND

- Major Roads
- Watercourse

Risk Level

- Trails Tolerable

REFERENCE(S)

1. PROJECTION: GDA 1994 VICGRID94
2. AERIAL IMAGERY SOURCED FROM ESRI.
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

0 30 60 90

1:2,500 **Scale @ A3** METRES

CLIENT
WORLD TRAIL

CONSULTANT
WSP GOLDER

YYYY-MM-DD	2024-05-13
DESIGNED	-
PREPARED	AN
REVIEWED	DRP
APPROVED	DRP

PROJECT
GREAT OCEAN ROAD COASTAL TRAIL - GEOTECHNICAL RISK MITIGATION

TITLE
MITIGATION MEASURES

PROJECT NO.	CONTROL	REV.	FIGURE
PS210421	002-R	0	Sheet 1

LEGEND

- Major Roads
- Watercourse

Risk Level

- Trails Tolerable

REFERENCE(S)

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TITLE
MITIGATION MEASURES

PROJECT NO.	CONTROL	REV.	FIGURE
PS210421	002-R	0	Sheet 2

LEGEND

Major Roads

Risk Level

Trails Tolerable

REFERENCE(S)

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PROJECT NO.	CONTROL	REV.	FIGURE
PS210421	002-R	0	Sheet 3

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ISO A3

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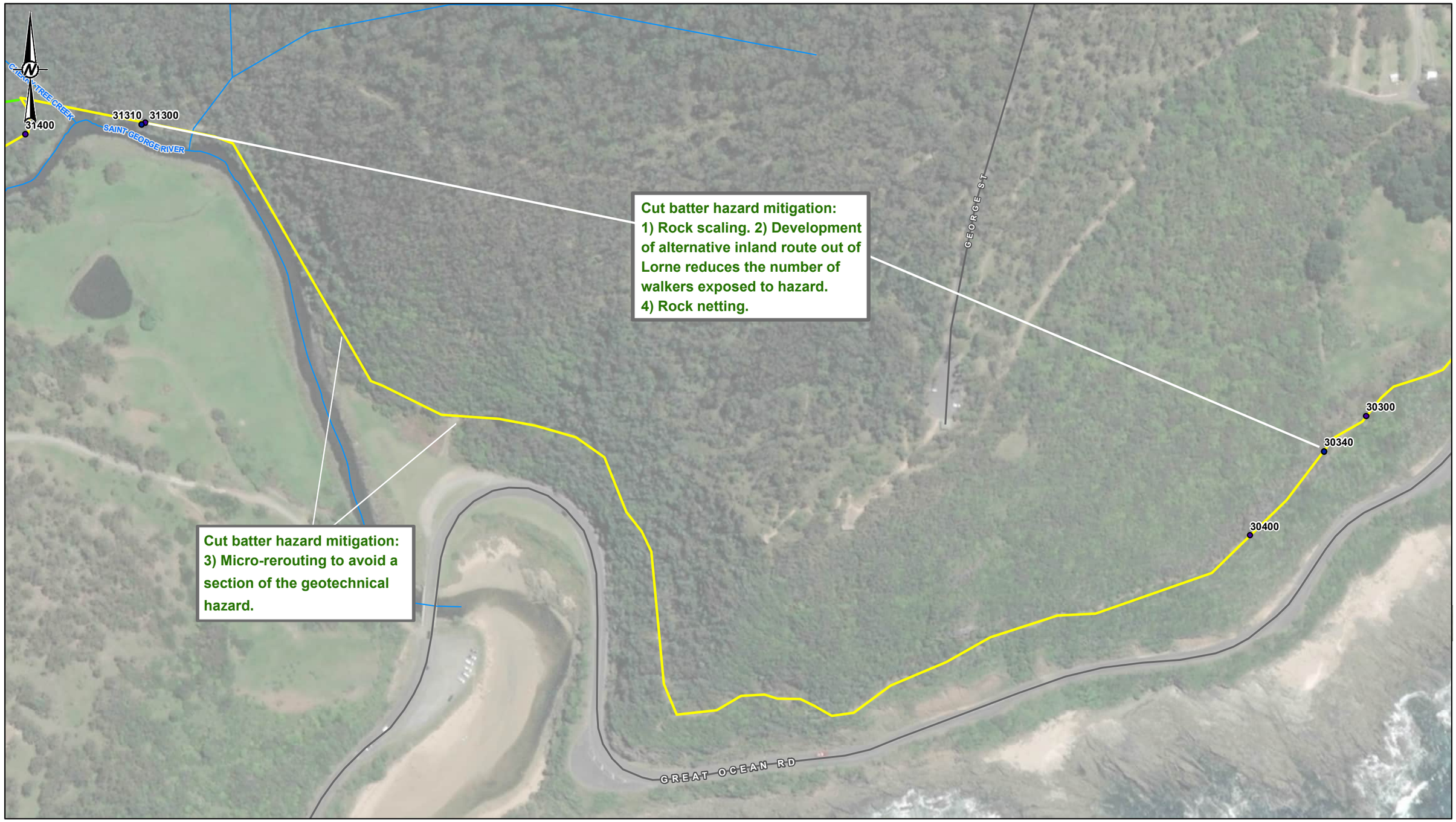

LEGEND

- Major Roads
- Watercourse

Risk Level

- Portions of the trail segment are not acceptable
- Portions of the trail segment are Acceptable
- Portions of the trail segment are Tolerable

REFERENCE(S)

1. PROJECTION: GDA 1994 VICGRID94
2. AERIAL IMAGERY SOURCED FROM ESRI.
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MITIGATION MEASURES

PROJECT NO.	CONTROL	REV.	FIGURE
PS210421	002-R	0	Sheet 4

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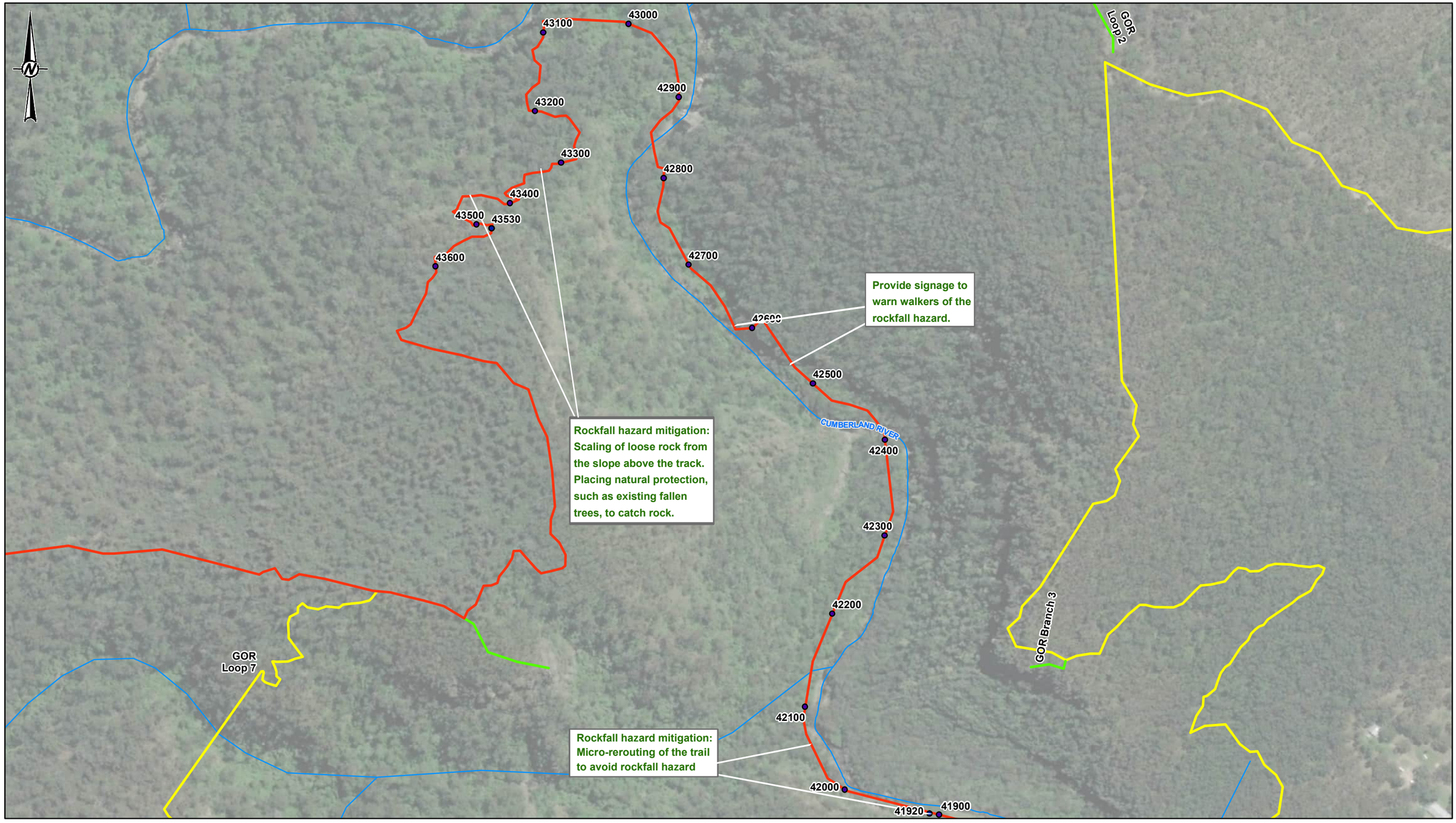

LEGEND

- Watercourse

Risk Level

- Portions of the trail segment are not acceptable
- Trail Acceptable
- Trail Tolerable

REFERENCE(S)

1. PROJECTION: GDA 1994 VICGRID94
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0 60 120

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MITIGATION MEASURES

PROJECT NO.	CONTROL	REV.	FIGURE
PS210421	002-R	0	Sheet 5

LEGEND

Major Roads

Risk Level

Portions of the trail segment are not acceptable

REFERENCE(S)

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TITLE
MITIGATION MEASURES

PROJECT NO.	CONTROL	REV.	FIGURE
PS210421	002-R	0	Sheet 6

REFERENCE(S)
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1:1,250 **Scale @ A3** METRES

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TITLE
MITIGATION MEASURES

PROJECT NO.	CONTROL	REV.	FIGURE
PS210421	002-R	0	Sheet 7

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2. AERIAL IMAGERY SOURCED FROM ESRI.
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TITLE
MITIGATION MEASURES

PROJECT NO.	CONTROL	REV.	FIGURE
PS210421	002-R	0	Sheet 8

KARINGAL DR
KOONYA AV
DUNOON RD
DURIMBIL AV
WYE RIVER
WALLACE ST
ILUKA AV
STANWAY DR
THE BOULEVARDE
MCLELLAN CT
GREAT OCEAN RD
WYE RIVER

56600
56700
56770
56800
57480

Cut batter hazard mitigation: Rock scaling, local trimming where slope angles are vertical or overhanging

Cut batter hazard mitigation: Construction of a one metre high rock fence at the base of the cut.

REFERENCE(S)
1. PROJECTION: GDA 1994 VICGRID94
2. AERIAL IMAGERY SOURCED FROM ESRI.
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TITLE
MITIGATION MEASURES

PROJECT NO.	CONTROL	REV.	FIGURE
PS210421	002-R	0	Sheet 9