REPORT

Great Ocean Road Trail

Geotechnical Hazard Assessment

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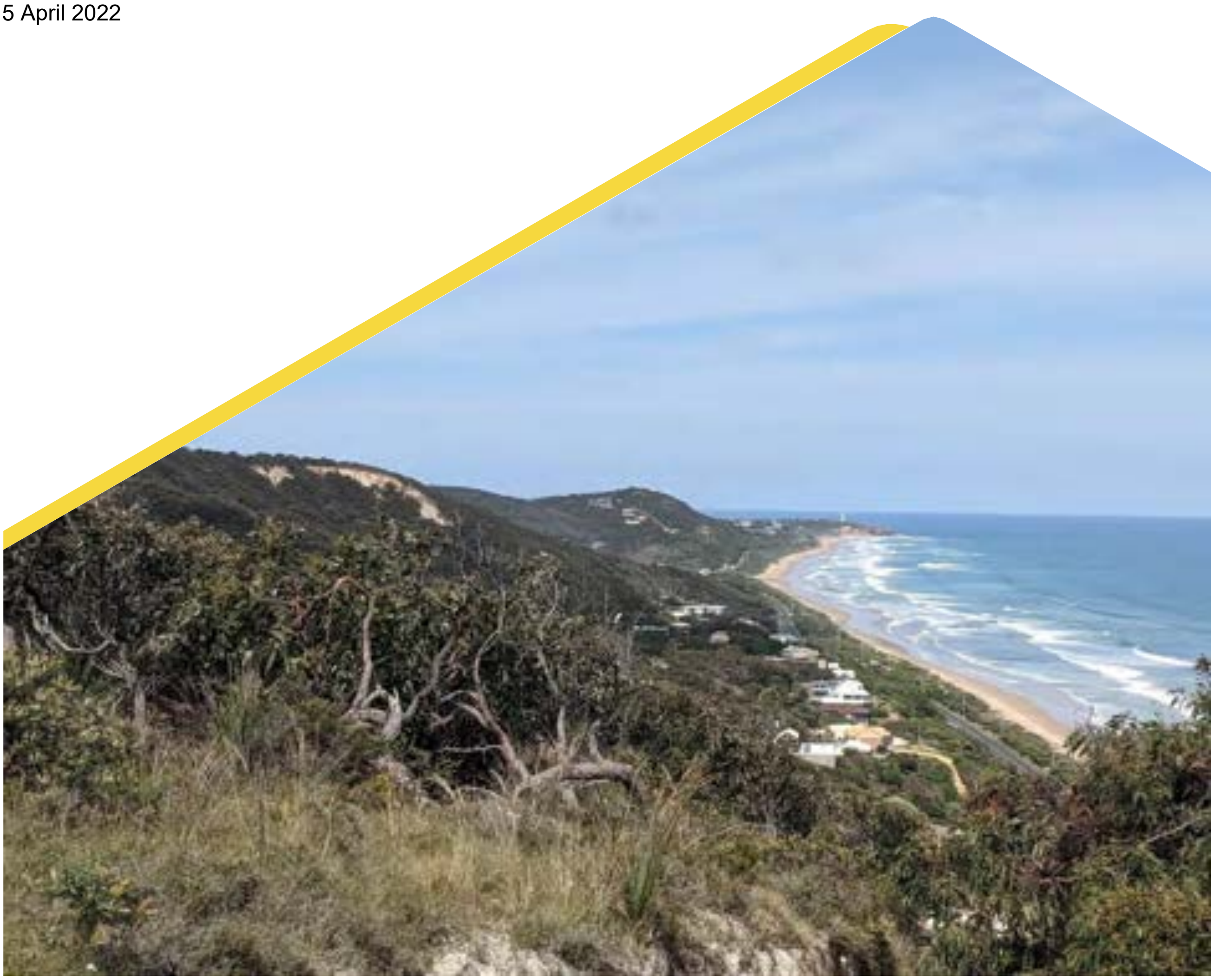

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Executive Summary

The proposed Great Ocean Trail is intended to be a world class hiking trail which traverses spectacular terrain near the iconic Great Ocean Road. As part of feasibility studies for the portion of the trail between Fairhaven and Skenes Creek, Golder in conjunction with A.S. Miner Geotechnical and Environmental Geosurveys has undertaken an assessment of geohazards that could impact the trail and trail users and developed a series of geotechnical hazard maps intended for use in trail planning and routing. In addition, an assessment has been undertaken at five proposed bridge sites to identify potential bridge abutment locations and to provide preliminary information for the purposes of developing concept designs and assessing the feasibility of the bridge sites.

The study indicates that the proposed alignment is exposed to various types of geotechnical hazards (geohazards), including:

- Failure of existing earthworks, including cuts and fill embankments.
- Rockfall from natural and made slopes.
- Natural shallow landslides in soil.
- Deep seated landslides in rock.
- Channelised debris flow along gullies.
- Coastal erosion, including episodic erosion (e.g., cliff collapse) and progressive erosion (e.g., beach erosion).

Hazard maps (Appendix D) have been developed which indicate areas along the proposed trail alignment that could be affected by these geohazards. The maps have been developed through an analysis of each hazard which involved:

- Identifying locations previously affected by these hazards by remote mapping using available digital elevation information and historical records of hazards.
- Collating data on previous hazard occurrences, including their size, frequency, geologic and geomorphic conditions and triggering event.
- Developing criteria to indicate where future hazards could occur.
- Developing hazard maps based on those criteria.

The hazard maps indicate that whilst the proposed trail will be subject to hazards over parts of its length, there are significant portions, typically close to ridgelines and highpoints that are not exposed to hazards. Around 50% of concept route 2 is exposed to existing geotechnical hazards with an estimated hazard rating of ‘Medium’ or higher, with nearly all of the hazards attributed to shallow landslides or deep rock landslides. Other hazard types with ‘Medium’ or higher rating do not affect more than about 5% of the proposed route. It is recommended that where practical, areas identified as prone to geological hazards are avoided in future alignment revisions. Where geohazards cannot be avoided, a risk assessment will be required to assess the risk to life, which may lead to a requirement to provide risk mitigation measures (e.g., rock fall netting, retaining walls etc.).

The valleys over which the 6 (nominal) suspension bridges are proposed to span are typically subject to shallow landslides, necessitating that the bridge abutments and anchors are located far enough upslope (out of the valley) to avoid landslides). Potential bridge abutment locations have been nominated. All bridge locations are inferred to be underlain by the sandstone and siltstone rock of the Eumeralla Formation which depending on the thickness of overlying soils is expected to be able to support shallow or deep footings and ground anchors. Intrusive site investigation (e.g., drilling) will be required at proposed bridge abutment and anchor locations as part of subsequent design phases.

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APPENDICES

1.0 ENGAGEMENT

Golder Associates Pty Ltd (Golder) in conjunction with AS Miner Geotechnical Pty Ltd (ASMG) and Environmental GeoSurveys (EGS) has been engaged by World Trail Pty. Ltd. (World Trail) to undertake geotechnical hazard and risk assessment for the proposed Great Ocean Road Trail between Fairhaven and Skenes Creek along the coastline of south west Victoria.

Stage 1 of the geotechnical scope of the project seeks to inform the master plan for the proposed trail by identifying areas along the proposed route that are subject to geotechnical hazards such as landslide and rockfall and to allow consideration to be given to geotechnical hazards as part of trail set out and route selection. This report accompanies hazard maps produced to communicate the location and extent of geotechnical hazards that could affect the proposed trail alignment. A preliminary assessment of the likely subsurface conditions at proposed bridge abutment locations has also been made as part of Stage 1 of the geotechnical scope.

The second stage of the geotechnical scope (not part of this report) includes an assessment of the risk to life and property along the proposed alignment, which is required for the purposes of supporting a planning application.

This report sets out the findings of Stage 1 of the geotechnical scope which is to identify and communicate geotechnical hazards along the proposed trail alignment including proposed bridge abutment locations.

The study has been undertaken in general accordance with Golder proposal CX214568192-001-P-Rev0 dated 25 May 2021. Authorization to undertake the geotechnical hazard assessment was provided by World Trail via the execution of a sub-contract between Golder and World Trail dated 17 September 2021.

2.0 PROPOSED GREAT OCEAN ROAD 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 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 1.

[1] Ernst and Young, Fairhaven to Skenes Creek Coastal Trail Feasibility Study, 2019.

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

Subsequent to issue of the alignment show in Figure 1, changes have been made and a second concept route (Concept Route 2) developed. At the time of issuing this report, Concept Route 2 has not been finalised. The study set out in this report is based on what was known of Concept Route 2 at the time. Concept Route 2 has two main departures from Concept Route 1, being:

- Realignment of the track around Devil's Elbow, near Eastern View. Rather than following the coast, the trail will pass to the north of private land (St Bernards College camp) with a bridge crossing of Grassy Creek, rejoining the Concept Route 1 alignment at Anderson Creek.
- Removal of a proposed suspension bridge over the Cumberland River.

Other alignment modifications may be made as the trail alignment design progresses.

Based on information within the Ernst and Young feasibility study and the work in progress towards Concept Design 2, we understand the following about the concept design for the proposed trail.

- The trail passes through a number of coastal towns and 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 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. The Concept Route 2 design includes suspension bridges over the following:
  - Grassy Creek (Bridge 0)
  - Big Hill Creek (Bridge 1)
  - Reedy Creek (Bridge 2)
  - Cumberland River (Bridge 3)
  - A tributary to the Cumberland River at Winterbrook Falls (Bridge 4)
  - A minor water course on the southern flanks of Mount Defiance (Bridge 5).

The minimum length of these bridges will be based on geotechnical considerations. Nominal positioning of the bridges at locations not susceptible to landslide is discussed in this report.

The coastal landscape through which the trail will be constructed has been formed through millennia of natural geomorphological and erosion processes. However, the same processes that have formed and continue to shape the landscape create slope stability hazards that present risks to people and property. The proposed Great Ocean Road Trail will traverse through areas at risk from slope instability processes, including landslide and rockfall. The study set out in this report is intended to inform trail designers of geotechnical hazards to which the proposed trail could be exposed.

3.0 OBJECTIVES

Based on our understanding of the project, the objectives of the geotechnical hazard mapping are to:

- Identify and map geotechnical hazards that could affect the proposed trail alignment, including bridges.
- To work with World Trail and other subconsultants to prepare a final alignment that reduces exposure to geotechnical hazards where possible.
- To provide preliminary information on geotechnical conditions at proposed bridge locations.

4.0 GEOTECHNICAL HAZARD MAPPING

The geotechnical hazard mapping, which is presented in Appendix D, has included the tasks set out in Figure 2. Cross reference is provided to subsequent sections describing in further detail the work undertaken and method used for each task. Reference is also made to Appendix B which sets out the technical basis for the hazard mapping.

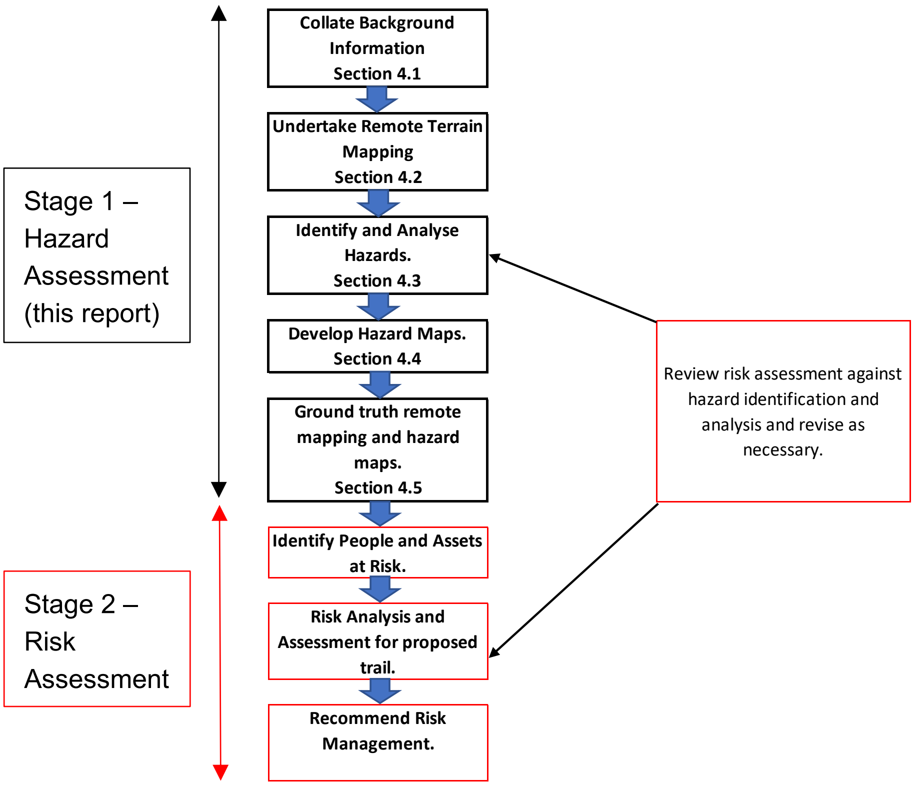

Figure 2: Outline of scope of work

4.1 Collate Background Information

A survey of existing information and previous studies relevant to the geology, geomorphology and geotechnical hazards along the proposed trail route was undertaken and relevant information collated. Key sources of information are described below.

4.1.1 Past Studies

The Great Ocean Road and surrounds are susceptible to various geotechnical hazards, including landslide, debris flow and rockfall and there have been a number of studies undertaken over the years related to hazard identification, assessment and management.

A summary of select previous studies and the relevant information acquired from those studies is set out in Table 1.

Table 1: Summary of information acquired from past reports and studies

Report / Paper	Relevance to this Study
ASMG and EGS[2] (2020)	Provides identification of natural hazards along the full length of the Great Ocean Road, including landslide hazards. Includes a comprehensive discussion on the regional geology and geomorphology which informs the discussion presented in this report.

[2] A.S. Miner Geotechnical, Environmental Geo-Surveys, Great Ocean Road Hazard Study, Report No: 1134/01/20, 29 June 2020.

Report / Paper	Relevance to this Study
Miner, et al. (2010) [3]	Includes a discussion of factors which influence landslides on the Bellarine Peninsula. Although the Bellarine Peninsula is to the east of the proposed trail, it is in an area with geology and climate similar to that at the eastern end of the proposed trail (Fairhaven to Eastern View) and the discussion of factors which influence landslides is relevant to this study.
Flentje, et. al. (2007)[4]	Sets out the results of data mining techniques used to assess landslide susceptibility within the Corangamite Catchment Management Authority (CCMA) area. Discusses parameters which influence landslide susceptibility in that area, noting that the area of this study overlaps partly with the trail study area.
Golder (2019)[5]	A study of landslide risk within the Wye River and Separation Creek area, which overlaps with the proposed trail alignment. Includes susceptibility maps and discussion on factors which influence landslide, including discussion on landslide frequency based on rainfall and earthquake triggers.
Golder (2020a)[6]	A study of landslide resilience for the Skenes Creek township which is on the proposed trail alignment. Includes susceptibility maps and a discussion on factors which contribute to landslide.
Golder (2020b)[7]	A study of landslide resilience for the Kennett River and Grey River townships which is on the proposed trail alignment. Includes susceptibility maps and a discussion on factors which contribute to landslide.
Gill and Lang (1983)[8]	Includes a discussion of coastal erosion rates along the Otways Coast, covering the proposed trail alignment. This information helps to inform the frequency of landslides induced by coastal erosion.
Stephenson et. al. (2012)[9]	Provides an updated discussion on Gill and Lang 1983, presenting revised estimates for rates for shore platform lowering. This information helps to inform estimates of the frequency of landslides induced by coastal erosion.
Medwell (1971)[10]	Includes a map of structural geology within the Otway Ranges. Used to inform the identification of areas where the ground slope is parallel to bedding dip.

Appendix B presents an overview of the geology and geomorphology along the proposed trail alignment, based on information acquired from the references set out in Table 1.

[3] Miner, A.S., Vamplew, P., Windle, D.J., Flentje, P., Warner, P, A Comparative Study of Various Data Mining Techniques as applied to the Modelling of Landslide Susceptibility on the Bellarine Peninsula, Victoria, Australia, Proceedings of the 11th IAEG Congress of the International Association of Engineering Geology and the Environment, Auckland, 2010.

[4] Flentje, P., Stirling, D., Landslide Susceptibility and Hazard derived from a Landslide Inventory using Data mining – An Australian case study, First North American Landslide Conference, Landslide and Society: Integrated Science, Engineering, Management and Mitigation, Vail, Colorado, 2007.

[5] Golder, Wye River and Separation Creek, Great Ocean Road, Post Bushfire Landslide Risk Assessment, Ref: 18101896-002-R-Rev0, 1 March 2019.

[6] Golder, Skenes Creek, Great Ocean Road, Victoria, Geotechnical Assessment of Community Resilience, Ref: 19126225-003-R-Rev0 dated 2 April 2020.

[7] Golder, Kennett/Gray River, Great Ocean Road, Victoria, Geotechnical Assessment of Community Resilience, Ref: 19126225-002-R-Rev0 dated 2 April 2020.

[8] Gill, E.D., Lang, J.G., Micro-Erosion Meter Measurements of Rock Wear on the Otway Coast of Southeast Australia, Marine Geology, 52, 1983 pp. 141-156.

[9] Stephenson, W.J., Kirk, R.M., Kennedy, D.M., Finlayson, B.L., Chen, Z. Long term shore platform surface lowering rates: Revisiting Gill and Lang after 32 years. Marine Geology, 299-302, 2012 pp. 141-156, pp 90 -95

[10] Medwell, G.J. (1971) 'Structures of the Otway Ranges in the Otway Basin of South Eastern Australia', Special Bulletin of the Geological Surveys of South Australia and Victoria, p. 339-362

4.2 Remote Terrain Mapping

Prior to visiting the site, hazard maps were produced using available information, including:

- Digital elevation information provided by DELWP (data package provided on 17 September 2021). This information was processed and viewed various ways to assess terrain characteristics, including hillshade, slope aspect, slope angle, and elevation derivatives.
- Publicly available geological information, including the 1:250,000 scale Geological Survey of Victoria (GSV) mapsheets of Colac and Queenscliff, which cover the proposed trail alignment.
- Structural geological mapping after Medwell (1971)[10].

This information was collated into a geographical information system (GIS) and used to undertake remote desktop mapping at a scale of between 1:1,000 and 1:10,000. The extent of the mapping undertaken incorporated an area within approximately 250 m from the Concept Route 2 alignment, intended to encompass the area within which the alignment could ultimately be located. The following sections describe the remote mapping undertaken.

4.2.1 Remote Landform Mapping

Geotechnical hazards are related to geomorphic processes. For example, a hard coastline subject to sporadic regression in the form of cliff collapse can be related to hazards that could affect the proposed trail where it is close to cliffs. A hillside subject to shallow landslides in soils or a gully subject to debris flows present hazards of different forms to the proposed trail.

A key element of identifying hazards is to understand the geomorphic processes acting in different terrain. Landform mapping was undertaken by ASMG and EGS. This work used the digital elevation information to zone the terrain along the proposed alignment based on the landform and the geomorphic processes acting within the landform. Landforms were delineated based on the categories set out in Table 2, with coastal and inland landforms delineated separately.

Table 2: Summary of landforms delineated

Coastal Landforms		Inland Landforms	
Cliff – hard rock	Creek mouth	Valley	Slopes – convex
Cliff – debris	Shore platform	Valley side slopes	Slopes – concave
Bluff – hard coast	Beach (sand-gravel)	Slopes – simple	Ridge – sharp
Bluff – debris	Barrier (low dune at back of beach)	Slopes – undulating	Crest – plateau
Sloping land	Platform beach (relatively flat, level beach)	Slopes – dissected	Crest – step
Slope over cliff	Stream channel (incl. stream bed and banks)		Mapped landslide
Landslide slopes	Stream channel – bedrock		Spur
Transgressive dunes	Coastal ridge		
Foredunes/ridges	Coastal ridge and sand beach		
Engineered (e.g., coastal protection structures)	Shore platform/Platform beach		
Estuary mouth	Divide/Saddle		

Within each landform mapped, geomorphic processes acting have been identified, along with an indication of the level of confidence assigned to the identification of the landform.

The following geomorphic processes were identified. An indication of the geotechnical hazards associated with the process is also indicated.

- **Channel Migration –** Refers to changes in the alignment of creeks and water courses due to natural migration of the channel. Possible hazards to the trail relate to erosion and collapse of creek banks.
- **Flood/Inundation** – Refers to areas that could be prone to inundation. Processes associated with inundation could lead to erosion and possible landslides.
- **Alluvial Slope Processes** – Alluvium describes material that has been deposited by rivers. Where the alluvium is on a slope, landslide processes could occur, including lateral spreading (low angle landslides) and soil creep.
- **Colluvial Slope Processes** – Colluvium is described as soil and rock that has been transported downslope under the action of gravity and accumulated on or at the base of the slope. This material is often deposited at close to its angle of repose and can be susceptible to landslide.
- **Shallow Landslides in Regolith** – Regolith refers to soils that form on rock as a result of weathering processes. Rock is typically able to support steeper slope angles than soil, and soil regolith can be susceptible to landslide, however the size of the landslide is typically constrained by the depth to the underlying rock. Landslides present a hazard if they cause undermining of areas or if the travelling debris arising from a landslide causes an impact to people or assets.
- **Deep Landslides in Rock** – The Cretaceous sedimentary rock underlying much of the Otway Ranges (refer to Appendix B) has bedding planes and other discontinuities within it. Large landslides, sometimes greater than 1 hectare can occur, as a result of sliding on the bedding planes or discontinuities within the rock.
- **Rockfall** – Refers to the detachment of rock blocks and travel of the rock blocks downslope. Impact to people or assets from rockfall is a potential hazard.
- **Debris Flow** – Describes the process of landslides, typically triggered by heavy rainfall and resulting in mixed soil and rock debris with a high water content. The landslide debris forms into a flow, typically concentrating in and flowing down gullies as high energy flows.
- **Terrestrial Erosion** – Refers to the progressive removal of material through the action of wind and water. In this report, 'terrestrial erosion' excludes 'coastal erosion' (see below) caused by wave action of the sea. Terrestrial erosion is a potential hazard if it may cause undermining of assets.
- **Coastal Erosion, Hard Coasts** – Refers to the progressive erosion of rocky or 'hard' coasts. Presents a hazard if erosion causes collapse of rock cliffs or the undermining of assets.
- **Coastal Erosion, Soft Coasts** – Refers to the progressive erosion of coasts comprised of soils, or 'soft' coasts. Presents a hazard if erosion causes collapse of slopes or the undermining of assets.
- **Coastal Erosion, Rock Debris Coasts** – Refers to the progressive erosion of coasts comprised of rock debris, or talus. These coasts are in between 'soft' and 'hard' coasts. Presents a hazard if erosion causes collapse of rock cliffs or the undermining of assets.
- **Coastal Erosion, Beaches** – Refers to the erosion or removal of sand from beaches. This process leads to potential hazards if assets on the beach are lost.
- **Coastal Erosion, Estuary** – Refers to erosion associated with an estuarine environment, which may be caused by ocean (tidal) or riverine influence. A potential hazard where erosion causes collapse of rock cliffs or slopes or the undermining of assets.

- **Other geomorphological processes –** Other geomorphological processes have been identified, including faults and associated movement along the fault, intermittent blocking of estuaries.

In addition to the natural landforms, anthropogenic (human made) landforms have been mapped, which principally includes cuts and fills, in particular those associated with the Great Ocean Road. The 'process' of forming the cut or fill can create hazards, whereby the ground is steepened beyond its naturally stable slope angle, disturbed and therefore more susceptible to landslide or rockfall. Engineering measures (e.g., retaining walls), where present, may reduce susceptibility. The Great Ocean Road and other roads in the Otways are regularly subject to hazards associated with cut and fill. These hazards are further described in Section 4.2.4.

Landform mapping has been provided as a GIS layer on the accompanying GIS package. Refer to Appendix A for details of GIS layers provided with this report.

4.2.2 Landslide Mapping

A landslide inventory has been produced by ASMG for the Corangamite catchment area, which includes the proposed trail alignment. This inventory is provided as a public online resource via Federation University[11] and CCMA. This inventory indicates a number of landslides within the vicinity of the proposed trail. However, the inventory covers all the Corangamite catchment area, and the mapping is undertaken at a scale appropriate to that area of coverage. The inventory does not include smaller landslides, noting that smaller landslides could present hazards to the proposed trail and are therefore of relevance to this study.

Smaller landslides along the length of the proposed trail have been identified during the desktop remote mapping using the digital elevation information. This mapping helps to inform assessment of the factors which could contribute to landslide.

Mapped landslides are included in the accompanying GIS data package. Refer to Appendix A for data package details and the maps in Appendix D (Figure 6 in Appendix D shows mapped landslide extents).

4.2.3 Structural Geology Mapping

The Cretaceous sedimentary rock underlying much of the study area contains bedding planes, faults and folds, all of which are features that could influence the susceptibility of the ground to geological hazards such as landslides. Indications of structural geology were obtained from previous studies which are set out in Appendix B. In addition, structural geology mapping was undertaken by delineating areas where the rock structures (typically bedding planes) are approximately parallel to the slope angle and where they are approximately obverse (bedding orientation opposite) to the slope angle. This assessment was informed by the structural mapping undertaken by Medwell (1971) and the information in the 1:250,000 scale GSV Colac and Queenscliff mapsheets.

4.2.4 Earthworks Mapping

The construction of the Great Ocean Road required relatively extensive cut to fill earthworks, with cuts made into the side of relatively steep slopes. Failures of the cut and fill batters have occurred along the Great Ocean Road with a relatively high frequency, which historically has required mitigation works to be undertaken along the road. Where the proposed trail passes near the Great Ocean Road, it may be subject to hazards associated with failure of the earthworks along the road. For example, where the track passes below the road embankment it may be susceptible to impact from debris from the failure of the fill embankment and where it passes above, could be subject to failure of a road cut batter.

[11] https://www.ccmaknowledgebase.vic.gov.au/soilhealth/soils_map.php

In addition to the Great Ocean Road, the proposed trail passes along fire trails, former telegraph tracks and existing walking tracks which have also been formed by cut and fill earthworks and are susceptible to similar hazards.

Mapping of cut and fill batters within the vicinity of the trail has been undertaken.

4.3 Identify and Analyse Hazards

Based on the remote mapping information, a workshop was held at which the remote mapping and background information was reviewed and criteria were developed to indicate areas susceptible to hazards and the degree of hazard to which they are subject. An outline of the process by which this was done is described below:

- Review landform mapping and geomorphic processes and use this to identify the hazards acting within the study area, the factors that contribute to landslide.
- Undertake likelihood analysis for the identified hazards to estimate the frequency with which the hazards have occurred in the past (Appendix D)
- Review collated landslide mapping and hazards with a view to identifying what terrain attributes appear to contribute to hazards.
- Review previous data mining exercises undertaken in the area, including Miner et. al. (2010)[12] and Flentje et. al. (2007)[13] and review the attributes identified as contributing to hazards.
- Develop criteria to identify hazard type and level based on terrain attributes, including landform, slope angle, slope aspect, presence of earthworks and structural geology.

Appendix B sets out the results of the hazard identification and analysis.

4.4 Develop Hazard Maps

A hazard map provides an indication of the locations at which hazards could occur (susceptibility) *and* how likely they are to occur. Hazard maps have been produced at 1:5,000 and 1:10,000 scale in accordance with the methods described in AGS (2007a)[14].

A precursor to assessing hazard is to assess susceptibility, which provides an indication of the proportion of an area that could be affected by a hazard. Susceptibility has been assessed based on the indications provided in AGS (2007a). An additional category, Very High has been introduced for consistency with previous studies in the Great Ocean Road area and is replicated in Table 3.

[12] Miner, A.S., Vamplew, P., Windle, D.J., Flentje, P., Warner, P, A Comparative Study of Various Data Mining Techniques as applied to the Modeling of Landslide Susceptibility on the Bellarine Peninsula, Victoria, Australia, Proceedings of the 11th IAEG Congress of the International Association of Engineering Geology and the Environment, Auckland, 2010

[13] Flentje, P., Stirling, D., Landslide Susceptibility and Hazard derived from a Landslide Inventory using Data mining – An Australian case study, First North American Landslide Conference, Landslide and Society: Integrated Science, Engineering, Management and Mitigation, Vail, Colorado, 2007

[14] Australian Geomechanics Society, Guideline for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Planning, Journal and News of the Australian Geomechanics Society, Vol.42, No.1, March 2007.

Table 3: Summary of Susceptibility Mapping Descriptors (adapted from AGS 2007a)

Susceptibility Descriptor	The proportion of the study area affected
Very High	50% to 100%
High	25% to 50%
Moderate	10% to 25%
Low	1% to 10 %
Very Low	0 to 1%

Whilst susceptibility maps were not produced, assessment of susceptibility was used as an incremental step to developing hazard maps.

The following hazard maps have been produced covering the area along the proposed trail and are presented in Appendix D:

- Cut and fill hazard maps.
- Rockfall hazard maps.
- Landslide hazard maps (including shallow soil landslides and deep rock slides.
- Debris flow hazard maps.
- Erosion hazard maps – episodic erosion.
- Erosion hazard maps – progressive erosion.

The hazard maps consider susceptibility (the proportion of an area where a hazard is present) and likelihood (how frequently the hazard occurs). Likelihood has been adopted from AGS (2007c), with the likelihood categories adopted set out in Table 4.

Table 4: Likelihood categories (adapted from AGS 2007c)

Likelihood Descriptor	Indicative Annual Probability of Occurrence
Almost Certain	10^{-1}
Likely	10^{-2}
Possible	10^{-3}
Unlikely	10^{-4}
Rare	10^{-5}
Barely Credible	10^{-6}

Susceptibility (Table 3) is combined with Likelihood (Table 4) to estimate hazard. Hazard categories have been adapted from Table 5 of AGS (2007a), using five levels, Very High, High, Medium, Low and Very Low where:

- **Very High –** The hazard could affect greater than 1% of an area (or lineal length for hazards associated with linear features such as road batter failures or coastline regression) per annum.
- **High –** The hazard could affect 0.1% to 1% of an area (or lineal length for hazards associated with linear features such as road batter failures or coastline regression) per annum.
- **Moderate –** The hazard could affect 0.01% to 0.1% of an area (or lineal length for hazards associated with linear features such as road batter failures or coastline regression) per annum.

- **Low –** The hazard could affect 0.001% to 0.01% of an area (or lineal length for hazards associated with linear features such as road batter failures or coastline regression) per annum.
- **Very Low –** The hazard could affect less than 0.001% an area (or lineal length for hazards associated with linear features such as road batter failures or coastline regression) per annum.

The hazard level is estimated by multiplying the indicative values for susceptibility (Table 3) with indicative values of likelihood (Table 4). This is provided in Table 5.

Table 5: Hazard estimation (% of area affected per annum)

Susceptibility		Likelihood – Descriptor and indicative annual probability					
Descriptor	Proportion of area affected	Barely Credible 10^{-6}	Rare 10^{-5}	Unlikely 10^{-4}	Possible 10^{-3}	Likely 10^{-2}	Almost Certain 10^{-1}
Very High	50% to 100%	0.00005 to 0.0001% **Very Low**	0.0005 to 0.001% **Very Low**	0.005 to 0.01% **Low**	0.05 to 0.1% **Moderate**	0.5 to 1% **High**	>5% **Very High**
High	25% to 50%	0.000025 to 0.00005% **Very Low**	0.00025 to 0.0005% **Very Low**	0.0025 to 0.005% **Low**	0.025 to 0.05% **Moderate**	0.25 to 0.5% **High**	2.5 to 5% **Very High**
Moderate	10% to 25%	0.00001 to 0.000025% **Very Low**	0.0001 to 0.00025% **Very Low**	0.001 to 0.0025% **Low**	0.01 to 0.025% **Moderate**	0.1 to 0.25% **High**	1 to 2.5% **Very High**
Low	1% to 10%	0.01 to 0.00001% **Very Low**	0.01 to 0.0001% **Very Low**	0.0001 to 0.001% **Very Low**	0.001 to 0.01% **Low**	0.01 to 0.1% **Moderate**	0.1 to 1% **High**
Very Low	<1%	<0.000001% **Very Low**	<0.00001% **Very Low**	<0.0001% **Very Low**	<0.001% **Very Low**	<0.01% **Low**	<0.1% **Moderate**

A single occurrence of different hazards will affect different sized areas. The following assumptions have been made with respect to the typical areas affected by the hazards that will be assessed in the vicinity of the Great Ocean Road and the proposed trail.

- A single occurrence of a shallow landslides in soil might affect an area of 1000 m^2.
- A single rockfall might affect a 1 m width of a cutting or outcrop.
- Failure of a cut or fill batter might affect a 10 m length of the cut or fill batter.

Based on the hazard categories described above, Table 6 sets out the numbers of hazards per annum assumed in each hazard category. This table is consistent with Table 5 of AGS (2007a).

Table 6: Summary of Hazard Map Descriptors (adapted from AGS 2007a)

Hazard Descriptor	Rock falls from cliff or road batter (No. per annum/km of cliff or road batter assuming 1 m wide rockfall)	Road batter failures (cut or fill) (No. per annum/km of cliff or road batter assuming 10 m wide failure)	Small distributed hazards – Shallow landslides in soil (No. per km^2 per annum assuming 1000 m^2 average landslide size)	Individual, large hazards – deep rock slides, debris flows (Annual probability of active sliding)	Erosion and recession – coastal, riverine and estuarine erosion (Annual probability of erosion impacting an area)
Very High	>10	>1	>10	$>10^{-2}$	$>10^{-2}$
High	1 to 10	$>10^{-1}$ to 1	1 to 10	10^{-3} to 10^{-2}	10^{-3} to 10^{-2}
Moderate	10^{-1} to 1	10^{-2} to 10^{-1}	10^{-1} to 1	10^{-4} to 10^{-3}	10^{-4} to 10^{-3}
Low	10^{-2} to 10^{-1}	10^{-3} to 10^{-2}	10^{-2} to 10^{-1}	10^{-6} to 10^{-4}	10^{-6} to 10^{-4}
Very Low	$<10^{-2}$	$<10^{-3}$	$<10^{-2}$	$<10^{-6}$	$<10^{-6}$

Information relevant to the identification and assessment of hazards is set out in Appendix B, with this information being the supporting evidence for the hazard maps presented in Appendix D and included on the accompanying GIS package.

4.5 Ground Truthing

A ground truthing exercise was undertaken between 21 and 26 November 2021. The purpose of the ground truthing exercise was to review the outcomes of the desktop mapping and the hazard criteria developed from that study, including:

- Identification and description of hazards based on observation of hazards that have occurred previously.
- Assessment of the density and frequency of hazards, for example the numbers of rockfalls and how frequently they appear to have occurred over different sections of the proposed trail. This information helps to inform the assessment of hazard frequency as shown on the hazard maps.

The assessment was undertaken along existing tracks. All existing tracks along Concept Route 1 were walked and observations of hazards were made. The observations made during the ground truthing exercise were compared to the hazard criteria developed through the hazard identification and mapping process and the results are set out in Appendix C. There was reasonable agreement between the hazard maps and site observations.

In addition to walking existing tracks, each of the five proposed bridge sites were visited, which is discussed in the following section.

5.0 BRIDGE SITES

Six sites at which suspension bridges are under consideration were assessed as part of the study, including:

- Bridge 0 – Grassy Creek
- Bridge 1 – Big Hill Creek
- Bridge 2 – Reedy Creek
- Bridge 3 – Cumberland River
- Bridge 4 – Winterbrook Falls
- Bridge 5 – Mount Defiance.

Locations of bridges are indicated on the plan on Figure 3.

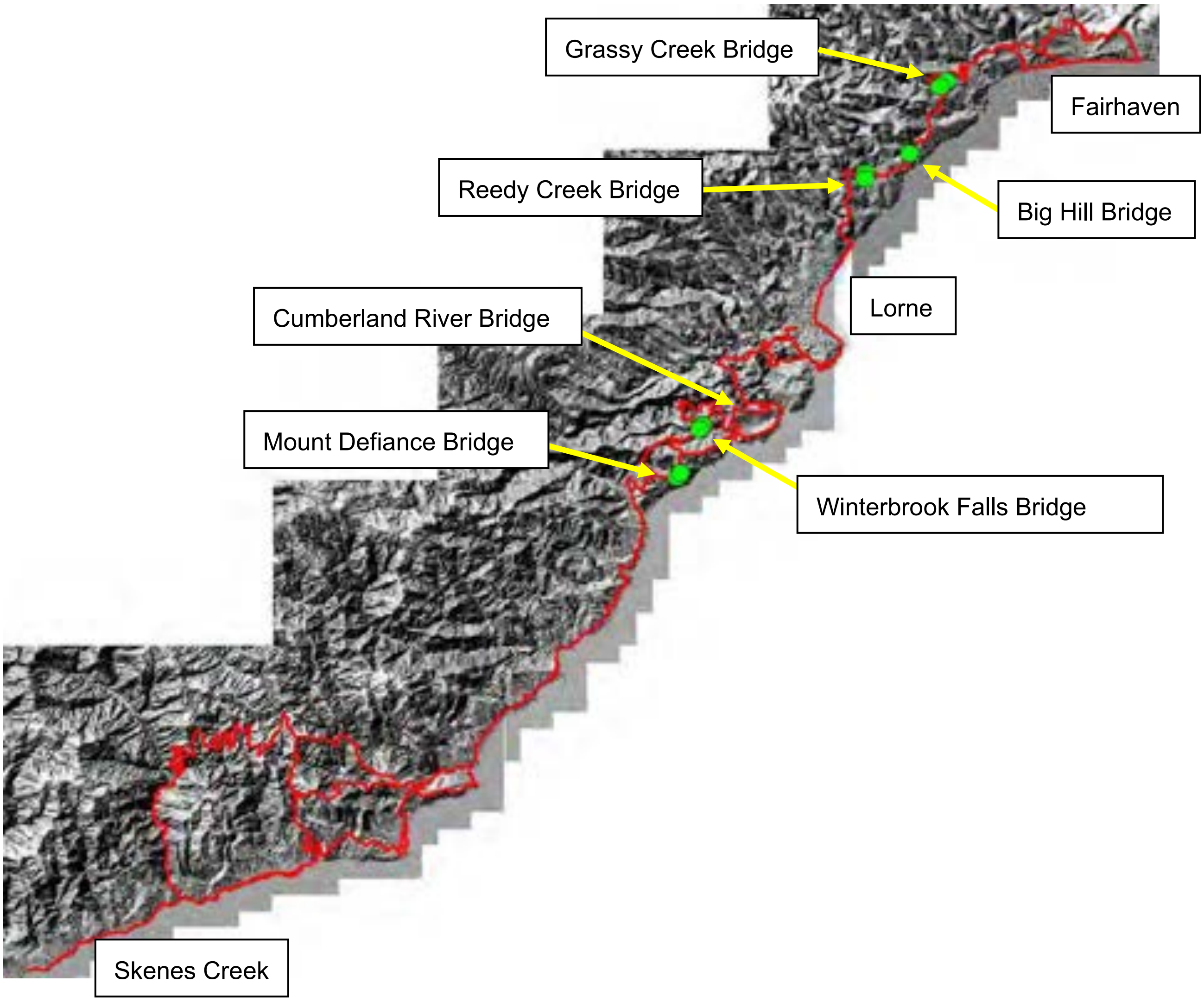

Figure 3: Locations of proposed bridge sites (green dots show proposed abutment locations) assessed as part of study (note Cumberland River excluded)

The scope of works and objectives at each of the proposed bridge sites was to:

- Identify geohazards in the vicinity of the proposed bridge site, which for the suspension bridges was found to be mainly shallow landslide.
- Identify potential bridge abutment locations to avoid impact or undermining from shallow landslides.
- Ground truth potential bridge abutment locations.
- Compile observations at potential bridge abutment locations indicative of subsurface conditions, including rock outcrops and surface morphology.
- Provide indicative engineering parameters and preliminary commentary on geotechnical aspects of bridge abutment and anchor design.

Note that due to accessibility constraints, it was not practical to visit the proposed Cumberland River bridge location which limits our assessment of this location. The following sections address the above points for each of the proposed bridge sites.

5.1 Bridge 0 – Grassy Creek

Bridge 0 spans Grassy Creek at the base of a significant valley inland from Eastern View.

The slopes on both sides of the valley steepen towards its base. On the southern side of the valley, the slope is on the flank of spur running approximately northeast to southwest, with the flattening of the slope with elevation more gradual than the northern side. Due to vegetation coverage meaningful photographs of terrain features were not possible.

Significant exposures of the subsurface materials were not present at the site, so inference of the subsurface conditions based on observed terrain features is provided, which will need to be confirmed with targeted intrusive investigation works as the design is developed.

Landslide footprint mapping has not yet occurred for this section of the trail as part of the overall desktop mapping part of the study. However, terrain features indicating probable landslides have been provided on the annotated cross section and plan view of hillshade terrain at the proposed bridge site in Figure 4 and Figure 5 respectively.

5.1.1 Northern Abutment

It is inferred from terrain characteristics that the northern valley slope may comprise relatively old landslide colluvium due to the signs of headscarps of large, old landslides in the upper parts of the slope and the reasonably constant slope angle in the middle and lower parts of the slope, until the slope steepens near the base. Rock exposures were not observed on the northern side of the valley. The slope did not show signs of distress or movement and appeared to have been stable for a significant period of time. Further investigation activities will be required to confirm the inferred subsurface geology for both slope stability and bridge engineering design purposes. The slope of the upper part of the northern slope is approximately 20° to 25°, increasing to approximately 35° and up to 45° locally on the lower slopes near the creek. The steepening of the northern slope in the lower part of the valley may be where the creek has cut down into the toe of the landslide debris and possibly into the underlying rock over time. Should the northern slope comprise landslide colluvium, the stability of the slope on smaller scales as well as the overall slope stability will be a critical factor, especially considering the steepening at the toe of the overall slope.

During the site visit, considering signs of slope instability were not observed and the inferred underlying colluvium cannot be avoided, the potential location for the northern abutment was assessed primarily based on slope angle and located slightly upslope of where the slope steepens in the vicinity of the creek. The elevation of the location was also similar to World Trails' proposed location for the southern side with the location measurement based on hand-held GPS (nominal horizontal accuracy of 5 m) shown in Figure 4. The approximate position of the potential abutment location is also shown on the cross section in Figure 5. Further investigation work will be required to investigate the geotechnical properties of the colluvium and to further assess footing requirements. If the proposed bridge abutment location is underlain by deep colluvium, there may be a requirement to provide deep piled footings.

5.1.2 Southern Abutment

At World Trail's proposed location of the southern abutment, the slopes are approximately 25° or less, with the lower slopes steepening to approximately 35°, and up to 45° locally.

The southern abutment area appears to have relatively shallow sandstone rock at some locations as outcropping was occasionally observed. Outcrops were not observed in the relatively shallow gullies in the slopes. Signs of slope instability were not present, however small areas of scree with cobble sized rocks, likely to be reasonably shallow, were observed on the slopes above the proposed abutment location. The characteristics of the rock, including intact strength, defects, bedding, etc. could not be fully assessed based on the site observations.

However, as a general comment we expect that where rock is present it is likely to be practical to design abutment footings (e.g., anchored pad footings or piles) founding on or within the rock and subject to analysis and design to mitigate potential slope instability.

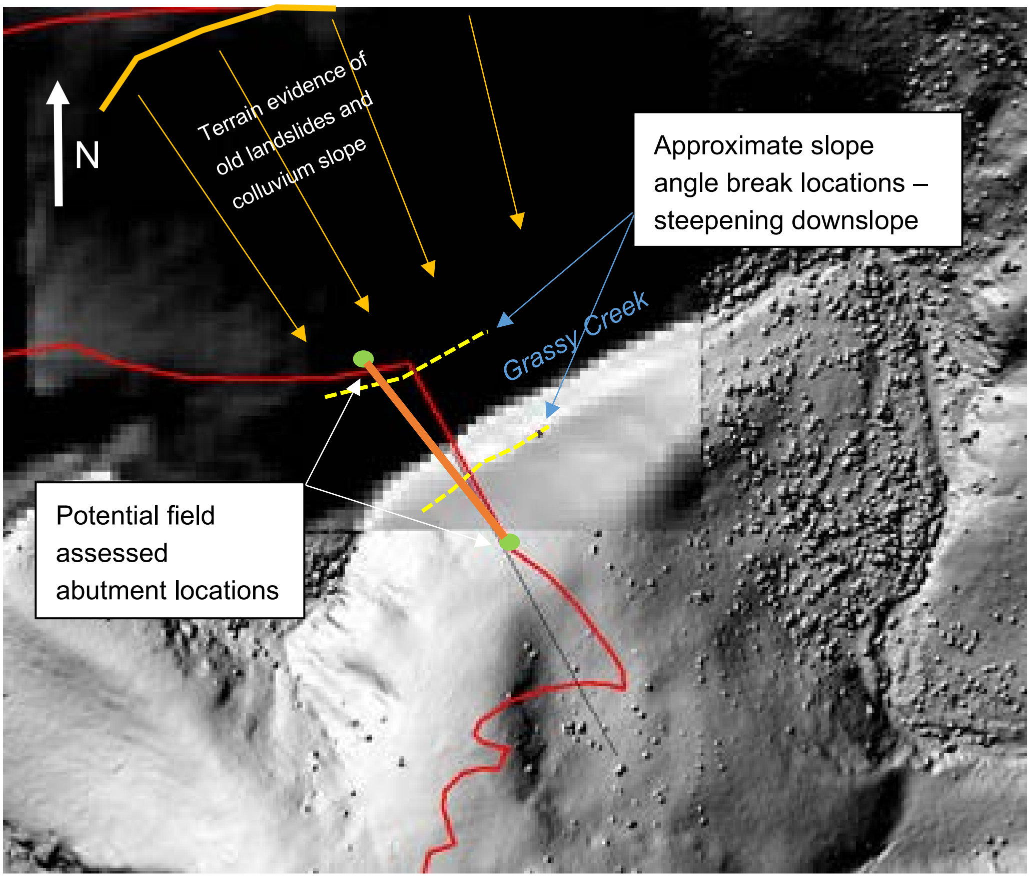

Figure 4: Hillshade terrain representation showing approximate trail route and proposed Bridge 0 abutment locations

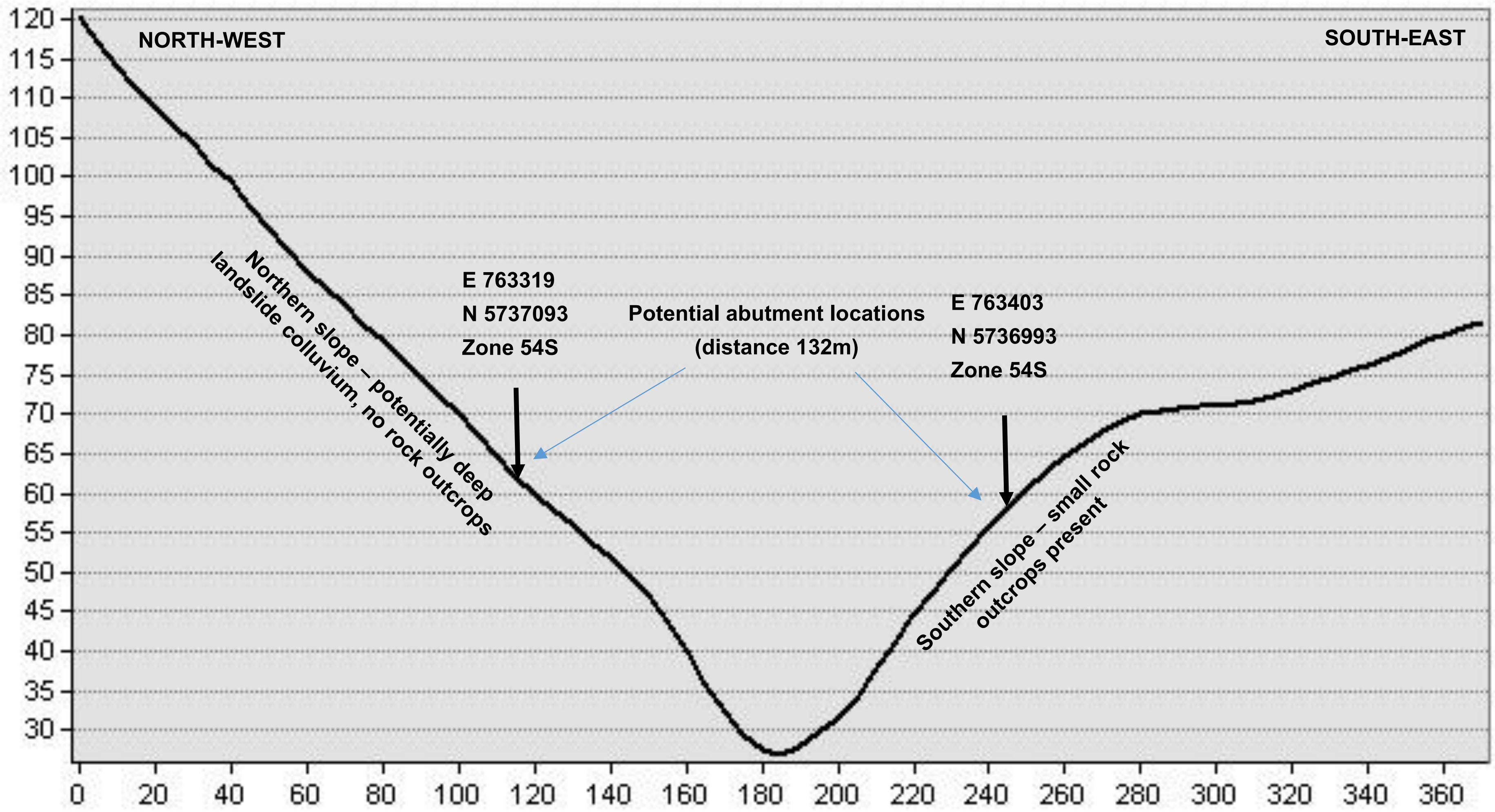

Figure 5: Terrain cross section at potential Bridge 0 abutment locations, looking east (axes in m)

5.2 Bridge 1 – Big Hill Creek

Bridge 2 spans a moderately sloped valley leading down to a small unnamed creek. Due to the presence of thick vegetation at this location, it was difficult to obtain a photograph showing the location of the full bridge span over the valley. The landslide hazard map indicates the valley to be susceptible to landslides as indicated in Figure 9. A cross section profile of the valley at the bridge location, showing the positions on the slope of suggested abutment locations, is presented in Figure 10.

This observation was confirmed in the field at both the north east and south west abutment.

5.2.1 North east Abutment

A track leading to the abutment location exposed up to 4 m of colluvium in an existing cut that runs along the track. The cut exposes colluvium for much of its length, including at the abutment location, indicating a continuous landslide.

Near the abutment location, the cut ranges from 1.5 m up to 4 m in height. The exposed material was highly variable, comprising a combination of silty clay with angular rock fragments overlying moderately weathered sandstone with a distressed rock mass and open joints, as indicated in Figure 6. No clear bedding or vertical joints were observed in the sandstone with various oblique surfaces suggesting this is not a competent rock outcrop and that it has been affected by ground instability. The face of the cutting is also variable ranging from 50° to 70°. Approximately 70 m down the walking track, further south of the proposed abutment location, the rear headscarp of the large landslide mapped in the landslide hazard map can be observed.

Downslope of the track, the ground slopes into the valley at an angle ranging from 25° to 35°. Relatively young trees were observed to be tilting downslope, as indicated in Figure 7, suggesting ongoing active creep or shallow slope movements.

Figure 6: Colluvium overlying distressed sandstone exposed in a cut at the north east abutment

Figure 7: Trees tilting downslope at the north east abutment, indicating ongoing shallow soil movement

From a geotechnical perspective, the preferred approach would be to relocate the abutment and cable anchors at least 20 m above the observed landslide headscarp. However, this would significantly raise the elevation and subsequently the length of the bridge. Based on field observations it is not possible to confirm depth to competent rock. A possible rock exposure was observed at the base of the cut along the walking track but without further investigation it is not possible to confirm if this is the top of intact rock.

5.2.2 South west Abutment

Slopes on the western side of the valley are between 20° and 22° with an increase in slope angle up to 32° below the escarpment of an old slide on the creek flank. The proposed abutment location is approximately 12 m from this observed scarp. Trees below the scarp were observed to be leaning downslope, indicating possible ongoing slope instability. An older landslide scar was also observed approximately 12 m north of the proposed abutment which was evident by a surface depression and also identified in the landslide hazard maps as indicated in Figure 9.

Due to the proximity of the observed landslide features, it is recommended the south west abutment is moved further upslope. A preferred location was assessed, approximately 20 m upslope from the escarpment on the creek flank. Slope angles in this location are more consistent and lack undulations, hummocks or distinct breaks in slope, as indicated in Figure 8. However, a lack of outcrops or cuttings anywhere in the vicinity of the abutment made it difficult to assess the depth to rock, although an estimate is provided in Table 7.

Figure 8: General slope characteristics at the south west abutment preferred location

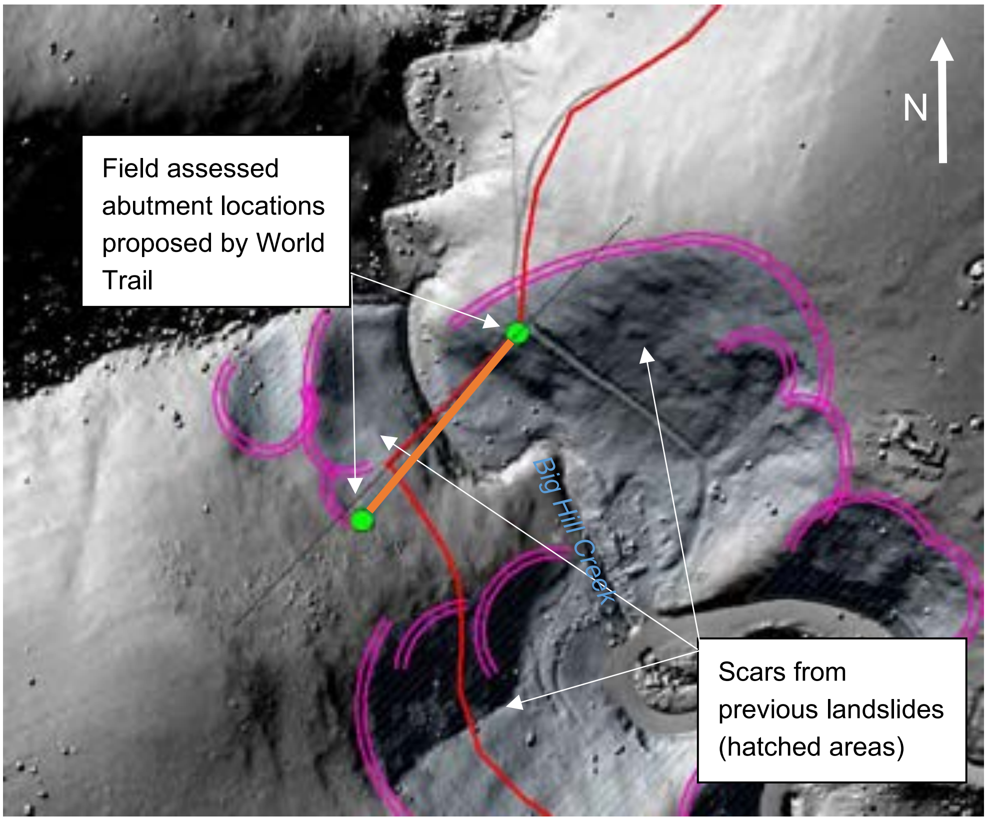

Figure 9: Extract from landslide hazard map at the proposed Bridge 1 location

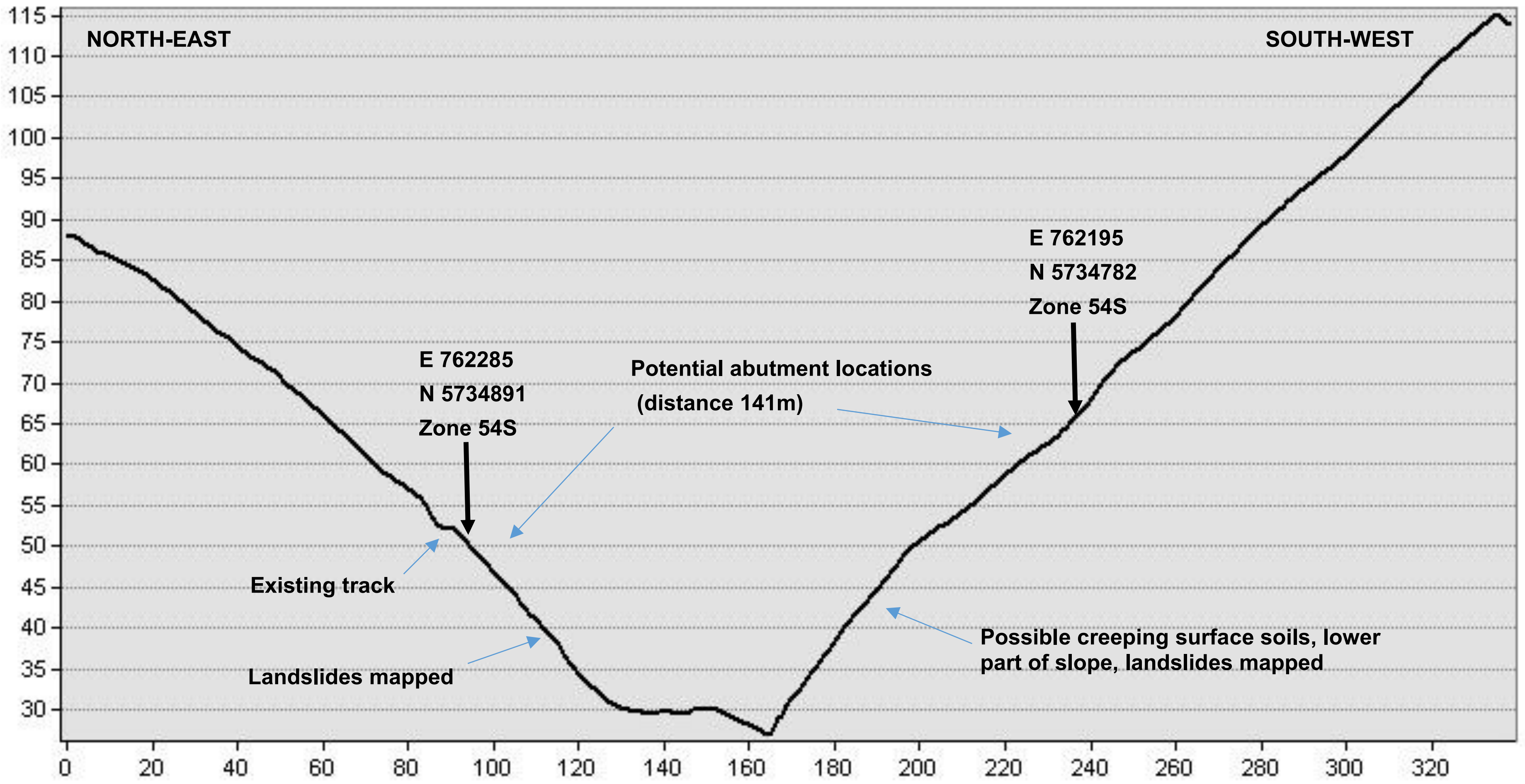

Figure 10: Terrain cross section at the potential Bridge 1 abutment location, looking south-east (axes in m)

5.3 Bridge 2 – Reedy Creek

Bridge 2 spans Reedy Creek in a section of track that traverses the hills to the north of Lorne. The bridge would span over the relatively steep sided base of the creek valley at this location.

Potential abutment locations were identified during the site visit, based on observed slope angles and surface geological conditions. Due to dense vegetation meaningful photographs of the sites described were not possible.

5.3.1 Western Abutment

The western slope of the valley appears to have undergone extensive landsliding of varying scales, including relatively large ground movements. The evidence for landslides on the western hillslope is shown in Figure 11.

The lower part of the Reedy Creek valley is relatively steep sided, with slope angles typically greater than 45°, and with near subvertical rock outcrops locally. The slope angles generally decrease with increasing elevation on both sides of the valley, except in some locations on the western side where landslide activity has disrupted the natural hillslopes.

Geological observations in the vicinity of the proposed western abutment location include landslide colluvium with boulders, which indicates reasonably deep seated landsliding including rock. To the south of the proposed abutment location, a raised hillock of material containing boulders is inferred to be landslide debris that has heaved as a large landslide has come to rest. The preferred abutment location based on geohazaed considerations is at the crest of what appears to be a smaller landslide scar in the lower part of the valley. Exposed intact rock mass was observed in the headscarp of the smaller landslide, however based on the larger scale landforms present, the intact rock mass could either be part of the material within the larger landslide mass that HAS NOT been disrupted during sliding, or it may underlie the debris from the larger landslide. Should the preferred location be sited on the larger landslide mass, it appears to be relatively old and stable as a larger mass, with no signs of recent slope distress observed, so is expected to present a relatively low risk of movement.

The suggested abutment location is approximately 5 m to 10 m back from the crest of the smaller landslide scar discussed above, to reduce the potential for the instability in the headscarp being triggered by bridge loading as well as reducing the risk of natural headscarp regression impacting the bridge abutment.

The ground surface materials at this location were not observed due to vegetation cover, however the rock exposed in the smaller landslide scarp appeared to be low strength. The rock structure such as defects and bedding could not be assessed. Should similar intact rock be present at the proposed location, assuming it is not underlain by more disturbed landslide debris material, it is likely to be practical to design abutment footings (e.g., anchored pad footings or piles) founding on or within the rock.

5.3.2 Eastern Abutment

The eastern slope of the valley does not appear to be significantly affected by landslide, with no signs of slope distress observed. In the base of the valley, the slope angles are generally above 45°, with slopes locally steeper than 60°. The material exposed in the steeper slopes is low strength sandstone rock. Further up the slope, the slope angles decrease, with the proposed abutment location on a slope of about 20° to 25°.

It can be inferred that based on the large scale landsliding on the western slope and the absence of landsliding on the eastern slope, that the sandstone bedding is likely to dip down towards the east, which would reduce the potential for landsliding on the eastern slope.

Based on the landforms observed, it is inferred that rock will be relatively shallow in the vicinity of the proposed eastern abutment location, with overlying layers of residual soil and possibly a relatively thin surface covering of colluvium present. It appears likely to be practical to design abutment footings (e.g., anchored pad footings or piles) founding on or within the rock.

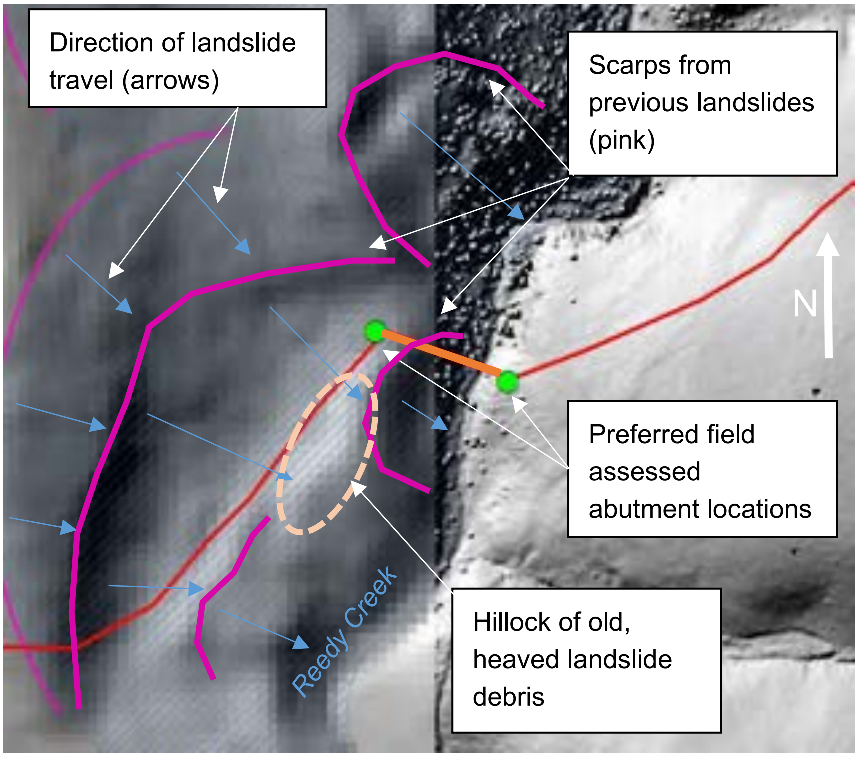

Figure 11: Extract from landslide hazard map at proposed Bridge 2 location

5.3.3 Suggested Bridge Layout

Based on the hazard mapping and site observations set out above, Figure 12 presents a cross section along the proposed bridge indicating abutment locations positioned to avoid potentially unstable ground. We note that these locations are indicative only and that intrusive site investigation will be required to inform detailed design. Other pertinent observations at each bridge location are also presented on Figure 12.

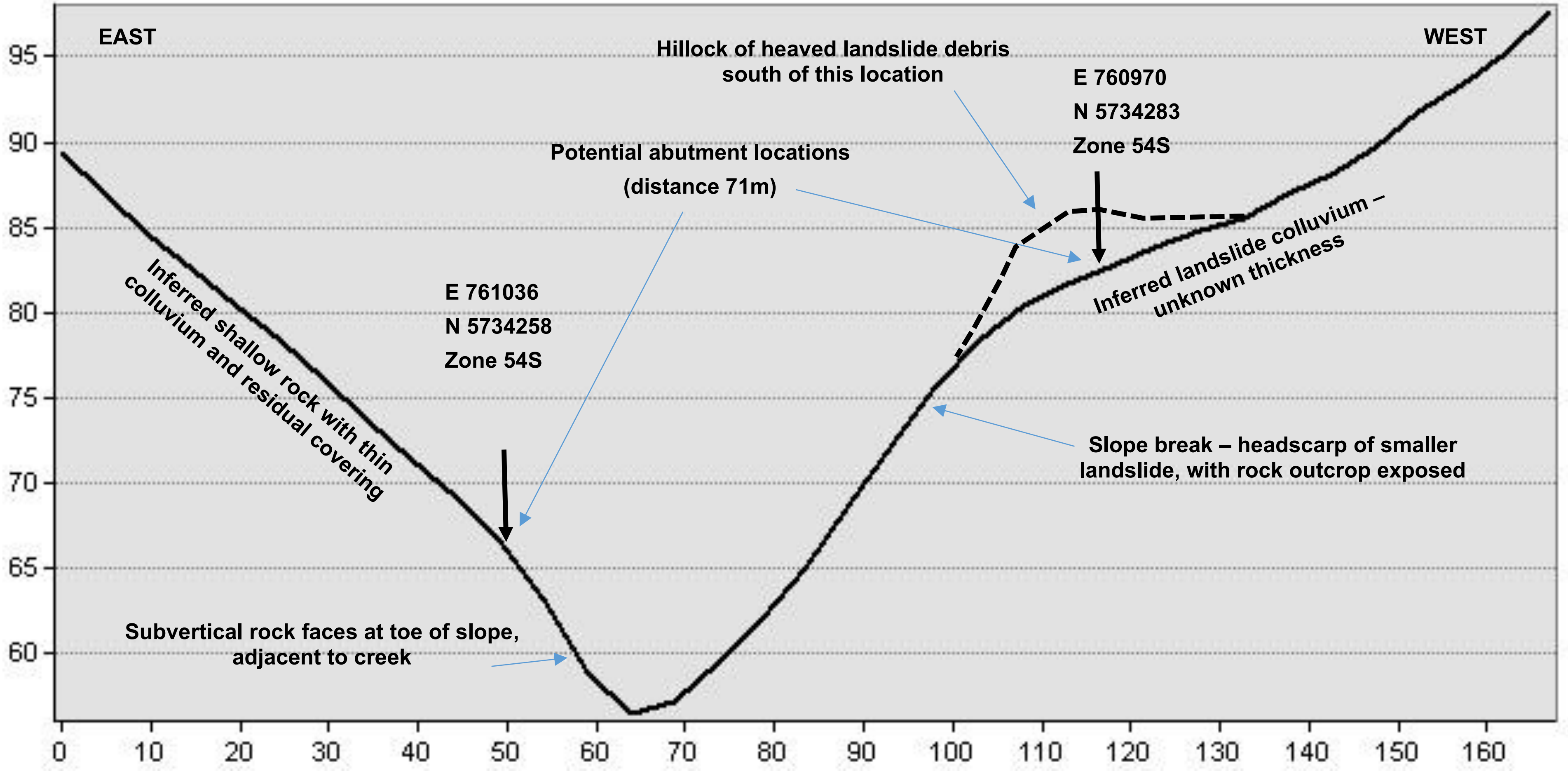

Figure 12: Terrain cross section at the potential Bridge 2 abutment location, looking south (axes in m)

5.4 Bridge 3 – Cumberland River

Bridge 3 spans the Cumberland River. This site was not visited due to accessibility constraints. However, assessment of the bridge based on remote mapping (Figure 13) suggests it would require a length of about 450 m so that the abutments are located within areas that are not susceptible to mapped hazards.

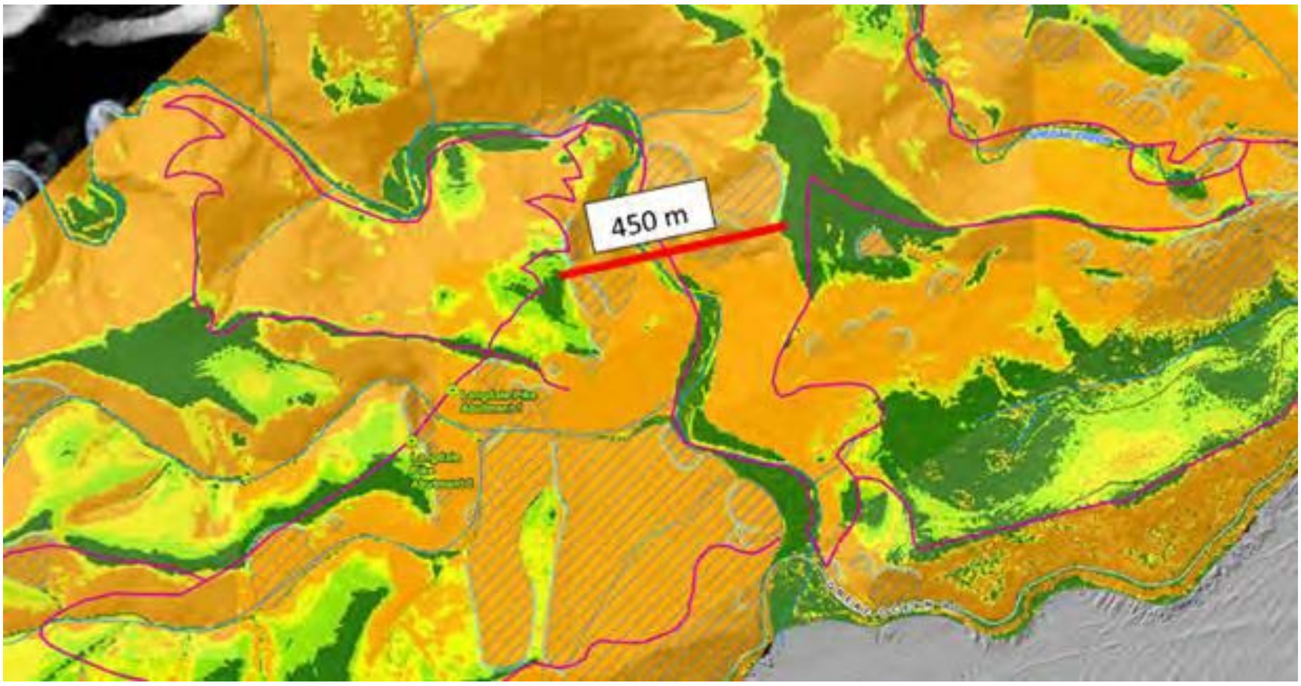

Figure 13: Shallow soil landslide hazard map extract showing approximate location and length of the proposed Cumberland River bridge

5.5 Bridge 4 – Winterbrook Falls

Bridge 4 spans a steep-sided valley, the sides of which expose flat-dipping Cretaceous rock as indicated in Figure 14.

Figure 14: View towards south west along proposed bridge alignment

The landslide hazard map indicates the valley to be susceptible to landslides as indicated in Figure 20. This observation was confirmed by site observation, with the prominent landslide scarp as indicated in Figure 20 observed in the field.

Figure 15: Headscarp of landslide to east of proposed north east bridge abutment

5.5.1 North east Abutment

The crest of the valley is defined by a prominent break in slope with slope angles above the break in slope of about 10° and below of 60° to 80°. The steep slopes below the break in slope appear to be subject to landslide, rock fall and creep, consistent with indications from the hazard mapping. For a distance of about 10 m back from the edge of the break in slope the ground is irregular with low terraces about 200 mm high which may indicate previous ground movement.

Outcrop of subhorizontal (dip of less than 10°) sandstone beds are exposed near the crest of the valley over which the bridge is proposed to span as indicated in Figure 16. The sandstone is typically medium to high strength, with bedding spacing of 300 mm to 500 mm, although some local thicker beds were observed. Based on these observations, the soil depth below the ground upslope of the break in slope is inferred to be relatively shallow, perhaps 1 m to 2 m.

A location at which no evidence for past ground movement is evident was identified about 30 m back from the escarpment. Its location is indicated in Figure 21.

Figure 16: Sandstone exposed on side of valley, below proposed north east abutment

5.5.2 South west Abutment

There is a similar, but less pronounced, break in slope at the south west bridge abutment with slope angle upslope of the break in slope of about 20° and below the break in slope of about 50°. The break in slope appears to be a landslide headscarp as indicated in Figure 17.

Figure 17: Break in slope at south west bridge abutment

Prominent sandstone beds were observed outcropping on the side of the valley as indicated in Figure 17. The beds are highly weathered, and of medium to high strength. The beds dip at about 10° back into the hillside and have typical thickness of 300 mm to 500 mm although there are some locally thicker beds and some interbedded, but thinner shale beds. Soil overlying the sandstone was observed. The soil is typically about 1 m to 2 m thick as indicated in Figure 19 and comprised of angular cobbles of sandstone embedded within a silt and clay matrix. This material is inferred to be colluvium (soil transported under the action of gravity) derived from residual soils further upslope.

A potential bridge abutment location was identified approximately 20 m upslope of the break in slope at a location that does not appear to be disturbed by past ground movement and is sufficiently offset from the landslide headscarp such that the likelihood of landslide regression up to the abutment location within the lifetime of the bridge is assessed to be insignificant.

Figure 18: Sandstone beds located about 20 m from proposed abutment location

Figure 19: Break in slope at south west bridge abutment

5.5.3 Suggested Bridge Layout

Based on the hazard mapping and site observations set out above, Figure 21 presents a cross section along the proposed bridge indicating abutment locations positioned to avoid potentially unstable ground. We note that these locations are indicative only and that intrusive site investigation will be required to inform detailed design. Other pertinent observations at each bridge location are also presented on Figure 21. Based on this assessment, the bridge span between abutments would need to be a minimum of 164 m.

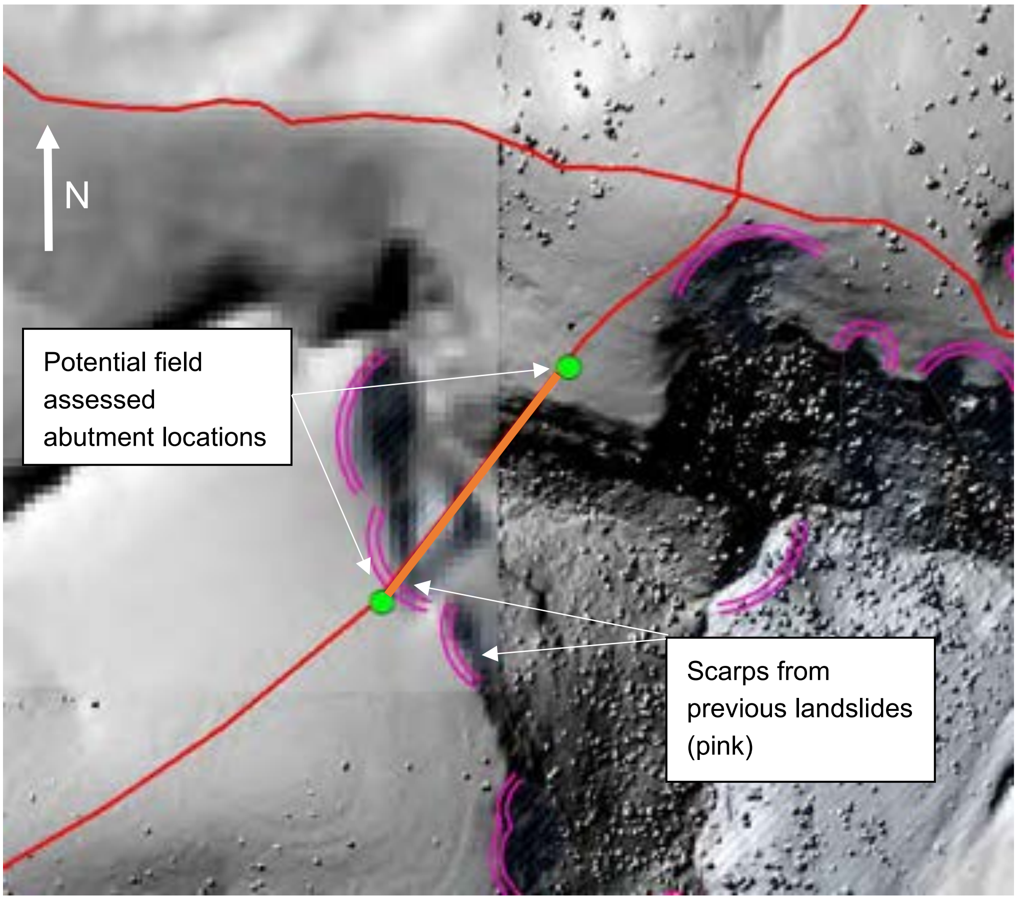

Figure 20: Extract from landslide hazard map at proposed Bridge 4 location

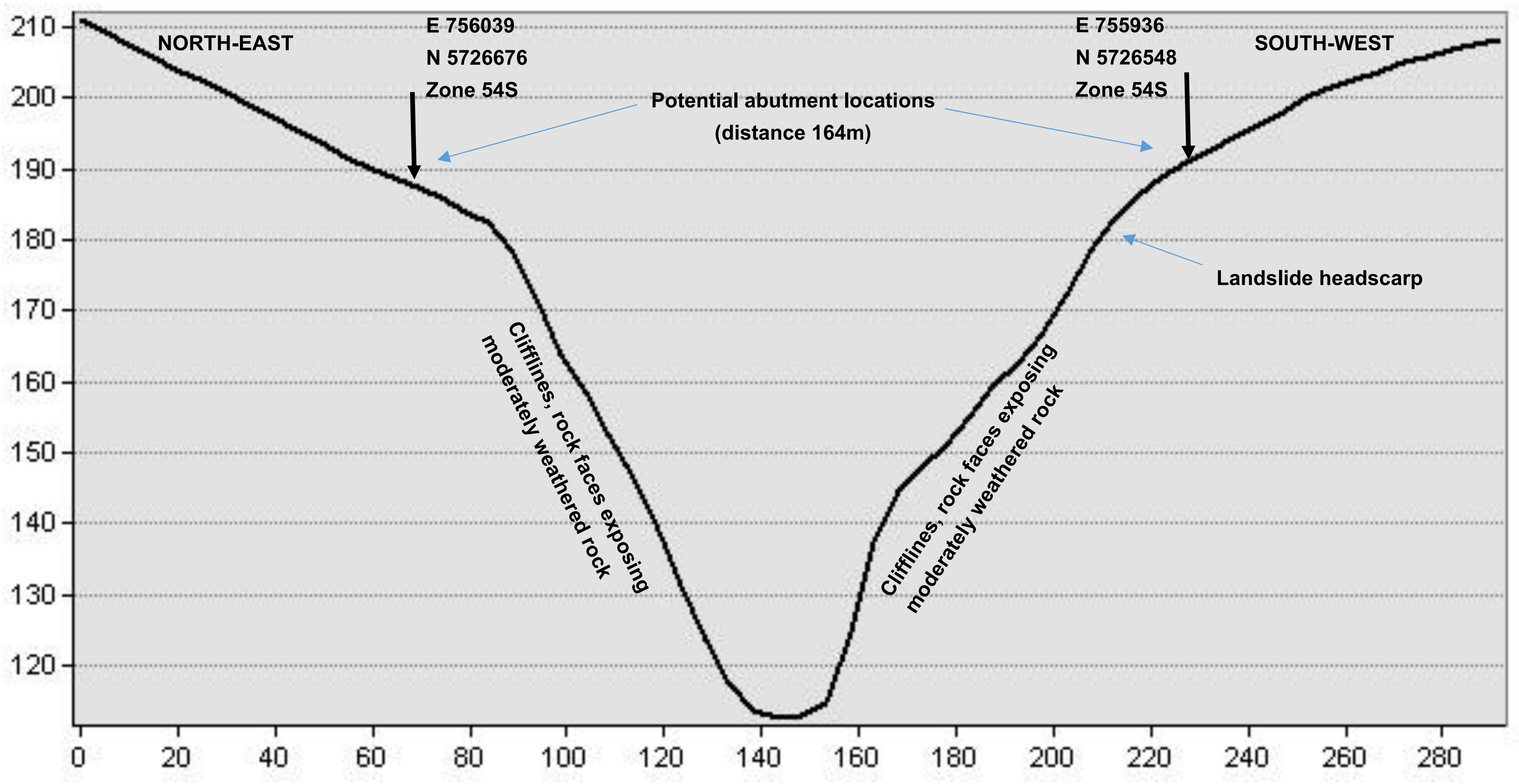

Figure 21: Cross section along proposed Bridge 4 indicating suggested abutment locations

5.6 Bridge 5 – Mount Defiance

Bridge 5 spans an unnamed creek which flows south east off Mount Defiance to the coast, entering the sea near the Mount Defiance lookout on the Great Ocean Road. Due to thick vegetation at this location, it was difficult to obtain photographs that show geological and geomorphological features. The creek over which the bridge spans is indicated in Figure 22.

Figure 22: View to south east along creek over which proposed Mount Defiance bridge spans

Figure 23 presents an extract from the landslide hazard map and indicates mapped landslides on the edges of the valley. The map indications are consistent with ground observations with features in the landscape indicative of past landslides observed at the same locations indicated on the hazard maps.

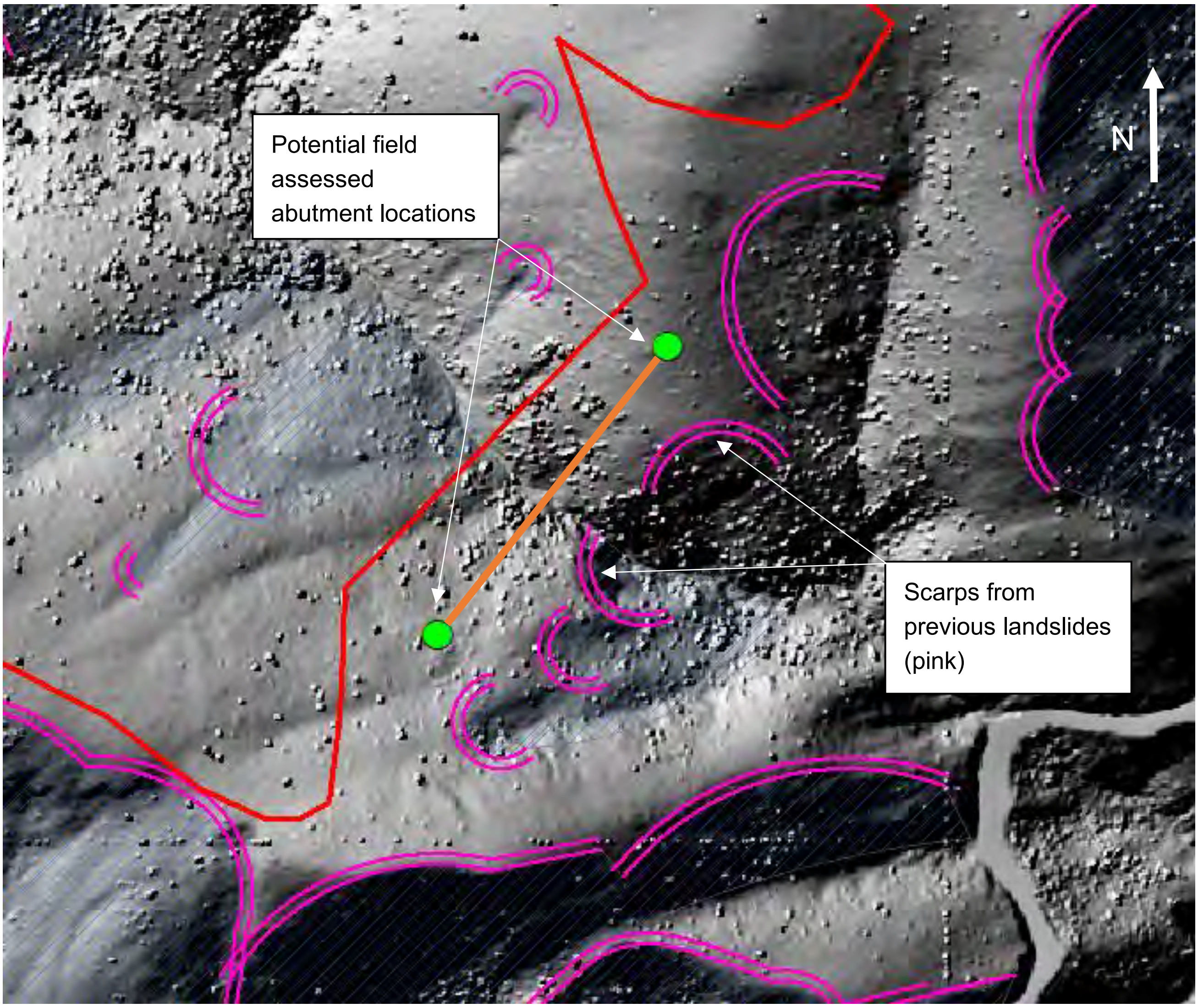

Figure 23: Extract from landslide hazard map at proposed Bridge 5 location

Breaks in slope at the Mount Defiance bridge site are less well defined compared to at other sites. Slopes on either side of the bridge are convex, with increasing slope angle down towards the creek. Slopes vary between about 20° and 24° about 50 m from the base of the creek, increasing to about 35° in the vicinity of the landslides as indicated in Figure 23 and near vertical at the creek where rock is exposed (Figure 22).

Rock outcrop is exposed in the creek valley and at the landslide headscarps on the western side of the creek. The exposed rock is sandstone, with bedding thickness variable, but up to 1 m. Bedding orientation can be measured at outcrops in the creek valley and whilst found to vary over short distances, measured bedding dip is typically less than 30°.

Soil thickness appears to increase towards the base of the valley. The soil on the sides of the valley appears to be colluvial, comprised of silt and clay which contains angular cobbles and boulders of sandstone. Terracing on the sides of the valley suggests some creep in the colluvium. Higher up the valley, the ground surface becomes more uniform, and it is postulated that soils are comprised of in situ residual soils.

The headscarp of landslides on the western side of the proposed bridge exposes rock as indicated in Figure 24. The exposed rock is dilated, with open defects between joints and bedding planes. Upslope of the inferred landslide headscarps, the soil appears to be relatively thin (Figure 24).

Figure 24: Rock outcrop on western side of proposed bridge

Based on the hazard mapping and site observations set out above, Figure 25 presents a cross section along the proposed bridge indicating abutment locations positioned to avoid potentially unstable ground. We note that these locations are indicative only and that intrusive site investigation will be required to inform detailed design. Other pertinent observations at each bridge location are also presented on Figure 25. Based on this assessment, the bridge span between abutments would need to be about 165 m.

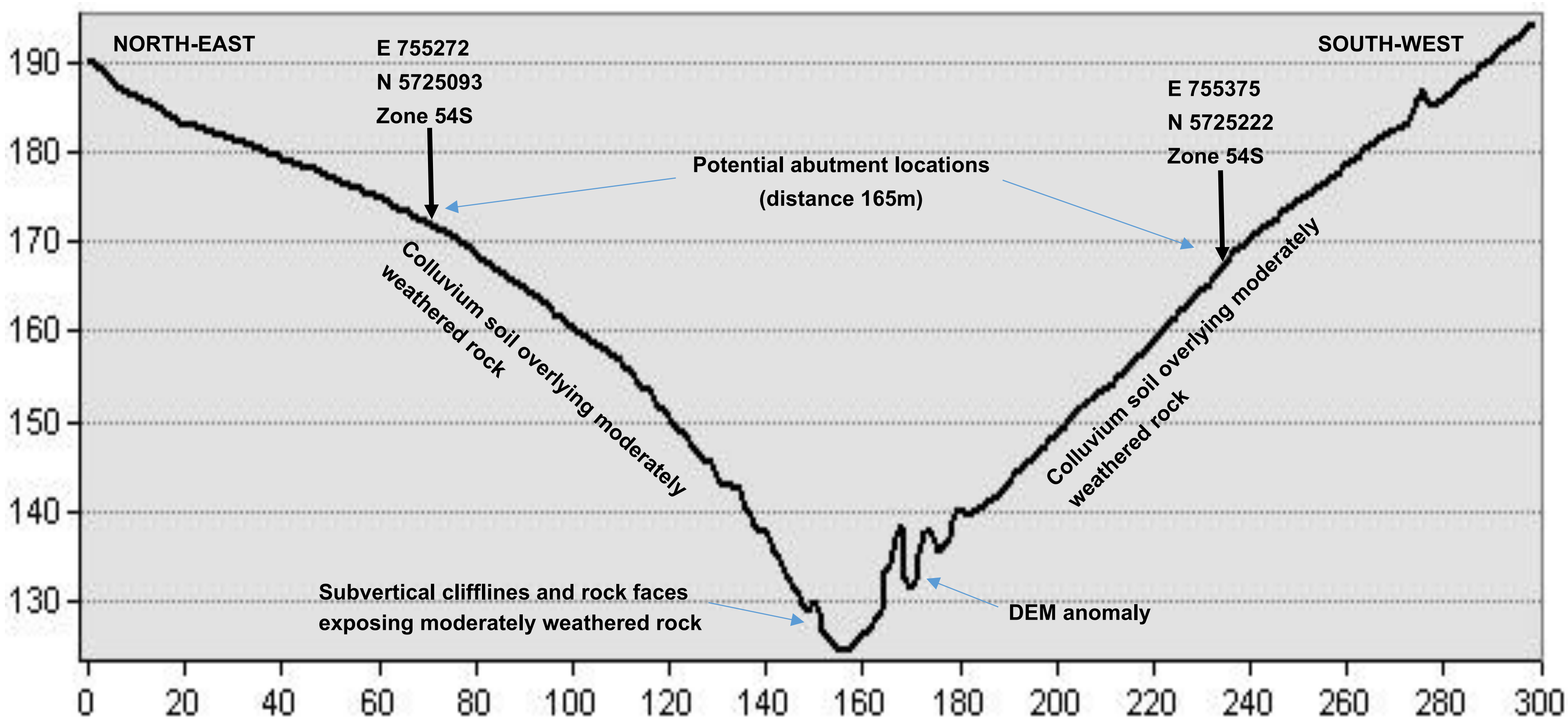

Figure 25: Cross section along proposed Bridge 5 indicating potential abutment locations

5.7 Geotechnical Conditions

A summary of geotechnical conditions at the potential bridge abutment locations is indicated in Table 7. Note that the anticipated conditions are based on surface observations only, and that targeted intrusive investigation will be required to investigate conditions at the proposed bridge locations.

Table 7: Summary of inferred subsurface conditions at bridge abutment locations

Bridge	Estimated depth to rock	Summary of expected subsurface conditions
Bridge 0 – Grassy Creek	Unknown at north-west abutment. 1 m to 2 m at south-east abutment.	The north-west abutment is underlain by what is inferred to be landslide colluvium of unknown thickness. Sandstone outcrops were observed in the vicinity of the south-east abutment, indicating relatively shallow rock. Overlying soils would be expected to comprise clayey sandy residual soils and slopewash colluvium.
Bridge 1 – Big Hill Creek	1.5 m to >4 m at north east abutment. 1 m to 2 m at south west abutment.	Competent sandstone was not observed at either abutment location, however, is expected to be present within a depth of several meters below the surface. Overlying colluvium materials consist of silty clay with angular gravel and cobbles, and distressed moderately weathered sandstone.
Bridge 2 – Reedy Creek	Unknown at north-west abutment – inferred thick landslide colluvium. 1 m to 2 m at southern abutment.	The north-west abutment is underlain by what appears to be intact rock mass, which may either be intact insitu rock or undisturbed rock mass as part of landslide colluvium of unknown thickness. No surface geology was observed at the abutment location, however rock outcrops at the base of the slope indicate shallow rock may be present. Overlying soils would be expected to comprise clayey sandy residual soils and slopewash colluvium.
Bridge 3 – Cumberland River	Not assessed, likely less than 2 m.	Based on exposures in the river valley observed from distance, rock is expected to be highly or less weathered with relatively flat dipping bedding planes.
Bridge 4 – Winterbrook Falls	1 m to 2 m both abutments	Sandstone, medium to high strength, highly weathered. Bedding dip of less than 10° with bedding spacing of 300 mm to 500 mm. Overlying soil is silt and clay, residual soil or colluvium containing cobbles of angular boulders.
Bridge 5 – Mount Defiance	1 m – 2.5 m, both abutments.	Sandstone, medium to high strength, highly weathered. Bedding dip variable, but up to 30° with bedding spacing up to 1 m. Overlying soil is inferred colluvium comprising silt and clay and containing angular cobbles and boulders.

Typical design parameters are presented in the following sections, noting that these are intended for use in assessing feasibility. Detailed investigation at proposed bridge abutment locations will be required to gather sufficient information to develop parameters suitable for detailed design. Access to abutment locations for geotechnical investigation may present significant practical difficulties. Given the size of the proposed bridge spans and the importance of confirming whether rock materials encountered in boreholes comprise intact weathered rock, or colluvial boulders, we consider it will be important that future investigation works are undertaken by mechanical drilling equipment able to advance boreholes by rock coring techniques. A working platform may need to be cleared of vegetation and levelled manually from which to undertake investigation work using drilling equipment air-lifted in by helicopter. Subsequent construction works will also need to consider the practical constraints associated with access to the proposed abutment locations.

For preliminary purposes, we expect the bridge abutment footings are likely to need to found on or within intact weathered rock. Where the depth to rock is less than about 1.5 m it may be practical to construct shallow spread footings (e.g., pad footings) that found on the rock, with ground anchors drilled into the rock to support tension loads. Based on the information in Table 7 shallow spread footings may be a practical alternative at the following abutment locations:

- Bridge 1 southeast abutment.
- Bridge 2 southwest abutment.
- Bridge 3 southern abutment.
- Bridge 4 both abutments.
- Bridge 5 both abutments.

Where the depth to rock means it is not safe or practical to construct shallow spread footings (i.e., abutment locations not listed above), bored piles socketed into the weathered rock may be required. Bored piles may be able to carry tension loads in the pile socket. Otherwise, ground anchors drilled into the rock may also be required.

For preliminary assessment of footing size and cost we suggest using the following preliminary design parameters. Targeted intrusive investigation will be required to confirm the design parameters to be adopted for detailed design:

- **Shallow footings:** Maximum allowable bearing pressure of 1000 kPa for pad or strip footings founding on highly or less weathered sandstone. Overlying soils should be removed to provide a clean rock surface on which to support footings.
- **Deep footings (piles):** Allowable unit skin friction of 150 kPa and allowable base resistance of 1500 kPa for highly or less weathered sandstone. Extremely weathered sandstone and soil above the weathered rock socket should be ignored for preliminary assessment. Detailed design of pile sockets will need to be undertaken in accordance with the requirements of AS2159 (2009) ‘Piling – Design and Installation’ using ultimate skin friction and base resistance values and a geotechnical strength reduction factor.
- **Ground anchors:** Allowable anchor grout/ground bond strength of 200 kPa in highly or less weathered sandstone. The geotechnical capacity achieved by anchors is dependent upon the method of construction. Anchor testing will be required as part of construction to confirm the capacities achieved. The effects of cone pullout should also be considered. The total weight of the rock or soil mobilised by the anchor system, multiplied by an appropriate design factor should be greater than the total applied pull out load. A cone with apex of about 60° extending from the embedded end of the anchor to the top of the bonded length should be used to estimate the volume of ground mobilised by the anchor. The load carrying portion of the bonded anchor length should be assumed to start at 0.5 m below the top of the bonded anchor length.
- **Sliding Resistance:** A typical interface friction angle to assess sliding resistance for concrete on highly or less weathered rock of 23°. This assumes the rock surface is clean of loose debris and roughened prior to concrete placement. The passive resistance to sliding derived from an embedded block may be defined by assuming a passive rock wedge defined by a plane extending 45° up from the base of the footing to the ground surface, a frictional resistance along the plane of 23° and a weight for the rock wedge of 23 kN/m^3.

- **Earthquake design:** Detailed design should be in accordance with AS1170.4 (2007) 'Structural design actions – Part 4: Earthquake actions in Australia'. For preliminary purposes adopt Class Be – Shallow Rock for abutment locations where the depth to weathered rock below residual soils or colluvium is expected to be less than 3 m (Bridge 1 southeast abutment, Bridge 2 southwest abutment, Bridge 3 southern abutment, Bridge 4 both abutments and Bridge 5 both abutments). For other abutment locations adopt Class Ce – Shallow Soil for preliminary purposes. Adopt a hazard factor (Z) of 0.10 based on the information on Figure 3.2(A) of AS1170.4 (2007) for the Otway Ranges.

6.0 NEXT STEPS

The following sets out the scope of works to be undertaken in the second stage:

- Once the draft trail alignment has been established, we will undertake a risk assessment which considers the risk to life and property for the proposed trail. This work will be required to support the planning submission. The risk assessment will take into account the geotechnical hazards through which the trail passes as have been identified in this study.
- The risk assessment will consider the number of people expected to use the trail and estimate the risk to life.
- The risk to property will also be considered

A coastal hazard vulnerability assessment will be undertaken for those areas where the trail is identified as being subject to moderate or high hazards associated with coastal erosion. This is also a planning requirement.

Targeted intrusive geotechnical investigation will also be required as part of future studies (not part of the current scope) at the proposed bridge abutment locations. Constraints on access will present practical difficulties for investigation of the proposed abutment locations.

7.0 IMPORTANT INFORMATION

Your attention is drawn to the document – 'Important Information Relating to This Report', which is included in Appendix E. The statements presented in this document are intended to advise you of what your realistic expectations of this report should be. The document is not intended to reduce the level of responsibility accepted by Golder, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing.

Signature Page

Golder Associates Pty Ltd

Darren Paul
Principal Engineering Geologist

DRP/SC/hn

A.B.N. 64 006 107 857

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APPENDIX A

Summary of GIS Information Provided

The following summarises the information provided on the GIS package which accompanies this report.

Layer	Description
Geomorphic and Landform Mapping	
Landforms	Delineation of landform units within a corridor approximately 100 to 250 m from the concept alignment. Includes an assessment of geomorphic processes acting within each terrain unit and estimate of the level of confidence of that process occurring. Produced by ASMG and EGS. (*Layer: Draft_GOR_Trail_Dec_2021_ASMG_Mapped_Landform_Units*)
Surface Geology	1:50,000 geological maps showing mapped geology at the ground surface according to publicly available geological maps produced by the GSV. (*Layer: GOR_Trail_Dec_2021_GSV_Surface_Stratigraphy_50K; GOR_Trail_Dec_2021_GSV_Surface_Geological_Age_50K*)
Structural Geology	1:50,000 geological maps showing mapped geological structure at the ground surface according to publicly available geological maps produced by the GSV. (*Layer: GOR_Trail_Dec_2021_GSV_Surface_Geological_Structures_50K*)
	Geological information pertaining to dykes and marker beds as sourced from the GSV. (*Layer: GOR_Trail_Dec_2021_GSV_Surface_Geological_Dykes_Marker_Beds_50K*)
Landslides	Delineation of existing landslides produced using digital elevation information. Expanded by Golder from publicly available CCMA landslide inventory available at https://www.ccmaknowledgebase.vic.gov.au/soilhealth/soils_map.php (*Layers: Draft_GOR_Trail_Dec_2021_Golder_Mapped_Landslide_Headscarps: Draft_GOR_Trail_Dec_2021_Golder_Mapped_Landslide_Footprints; GOR_Trail_Dec_2021_CCMA_Landslides_point; GOR_Trail_Dec_2021_CCMA_Landslides_polyline; GOR_Trail_Dec_2021_CCMA_Landslides_washaways*)
Earthworks	Delineation of cut and fill batters in the vicinity of the route. (Layers: *Draft_GOR_Trail_Dec_2021_Golder_Mapped_Cuts; Draft_GOR_Trail_Dec_2021_Golder_Mapped_Fills*)
Hazard Maps	
Earthworks	Maps indicate hazard level with respect to failures associated with earthworks. Two susceptibility maps are provided for cuts, with one applying when the cut is comprised of rock and one applying when the cut is comprised of soil. Investigation has not been undertaken to identify which cuts are comprised of rock and which are comprised of soil. The maps are intended to be used in conjunction with field inspection. (*Layers: Draft_GOR_Trail_Dec_2021_Golder_Cut_Failure_Hazard_Rock; Draft_GOR_Trail_Dec_2021_Golder_Cut_Failure_Hazard_Soil; Draft_GOR_Trail_Dec_2021_Golder_Fill_Failure_Hazard*)
Rock Falls	Rock fall hazard rated as very high to very low hazard. The data is provided in eight (8) separate files covering the original concept route corridor. *(Layers: Draft_GOR_Trail_Dec_2021_Golder_Rockfall_Hazard_1 to Draft_GOR_Trail_Dec_2021_Golder_Rockfall_Hazard_8)*

Layer	Description
Landslides	Maps indicating very high to very low hazard to shallow landslides in soil materials and deep landslides in rock. The data is provided in eight (8) separate files covering the original concept route corridor. *(Layers: Draft_GOR_Trail_Dec_2021_Golder_Shallow_Landslide_Hazard_1 to Draft_GOR_Trail_Dec_2021_Golder_ Shallow_Landslide_Hazard_8: Draft_GOR_Trail_Dec_2021_Golder_Deep_Landslide_Hazard_1 to Draft_GOR_Trail_Dec_2021_Golder_Deep_Landslide_Hazard_8)*
Debris Flow	Maps indicating very high to very low hazard to debris flow. *(Layer: Draft_GOR_Trail_Dec_2021_Golder_Debris_Flow_Hazard)*
Episodic Erosion	Maps indicating very high to very low hazard to episodic erosion, defined by the episodic collapse of cliffs of shorelines. (Electronic data will be provided with final version of report)
Progressive Erosion	Maps indicating very high to very low hazard to erosion. (Electronic data will be provided with final version of report)

APPENDIX B

Hazard Identification and Analysis

TABLE OF CONTENTS

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Tables

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1.0 FACTORS CONTRIBUTING TO GEOHAZARDS

Geological hazards (geohazards) require *preparatory* and *causal* factors:

- Preparatory factors refer to the conditions required for geohazards to occur at a particular location, these include:
  - Geology – rock or soil type encountered at the ground surface. Different rock or soil types have different susceptibility of rockfall and landslide.
  - Structural geology – discontinuities within rock or soil (faults, bedding planes, joints). Ground is weakest along discontinuities and their frequency and orientation has an influence on where geohazards occur.
  - Geomorphology – land formation, including slope angles and the 'shape' or 'form' of the ground surface has an influence on where geohazards could occur. The angle of the slope being perhaps that most common influence. Note that earthworks, which are essentially human induced modifications to geomorphology are also a preparatory factor.
- Causal factors are those that actually trigger the geohazard, for example:
  - Rainfall – water infiltration into the ground is the most common trigger of landslides in Victoria.
  - Earthquake – earthquakes can trigger landslide or rockfall.
  - Climate and climate change – although not a causal factor in itself, climate change and climate trends can influence the frequency within which other causal factors occur and are therefore an important consideration. For example, changes in rainfall patterns, coastal erosion rates, or vegetation (e.g., bushfire losses).

The following provides background information with respect to the preparatory and causal factors described above that could lead to the occurrence of geohazards in the vicinity of the proposed trail.

1.1 Geology and Structure

The underlying geology is a significant preparatory factor for geohazards in the Otway Ranges. The proposed trail is broadly underlain by two separate geological units.

The most extensive surficial geology is the Early Cretaceous Eumeralla Formation of the uplifted Otway Ranges extending northwest from the coast between Cape Otway and Anglesea and inland from Moonlight Head to Wensleydale north of Anglesea. Eumeralla Formation rocks outcrop as almost continuous coastal cliffs and shore platforms for most of the proposed trail alignment between Eastern View and Skenes Creek.

The eastern approximately 8 km of the proposed trail between Fairhaven and Eastern View is underlain by younger (Cenozoic) geology (Figure B1). These weak sedimentary rocks were deposited by a marine incursion in an embayment (Torquay Embayment or Torquay Basin). The Cretaceous and Cenozoic rocks are discussed separately in the subsequent sections.

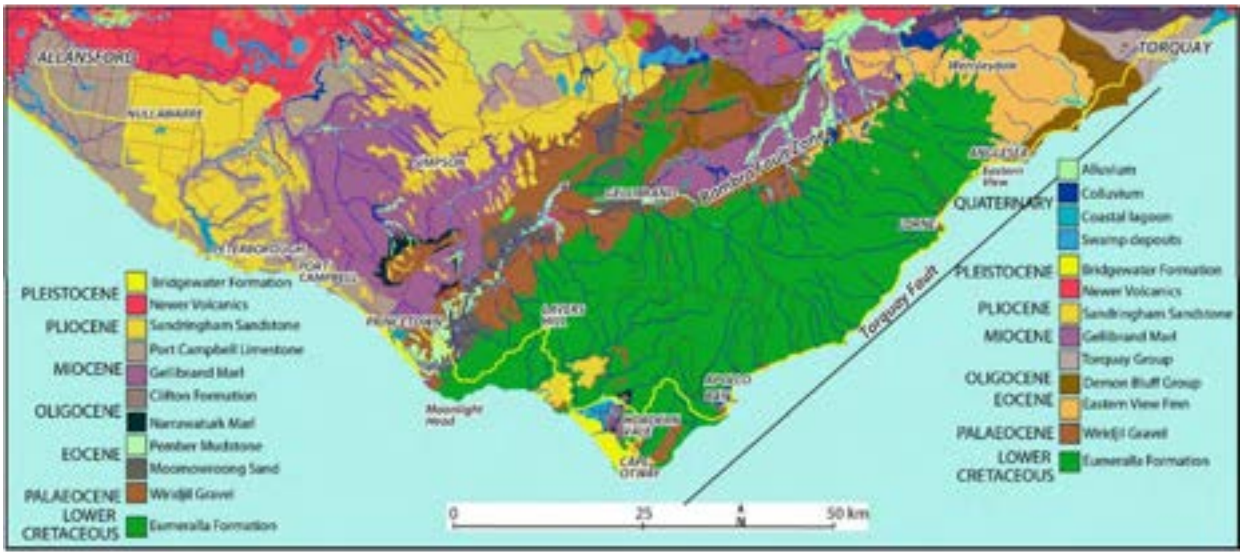


Figure B1: Generalised geology of Great Ocean Road and bounding faults of Otway Ranges (after GSV 1:250,000 scale Seamless Geology)

1.1.1 Early Cretaceous: Eumeralla Formation

The Eumeralla Formation is of sedimentary origin (Duddy, 2003)[1]. A range of sedimentary rocks occurs (generically termed arkose or greywacke) with medium to fine-grained sandstones and siltstone-mudstone dominant. Volcanic rock fragments comprise 60% to 70% of most beds with minimal free quartz grains.

Rounded to elongate carbonate-cemented concretions of decimetre to metre size are an integral part of the sedimentary beds and occur along bedding planes—in places locally abundant e.g., Artillery Rocks.

1.1.2 Cenozoic: Torquay Basin

The Cenozoic sediments of the Torquay Basin occur in an intra-basinal structural embayment or trough as indicated in Figure B2.

[1] Duddy I.R. (2003). Mesozoic: a time of change in tectonic regime. In: Birch W.D. ed. Geology of Victoria, pp. 239-286. Geological Society of Australia Special Publication 23. Geological Society of Australia (Victoria Division).

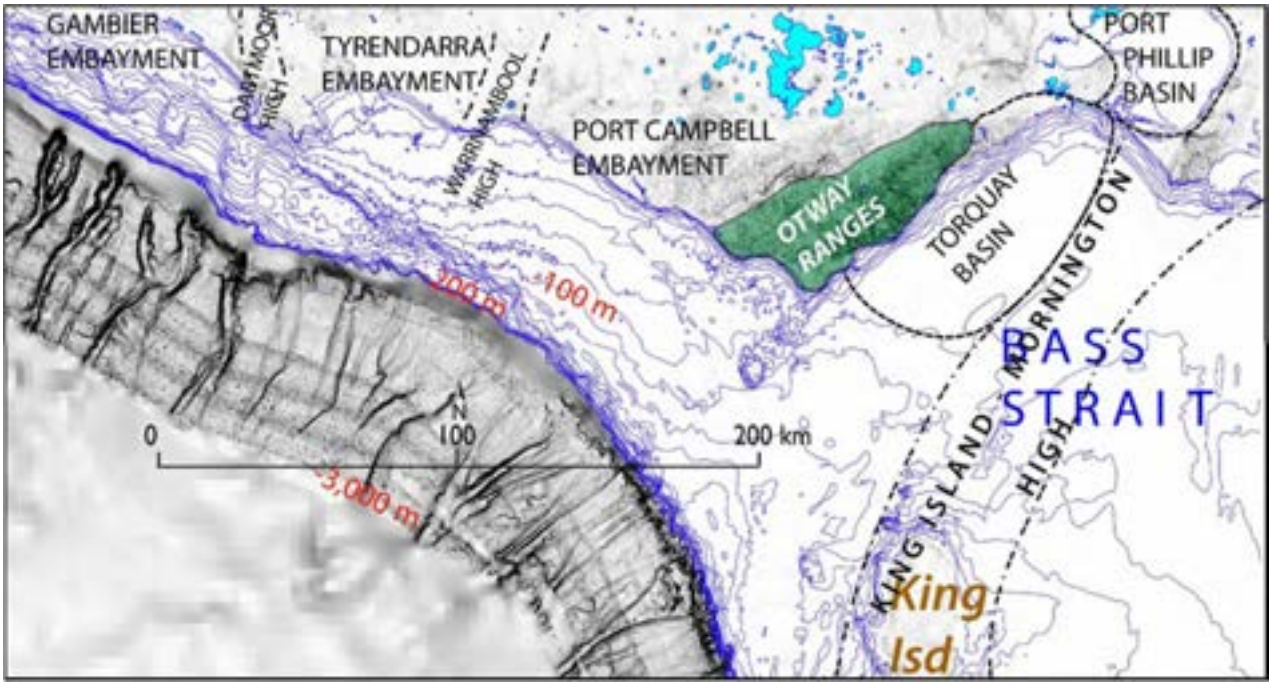


Figure B2: Early Cenozoic embayments and separating highs in relation to Eumeralla Formation of Otway Ranges

The type of sediment deposited in the embayment basins was influenced by the depth of the ocean, marine conditions, the landward position of the shoreline and sediments deposited from fluvial sources as deltas. The transgressive-regressive sequences are now exposed in coastal cliffs. The nature of the contact between the Cenozoic and Cretaceous materials is illustrated in Figure B3.

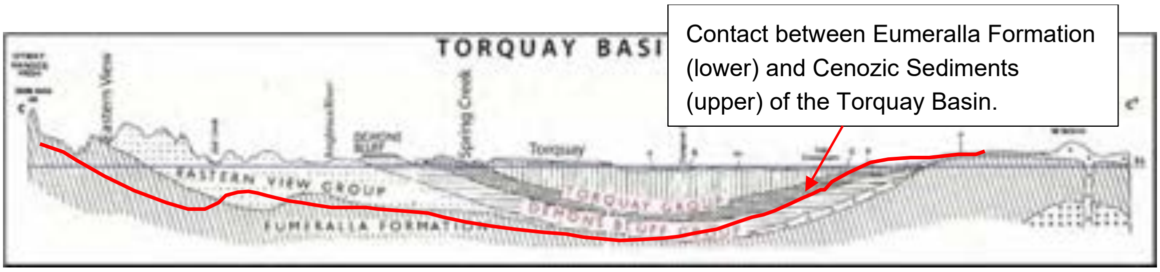


Figure B3: Diagrammatic profile southwest to northeast of main units of onshore Torquay Basin (Modified after Abele 1979[2])

The sediments comprising the Torquay Basin are up to 7 km thick, and are comprised of three main stratigraphic units interpreted to represent a transgressive sequence deposited on a shallow to open shelf: The Eastern View Group, Demons Bluff Group and Torquay Group (McLaren et al. 2009[3]).

The eastern portion of the proposed trail between Fairhaven and Eastern View crosses the two older groups, namely the Demons Bluff Group and the Eastern View Formation (Figure B4). These groups are discussed below.

[2] Abele, C., Geology of the Anglesea Area (1979), Central Coast, Victoria, Geological Survey of Victoria, Memoir 31

[3] McLaren, S., Wallace, M., Gallagher, S.J., Dickinson, J., McAllister, A. (2009). Age constraints on Oligocene sedimentation in the Torquay Basin, southeastern Australia. Australian Journal of Earth Science, 56: 595–604

Figure B4: Geology of onshore Torquay Basin (After GSV 1:50,000 scale Seamless Geology)

Demons Bluff Group

The proposed trail is expected to be underlain by the Demons Bluff Group from west of Fairhaven to Moggs Creek where it forms the plateau surface and bordering coastal slopes. The stratigraphy of the Demons Bluff Group comprises a range of sediments and interbedded volcanic materials as shown in the annotated photograph (Figure B5).

The predominant materials are carbonaceous clayey silts, fine sands and silty clays. Abele (1979)[4] summarised the nature and relationship of the Demons Bluff Group (then known as Demons Bluff Formation) as "…a somewhat variable unit including marine, continental and volcanic deposits sandwiched between continental Eastern View Formation and marine Torquay Group strata". The beds are gently folded and often closely fractured and the occurrence of weathered volcanic and other clay beds provide slip planes resulting in local- scale to landscape-scale landslides.

[4] Abele, C., Geology of the Anglesea Area (1979), Central Coast, Victoria, Geological Survey of Victoria, Memoir 31

Figure B5: Demons Bluff Group stratigraphy in cliff east of Anglesea River mouth

Eastern View Formation

The Eastern View Formation is the lowermost of the Torquay Basin units and crops out inland with limited coastal exposure or topographic expression. It is expected to underlie the portion of the proposed trail alignment between Moggs Creek and Eastern View. The Eastern View Formation is predominantly comprised of silt and clay beds with local accumulations of gravel.

1.1.3 Quaternary

The Quaternary Period spans the last 2.6 million years. It was a geologically active episode in south-western Victoria with extensive volcanicity, tectonics (resulting in local uplift and deformation), and changing climates and sea-levels leaving footprints which are very evident in the modern landscape. Geological materials deposited in the Quaternary relevant to this study include colluvium and other mass movement deposits, stream alluvium, lithic and organic sediments in lagoons and estuaries, and unconsolidated dunes.

Slope deposits from ancient and active landslides and other mass movement occur variably across the Eumeralla Formation and locally in the Demons Bluff Group. Fluvial sediments, or floodplains and terrace sediments are predominantly silt and clay with local concentrations of gravels in the Otway Ranges and are expected to be encountered at stream crossings.

Unconsolidated to weakly cemented dune sediments are expected to be encountered near the commencement of the proposed trail at Fairhaven.

1.2 Structural Geology

The Eumeralla Formation which underlies most of the proposed trail alignment is a bedded sedimentary rock which has been subject to tectonic deformation. It is structurally complex, both at the intra-bed and whole of rock mass scales. Jointing is common and typically closely spaced and at a high angle to bedding. Faults occur on a formation wide to local and micro scale (Medwell, 1971)[5].

On a macro-scale, the Eumeralla Formation of the Otway Ranges is an elongated dome, with pronounced southwest to northeast structural trend repeated in the axial strike of major faults and folds (monoclines, anticlines, synclines) across the ranges (Figure B6). The major faults have wide shatter zones with close-spaced fractures (Figure B7). A series of faults transverse to this trend are obvious along the coast where the offset can be traced across the shore platform exposures (Gill 1973[6], Medwell 1988[7]). Many valleys and ridges are oriented along fold and fault structures.

The inclined bedding within the Eumeralla Formation facilitates the occurrence of large scale, structurally controlled landslides, in particular where the bedding dip is parallel to slopes.

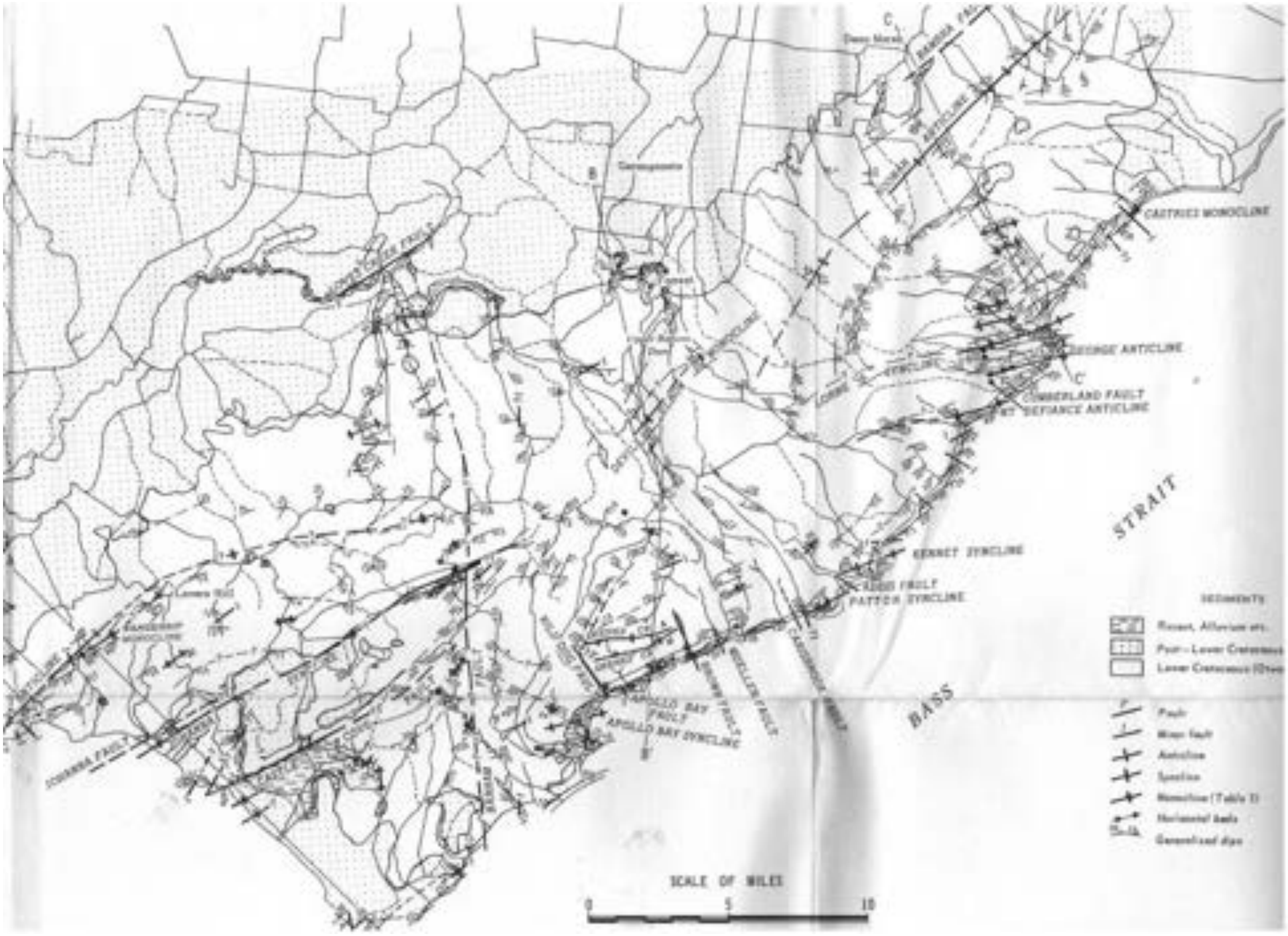


Figure B6: Structural features of Otway Ranges (Medwell, 1971)

[5] MedwellL, G.J. (1971). "Structure of the Otway Ranges" (in) The Otway Basin of South- eastern Australia". (eds). H. Wopfner and J.G. Douglas). Spec. Pub. geol. Survs. S. Aust. andVict.:339-362

[6] Gill, E.D. (1973) Rate and mode of retrogradation on rocky coasts in Victoria, Australia, and their relationship to sea level changes. Boreas 2(3):143-171

[7] Medwell, G.J. (1988), Western District – Otway Ranges. (in) 'Victorian Geology Excursion Guide' Clark I., Cook B., Cochrane G.C. (eds), Australian Academy of Science and Geological Society of Australia (Victorian Division), Section 11(3), pp. 133-156

Figure B7: Lorne Fault with a 100 m wide zone of shattered and crushed sandstone and mudstone beds of Eumeralla Formation [A small seaward-plunging synclinal fold west of the fault is probably created by drag on the fault. (Image from Nearmap Dec 2015, structure from Medwell 1988)]

1.3 Geomorphology

ASMG and EGS[8] in a study for the Great Ocean Road nominated a series of geomorphic ‘compartments’ or areas which have common geomorphic characteristics. Of relevance to this study are the geomorphic compartments between:

- Anglesea and Eastern View,
- Eastern View and Lorne,
- Lorne and Sugarloaf Creek,
- Sugarloaf Creek and Skenes Creek.

Geomorphic features in each of these compartments relevant to the proposed trail are summarized in the following sections.

1.3.1 Fairhaven to Eastern View

This portion of the proposed trail is underlain by Cenozoic sedimentary geology (Demons Bluff Group, Eastern View Formation). The landforms comprise a mix of gently sloping terrain and some steeper slopes with a relief range of approximately 70 m. The commencement of the trail at Fairhaven is on a low dune between the Great Ocean Road and beach. The trail then traverses a series of south east trending V-shaped valleys between Fairhaven and Eastern View. Figure B8 shows the hillshade terrain relief for this compartment.

[8] A.S. Miner Geotechnical, Environmental Geo-Surveys, Great Ocean Road Hazard Study, Report No: 1134/01/20, 29 June 2020

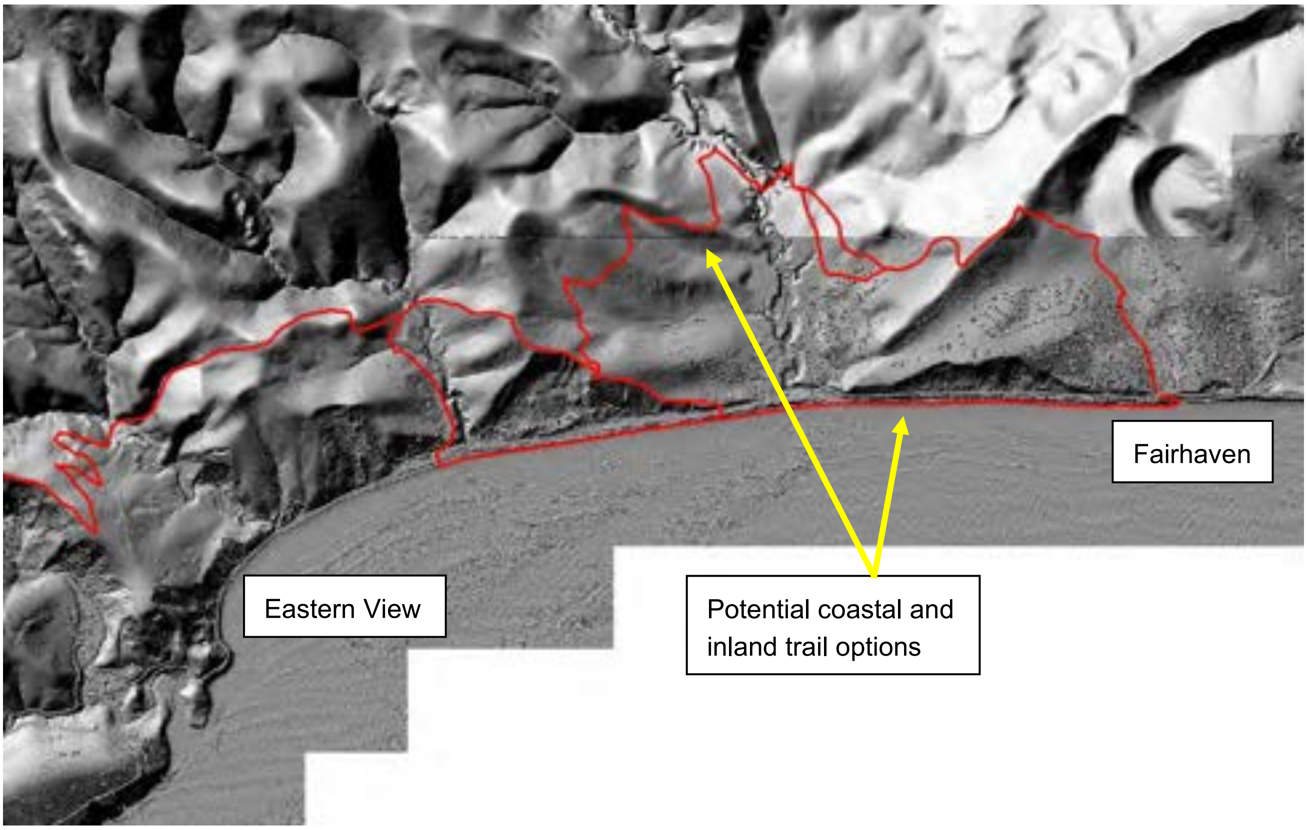


Figure B8: Fairhaven to Eastern View compartment on hillshade terrain relief (Proposed Concept Route 2 in red)

1.3.2 Eastern View to Lorne

Between Eastern View and Lorne, the trail traverses over the Eumeralla Formation, comprised of dipping sandstone and mudstone and comprising a mix of gently sloping terrain and some steeper slopes with relief range of about 100 m.

At some locations, the stratigraphic bedding dips towards the coast, resulting in significant landslides. Parts of the coast are formed by colluvium (landslide debris arising from these landslides). There are a series of low elevation areas near the coast at Grassy Creek, Spout Creek, Stony Creek, Reedy Creek and Erskine River with narrow floodplains underlain by alluvium. The coast is formed mostly from rocky shore platforms with occasional sandy interludes forming beaches. The most significant sand deposits are at Loutit Bay (near Lorne) with a beach and low dune deposit.

Figure B9 and Figure B10 show the hillshade terrain relief and typical coastal terrain respectively for this compartment.

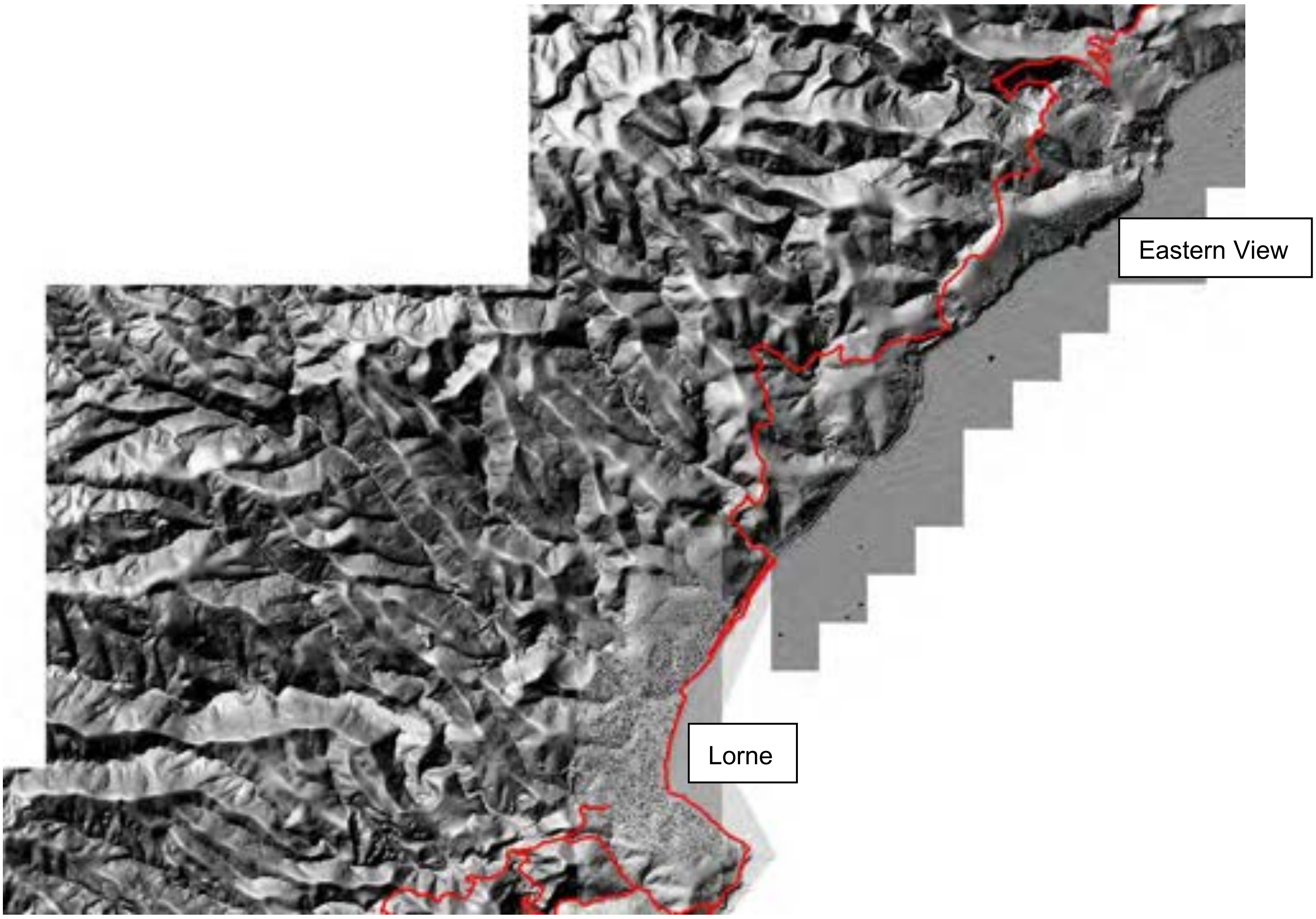


Figure B9: Eastern View to Lorne compartment on hillshade terrain relief (Proposed Concept Route 2 in red)

Figure B10: Aerial view showing example of typical coastal terrain between Eastern View and Lorne

1.3.3 Lorne to Sugarloaf Creek

This section of the proposed trail alignment is underlain by the Eumeralla Formation including sandstone and mudstone with clay inter beds. There are steep slopes down towards the coast and relief range of more than 100 m. There are some locations, for example Windy Point and Cumberland River where beds dip at up to 40° inclination towards the coast. These areas are subject to significant landslides. Furthermore, there are scree slopes derived from landslide material at the toe of the slopes.

There are several low elevation streams which meet the coast along this section. They typically flow out of steep V-shaped gullies, with narrow strips of associated alluvium in places. The water course crossings include Saint George River, Cumberland River, Jamieson Creek, Separation Creek, Wye River, Kennett River, Grey River and Sugarloaf Creek.

Figure B11 and Figure B12 show the hillshade terrain relief and typical coastal terrain respectively for this compartment.

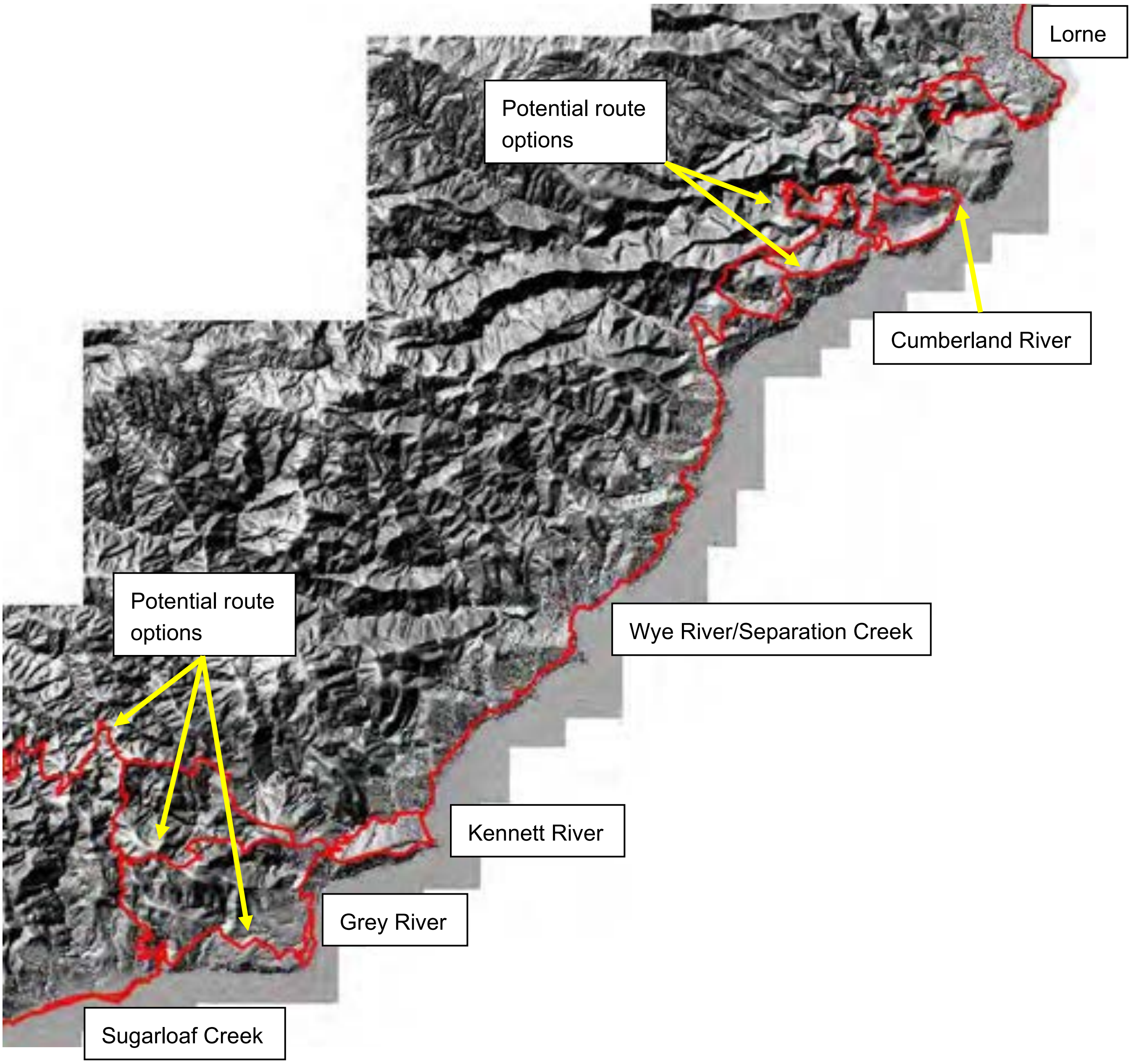


Figure B11: Lorne to Sugarloaf Creek compartment on hillshade terrain relief (Proposed Concept Route 2 in red)

Figure B12: Aerial view showing example of coastal terrain between Lorne and Sugarloaf Creek

1.3.4 Sugarloaf Creek to Skenes Creek

This section is comprised of colluvial and terrace slopes, overlying the Eumeralla Formation. Terrain is gently sloping. The coast is formed from rocky shore platforms with occasional beaches and with occasional low coastal foredunes. There is little rock outcrop along this section.

Figure B13 and Figure B14 show the hillshade terrain relief and typical coastal terrain respectively for this compartment.

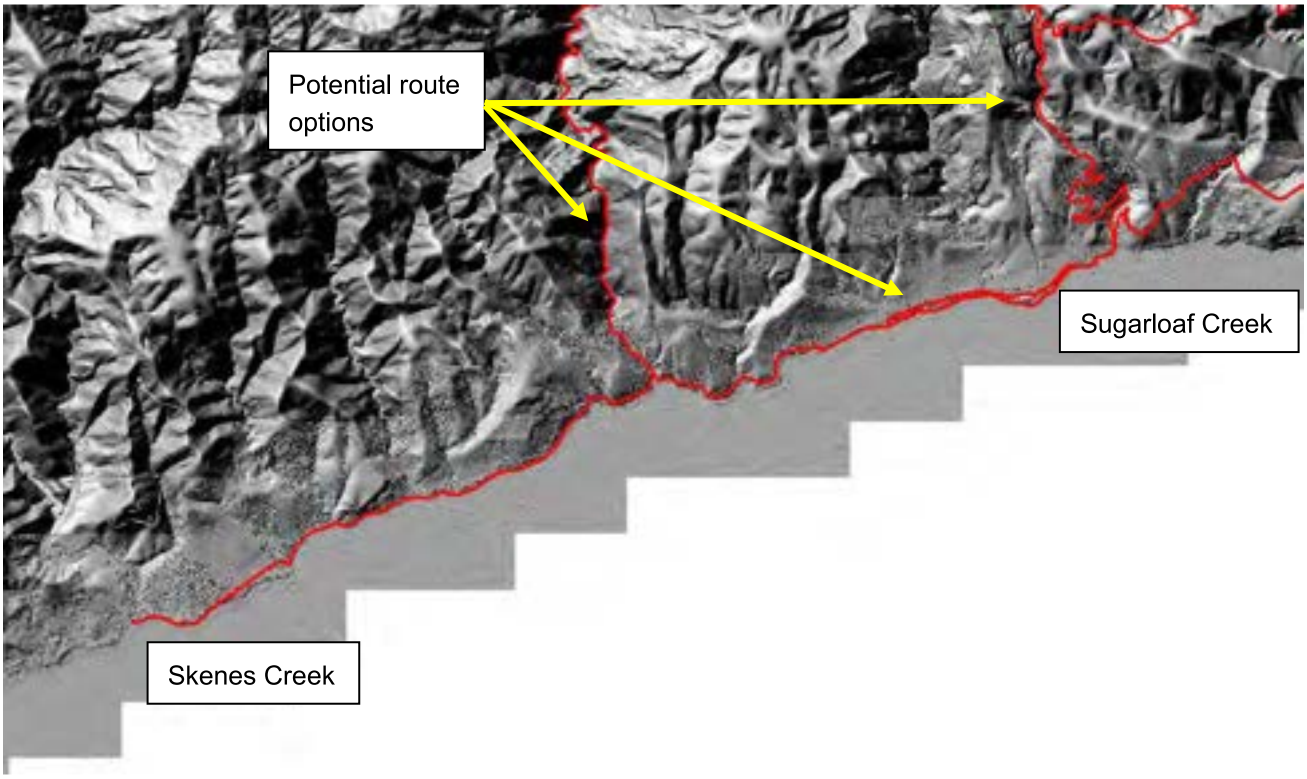


Figure B13: Sugarloaf Creek to Skenes Creek compartment on hillshade terrain relief (Proposed Concept Route 2 in red)

Figure B14: Aerial view showing example of coastal terrain between Sugarloaf Creek and Skenes Creek

1.4 Climate and Climate Change

Climate, and in particular rainfall is the key causal factor for landslides, rockfalls and erosion along parts of the proposed trail. A discussion on prevailing climate and potential climate change is provided below.

1.4.1 Prevailing Climate

The general weather patterns of south-western Victoria are determined by the passage of alternating high and low pressure systems that regularly pass west to east across southern Australia. Rainfall is strongly influenced by elevation (Figure B15). The highest rainfall – >1800 mm annually – occurs along the main ridge, generally to the north of the proposed trail with 1935.8 mm annual average rainfall at Weeaproinah ranking it among the wettest areas of Victoria. The northeast is a marked rain shadow with <600 mm rainfall annually at Torquay.

Figure B15 shows the marked seasonality of rainfall with average July rainfall being 250% more than in January. On average the wettest months are May to October with 60% to 65% of the rain occurring over those months. Rainfall is very reliable with the coefficient of variation for the West Coast region including the Otways of 0.16, the lowest in Victoria. Although the summer rainfall total is lower, heavy falls with high intensity can be experienced between November and March. Rainfall is a key contributing factor to landslides in the Otways. Antecedent rainfall (the accumulation of rainfall over time) can cause a build up water in the soil which eventually leads to instability. Heavy, short duration rainfall can also trigger landslides.

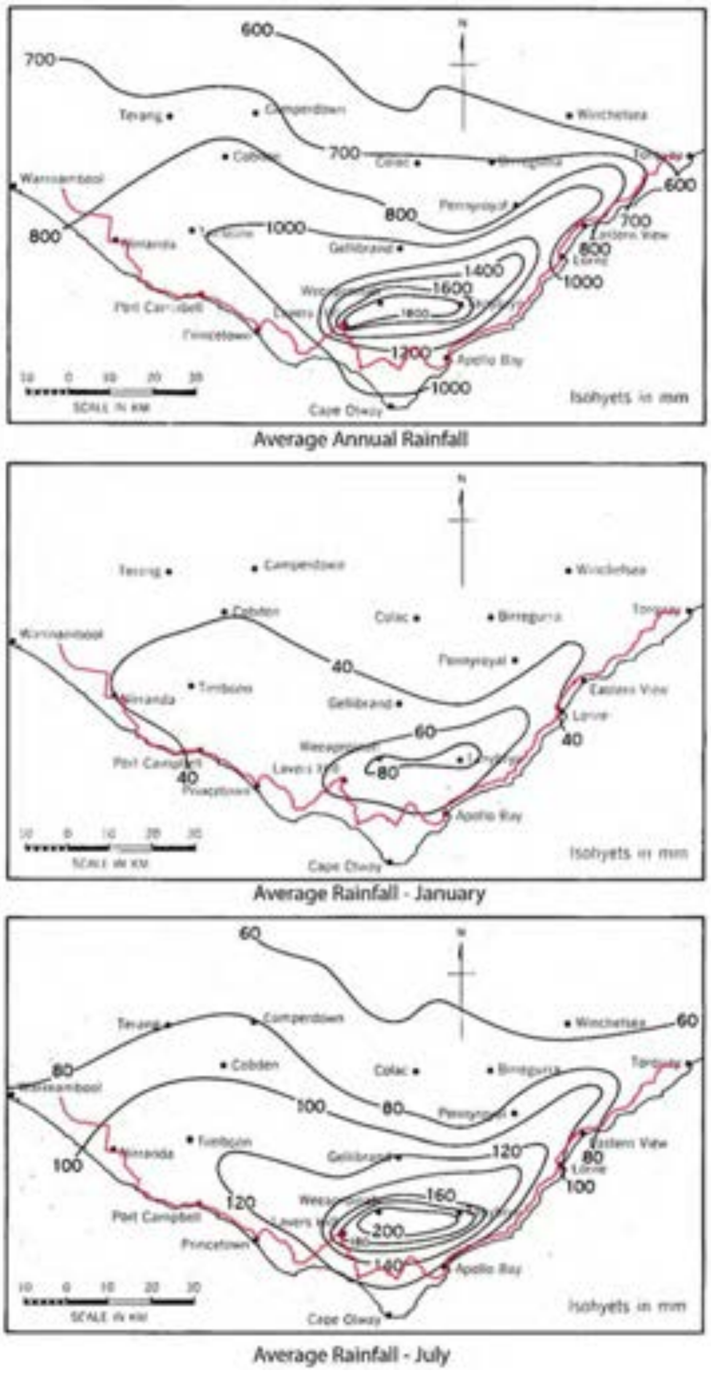


Figure B15: Rainfall (isohyets) [Average annual, average January (centre), average July (bottom). From Linforth (1977)[9]]

1.4.2 Climate Trends

The Victorian Government's 'State of the Environment Report' (2018)[10], provides an overview of both the current condition of Victoria's climate and trends based on past climatic data. This indicates anomalously low rainfall since the mid 1990's as shown in Figure B16. Future climate modelling predicts a reduction in rainfall within Victoria as indicated in Figure B17.

[9] Linforth, D.J. (1977) The Climate of the Otway Region. Proceedings of the Royal Society of Victoria. Vol. 89 Part 1 pp. 61-68

[10] Commissioner for Environment Sustainability Victoria, Climate Change Impacts, Scientific Assessments Part III, 2018

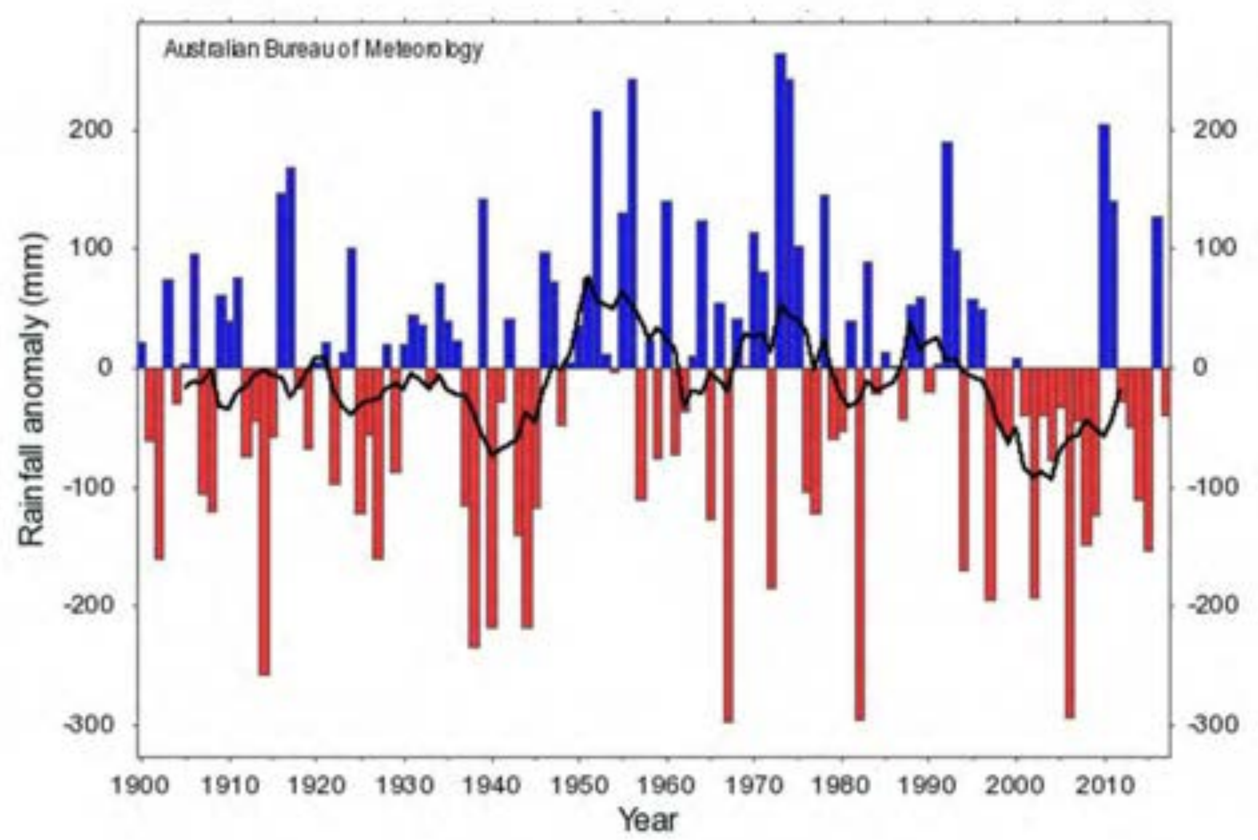


Figure B16: Victorian Rainfall Anomaly, 1900 – 2017, Victorian State of the Environment report, 2018 (Black curve indicates 11 year running average)

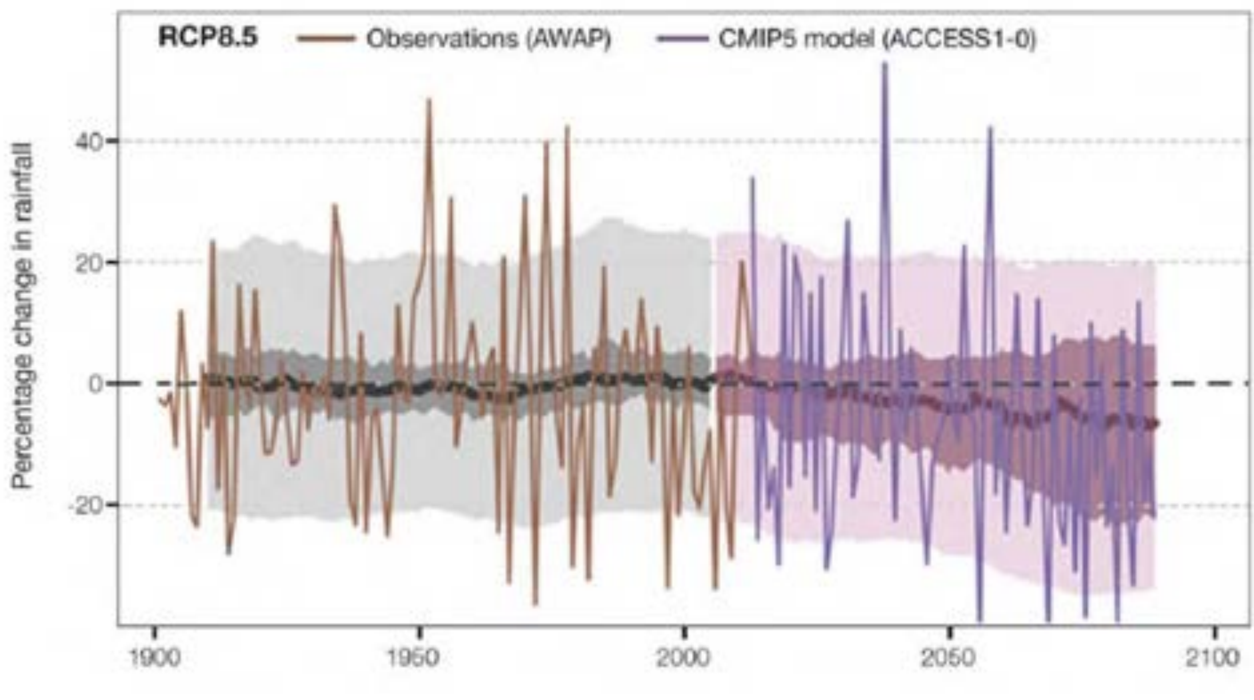


Figure B17: Observed annually averaged and simulated historical Victorian Rainfall, Victorian State of the Environment report, 2018

Climate change projections for the south west Victoria region indicate there will be:

- less rainfall in winter and spring;
- increased frequency and intensity of extreme rainfall events;
- time spent in drought to increase over the course of the next century; and
- increased incidence of flooding events.

Sea level is forecast to increase over the next century. For south West Victoria, the Victorian State of the Environment Report (2018) predicts sea level rise of 0.22 m to 0.82 m, with median of 0.74 m by 2090. This has the potential to alter the rates of erosion and coastal processes along the coast near the proposed trail alignment.

Changes in climate conditions also have the potential to alter the frequency and intensity of bushfires, which via the resulting changes to vegetation have the potential to impact landslide susceptibility[11]. The loss of vegetation arising from a bushfire could lead to a greater frequency of landslide post bushfire.

1.5 Earthquakes

The Otway region is being uplifted at a rate of about 100 m per 1 million years[12] affected by earthquakes which have the potential to trigger landslide or rockfall and therefore present a hazard to the proposed trail. There have been several large earthquakes with epicentres offshore about 25 km southeast of the study area as indicated in Figure B18 including the 1965 event (M5.7) which is one of the largest magnitude events recorded in Victoria.

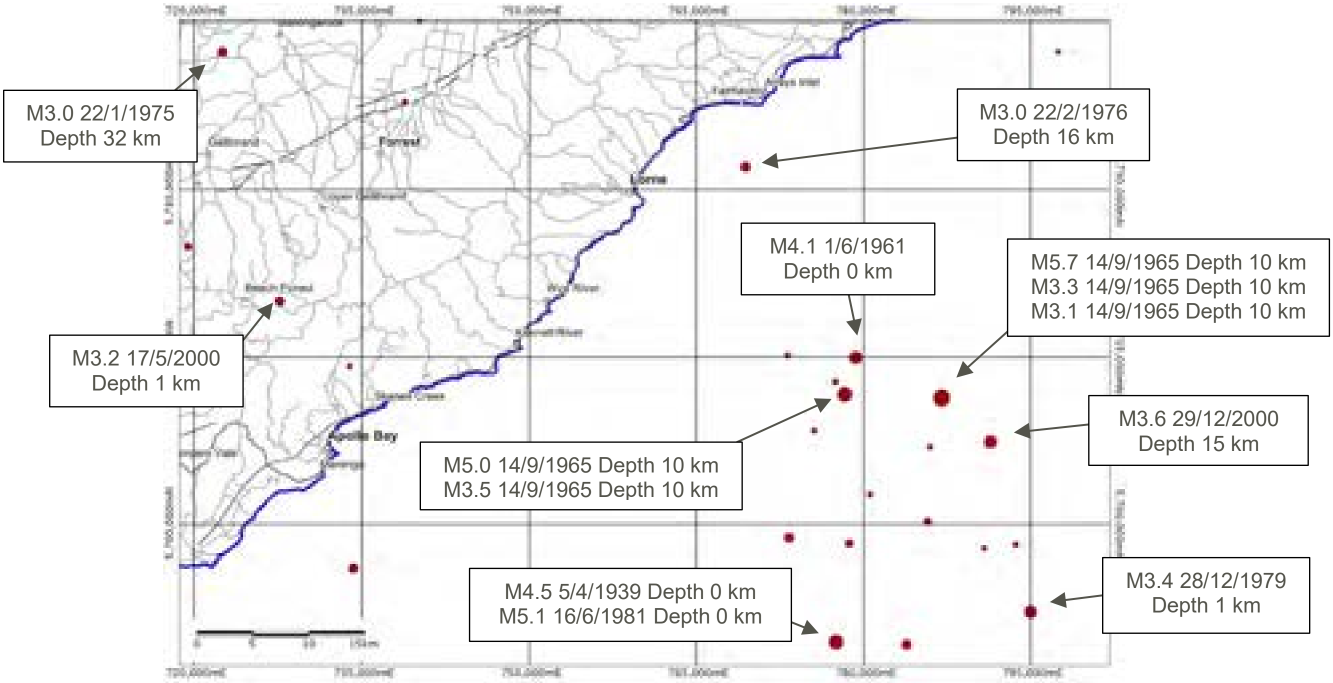


Figure B18: Earthquake epicentres (M≥2.0) from DEDJTR GeoVic website [Details (date and inferred depth) for earthquakes of M3.0 and above indicated]

[11] Colls, S., Miner, A.S., Bushfires, Landslides and geotechnical challenges in the Otway ranges, Victoria

[12] Quigley, M., Clark, D., Sandiford, M. (2010) Tectonic geomorphology of Australia, in Australian Landscapes, Geological Society (London) Special Publication 346, pp. 243-265.

2.0 GEOHAZARD ANALYSIS

Based on the geological and geomorphological processes identified within the vicinity of the proposed trail, the following describes hazards to which the proposed trail and its users could be subject. The following hazard types have been identified:

- Earthworks (failure of cut and fill batters)
- Rock falls
- Shallow soil landslides
- Deep rock landslides
- Debris flow
- Riverine and coastal erosion

A tabulated analysis of the preparatory and causal factors for each hazard type, characteristics and likelihood is presented in Appendix C as the basis for the method by which criteria for delineated geohazards have been established.

Each of the hazards is discussed in more detail below, including observations made during the ground truthing exercise, a discussion on the hazard frequency and method by which the zoning for the hazard maps has been developed. A series of hazard maps has been produced for each hazard, which is included in the accompanying electronic GIS data package described in Appendix A and on map sets presented in Appendix D.

2.1 Earthworks

2.1.1 Hazard Description

The proposed trail alignment is close to the Great Ocean Road and at some locations is aligned along existing fire trails, walking tracks and former telegraph tracks all of which have been formed through modification of the natural landscape with earthworks. Along with multiple cuttings, there was also a need to construct numerous fill embankments. Failures associated with existing earthworks, either cut or fill therefore present a hazard to the trail and trail users at some locations. Cut and fill are addressed separately below.

Fill Embankments

Many of the fill embankments on the Great Ocean Road and surrounds are comprised of residual soils and various grades of weathered rock including boulders and fresh rock materials. Many of these fills were constructed over existing topographic lows such as gullies and drainage lines or are built on steep slopes, often with outer batter angles steeper than would normally be preferred. Fill batter failures tend to be triggered by extreme rainfall events with frequency of about 1 in 50 to 1 in 100 years.

Failures are usually in the form of landslides which can be either rotational and/or translational depending on the material composition and the preparation of the underlying foundation slope. They rarely affect more than a 5 m to 10 m length of the embankment. For this assessment a 10 m failure length of batter has been assumed. Key causal factors involved in fill failures include the overall geometry of the fill (batter slope angles and height), the steepness of the natural slopes upon which they are constructed, the strength and nature of the fill and underlying natural materials, the presence of subsurface water being either groundwater or surface water infiltration and the drainage provisions provided upslope of the fill. Many failures have occurred where uncontrolled flows transit across the pavement and spill over the fill during times of prolonged or intense rainfall. An example of an embankment failure is presented in Figure B19.

Figure B19: Example of fill batter failure on Great Ocean Road, Cathedral Rocks

Cut Batters

Most of the cuttings along the Great Ocean Road and existing tracks and trails within the vicinity of the proposed trail are within the Cretaceous age Eumeralla Formation and expose the bedded sedimentary rock of this unit. Some cuttings are within colluvial material derived from the Eumeralla Formation. Failure of cuttings resulting in mixed soil and rock debris impacting the roads and trails is a relatively frequent occurrence, leading to extensive risk mitigation measured on parts of the Great Ocean Road. Failures from cuttings can have a width of about 10 m, similar to that which occurs in fill batters. Figure B20 presents an example of a failure from a cutting on Paddy's Path between Wye River and Separation Creek.

Figure B20: Cutting failure, on Paddys Path between Wye River and Separation Creek which has caused debris to be deposited on track

2.1.2 Hazard Analysis

Fill Batters

Existing earthworks slope extents have been mapped to allow assessment of hazard level of the fill batters.

Experience on fill batter failures in the vicinity of the Great Ocean Road is set out in this appendix and indicates that fill batters are typically comprised of loose or non-engineered fill materials which are likely derived from side cast fill materials. Fill batter failures occur relatively commonly and 1 in 50 or 1 in 100 year rain events typically trigger a significant number of fill batter failures. When they do occur, fill batter failures typically have a width of 5 m to 10 m and can run out a distance approximately equal to the fill batter height.

The frequency of fill batter failure is assumed to be related primarily to the steepness of the fill batter. Table B1 sets out the hazards estimated for fill batters along with the rationale for the selection.

Table B1: Estimated Hazard Attributes for Fill Batter Failure

Fill Batter Angle	Ratio H:V	Susceptibility	Annual Frequency	Estimated Hazard
<18°	<3:1	Very Low	Unlikely	Very Low
18° to 27°	3:1 to 2:1	Moderate	Possible	Moderate
30° to 45°	2:1 to 1:1	High	Likely	High
>45°	>1:1	Very High	Almost Certain	High

Notes: Hazard Levels (refer also to Table 6 in main report):

Very High = At least one 10 m wide embankment failure per km, per year.

High = 0.1 to 1, 10 m wide embankment failures per km, per year.

Moderate = 0.01 to 0.1, 10 m wide embankment failures per km, per year.

Low = 0.001 to 0.01, 10 m wide embankment failures per km, per year.

Very Low = <0.001, 10 m wide embankment failures per km, per year.

Cut Batters

Existing cut batters have been mapped. These batters are considered to be susceptible to instability. The frequency of cut batter failure is assumed to be dependent upon the height and slope angle of the cut batter with steeper and/or higher batters exhibiting a greater frequency of failure. Failure of cut batters is more prevalent in soil and extremely or highly weathered rock and from soils comprising colluvium. Failure is most common at wetter times of the year, winter, and spring.

Hazard analysis as set out in this appendix indicates that cut batters in the Otway Ranges are typically steeper than 50° to 60°. 1 in 25 to 1 in 50-year rain events trigger significant numbers of cut batter failures. When failure occurs, debris typically does not travel further than a distance approximately equal to the height of the cut.

The frequency of cut batter failure is assumed to be related primarily to the steepness of the cut batter. Table B2 sets out the hazards estimated for cut batters along with the rationale for the selection.

Table B2: Estimated Hazard Attributes for Cut Batter Failure

Material Type	Cut batter angle	Ratio H:V	Susceptibility	Likelihood	Estimated Hazard
Rock	<45°	<1:1	Very Low	Unlikely	Low
	40° to 63°	1:1 to 1:2	Low	Likely	Moderate
	>63°	>1:2	High	Almost Certain	Very High
Soil	<18°	<3:1	Very Low	Unlikely	Very Low
	18° to 27°	3:1 to 2:1	Low	Possible	Low
	27° to 45°	2:1 to 1:1	Moderate	Possible	Moderate
	45° to 63°	>1:1	High	Likely	High
	>63°	>1:2	Very High	Almost Certain	Very High

Notes: Hazard Levels (refer also to Table 6 in main report):

Very High = At least one 10 m wide cut failure per km, per year.

High = 0.1 to 1, 10 m wide cut failure per km, per year.

Moderate = 0.01 to 0.1, 10 m wide cut failure per km, per year.

Low = 0.001 to 0.01, 10 m wide cut failure per km, per year.

Very Low = <0.001, 10 m wide cut failure per km, per year.

2.1.3 Consequences to the proposed trail

Fill Batters

Parts of the proposed trail could be constructed on the edge of the Great Ocean Road or on existing trails and tracks at the crest of fill embankments, or downslope of the Great Ocean Road below potentially unstable fill embankments. If a fill embankment were to fail, it could cause the trail to be undermined, blocking the trail or, where the trail is downslope of the embankment could cause mixed soil and rock debris to impact upon the trail and potentially hikers.

Cut Batters

If the track is near the crest of a cut batter, it could potentially be undermined as a result of a cut batter failure. If the track is near the toe of a cut batter, debris arising from batter failure could impact people at the base of the batter.

2.1.4 Ground Truthing

Observations of cut and fill embankments were made during the ground truthing exercise. On each traverse, observations of previous cut and fill failures were made along with attributes of the slopes from which the failures had occurred. A summary of observed fill batter failures on each field traverse is set out in Table B3 and for cut batter failures in Table B4. A comparison to the criteria set out in Table B1 and Table B2 has been made and indicates that the expected hazard level based on the criteria is similar to the calculated hazard level based on traverse observations, with the hazard levels being either the same or in adjacent categories. There is also no discernable trend for the expected hazard level being consistently higher or lower than the calculated hazard level.

Table B3: Summary of Fill Batter Observations

Traverse				Number of failures observed	Total length (m) of failures observed	Length of traverse in fill batter (m)	Typical fill batter angle	10 m wide failures per kilometer of fill	Estimated time frame of failures (age of batter, yrs)	Typical occurrence (per km/year)	Calculated Hazard Level	Expected Hazard Level	Comparison
No.	From	To	Length (m)										
1	Cumberland River	Turn off Cumberland Track to north	2350	4	16	800	30° – 40°	2	20	0.1	Medium to High	High	Criteria are consistent with observations
2	Fairhaven SLSC	Tallawalla Campsite	3100	1	3	40	45° – 50°	7.5	10	0.75	High	High	Criteria are consistent with observations
3	Tallawalla Campsite	Moggs Creek Picnic Ground	550	0	0	0	N/A	0	N/A	0	N/A	N/A	N/A
4	Moggs Creek Picnic Ground	Coalmine Creek	2130	0	0	0	N/A	0	N/A	0	N/A	N/A	N/A
5	Coalmine Creek Crossing (natural "cut")	(Motorbike track crossing, trail off alignment)	25	0	0	0	N/A	0	N/A	0	N/A	N/A	N/A
6	Coalmine Creek	Coalmine Track (bend to north)	865	0	0	0	N/A	0	N/A	0	N/A	N/A	N/A
7	Kennett River Mouth	Rear of Kennett River township	500	8	55	500	60° – 70°	11	10	1.1	Very High	High	Observations are higher than expected from criteria

Traverse				Number of failures observed	Total length (m) of failures observed	Length of traverse in fill batter (m)	Typical fill batter angle	10 m wide failures per kilometer of fill	Estimated time frame of failures (age of batter, yrs)	Typical occurrence (per km/year)	Calculated Hazard Level	Expected Hazard Level	Comparison
No.	From	To	Length (m)										
8	Rear of Kennett River township	End of existing trail along Kennett River	600	2	8	75	70° - 90°	10.7	10	1.1	Very High	High	Observations are higher than expected from criteria
9	Godfrey Track	Gully (heading south – (stepped)	650	1	10	130	30° – 35°	8	20	0.4	High	High	Criteria are consistent with observations
10	Entering Large Gully (stepped)	Exit Large Gully (stepped)	180	1	5	100	25° – 30°	5	20	0.25	High	Moderate to High	Observations are higher than expected from criteria
11	Wye Road	Separation Creek	1700	2	15	500	30° – 40°	3	20	0.15	High	High	Criteria are consistent with observations
12	Cherry Tree Creek	Turn off west to Ocean Walk	620	5	55	620	45° – 63°	8.9	20	0.4	High	High	Criteria are consistent with observations
13	Turn off west to Ocean Walk	Powerline Easement	270	0	0	0	<18°	-	-	-	N/A	N/A	N/A
14	Powerline Easement	Allenvale Road	380	0	0	0	<18°	-	-	-	N/A	N/A	N/A
15	Allenvale Road	Allenvale Road Carpark	410	0	0	0	-	-	-	-	N/A	N/A	N/A

Traverse				Number of failures observed	Total length (m) of failures observed	Length of traverse in fill batter (m)	Typical fill batter angle	10 m wide failures per kilometer of fill	Estimated time frame of failures (age of batter, yrs)	Typical occurrence (per km/year)	Calculated Hazard Level	Expected Hazard Level	Comparison
No.	From	To	Length (m)										
16	Sheoak Falls Track	Castle Rock lookout	1360	0	0	0	-	-	-	-	N/A	N/A	N/A
17	Sheoak Falls Track	Swallow Caves	330	0	0	100	45° – 63°	0	20	0	Very Low	High	Observations are lower than expected from criteria
18	Bird Track	Wye River	1140	0	0	60	40°	NA	NA	NA	NA	High	Track >1 year old, no failures yet. Over steepened fill batters highly likely to fail
19	Kennett River	Bird Track	3300	1	2	700	20° – 30°	0.7	50	0.014	Moderate	Moderate	Criteria are consistent with observations
20	Lorne	Stony Creek	3200	4	100	960	30° – 70°	10.4	50	0.21	Very High	High	Observations are lower than expected from criteria
TOTAL			**23 360**	**29**	**269**	**4585**	**30° – 45° (typ)**	**5.9**	**20 (typ)**	**0.3 (typ)**	**High**	**High**	**Criteria are typically consistent with observations**

Table B4: Summary of Cut Batter Observations

Traverse				Predominant Material Type	Number of failures observed	Total length of failures observed	Length of traverse in cut batter	Typical cut batter angle	10 m wide failures per kilometre of cut	Estimated time frame of failures (age of track, yrs)	Typical Occurrence (per km/year)	Calculated Hazard Level	Expected Hazard Level	Comparison
No.	From	To	Length (m)											
1	Cumberland River	Turn off Cumberland Track to north	2350	Weathered sandstone and colluvium	15	55	800	63° – 70°	6.9	20	0.34	High	Very High	Observations are lower than expected from criteria
2	Fairhaven SLSC	Tallawalla Campsite	3100	Tertiary Sands	5	8	50	65° – 75°	16	10	1.6	Very High	Very High	Criteria are consistent with observations
3	Tallawalla Campsite	Moggs Creek Picnic Ground	550	Quaternary Alluvium	4	30	120	55° – 60°	25	20	1.25	Very High	High	Observations are higher than expected from criteria
4	Moggs Creek Picnic Ground	Coalmine Creek	2130	N/A	0	0	0	N/A	0	N/A	0	N/A	N/A	N/A
5	Coalmine Creek Crossing (natural "cut")	(Motorbike track crossing, trail off alignment)	25	Tertiary Sands	1	15	25	80° – 90°	60	10	6	Very High	Very High	Criteria are consistent with observations
6	Coalmine Creek	Coalmine Track (bend to north)	865	Tertiary Sands (Cemented)	2	4	25	70° – 80°	16	20	0.8	High	Very High	Observations are lower than expected from criteria

Traverse No.	Traverse From	Traverse To	Traverse Length (m)	Predominant Material Type	Number of failures observed	Total length of failures observed	Length of traverse in cut batter	Typical cut batter angle	10 m wide failures per kilometre of cut	Estimated time frame of failures (age of track, yrs)	Typical Occurrence (per km/year)	Calculated Hazard Level	Expected Hazard Level	Comparison
7	Kennett River Mouth	Rear of Kennett River township	500	N/A	0	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	Rear of Kennett River township	End of existing trail along Kennett River	600	Weathered sandstone	0	N/A	80	55° – 63°	N/A	N/A	N/A	N/A	Moderate	Observations are lower than expected from criteria
9	Great Ocean Road (Jamieson Creek camp entry)	Wye Road	3220	Soil/ Colluvium	2	10	210	55°	5	20	0.2	High	High	Criteria are consistent with observations
10	Wye Road	Wye Road (upslope of track)	140	Soil	2	14	150	55°	9	20	0.5	High	High	Criteria are consistent with observations
11	Wye Road	Separation Creek	1700	Soil	4	5	500	60°	1	15	0.1	Moderate to High	High	Observations are lower than expected from criteria
12	Start of Paddys Path	Wallace Ave, Wye River	450	Soil	2	15	450	50° – 70°	3	5	0.7	High	High to Very High	Observations are lower than expected from criteria

Traverse				Predominant Material Type	Number of failures observed	Total length of failures observed	Length of traverse in cut batter	Typical cut batter angle	10 m wide failures per kilometre of cut	Estimated time frame of failures (age of track, yrs)	Typical Occurrence (per km/year)	Calculated Hazard Level	Expected Hazard Level	Comparison
No.	From	To	Length (m)											
13	Start Tramway Track	Old Abbatoir site	830	Soil	1	3	70	65°	4	15	0.3	High	Very High	Observations are lower than expected from criteria
14	Lorne Pier (Shipwreck trail)	North to Public BBQ area	900	Soil	3	20	800	45° – 55°	3	15	0.2	High	High	Criteria are consistent with observations
15	Cherry Tree Creek	Turn off west to Ocean Walk	620	Weathered sandstone and colluvium	3	10	620	45° – 60°	1.6	20	0.08	Moderate	High	Observations are lower than expected from criteria
16	Turn off west to Ocean Walk	Powerline Easement	270	Colluvium	0	0	0	<18°	N/A	N/A	N/A	N/A	N/A	N/A
17	Powerline Easement	Allenvale Road	380	Weathered sandstone and colluvium	0	0	0	<18°	N/A	N/A	N/A	N/A	N/A	N/A
18	Allenvale Road	Allenvale Road Carpark	410	Colluvium	2	50	410	45° – 50°	12.2	20	0.6	High	High	Criteria are consistent with observations
19	Sheoak Falls Track	Castle Rock lookout	1360	Weathered Sandstone	0	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Traverse				Predominant Material Type	Number of failures observed	Total length of failures observed	Length of traverse in cut batter	Typical cut batter angle	10 m wide failures per kilometre of cut	Estimated time frame of failures (age of track, yrs)	Typical Occurrence (per km/year)	Calculated Hazard Level	Expected Hazard Level	Comparison
No.	From	To	Length (m)											
20	Sheoak Falls Track	Swallow Caves	330	Colluvium	1	1	100	45° – 63°	1	20	0.05	Moderate	High	Observations are lower than expected from criteria
21	Bird Track	Wye River	1140	Weathered sandstone and colluvium	0	NA	120	60° – 70°	0	NA	NA	NA	High to Very High	Track <1 year old, no failures yet. Steep cuts highly likely to fail.
22	Kennett River	Bird Track	3300	Weathered sandstone and colluvium	10	25	1070	45° – 70°	2.7	50	0.05	Moderate	Moderate	Criteria are consistent with observations
23	Lorne	Stony Creek	3200	Fill and beach sand	0	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TOTAL			**18620**	**Soil**	**29**	**175**	**2910**	**45° – 60° (typ)**	**6.0**	**15 (typ)**	**0.4**	**High**	**High**	**Criteria are consistent with observations**
			10020	**Rock**	**28**	**90**	**2690**	**60° – 70° (typ)**	**3.3**	**30 (typ)**	**0.1**	**Mod. to High**	**Mod. To Very High**	**Criteria are consistent with observations**

2.2 Rockfall

2.2.1 Hazard Description

The proposed trail is expected to pass near some areas subject to natural rockfall, for example the steep cliffs of the Cumberland River valley and some rocky coastal cliffs. It may also pass below man made cuttings from which rock fall could originate such as on existing tracks and the Great Ocean Road.

Rockfall describes the detachment of an individual block/boulder or several discrete blocks or boulders from a steep face/cliff from a surface on which little or no shear displacement occurs. Rock blocks then travel downslope under the influence of gravity by falling, rolling or bouncing. Rockfall can also initiate as a toppling failure where there is forward rotation of blocks out of a slope about a point or axis below the centre of gravity of the displaced mass.

Hazard analysis as described in this appendix indicates that rocks can either detach from jointed rock outcrops, or from within soils, for example colluvial soils comprised of a mixture of soil and rock blocks. From natural rock outcrops, rock fall has historically been triggered by 1 in 50 to 1 in 100 year rainfall events. However, more frequent events can trigger rockfall from road cuttings and significant works have been undertaken over the years to manage rock fall risk associated with the cuttings of the Great Ocean Road. Where the proposed trail is near the road, it could be impacted by rockfall originating from the earthworks.

The size of rockfalls can vary widely, ranging from pebbles and cobbles only a few centimetres across to large intact individual boulders, meters in width. For this assessment, a rockfall impacting a 1 m section of trail has been assumed, i.e., a 1 m diameter boulder.

For part of its length the proposed trail is expected to follow the alignment of existing tracks, including those associated with now abandoned logging tramways and telegraph routes. An example of a rockfall hazard on an existing trail at Queens Park in Lorne is shown in Figure B21.

Figure B21: Example of rockfall hazard on tramway route, Queens Park, Lorne

2.2.2 Hazard Analysis

Landform mapping has sought to identify natural landforms that could be associated with rockfall and to identify the confidence that rockfall could occur within that landform unit. The terrain susceptible to units is typically underlain by the Eumeralla Formation at locations where rock outcrop is evident. Additionally, cuts into rock from which rock detachment could occur have also been mapped.

Experience of rockfall within the Otway Ranges (this appendix) indicates that rockfalls from cuttings which expose rock is a relatively common occurrence. Recently rockfall netting has been installed along relatively long sections of the Great Ocean Road as a rock fall mitigation measure and in response to the relatively high frequency of rockfall occurrence. Rockfall size of typically up to 1 m is common.

The frequency of rockfall is assumed to be related primarily to the steepness of the hillslope or cut batter from which the rockfall originates. On natural slopes, rockfall is assumed to be a 1 in 50 to 1 in 100 year event. For a 1 m wide rockfall, of which there would theoretically be 1000 along a 1 km length of cutting, Table B5 sets out the hazards estimated for rockfalls along with the rationale for the selection.

Table B5: Estimated Hazard Attributes for Rockfall

Geomorphic Process	Confidence Level	Slope angle	Susceptibility	Frequency	Estimated Hazard
Rockfall – Natural Slopes	High Medium	<40°	Low	Unlikely	Very Low
		>40°	Moderate	Possible	Moderate
	Low Uncertain	<40°	Very Low	Unlikely	Very Low
		>40°	Moderate	Possible	Low
Rockfall – Cut slopes	N/A	<40°	Low	Possible	Low
		>40°	High	Likely	High

Notes: Hazard Levels (refer also to Table 5 in main report):

Very High = More than 10 m rockfalls per km, per year.

High = 1 to 10 rockfalls per km, per year.

Medium = 0.1 to 1 rockfalls per km, per year.

Low = 0.01 to 0.1 rockfalls per km, per year.

Very Low = <0.01 rockfalls per km, per year.

2.2.3 Consequences to the proposed trail

Rockfall on to the proposed trail presents a risk to users of the trail from direct impact and a potential maintenance issue where rock needs to be removed from the trail.

2.2.4 Ground Truthing

Observations of rockfall were made during the ground truthing exercise. On each traverse, observations of previous rockfalls were made along with attributes of the slopes from which the rockfalls had occurred. A summary of observed evidence of rockfalls on each field traverse is set out in Table B6.

A comparison to the criteria set out in Table B5 has been made and indicates that in most instances where rockfalls were observed, the expected hazard level was similar to the calculated hazard level, with the difference in hazard levels generally being within one category. However, there are some locations where the difference is higher, i.e., the Cumberland River and Cherry Tree Walk sections. This infers that the rockfall hazard is likely to be site specific, with the nature of the rocks exposed in the slopes (e.g., joint frequency and orientation) being an influence. There is also no discernable trend for the expected hazard level being consistently higher or lower than the calculated hazard level. No adjustment was made to the estimated rockfall hazard criteria on the basis of the ground truthing exercise.

Table B6: Summary of Rockfall Observations

Traverse				Number of rockfalls observed	Source (natural or cut)	Length of traverse exposed to rockfall (m)	Typical slope or batter angle	Rock falls per kilometer of path exposed to hazard	Estimated time frame of failures (age of track, yrs)	Typical Occurrence (per km/year)	Calculated Hazard Level	Expected Hazard Level	Comparison
No.	From	To	Length (m)										
1	Cumberland River	Turn off Cumberland Track to north	2350	0	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	Fairhaven SLSC	Tallawalla Campsite	3100	0	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	Tallawalla Campsite	Moggs Creek Picnic Ground	550	0	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	Moggs Creek Picnic Ground	Coalmine Creek	2130	0	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	Coalmine Creek Crossing (natural "cut")	(Dirtbike track crossing, kmz trail off alignment)	25	0	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Traverse				Number of rockfalls observed	Source (natural or cut)	Length of traverse exposed to rockfall (m)	Typical slope or batter angle	Rock falls per kilometer of path exposed to hazard	Estimated time frame of failures (age of track, yrs)	Typical Occurrence (per km/year)	Calculated Hazard Level	Expected Hazard Level	Comparison
No.	From	To	Length (m)										
6	Coalmine Creek	Coalmine Track (bend to north)	865	0	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	Kennett River Mouth	Rear of Kennett River township	500	0	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	Rear of Kennett River township	End of existing trail along Kennett River	600	8	Cut	80	>60°	100	15	6.6	High	High	Criteria are consistent with observations
9	Rear of Kennett River township	End of existing trail along Kennett River	600	4	Natural Slope	100	>65°	40	20	2	High	Moderate	Observations are higher than expected from criteria
10	Start Tramway Track	Old Abattoir Site	840	4	Natural Slope	300	>65°	13	15	1	Moderate to High	Moderate	Observations are higher than expected from criteria

Traverse				Number of rockfalls observed	Source (natural or cut)	Length of traverse exposed to rockfall (m)	Typical slope or batter angle	Rock falls per kilometer of path exposed to hazard	Estimated time frame of failures (age of track, yrs)	Typical Occurrence (per km/year)	Calculated Hazard Level	Expected Hazard Level	Comparison
No.	From	To	Length (m)										
11	Cumberland River Caravan Park (northern end)	1st Cumberland River Crossing	500	15	Natural Slope	50	>65°	300	20	15	Very High	Moderate	Observations are higher than expected from criteria
12	Cherry Tree Creek	Turn off west to Ocean Walk	620	0	Cut	20	45° – 60°	N/A	N/A	N/A	Very Low	Moderate	Observations are lower than expected from criteria
13	Turn off west to Ocean Walk	Powerline Easement	270	0	Natural Slope	0	<18°	N/A	N/A	N/A	N/A	N/A	N/A
14	Powerline Easement	Allenvale Road	380	0	Natural Slope	0	<18°	N/A	N/A	N/A	N/A	N/A	N/A
15	Allenvale Road	Allenvale Road Carpark	410	0	Cut	0	45° – 50°	N/A	N/A	N/A	N/A	N/A	N/A
16	Sheoak Falls Track	Castle Rock Lookout	1360	0	Natural Slope	0	45° – 50°	N/A	N/A	N/A	N/A	N/A	N/A

Traverse				Number of rockfalls observed	Source (natural or cut)	Length of traverse exposed to rockfall (m)	Typical slope or batter angle	Rock falls per kilometer of path exposed to hazard	Estimated time frame of failures (age of track, yrs)	Typical Occurrence (per km/year)	Calculated Hazard Level	Expected Hazard Level	Comparison
No.	From	To	Length (m)										
17	Sheoak Falls Track	Swallow Caves	330	0	Cut	0	45° – 63°	N/A	N/A	N/A	N/A	N/A	N/A
18	Kennett River	Bird Track	3300	0	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
23	Lorne		Stony Creek	3200	0	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TOTAL			**1960**	**8**	**Cut**	**100**	**45° – 60°**	**80**	**15 (typ)**	**5.3**	**High**	**High**	**Criteria are consistent with observations**
			3950	**23**	**Natural slope**	**450**	**>65°**	**51**	**20 (typ)**	**2.5**	**High**	**Moderate**	**Observations are higher than expected from criteria**

2.3 Shallow Soil Landslides

2.3.1 Hazard Description

Landslides have been a regular event in the natural evolution of the landscapes within the vicinity of the Great Ocean Road over the past several million years. They occur as one of the principal processes of landscape development. The main process of a landslide is the removal of earth materials during the formation of valleys and coastlines. These processes are still operating in areas through which the trail is proposed. Whilst landslides can be categorized into many different types, for this study, they have been classified based on their being shallow landslides, predominantly within soils or large landslides within rock. The former, shallow soil landslides tend to be smaller although more frequent than large landslides within rock.

Landslides are prominent in the sediments of the Torquay Basin between Fairhaven and Eastern View and then become prolific within the residual and colluvial soils overlying Cretaceous age sandstones and siltstones of the Eumeralla Formation. Areas where landslides are more prolific include the south eastern slopes of the Otway Ranges from Lorne to Skenes Creek. The size of shallow landslides within soils can vary significantly, ranging from a few m^3 to hundreds of m^3. Shallow soil landslides often occur within areas of the larger landslides, since there is a close association between currently active landslides and previous failures. Cooney (1980)[13] considers all old failures as likely sites for further landslides.

Landslides mapped from LiDAR as part of this study are presented in this appendix. This mapping allows the correlation of terrain attributes including slope angle and slope aspect (direction slope faces) to landslide occurrence and informs the selection of criteria defining landslide hazard.

Under normal conditions, the most probable cause of failure is prolonged and/or intense rainfall or in some cases construction work. Landslides can occur some time, perhaps a few days after rainfall due to the time it takes for the rainfall to infiltrate. Although drier conditions are predicted under climate change scenarios, there is an increased likelihood of more frequent, higher intensity storm events. Such events are known to be the precursor to landslide activity within the shallow soils of the Otways through both rapid and prolonged elevation of groundwater pressures. Furthermore, because slopes will become drier and may suffer more extensive and deeper desiccation, it is likely that infiltration of these higher intensity events will increase and overall slope stability will decrease. As a result, it is expected that the occurrence of shallow landslides in soils will increase in response to climate change.

Shallow soil landslides comprise the detachment of and then runout of the soil mass. The length of runout is related to the moisture content of the soil, with wetter soil exhibiting a greater runout. Related to this, runout tends to be greater on unvegetated slopes (paddocks or fire affected areas) than on vegetated slopes. Landslides which produce fluid debris with run out are termed earthflows.

An example of a shallow landslide in soil is shown in Figure B22.

[13] Cooney, A.M. (1980). Otway Range Landslide Susceptibility Study, First Progress Report. Department of Minerals and Energy Unpublished Report 1980/176

Figure B22: Example of shallow soil landslide in 2016, which occurred above the Great Ocean Road and affected a significant length of Paddy's Path at Wye River (the landslide extends further across the hillside than the photograph extents. Note the rock bedding dipping downslope)

The Wye River Paddy's Path landslide is located below the proposed trail alignment. This landslide moved in September 2016, resulting in significant remedial works and the relocation of the path. The path had also previously been relocated in response to landslides.

2.3.2 Hazard Analysis

Based on previous studies and by inspection of landslides mapped as part of this study (this appendix), the occurrence of landslides within the soils overlying the Eumeralla Formation appear to be most closely related to slope angle and slope aspect (direction the slope faces).

This appendix provides an analysis of hazards associated with shallow landslides in soils and earthflows which for the purposes of this study are both considered the same type of hazard and are indicated on the same hazard map. Experience indicates that shallow soil landslides are commonly triggered in 1 in 50 to 1 in 100 year rainfall events. Landslide runout is typically only a few metres in vegetated areas however earthflows which typically occur in open, non-vegetated areas can travel over longer distances. The locations of past landslides has been mapped and is also included in this appendix. Assessment of past landslides indicates a strong correlation between natural slope angle and landslide prevalence. There is also a correlation between landslide prevalence and slope aspect, or the direction the slope faces, with southerly facing slopes having a greater prevalence of landslides than northerly facing slopes.

Hazard identification for shallow soil landslides is based on the identification of landforms that that appear to indicate past landsliding and with consideration then given to the slope angle and slope aspect within that landform. Table B7 sets out the hazards estimated for shallow soil landslides.

Table B7: Estimated Hazard Attributes for Shallow Soil Landslides

Geology	Location of Past Landslide	Slope Aspect	Slope angle	Susceptibility	Likelihood	Estimated Hazard
Cretaceous	No	90° – 270°	<9°	Very Low	Rare	Very Low
			9° to 14°	Low	Unlikely	Very Low
			14° to 21°	Moderate	Possible	Medium
			21° to 27°	High	Likely	High
			>27°	Very High	Likely	High
		270° – 90°	<9°	Very Low	Rare	Very Low
			9° to 14°	Very Low	Unlikely	Very Low
			14° to 21°	Low	Possible	Low
			21° to 27°	Moderate	Likely	Medium
			>27°	High	Likely	High
	Yes	N/A	N/A	Very High	Likely	High
Cenozoic (eastern 8 km of trail)	No	N/A	<9°	Very Low	Rare	Very Low
			9° to 14°	Low	Unlikely	Very Low
			14° to 21°	Moderate	Possible	Medium
			>21°	High	Likely	High
	Yes	N/A	N/A	Very High	Likely	High

Notes: Hazard Levels (refer also to Table 5 in main report):

Very High = More than 10, 1000 m^2 landslides per km^2, per year.

High = 1 to 10, 1000 m^2 landslides per km^2, per year.

Medium = 0.1 to 1, 1000 m^2 landslides per km^2, per year.

Low = 0.01 to 0.1, 1000 m^2 landslides per km^2, per year.

Very Low = <0.01, 1000 m^2 landslides per km^2, per year.

2.3.3 Consequences to the proposed trail

Shallow soil landslides could directly impact upon hikers, but are more likely to present a risk to property as a result of causing blockage or undermining of the trail. Shallow soils slides have also caused blockage of the Great Ocean Road to occur a number of times in the past.

2.3.4 Ground Truthing

Although ground truthing to assess landslide frequency cannot be practically be undertaken, where traverses passed across mapped landslides, as shown in this appendix, an assessment was made to see if the remotely mapped landslides could be identified on the ground. In all cases, it was possible to identify the landslide feature matter remotely from landform features on the ground.

2.4 Deep Seated Landslides in Rock

2.4.1 Hazard Description

The bedded siltstones and sandstones of the Eumeralla Formation can host large deep-seated landslides. These are ‘structurally controlled’ whereby the planes upon which landsliding occurs are bedding planes or other defects within the rock mass. These landslides are generally considered to have formed, or first activated 6000 or more years ago at a time of higher sea level than today, however they can and do reactivate (movement of a pre-existing landslide) with a relatively high frequency.]

Like smaller shallow landslides in soil, these landslides tend to be triggered by heavy or prolonged rainfall, however it is postulated that they might also be triggered by earthquake. Earthworks, for example the historical excavation for the construction of the Great Ocean Road at the toe of slopes may also contribute to landslides. These landslides can be hundreds of metres wide and up to 1.5 km long. They have the potential to cause major changes to the landscape such as the blocking and diversion of rivers and streams.

An example of a deep-seated landslide in rock (where construction of the Great Ocean Road is likely to have contributed to the landslide) at Windy Point between St Georges River and Sheoak Creek at Lorne is shown in Figure B23. Note bedding dipping towards the ocean. Works were undertaken in the 1970’s to anchor this landslide and control further movement.

Figure B23: Example of deep-seated landslide in rock at Windy Point (Photo EGS)

2.4.2 Hazard Analysis

This appendix sets out hazard analysis for deep seated rock slides. The large deep-seated landslides are apparent from digital elevation information. These features have been mapped as discrete features. Reactivation of large deep-seated landslides is difficult to estimate, but it is assumed to be of the order of 1 in 1000 years. The occurrence of deep-seated landslides is inferred to have been more prevalent around 6000 years ago, when sea level was higher than it is today.

Table B8 sets out the hazards estimated for deep landslides in rock.

Table B8: Estimated Hazard Attributes for Deep Landslides in Rock

Geomorphic Process	Confidence Level	Susceptibility	Frequency	Estimated Hazard
Mapped relict landslide	N/A	Very High	Unlikely	Low

Notes: Hazard Levels:

Very High = > 10^{-2} per annum

High = 10^{-3} to 10^{-2} per annum

Medium = 10^{-4} to 10^{-3} per annum

Low = 10^{-5} to 10^{-4} per annum

Very Low = <10^{-5} per annum

2.4.3 Consequences to the proposed trail

When they reactivate, deep-seated landslides are typically slow moving with warning signs ahead of the major movement. For example, the formation of tension cracks and surface distortion. However, there is potential for these landslides to build momentum and to move rapidly, for example as happened in 1954 when a large landslide rapidly filled and dammed a valley causing the formation of Lake Elizabeth near Forrest. These forms of landslide have caused the Great Ocean Road to be closed, for example as occurred at Windy Point between St Georges River and Sheoak Creek, Lorne in 1971 closing the road for 6 months. The proposed trail would have similar vulnerability whereby large landslides have the potential to block or destroy relatively long sections of the track.

2.5 Debris Flows

2.5.1 Hazard Description

Debris Flows are known to occur within the Otway Ranges, although they are not as common as landslide type failures. Debris flows tend to originate at the head of steep gullies and drainage lines or within colluvium and debris from other larger failures and are usually initiated by intense short duration rainfall events. They are distinguished from other landslide types based on their fluid nature, the rapid velocity at which they occur and their long runout distances which initially follow channels and drainage lines until they reach flatter, broader slopes where they fan out.

2.5.2 Hazard Analysis

Hazard analysis for debris flow is set out in this appendix and indicates there are no known occurrences of debris flow within the Otway Ranges. There is some evidence for past debris flow in the form of what appear to debris flow deposits on the sides of creek and river channels, however these deposits typically appear to be relatively old. Landforms indicative of debris flow have been identified through landform mapping along with the valleys or channels that could be affected by a debris flow. The frequency of debris flows is related to the frequency of high intensity rainfall events with the frequency of debris flows estimated to be in the order of 1 in 100,000 per annum at any particular location.

Table B9 sets out the hazards estimated for debris flow.

Table B9: Estimated Hazard Attributes for Debris Flows

Geomorphic Process	Confidence Level	Slope angle at source area	Proximity to base of gully	Susceptibility	Frequency	Estimated Hazard
Debris flow identified as geomorphic process within landform unit	High Medium	>25°	< 20 m	High	Possible	Medium
			>20 m	Low	Possible	Low
		<25°	<20 m	Moderate	Unlikely	Low
			>20 m	Very Low	Unlikely	Very Low
	Low Uncertain	>25°	<20 m	Moderate	Possible	Medium
			>20 m	Very Low	Possible	Very Low
		<25°	N/A	Low	Unlikely	Very Low

Notes: Hazard Levels:

Very High = > 10^{-2} per annum

High = 10^{-3} to 10^{-2} per annum

Medium = 10^{-4} to 10^{-3} per annum

Low = 10^{-5} to 10^{-4} per annum

Very Low = <10^{-5} per annum

2.5.3 Consequences to the proposed trail

Where the trail crosses the path of a potential debris flow, there is potential for it to be impacted. The impact of debris flow to the trail could serve to destroy or remove the trail over the impacted section. Impact to people from a debris flow is likely to be fatal.

2.6 Episodic Erosion

2.6.1 Hazard Description

Episodic erosion refers to erosion that results in periodic collapse. For example, erosion of a rocky coastline which causes undermining of a cliff or edge of a relict shore platform leading to collapse which affects the ground some distance back from the cliff. This differs from progressive erosion, such as might occur on a beach whereby sand is progressively removed, typically through a cycle of storm events. The magnitude of the hazards each event presents to trail users is different under each scenario.

Episodic erosion will generally result in the rapid collapse of a river bank or coastal cliff and is a hazard that could be present where the trail is in proximity to the coast or to a river bank which is subject to active undercutting or removal of material from the toe of a slope.

An example of episodic erosion is shown in Figure B24.

Figure B24: Example of episodic erosion, a rock stack formed from erosion and collapse of the surrounding rock at the lagoon mouth at Aireys Inlet

2.6.2 Hazard Analysis

Erosion, for example undermining of slopes is caused by the action of water, either wave action or river flow. High spring tides and storm surge conditions can exacerbate erosion rates, by advancing the rate at which undermining and episodic erosion occurs. With rising sea levels forecast over the next 100 years, erosion rates could increase as a result of changes in wave and current directions and energy, increase in storm surge strength and frequency, and local non-climatic factors such as ground subsidence or a combination of these. Erosion can cause coastline or river bank recession which refers to the long-term inland movement of the high water mark due to the sustained removal of material and is expressed in m/year.

Assessing the rate of recession is a complex task as there are many influencing factors, including:

- Metocean processes.

- Coastal sediment transport processes and pathways
- Climate change and sea level rise
- Backshore composition and geometry
- Shore zone/intertidal composition and slope profiles
- Subtidal composition, slope, and seabed profiles
- Presence and effectiveness (or negative impacts) of engineered infrastructure including coastal protection structures
- Past evidence for historical shoreline change

It is difficult to consider all these factors in the production of hazard maps, so for the purposes of this study, typical published recession rates have been adopted. The following are published recession rates for rocky coasts in Victoria, similar to those expected between Eastern View and Skenes Creek where the coast is formed by the Cretaceous rock of the Eumeralla Formation.

- Gill and Laing (1983)[14] present a study into the rate of erosion of the intact Cretaceous rocks of the Otway Coast and indicate downcutting of rocky shore platforms of up to 1.8 mm per year and shoreline recession (at Marengo) of about 13 mm per year over the past 6,000 years.
- Stephenson (2012)[15] reviews the measurements made by Gill and Lang 1983, concluding that after 32 years, erosion rates are similar to those measured by Gill and Laing.
- Sunamura (1992)[16] presents typical recession rates for different lithologies, noting a rate of about 0.01 m (10 mm per year), in Carboniferous sedimentary rock, which is analogous to the Cretaceous rock of the Eumeralla Formation.

The size of block that could detach as a result of erosion or undermining of a near vertical exposed rock face in the Eumeralla Formation, for example the edge of a shore platform is typically a function of the joint spacing. Our experience in the Eumeralla Formation indicates a typical joint spacing of about 1 m. At the estimated erosion rates, it is possible for the rocky edge of a shore platform to regress by about 1 m every 100 years. A similar rate has been assumed for rivers, noting this is conservative given the typically lower erosive energy acting on a river bank.

Soft river banks, where the river channel is within an alluvial floodplain deposit could erode at a greater rate. Notwithstanding this, we have not found any evidence in literature or through site inspection for rapid rates of erosion of river banks. For the purposes of the assessment, a more conservative erosion rate of 1 m per 50 years has been assumed.

The point form which the hazard maps indicate a setback is the ‘limit of swash’. This is taken as the current high water mark for the Otway Ranges, which based on the Victorian Coastal Hazard Assessment guide[17] is around RL 1.9 m AHD.

Table B10 sets out the hazards estimated for episodic erosion.

[14] Gill, E.D., Lang, J.G., Micro-Erosion Meter Measurements of Rock Wear on the Otway Coast of Southeast Australia, Marine Geology, 52, 1983 pp. 141-156

[15] Stephenson, W.J., Kirk, R.M., Kennedy, D.M., Finlayson, B.L., Chen, Z. Long term shore platform surface lowering rates: Revisiting Gill and Lang after 32 years. Marine Geology, 299-302, 2012 pp. 141-156, pp 90 -95

[16] Sunamura, T., Geomorphology of Rocky Coasts, Chichester, Wiley, 1992

[17] Department of Sustainability and the Environment, Victorian Coastal Hazard Assessment Guide, 2012

Table B10: Estimated Hazard Attributes for Episodic Erosion

Geomorphic Process	Confidence Level	Episodic Recession	Hazard level, distance from current edge of swash		
			High	Medium	Insignificant for this study
Coastal Erosion, Hard Coasts	High Medium	1 m / 100 years	Within 1 m	1 m to 2 m	>2 m
	Low Uncertain		N/A	Within 1 m	>1 m
Coastal Erosion Rock Debris Coast	High Medium	1 m / 50 years	Within 2 m	2 m to 5 m	>5 m
	Low Uncertain		N/A	Within 2 m	> 2 m
Channel Migration	High Medium	1 m / 50 years	Within 2 m	2 m to 5 m	>5 m
	Low Uncertain		N/A	Within 2 m	>2 m

2.6.3 Consequences to the proposed trail

Where the trail is within an area susceptible to episodic erosion it could be undermined and then fail rapidly. This could cause the loss of a section of the trail and presents a risk to life and property for trail users if they were to be on a part of the trail that is undermined.

2.7 Progressive Erosion

2.7.1 Hazard Description

Whilst the term episodic erosion is used here to refer to erosion that results in periodic collapse, progressive erosion refers to the gradual removal of material. Progressive erosion is distinguished from episodic erosion based on the risk it is assumed to present to life. Whereas episodic erosion could result in a rapid ground collapse, causing near instantaneous regression of a shore platform, cliff or riverbank, progressive erosion is more gradual and does not present as significant a risk to life as episodic erosion.

An example of progressive erosion is the gradual removal of sand from beaches and estuaries along the proposed trail alignment, noting that in parts, the trail is on the beach. In the context of beaches, within a dynamic environment, sand removal and accretion, occurs. Unlike hard coasts, where erosion is more episodic and shoreline regression occurs as a one-way process, sand can be removed and replenished, and the shoreline may not regress. Furthermore, where erosion does occur, the rate of erosion can be highly variable. Short term processes, associated with single extreme events or clusters of events such as storms can cause a short term increase in the rate of erosion, whereas longer term processes such as wave action and longshore drift can result in erosion (or accretion) over a longer period. Man-made shore protection and engineered shore protection measures further alter the rate of erosion.

An example of progressive erosion is shown in Figure B25.

Figure B25: Example of progressive erosion at Apollo Bay

2.7.2 Hazard Analysis

ASMG and EGS (2020) present an assessment of the vulnerability of 'soft' coasts along the Great Ocean Road, rating them qualitatively as having a Very Low to Very High vulnerability to recession and taking this assessment from one undertaken for DELWP by Spatial Vision in 2017[18]. The coastal vulnerability was rated based on a five-point scale, Very Low, Low, Moderate, High, and Very High Vulnerability. Table B11 presents those parts of the coast within the vicinity of the proposed trail that have been identified as having a moderate to very high vulnerability.

[18] Spatial Vision (2017). "Victorian Coastal Hazard Assessment 2017" Report to DELWP. 20 December 2017.

Table B11: Summary of Moderate to Very High coastal hazard vulnerability (ASMG and EGS 2020)

Location	Geomorphic Features
West of Fairhaven SLC Yarringa Road, Fairhaven (approx. 75 m).	High bluff in soft rock with no platform, foredune, narrow sand beach 
Moggs Creek, Bridge eastern approach (approx. 40 m)	High bluff in soft rock with no platform narrow sand beach. 
Eastern View	Foredune & established foredune, narrow beach. 
Cathedral Rock	Slope over wall (fill) sand beach on narrow platform 

Location	Geomorphic Features
Opposite Armstead St Lorne	Foredune & established foredune, sand beach over wide flat platform. 
All of sector east of bridge over Erskine River at Lorne	Barrier coast, estuary channel and lagoon, flat wide beach. 

Location	Geomorphic Features
All of sector at Jamieson Creek	Single barrier, narrow sand beach. 
Separation Creek (approx. 200 m centered bridge)	D1/22 Barrier coast, single barrier, wide beach. 

Location	Geomorphic Features
Wye River, (approx. 170 m south of bridge).	Barrier coast, single barrier, wide beach. 
Kennett River	Barrier coast, single barrier, narrow beach. 
Sugarloaf Creek bridge (all of sector).	Barrier coast, single barrier, narrow beach. 

<table>
<tr><th>Location</th><th>Geomorphic Features</th></tr>
<tr><td>Part of Sector at Wongarra 200 m south of Brown Creek (approx. 100 m).</td><td>Incipient foredune, narrow beach over wide inclined platform.
</td></tr>
<tr><td>Skenes Creek west of bridge (approx. 120 m).</td><td>Established foredune, wide beach. Engineered (fill).
</td></tr>
</table>

Parts of the coastline not included in Table B11 have been assessed by ASMG and ESG as having a low to very low vulnerability and are therefore not considered on the hazard maps.

Table B12 sets out the hazards estimated for progressive erosion.

Table B12: Estimated Hazard Attributes for Soft Coast Erosion

Geomorphic Process	Confidence Level	Vulnerability mapped by ASMG and EGS (2020)	Hazard level, distance from current edge of swash			
			High	Medium	Low	Insignificant for this study
Coastal Erosion, Rock Debris Coasts	High Medium	Moderate to Very High	Within 2 m	2 m to 5 m		>5 m
		Very Low to Low	N/A	Within 2 m		>2 m
	Low Uncertain	Moderate to Very High	N/A	Within 2 m		>2 m
		Very Low to Low	N/A	N/A	Within 1 m	>1 m
Coastal Erosion Soft Coasts	High Medium	Moderate to Very High	Within 5 m	5 m to 10 m		>10 m
		Very Low to Low	N/A	Within 5 m	5 m to 15 m	>15 m
	Low Uncertain	Moderate to Very High	N/A	Within 5 m	5 m to 15 m	>15 m
		Very Low to Low	N/A	N/A	Within 5 m	>5 m
Coastal Erosion Beaches	High Medium	Moderate to Very High	Up to backshore			Behind Backshore
		Very Low to Low	N/A	Up to backshore		
	Low Uncertain	Moderate to Very High	N/A		Up to backshore	
		Very Low to Low	N/A	N/A	Up to backshore	

2.7.3 Consequences to the proposed trail

Where the trail is within an area susceptible to progressive erosion, 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, there is also potential for sand to accrete and for the ground on which the trail is located to be reinstated.

APPENDIX C

Likelihood Analysis

The following table sets out an analysis of hazards and their frequency within the Cretaceous Otway Group (Eumeralla Formation).

Hazard Identification and Characterisation for Otway Group (Cretaceous) materials

Mode of Failure	Preparatory Casual Factors and other observations	Triggering Causal factors	Size and Nature	Mobility, Velocity and Runout	Estimates of Likelihood
Shallow landslides in soil and extremely weathered (XW) rock.	Can be translational along soil rock interface and/or shallow rotational within soil type materials. Sizes can vary from a few m^3 to many hundreds of m^3 Shallower slides develop on the sandstones where there is limited regolith and XW rock. Slightly deeper slides occur where the base material is siltstone dominated.	Prolonged seasonal rainfall leading to elevated groundwater levels with a significant daily event leading to final initiation. Oversteepening of slopes due to anthropogenic disturbance (e.g., cut earthworks) or erosion.	Extreme variability in size but rarely deeper than 5 m.	Tend to be of the order of a few metres max.	Need to consider rainfall frequency as a proxy with significant events such as 1 in 50 to 1 in 100 type frequencies initiating reactivations of existing larger slides is LIKELY. Possibly less for first time reactivations POSSIBLE to LIKELY
Earth Flows	Occur where there is deeper profile of regolith, colluvium and or previous landslide debris Will occur at groundwater seepage lines on hillsides during very wet periods These types of slides may start as a small slump but transition into composite slide/flows due to degree of saturation in materials Tend to occur in open fields and deforested areas.	More related to groundwater elevation within weaker materials.	Generally not large features maybe 5 m to 10 m diameter Volume at distal end of flow is usually very small.	Can travel many tens of metres.	Need prolonged period of wetting say 1 in 100 year. Overall POSSIBLE to LIKELY but only in non- forested open areas Tend to be UNLIKELY in forested areas.
Natural slope landslides- Deep seated within rock mass	Very commonly translational and related to weaker interbeds of siltstone or thin coal seams. P. Dahlhaus felt that many of the bigger deeper slides on the coast may only be 6000 years of so old very large slides inland can retain displaced materials and still have well defined headscarps and even side scarps. Many of the bigger slides on the coast present as planar surfaces covered in colluvium with much of the displaced mass removed through wave action and water. Deep-seated slides may be present even when overall topography is not over steep due in part to the weak interbeds within the mass and at the base of the shear plane. Last known very large translational slide in rock was Lake Elizabeth in 1952 (thought to be a rare event possibly 1 in 500+ type occurrence). Retain distinct morphology suggesting they are geologically not that old.	Postulated that seismic triggers may be important for this type of very large deep seated slide Also important is the presence of water (stream or wave action) at the toe of these large and very large slides.	Hundreds of metres wide and long to 500 m wide and up to 1.5 km long. Depth maybe in the order of 30 m or so.	Can travel many tens of metres and can divert stream and creeks.	Maybe of the vicinity of 1 in 1000 or more. Overall POSSIBLE TO UNLIKELY
Cut Failures	Steeply battered cuts are common. Seems to be quite steep typical cuts in the Otways of maybe 50° to 60°. Failure generally in regolith and XW to highly weathered (HW) rock. Can be an occasional rock failure from a cut where orientation of bedding strikes with slope direction (i.e., dip slopes). Cuts can expose previous landslide debris which is generally more susceptible to batter failure. Common in winter and spring when groundwater levels are higher.	Heavy or intense rainfall events at the end of prolonged wet period. Also, over steepening of cuts due to limited space.	Typically cut failures on major roads like Great Ocean Road, Wild Dog Creek, Barham River Road are relatively small to moderate Possibly 5 m wide and same height. Occasionally much bigger failures occur.	These type of cut batter failures typically travel less than a few meters and not beyond a distance equal to the height of the cut. These types of failures generally cover roadside drains and may encroach on to the inner lane by 0.5 m or so.	Experience suggests these small type of cut failures are relatively common occurring in 1 in 25 to 1 in 50 type rainfall events LIKELY TO VERY LIKELY

Mode of Failure	Preparatory Casual Factors and other observations	Triggering Casual factors	Size and Nature	Mobility, Velocity and Runout	Estimates of Likelihood
Fill Failures	Loose and/or poorly compacted fills comprising materials derived from onsite excavations including mainly XW/HW sandstone Key factors include the poor quality of the fill, poor compaction during construction and construction on steep slopes with inadequate preparation and keying in. Failures tend to occur as a result of poor or concentrated drainage Very common on outer edge of Cut/fill roads and tracks.	Saturation of fill from groundwater or surface water flows. Many embankment failures occur due to uncontrolled flows from roadside drains.	Generally, tend to be small, possibly 5 m to 10 m in width and continue for the entire length of the fill embankment.	Because of saturation usually present at the time, failure can be quite mobile and travel tens of metres. Regression tends to be of the order of a meter of so and rarely does failure stake out an entire road lane.	Thought to have a similar frequency to cuts but probably slightly less. 1 in 50 to 1 in 100 LIKELY.
Debris Flows	Some evidence of boulders in creeks and on the beach indicates credible at some time in the past. Nyman (2013) designated two types of debris flow “runoff generated debris flows involving hillslope erosion process and “failure/slide” generated debris flow involving a mass movement as the source and becoming channelized where accumulation and entrainment of scoured materials become important. Debris flow is invariably associated with an extreme rainfall event in locations where topography is steep and depth of soil or soil and (weathered) rock is significant. Nyman (2013) noted that the majority of debris flows in the Eastern Victorian uplands occurred on slopes >25° on Northerly facing catchments Nyman show common debris flow occurrence within sedimentary rocks Note however Sheridan et al (University of Melbourne) noted that post Wye River bushfire debris flows were less likely in the Otways compared to the northeast uplands of Victoria due to more developed soils, lower temperatures, lower aridity and the impact of the marine climate promoting increased “greenness” Initial landslide mapping by ASMG and Golder indicates a number of highly channelized debris paths which could be associated with past debris flows. As such debris flow occurrence is still somewhat uncertain but remains a credible hazard	High intensity short duration rainfall event. Greater potential for failure within 12 months after bushfire. Failure generated slides in the northeast uplands need large /exceptional rainfall events ranging from 1 in 50 to >1 in 2000 and usually involve the movement of significant volumes of soil and rock. Runoff generated debris flows appear to be triggered by more frequent but still intense rainfall and are influenced by a loss of vegetation in the catchment usually after bushfire. Runoff volumes and intensity of rainfall are key. Rutherford still considered debris flow to be rare events in northeast Victoria but the records show a surprising number of events in the past 20 years. All post fire runoff generated debris flows have occurred within less than one year after fire. No comparable data for Otways A large debris flow event in the Grampians in January 2011 was well in excess of 1 in 100 storm event. But there is more on ground evidence in the Grampians there than in the Otway Ranges.	The size of the source failure can be quite modest but the overall volume of accumulated and entrained materials can be very significant.	Nyman suggested for northeast Victoria debris flows that L/DZ (runout length vs change in elevation) = 0.34 on average This equates to a travel angle of 18.8° Observations in the Grampians suggest flows travelled onto slopes as low as 10°. Very little observed evidence of debris travel distances in the Otway Ranges. Some interpretations suggest debris can reach the coast.	Assume debris flows are less likely in the Otway Ranges compared to northeast Victoria or the Grampians. Runoff generated debris flow following fire are probably POSSIBLE to LIKELY for at least a few years following bushfire Landslide generated debris flows in significant catchments are considered POSSIBLE to UNLIKELY but acknowledged that there is little evidence to support this initial judgement.
Rockfall	Source areas have been modelled as being >40°. Rockfalls are very common from cuttings comprised of weathered to fresh jointed rock, usually sandstone. Rockfall also noted from natural exposures usually as a result of geological structure.	See discussion for rockfalls from cuttings Long term groundwater elevation and triggering events from heavy or intense rainfall are the most likely initiators. Also, some evidence of triggering from thermal shock/impacts after bushfires.	Falls from cuttings tend to be <1m in diameter Larger falls are possible as shown by a major fall from Cumberland River where a near vertical rock face is undermined by weaker erodible siltstone. Any high near vertical exposure can generate large rockfalls which could be in excess of 1.0 m but dependent on bedding, discontinuities and joint spacing	Travel distance tends to be a function of the fall height and slope below the detachment point but capable of travelling many meters from source.	Estimate rockfall from cuttings to be LIKELY Rockfall from natural exposures could be slightly less and estimate likelihood to be POSSIBLE to LIKELY under very adverse conditions.

Mode of Failure	Preparatory Casual Factors and other observations	Triggering Causal factors	Size and Nature	Mobility, Velocity and Runout	Estimates of Likelihood
Creep	Creep is observed on steep slopes throughout the Otway Ranges. Note: for soil slopes in Tertiary sandy clays and volcanics on the Bellarine Peninsula creep is of the order of 1 mm/yr to 5 mm/yr.	Associated with excessive groundwater levels and saturation of soils on steep natural slopes.			Depends on material type and degree of saturation/levels of groundwater. In general POSSIBLE if conditions are there to allow.

Maps showing:

- geotechnical hazards observed during ground truthing stage;
- shallow landslides mapped based off digital terrain information;

are presented in Appendix D. These maps inform estimation of hazard density and frequency and are used as input to the development of hazard criteria.

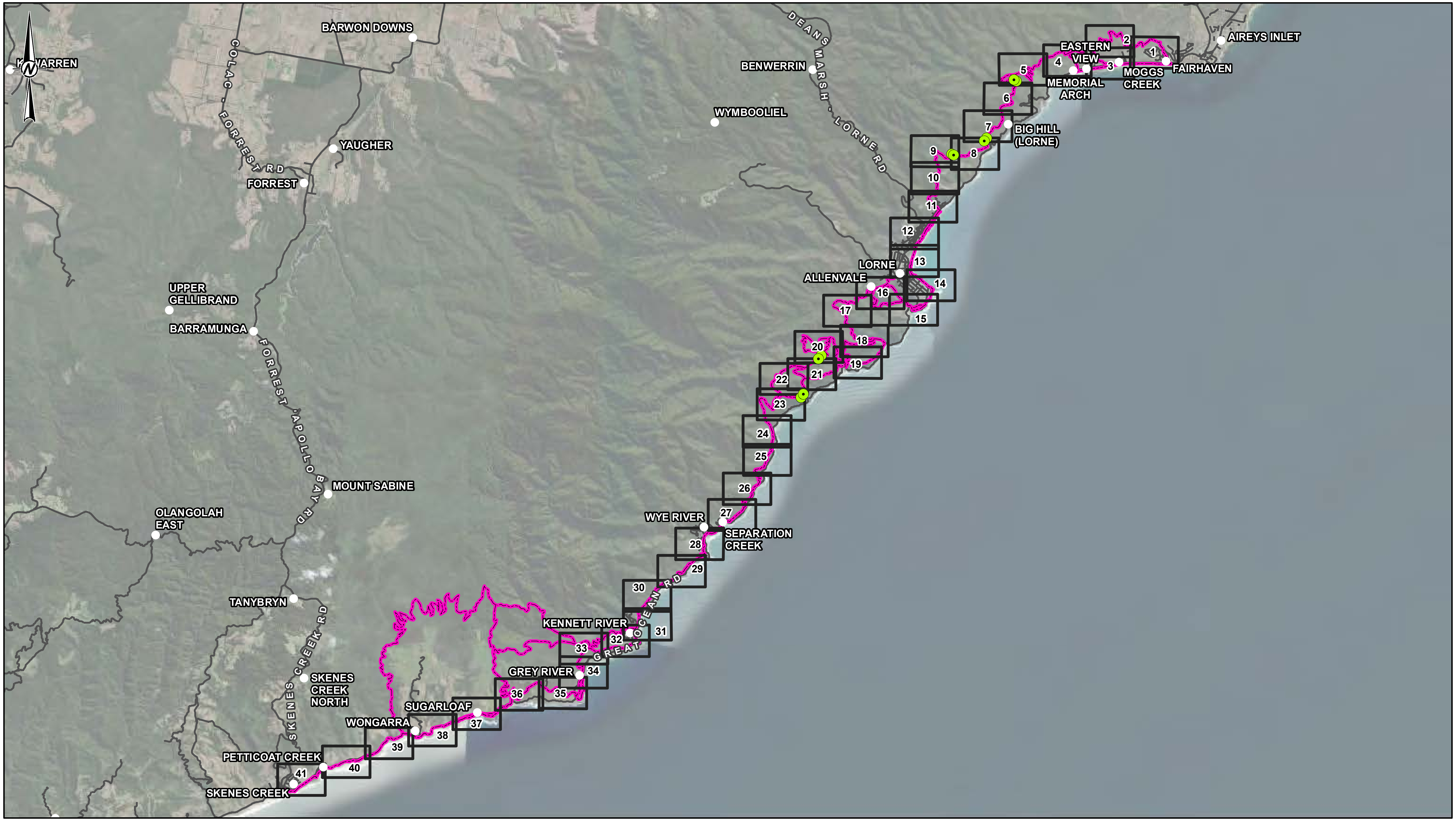
APPENDIX D

Hazard Maps

Index to Hazard Maps

Hazard Maps	Figures
Index Maps	Figure 1 and 2
Earthworks	Soil cut and fill batter failure hazard Figures 3.1 to 3.41
	Rock cut and fill batter failure hazard 4.1 to 4.41
Rock Falls	Rock fall hazard, Figures 5.1 – 5.41
Landslides	Shallow Soil Landslide Hazard, Figure 6.1 – 6.41
	Deep Landslides in Rock, Figure 7.1 to 7.41
Debris Flow	Debris Flow Landslide Hazard, Figure 8.1 to 8.41
Episodic Erosion	Episodic Erosion – Hard Rock Coast, Figure 9A.1 to 9A.27
	Episodic Erosion – Rock Debris Coast, Figure 9B.1 to 9B.27
	Episodic Erosion – Channel Migration, Figure 9C.1 to 9C.27
Progressive Erosion	Progressive Erosion – Soft Coast, Rock Debris, Figure 10A.1 to 10A.27
	Progressive Erosion – Soft Coast, Figure 10B.1 to 10B.27
	Progressive Erosion – Soft Coast, Beach Figure 10C.1 to 10C.27

Index Maps



LEGEND

- Bridge Locations
- Major Roads
- Trail Concept Route 2

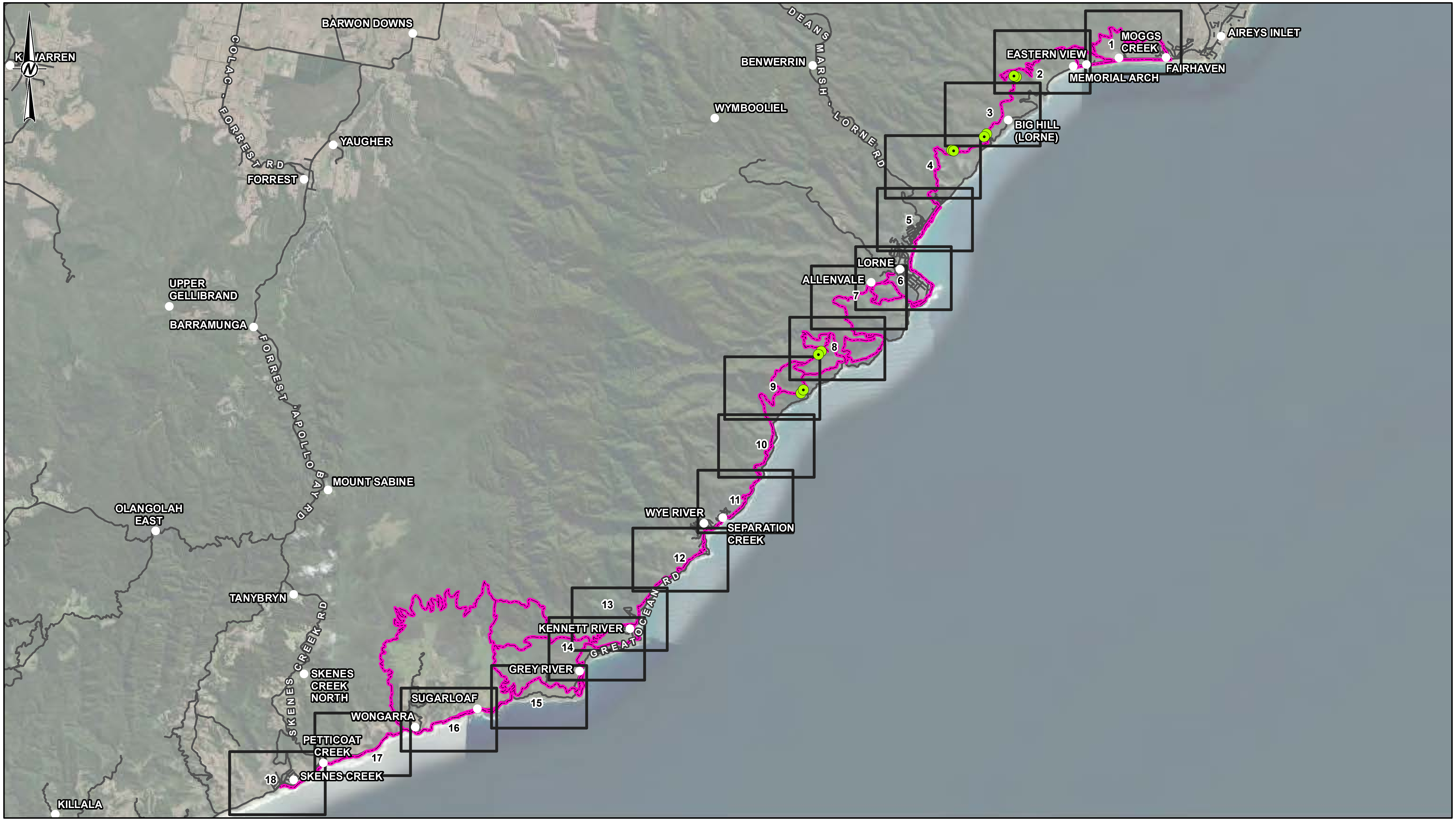
0 1,500 3,000 4,500 6,000

Scale @ A3 1:140,000 METRES

REFERENCE(S)

1. PROJECTION: GDA2020 MGA ZONE 54
2. AERIAL IMAGERY SOURCED FROM ESRI.
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

CLIENT WORLD TRAIL		PROJECT GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT	
CONSULTANT GOLDER MEMBER OF WSP	YYYY-MM-DD: 2021-12-22 DESIGNED: - PREPARED: DN REVIEWED: GM APPROVED: GM	TITLE INDEX MAP - 1: 5,000 MAP SETS	
		PROJECT NO. 21468192	CONTROL 001-R · REV. A · FIGURE 1



LEGEND

- Bridge Locations
- Major Roads
- Trail Concept Route 2

REFERENCE(S)

1. PROJECTION: GDA2020 MGA ZONE 54
2. AERIAL IMAGERY SOURCED FROM ESRI.
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

0 1,500 3,000 4,500 6,000

Scale @ A3 1:140,000 METRES

CLIENT WORLD TRAIL		PROJECT GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT	
CONSULTANT GOLDER MEMBER OF WSP	YYYY-MM-DD	2021-12-22	TITLE INDEX MAP - 1: 10,000 MAP SETS
	DESIGNED	-	
	PREPARED	DN	
	REVIEWED	GM	PROJECT NO. 21468192 · CONTROL 001-R · REV. A · FIGURE 2
	APPROVED	GM	

Earthworks

LEGEND

- Major Roads
- Watercourses
- Trail Concept Route 2

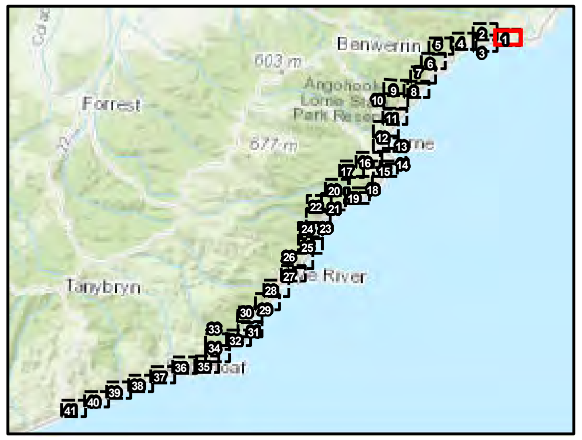
Hazard Levels

Cut

- Very High
- High
- Low
- Very Low

Fill

- High
- Moderate
- Very Low



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Scale @ A3 1:5,000 METRES

REFERENCE(S)
1. PROJECTION: GDA2020 MGA ZONE 54
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

CLIENT
WORLD TRAIL

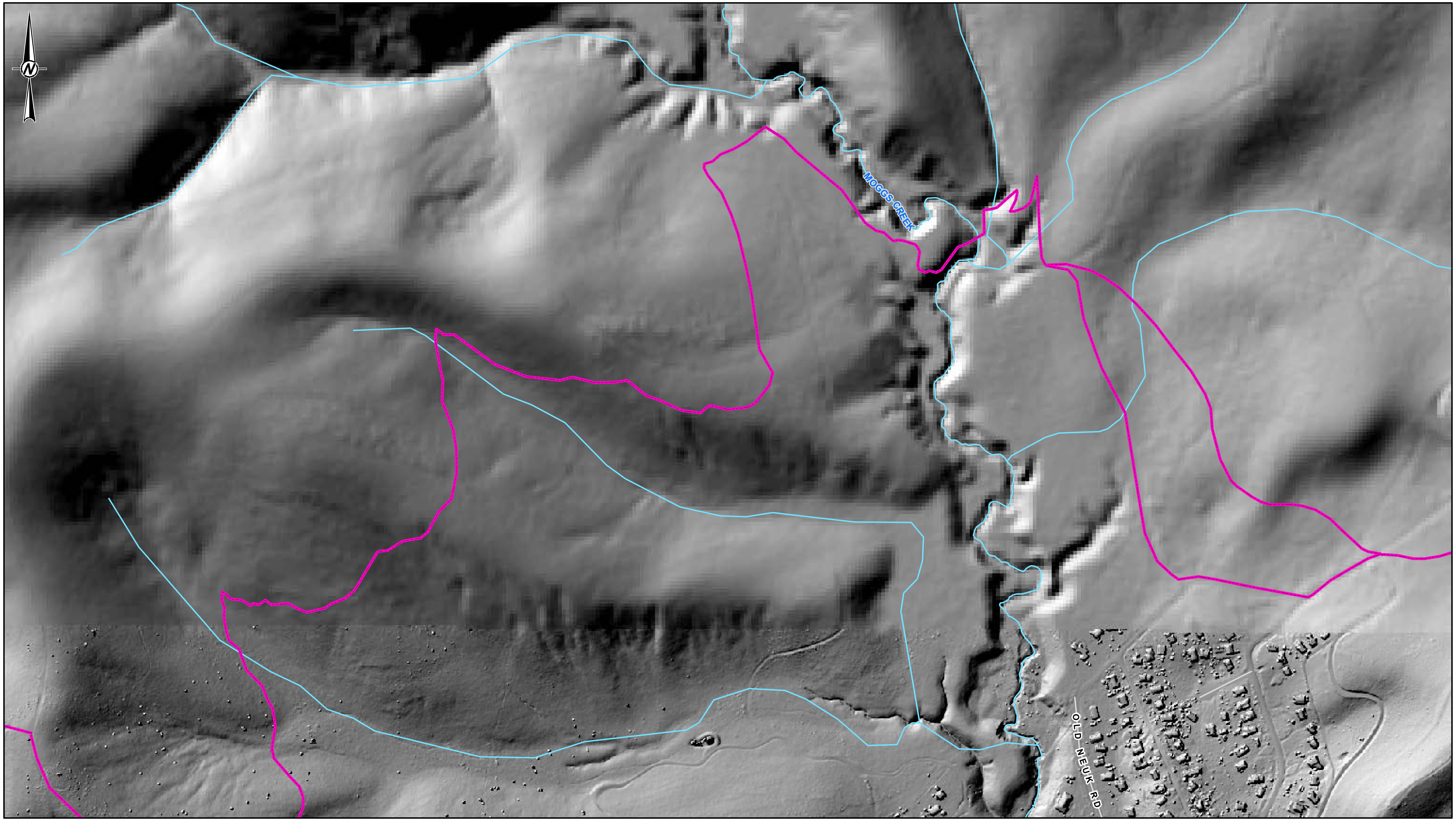
PROJECT
GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT

CONSULTANT
GOLDER MEMBER OF WSP

YYYY-MM-DD	2021-12-22
DESIGNED	-
PREPARED	DN
REVIEWED	GM
APPROVED	GM

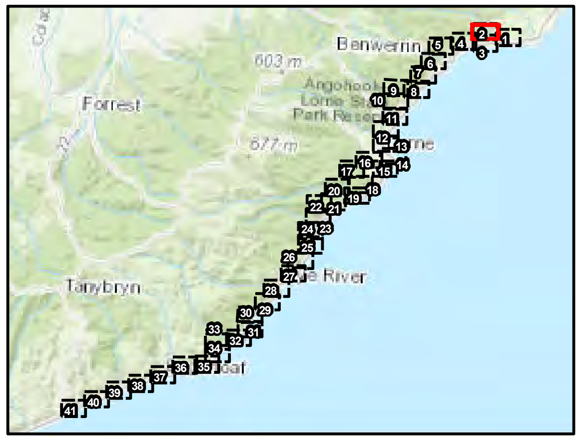
TITLE
SOIL CUT AND FILL BATTER FAILURE HAZARD

PROJECT NO.	CONTROL	REV.	FIGURE
21468192	001-R	A	3.1



LEGEND

- Major Roads
- Watercourses
- Trail Concept Route 2



REFERENCE(S)
1. PROJECTION: GDA2020 MGA ZONE 54
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

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Scale @ A3 1:5,000 METRES

CLIENT
WORLD TRAIL

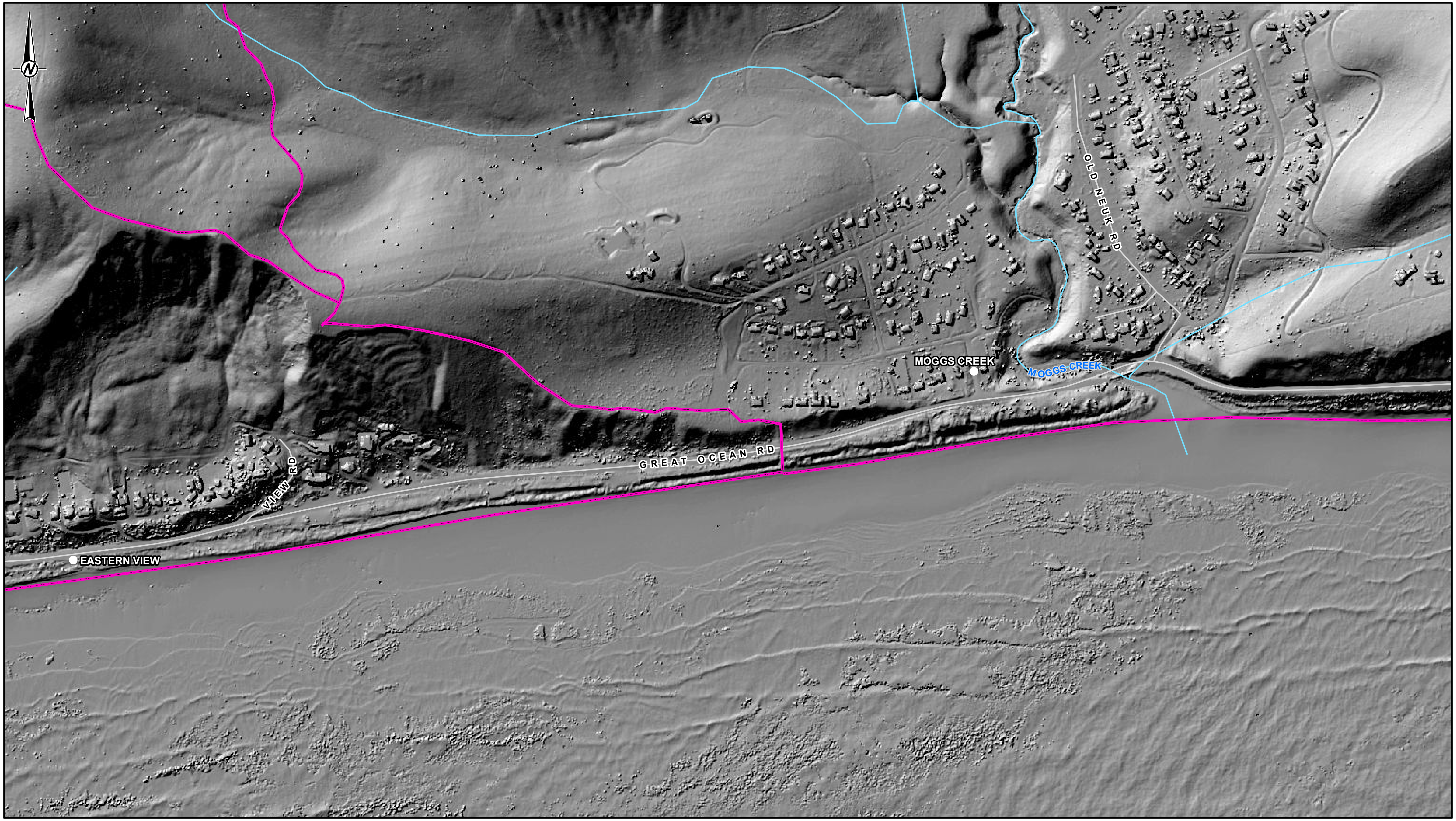
PROJECT
GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT

CONSULTANT
GOLDER MEMBER OF WSP

YYYY-MM-DD	2021-12-22
DESIGNED	-
PREPARED	DN
REVIEWED	GM
APPROVED	GM

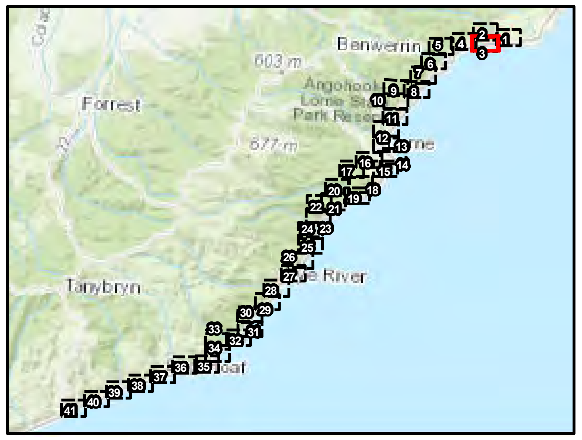
TITLE
SOIL CUT AND FILL BATTER FAILURE HAZARD

PROJECT NO.	CONTROL	REV.	FIGURE
21468192	001-R	A	3.2



LEGEND

- Major Roads
- Watercourses
- Trail Concept Route 2



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Scale @ A3 1:5,000 METRES

REFERENCE(S)
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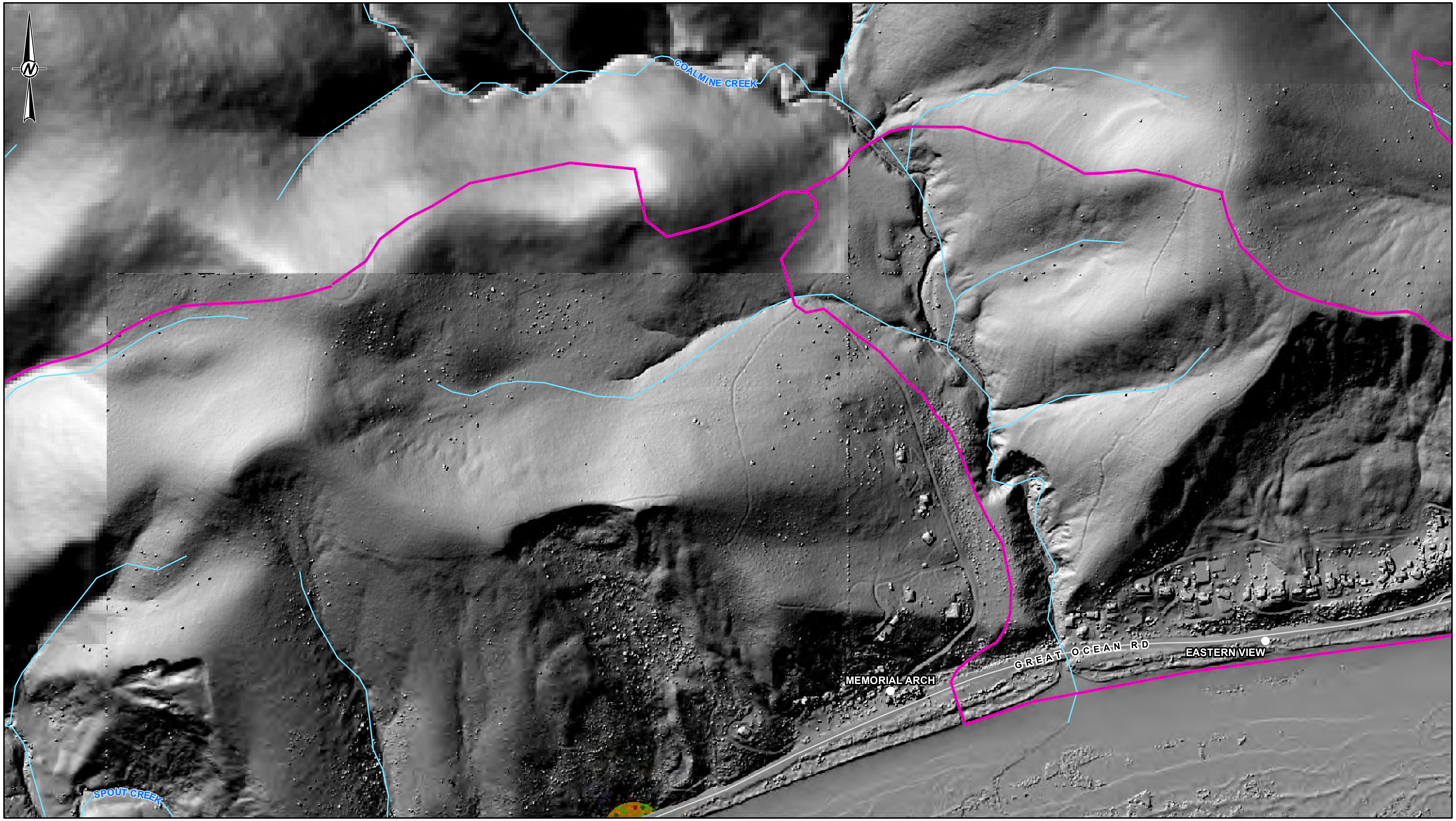
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

CLIENT	WORLD TRAIL
PROJECT	GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT
CONSULTANT	GOLDER MEMBER OF WSP
YYYY-MM-DD	2021-12-22
DESIGNED	-
PREPARED	DN
REVIEWED	GM
APPROVED	GM
TITLE	SOIL CUT AND FILL BATTER FAILURE HAZARD
PROJECT NO.	21468192
CONTROL	001-R
REV.	A
FIGURE	3.3



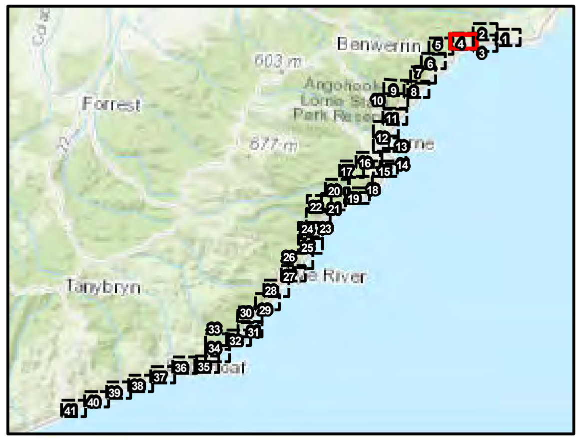
LEGEND

- Major Roads
- Watercourses
- Trail Concept Route 2

Hazard Levels

Cut

- Very High
- High
- Low
- Very Low



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Scale @ A3 1:5,000 METRES

REFERENCE(S)
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2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

CLIENT	WORLD TRAIL	PROJECT	GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT
CONSULTANT	GOLDER MEMBER OF WSP	TITLE	SOIL CUT AND FILL BATTER FAILURE HAZARD

YYYY-MM-DD	2021-12-22
DESIGNED	-
PREPARED	DN
REVIEWED	GM
APPROVED	GM

PROJECT NO.	CONTROL	REV.	FIGURE
21468192	001-R	A	3.4

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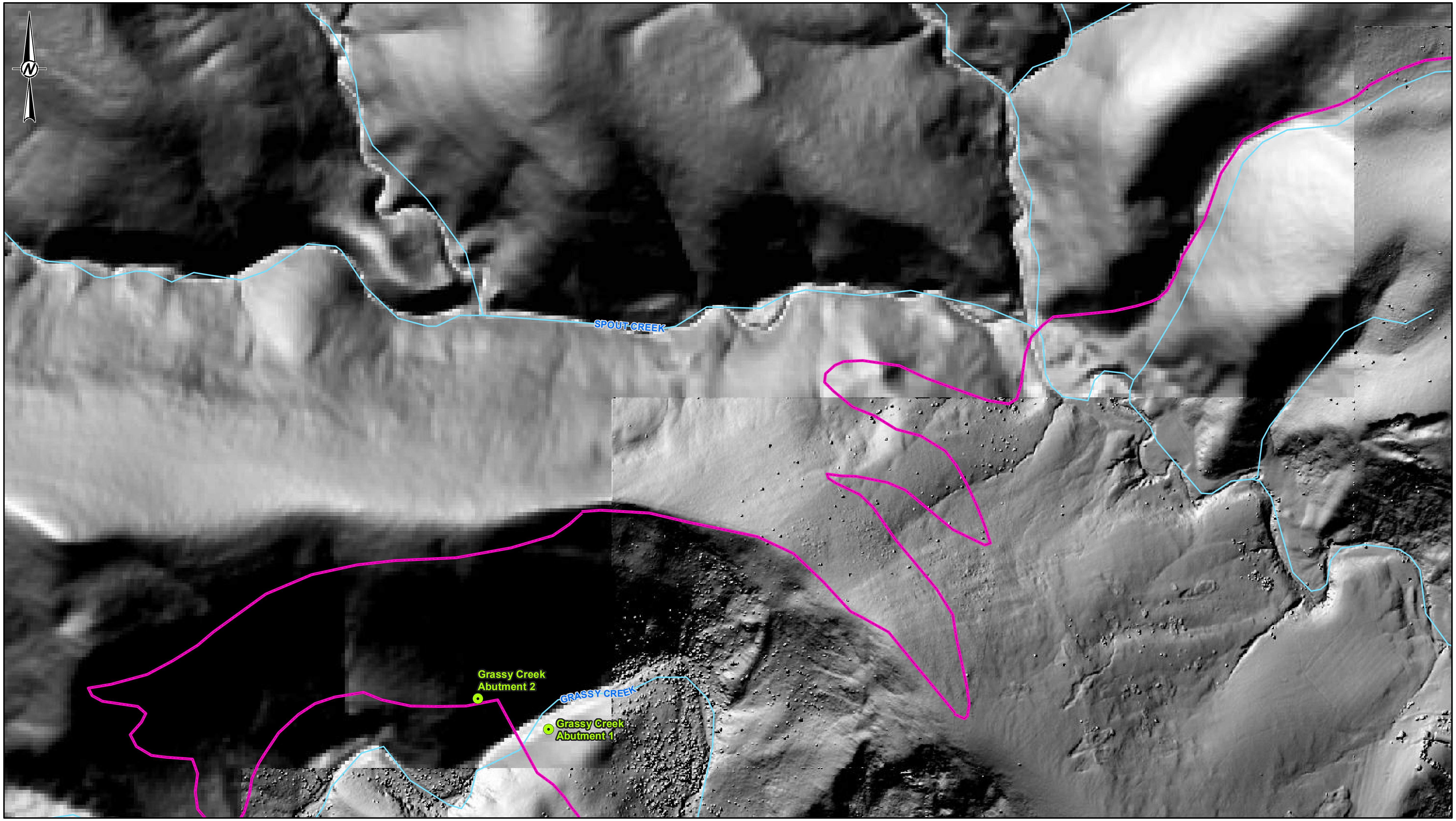
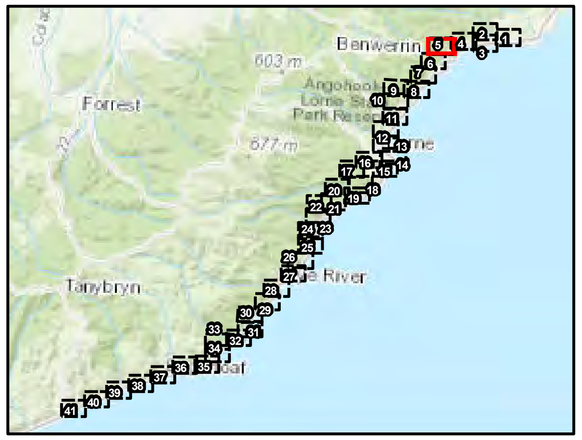


LEGEND

- Bridge Locations
- Watercourses
- Trail Concept Route 2



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REFERENCE(S)
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2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

CLIENT WORLD TRAIL		PROJECT GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT	
CONSULTANT GOLDER MEMBER OF WSP	YYYY-MM-DD	2021-12-22	TITLE SOIL CUT AND FILL BATTER FAILURE HAZARD
	DESIGNED	-	
	PREPARED	DN	
	REVIEWED	GM	PROJECT NO. 21468192 / CONTROL 001-R / REV. A / FIGURE 3.5
	APPROVED	GM	

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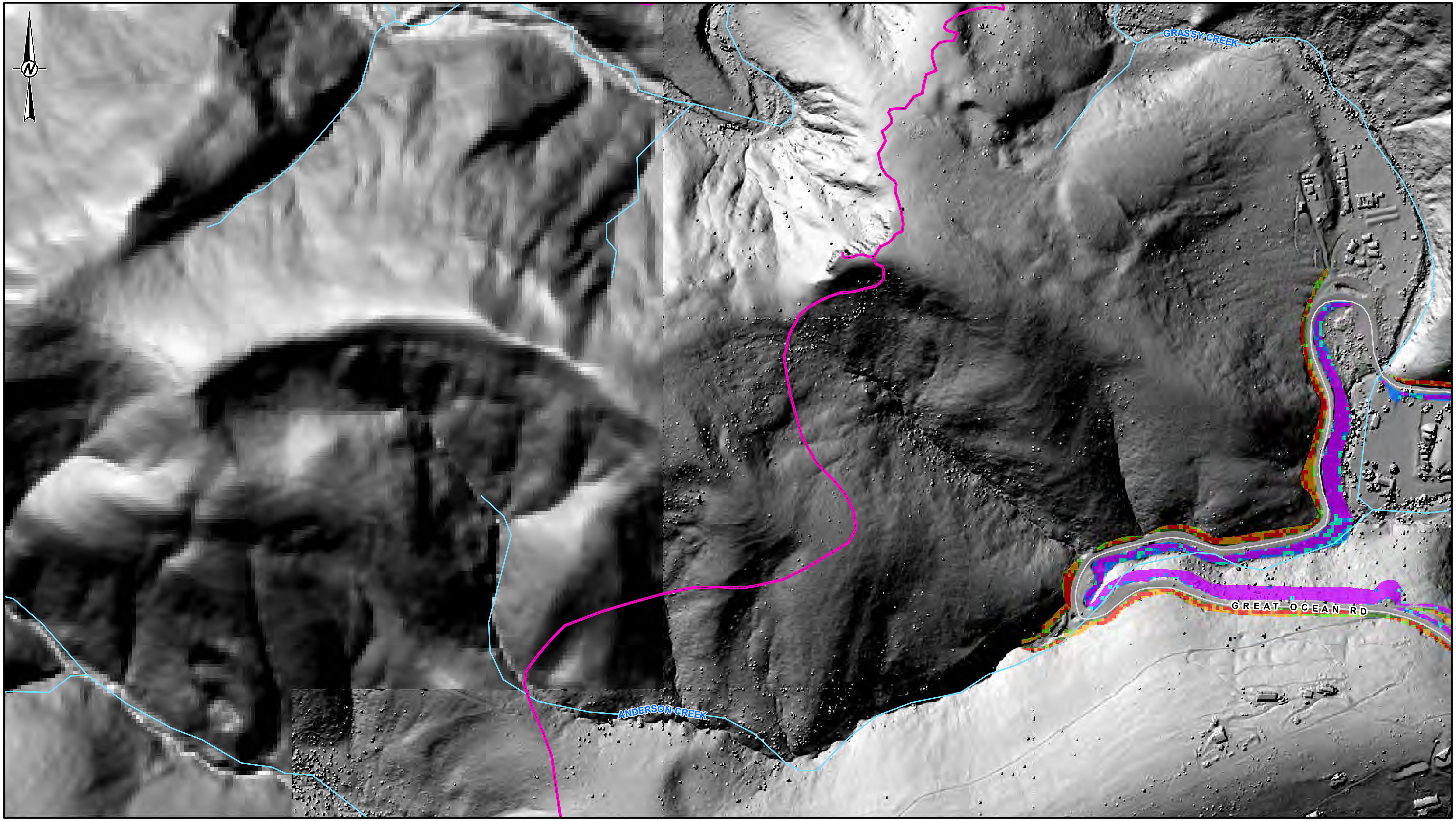


LEGEND

- Major Roads
- Watercourses
- Trail Concept Route 2

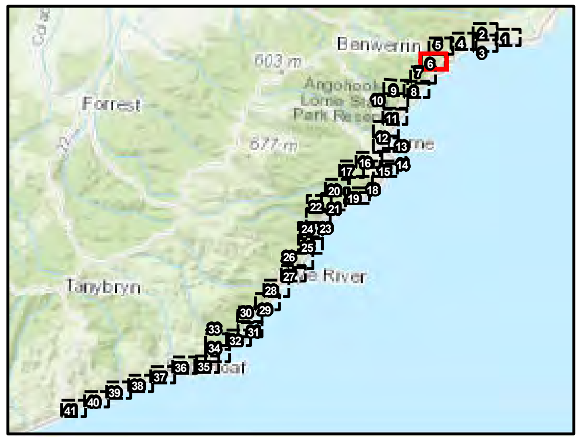
Hazard Levels

Cut

- Very High
- High
- Low
- Very Low

Fill

- High
- Moderate
- Very Low



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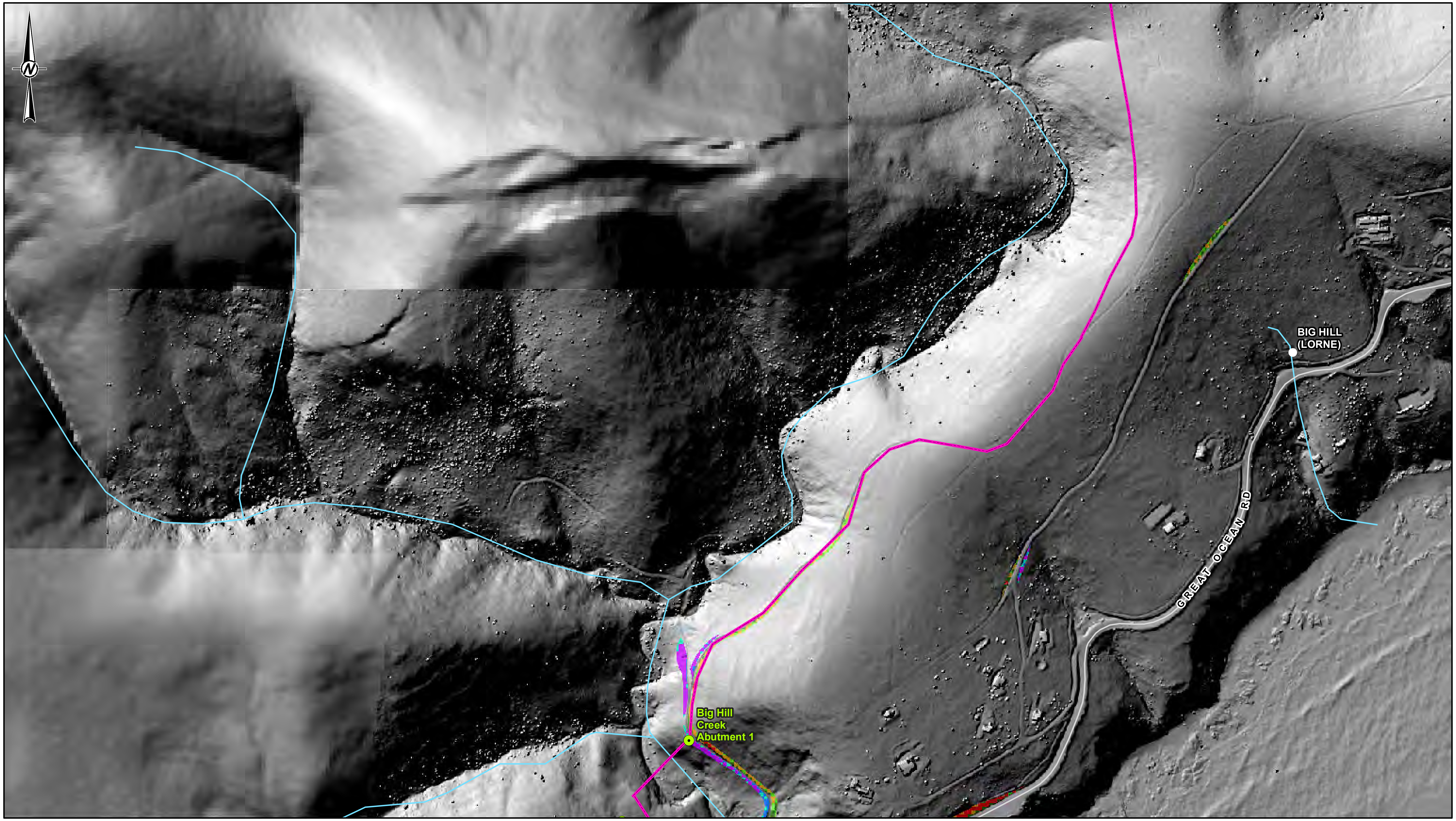
1. PROJECTION: GDA2020 MGA ZONE 54
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

CLIENT	WORLD TRAIL
CONSULTANT	GOLDER MEMBER OF WSP
YYYY-MM-DD	2021-12-22
DESIGNED	-
PREPARED	DN
REVIEWED	GM
APPROVED	GM

PROJECT
GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT

TITLE
SOIL CUT AND FILL BATTER FAILURE HAZARD

PROJECT NO.	CONTROL	REV.	FIGURE
21468192	001-R	A	3.6



LEGEND

- Bridge Locations
- Major Roads
- Watercourses
- Trail Concept Route 2

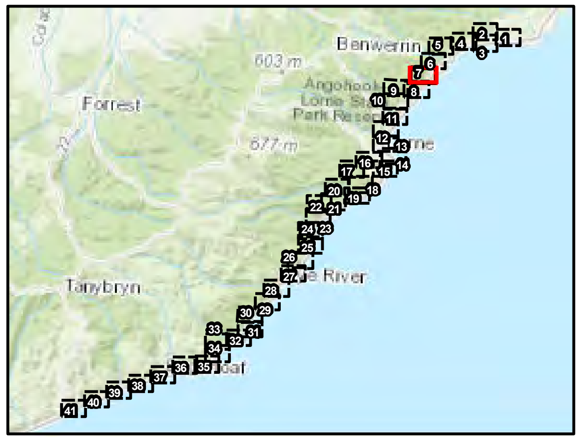
Hazard Levels

Cut

- Very High
- High
- Low
- Very Low

Fill

- High
- Moderate
- Very Low



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Scale @ A3 1:5,000 METRES

REFERENCE(S)
1. PROJECTION: GDA2020 MGA ZONE 54
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

CLIENT
WORLD TRAIL

PROJECT
GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT

CONSULTANT
GOLDER MEMBER OF WSP

YYYY-MM-DD	2021-12-22
DESIGNED	-
PREPARED	DN
REVIEWED	GM
APPROVED	GM

TITLE
SOIL CUT AND FILL BATTER FAILURE HAZARD

PROJECT NO.	CONTROL	REV.	FIGURE
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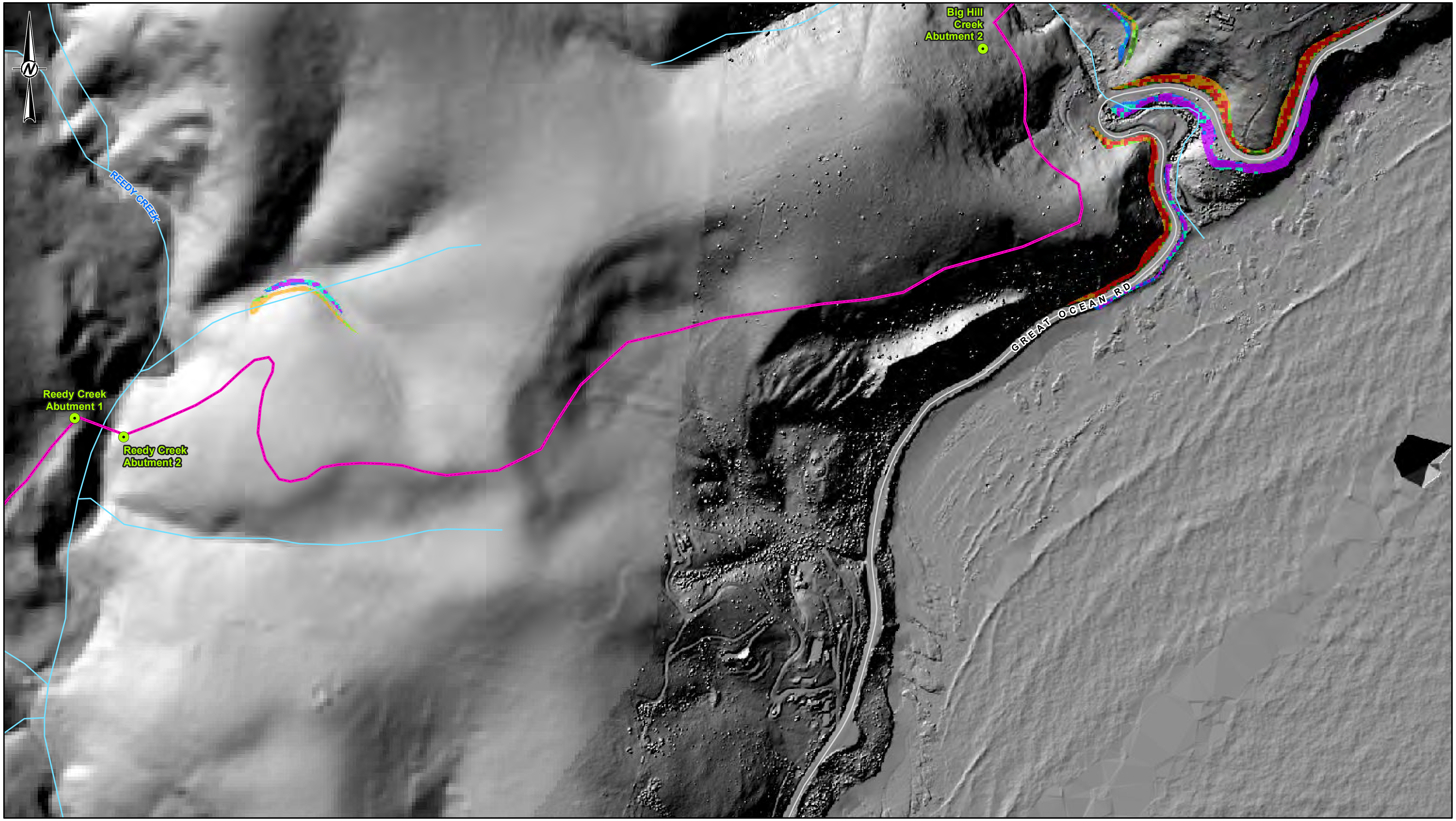


LEGEND

- Bridge Locations
- Major Roads
- Watercourses
- Trail Concept Route 2

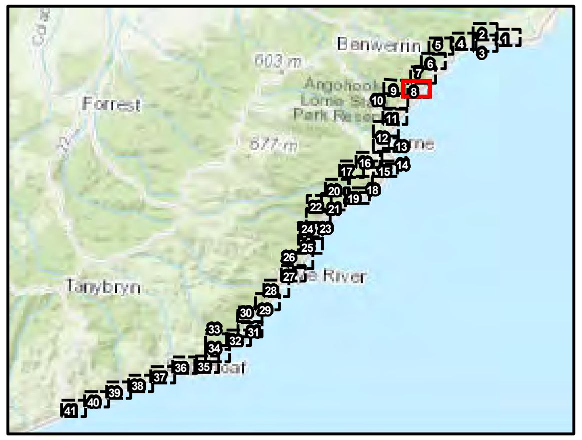
Hazard Levels

Cut

- Very High
- High
- Low
- Very Low

Fill

- High
- Moderate
- Very Low



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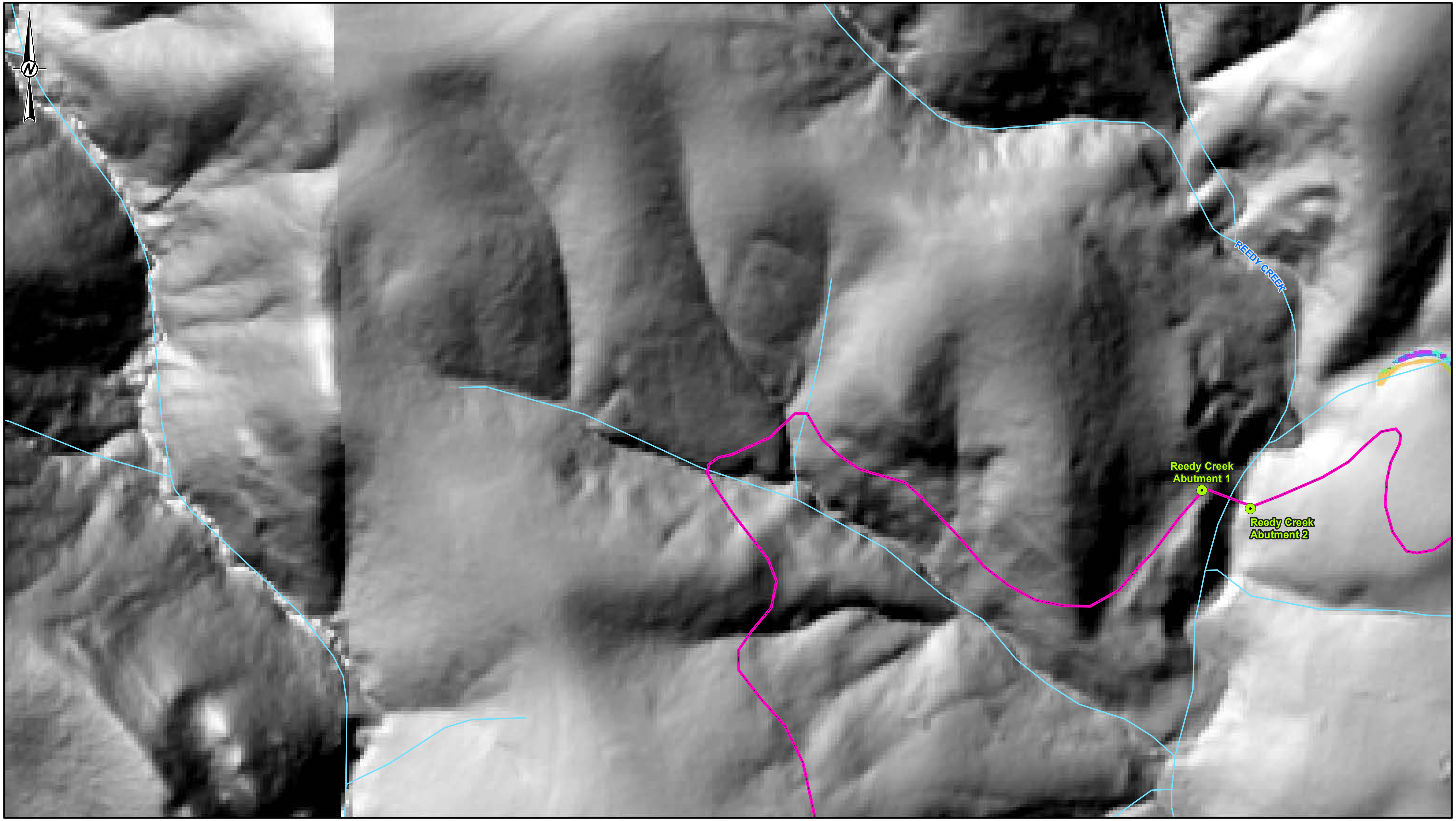
1. PROJECTION: GDA2020 MGA ZONE 54
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

CLIENT	WORLD TRAIL
PROJECT	GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT
CONSULTANT	GOLDER MEMBER OF WSP
YYYY-MM-DD	2021-12-22
DESIGNED	-
PREPARED	DN
REVIEWED	GM
APPROVED	GM
TITLE	SOIL CUT AND FILL BATTER FAILURE HAZARD
PROJECT NO.	21468192
CONTROL	001-R
REV.	A
FIGURE	3.8



LEGEND

- Bridge Locations
- Watercourses
- Trail Concept Route 2

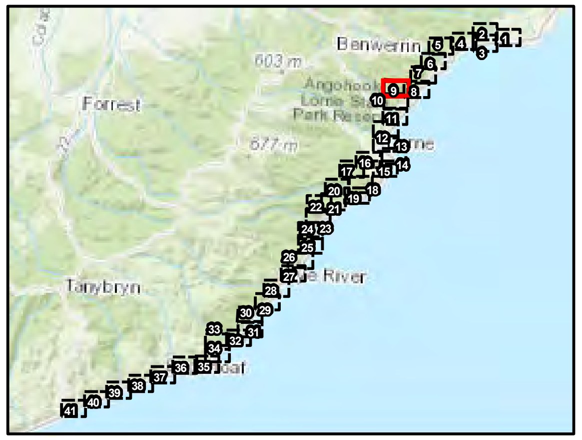
Hazard Levels

Cut

- High
- Low
- Very Low

Fill

- High
- Moderate
- Very Low



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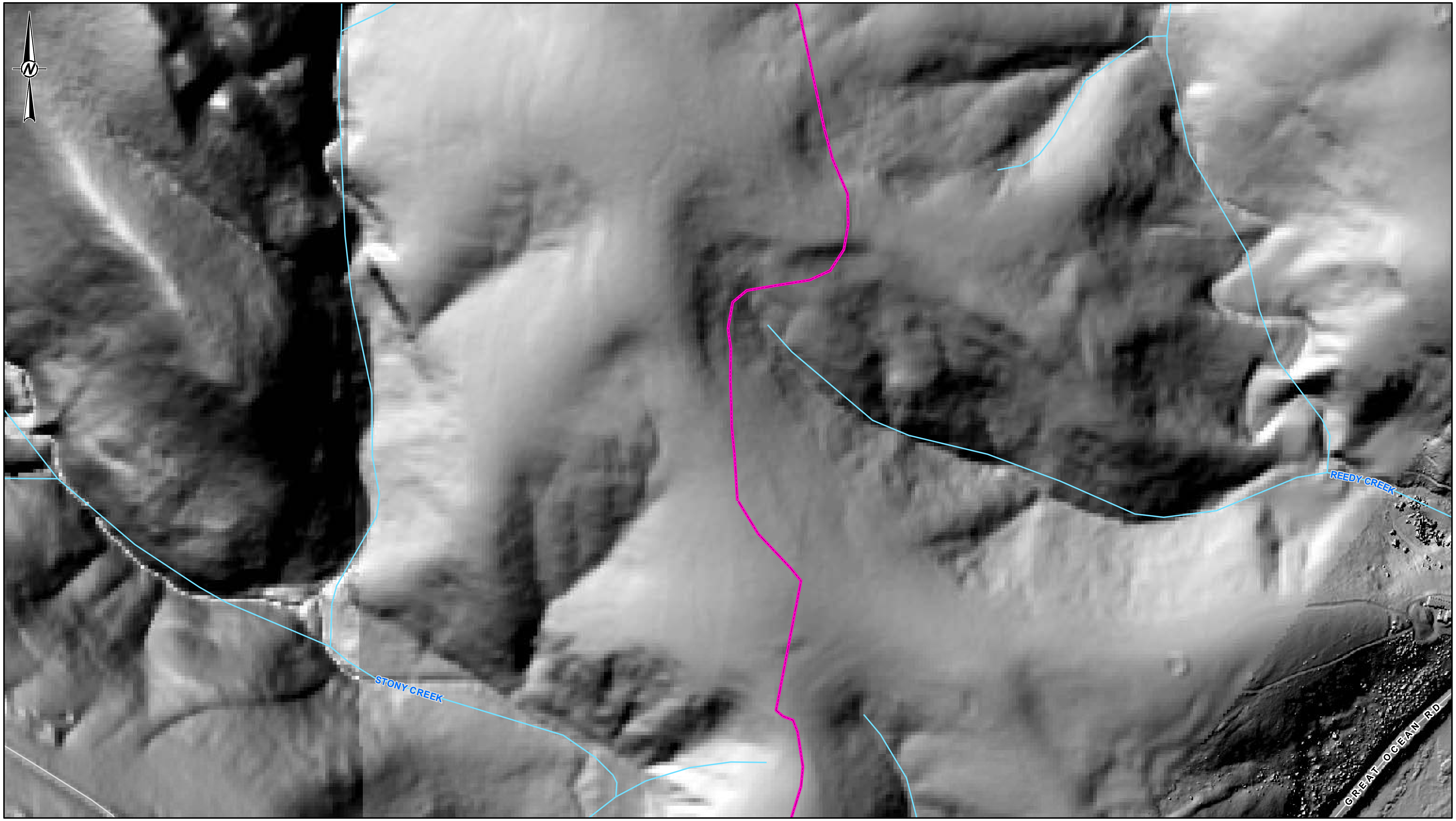
CLIENT	WORLD TRAIL
CONSULTANT	GOLDER MEMBER OF WSP
YYYY-MM-DD	2021-12-22
DESIGNED	-
PREPARED	DN
REVIEWED	GM
APPROVED	GM

PROJECT
GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT

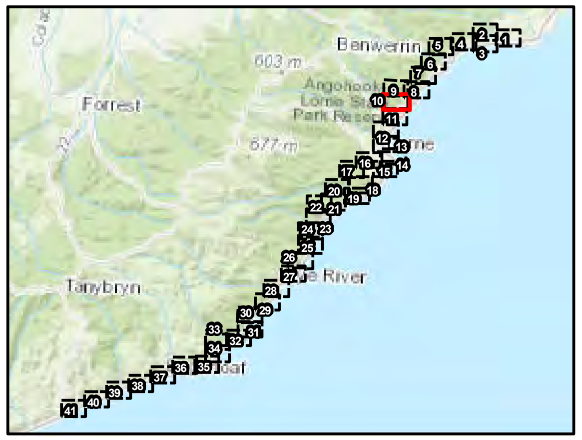
TITLE
SOIL CUT AND FILL BATTER FAILURE HAZARD

PROJECT NO.	CONTROL	REV.	FIGURE
21468192	001-R	A	3.9



LEGEND

- Major Roads
- Watercourses
- Trail Concept Route 2



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Scale @ A3 1:5,000 METRES

REFERENCE(S)
1. PROJECTION: GDA2020 MGA ZONE 54
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

CLIENT WORLD TRAIL		PROJECT GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT	
CONSULTANT GOLDER MEMBER OF WSP	YYYY-MM-DD: 2021-12-22 DESIGNED: - PREPARED: DN REVIEWED: GM APPROVED: GM	TITLE SOIL CUT AND FILL BATTER FAILURE HAZARD	
		PROJECT NO. 21468192	CONTROL 001-R
		REV. A	FIGURE 3.10

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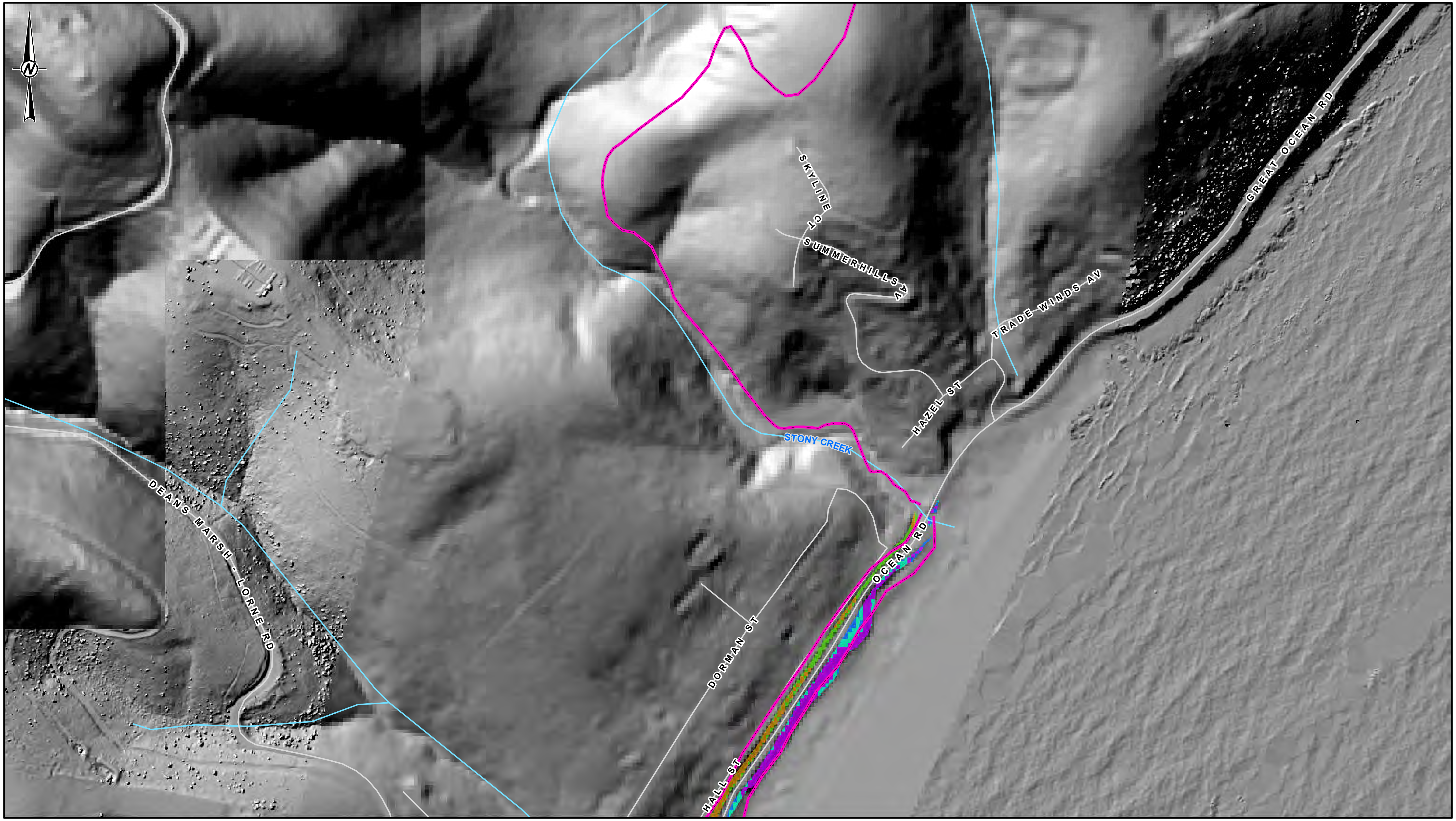


LEGEND

- Major Roads
- Watercourses
- Trail Concept Route 2

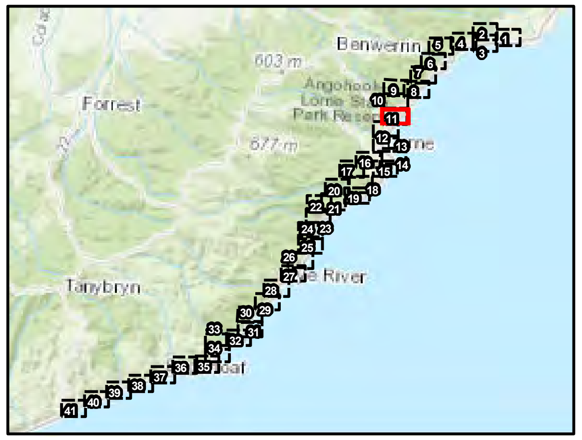
Hazard Levels

Cut

- Very High
- High
- Low
- Very Low

Fill

- High
- Moderate
- Very Low



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3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

CLIENT
WORLD TRAIL

PROJECT
GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT

CONSULTANT
GOLDER MEMBER OF WSP

YYYY-MM-DD	2021-12-22
DESIGNED	-
PREPARED	DN
REVIEWED	GM
APPROVED	GM

TITLE
SOIL CUT AND FILL BATTER FAILURE HAZARD

PROJECT NO.	CONTROL	REV.	FIGURE
21468192	001-R	A	3.11

LEGEND

- Major Roads
- Watercourses
- Trail Concept Route 2

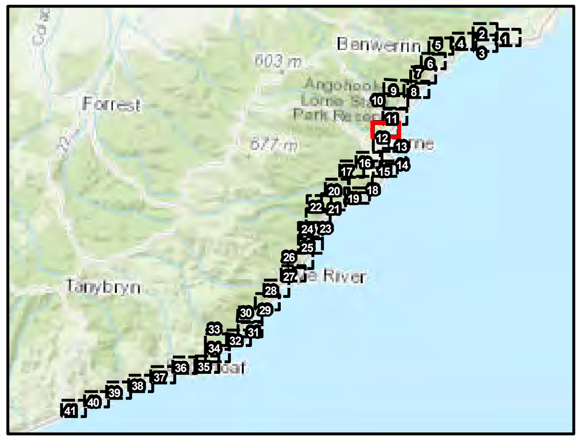
Hazard Levels

Cut

- Very High
- High
- Low
- Very Low

Fill

- High
- Moderate
- Very Low



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REFERENCE(S)
1. PROJECTION: GDA2020 MGA ZONE 54
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

CLIENT
WORLD TRAIL

PROJECT
GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT

CONSULTANT

GOLDER MEMBER OF WSP

YYYY-MM-DD	2021-12-22
DESIGNED	-
PREPARED	DN
REVIEWED	GM
APPROVED	GM

TITLE
SOIL CUT AND FILL BATTER FAILURE HAZARD

PROJECT NO.	CONTROL	REV.	FIGURE
21468192	001-R	A	3.12

LEGEND

- Major Roads
- Watercourses
- Trail Concept Route 2

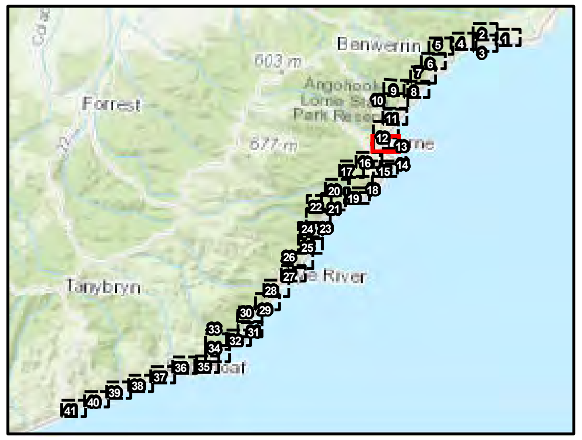
Hazard Levels

Cut

- Very High
- High
- Low
- Very Low

Fill

- High
- Moderate
- Very Low



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Scale @ A3 1:5,000 METRES

REFERENCE(S)
1. PROJECTION: GDA2020 MGA ZONE 54
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

CLIENT
WORLD TRAIL

CONSULTANT

GOLDER MEMBER OF WSP

YYYY-MM-DD	2021-12-22
DESIGNED	-
PREPARED	DN
REVIEWED	GM
APPROVED	GM

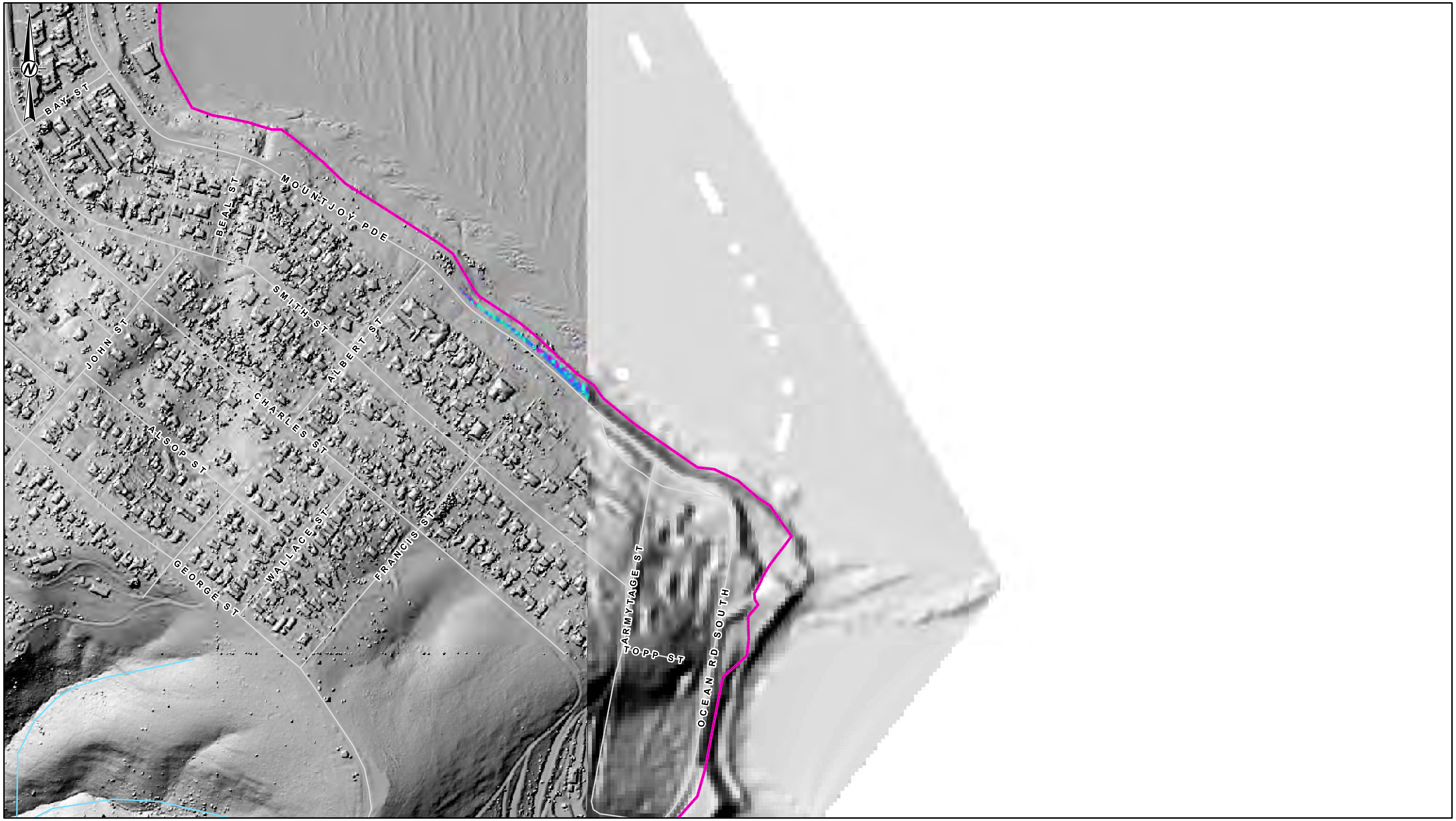
PROJECT
GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT

TITLE
SOIL CUT AND FILL BATTER FAILURE HAZARD

PROJECT NO.	CONTROL	REV.	FIGURE
21468192	001-R	A	3.13

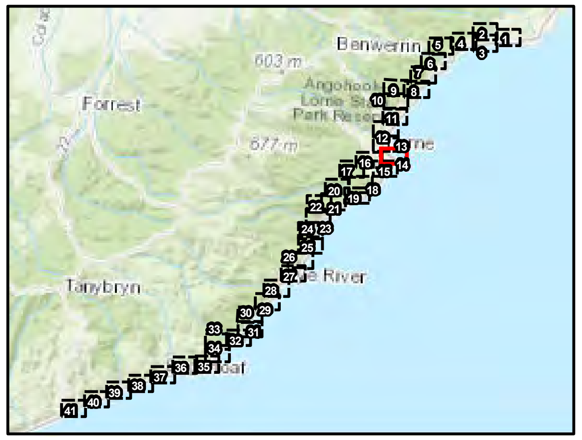
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ISO A3

25mm



LEGEND

	Major Roads	**Fill**	
	Watercourses		High
	Trail Concept Route 2		Moderate
			Very Low



0 75 150 225 300

Scale @ A3 1:5,000 METRES

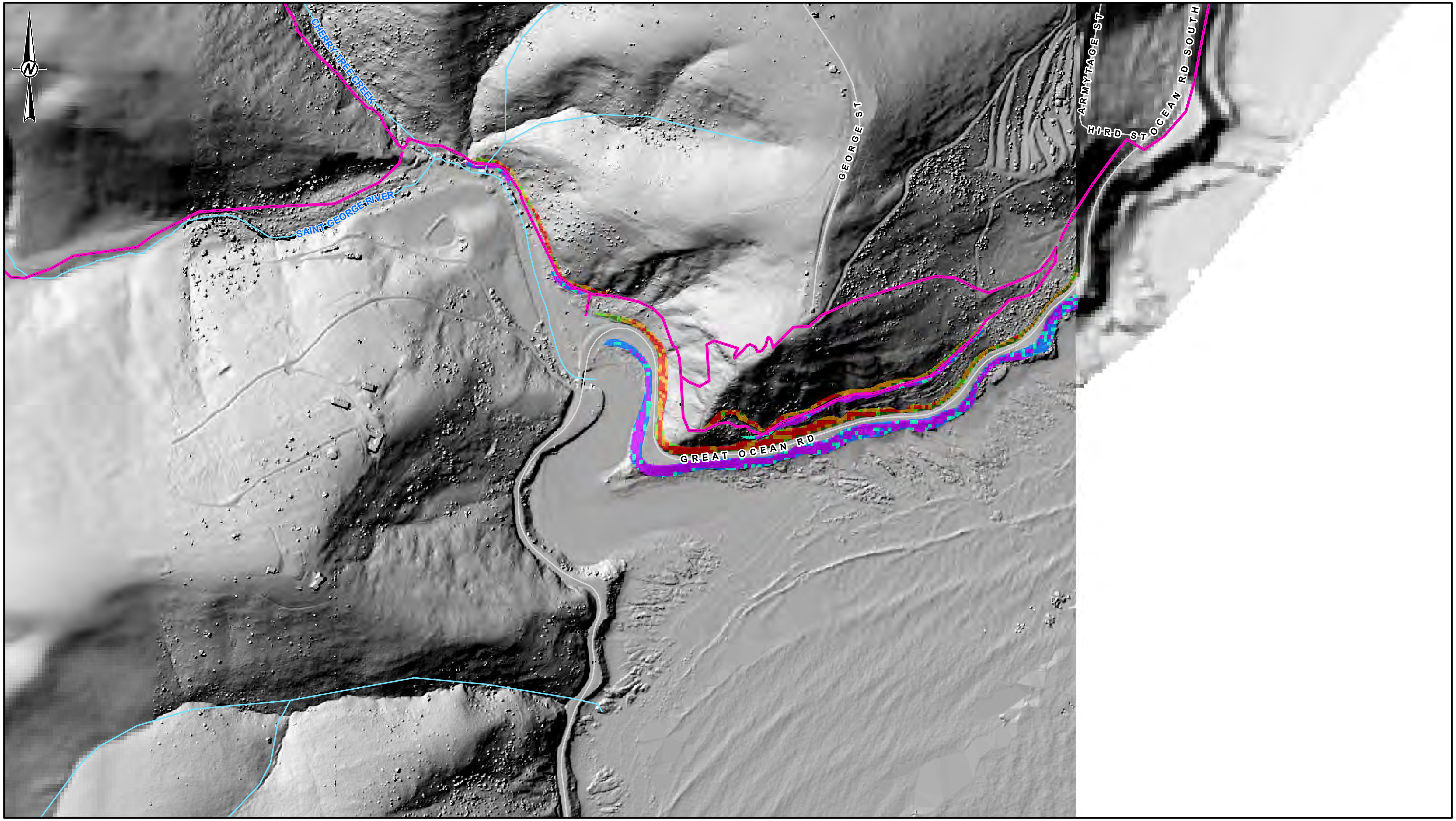
REFERENCE(S)
1. PROJECTION: GDA2020 MGA ZONE 54
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

CLIENT WORLD TRAIL		PROJECT GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT	
CONSULTANT GOLDER MEMBER OF WSP	YYYY-MM-DD	2021-12-22	TITLE SOIL CUT AND FILL BATTER FAILURE HAZARD
	DESIGNED	-	
	PREPARED	DN	
	REVIEWED	GM	PROJECT NO. 21468192 / CONTROL 001-R / REV. A / FIGURE 3.14
	APPROVED	GM	

PATH: B:\Melbourne\Geomatics\World_Trail\Great_Ocean_Road\99_PROJECTS\21468192_Great Ocean Road Trail\21468192_Geotechnical Hazard Assessment\02_PRODUCTION\MXD\21468192-001-R-RevA_F0003.mxd PRINTED ON: 2021-12-22 AT: 5:29:38 PM

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

25mm



LEGEND

Major Roads

Watercourses

Trail Concept Route 2

Hazard Levels

Cut

Very High

High

Low

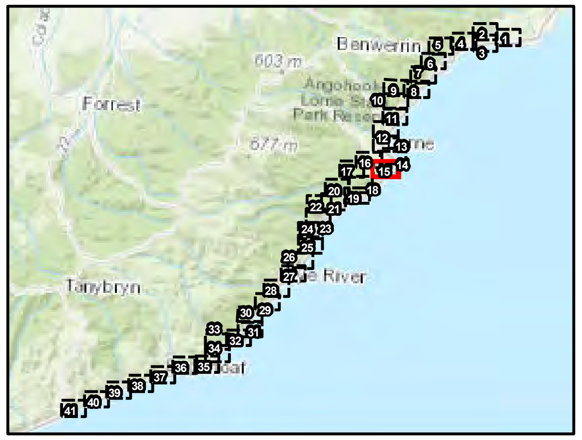
Very Low

Fill

High

Moderate

Very Low



0 75 150 225 300

Scale @ A3 1:5,000 METRES

REFERENCE(S)
1. PROJECTION: GDA2020 MGA ZONE 54
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

CLIENT
WORLD TRAIL

CONSULTANT

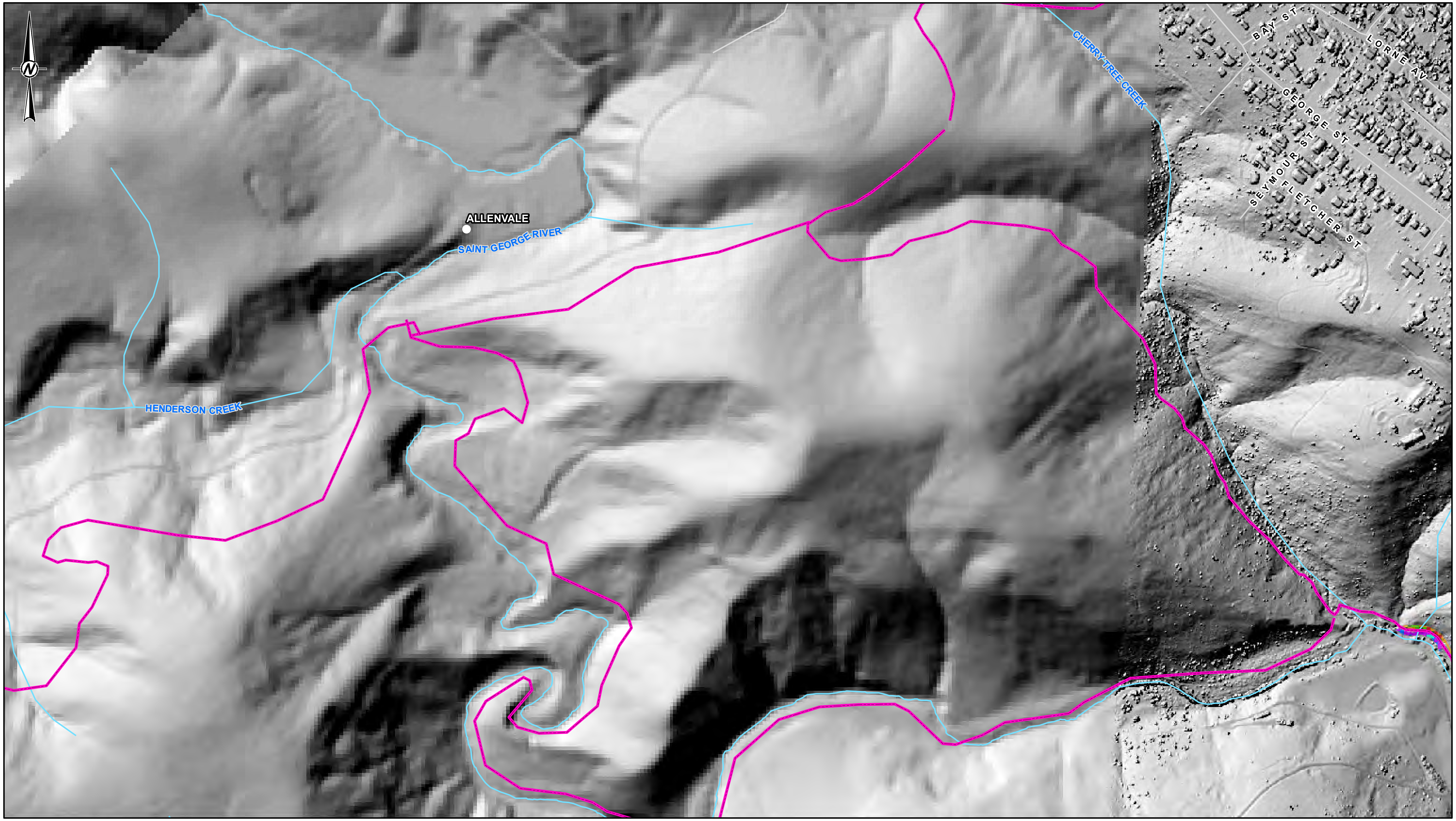
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-12-22
DESIGNED	-
PREPARED	DN
REVIEWED	GM
APPROVED	GM

PROJECT
GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT

TITLE
SOIL CUT AND FILL BATTER FAILURE HAZARD

PROJECT NO.	CONTROL	REV.	FIGURE
21468192	001-R	A	3.15



LEGEND

- Major Roads
- Watercourses
- Trail Concept Route 2

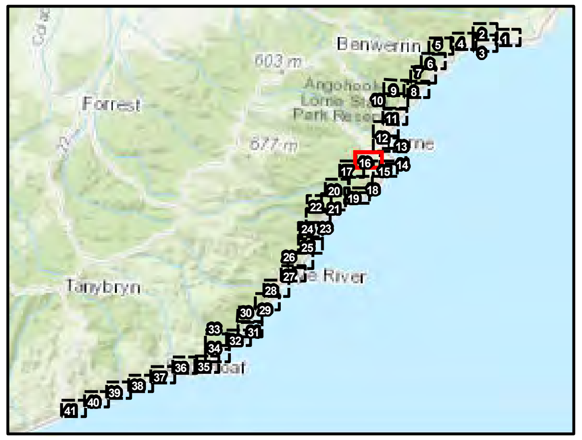
Hazard Levels

Cut

- Very High
- High
- Low
- Very Low

Fill

- High
- Moderate
- Very Low

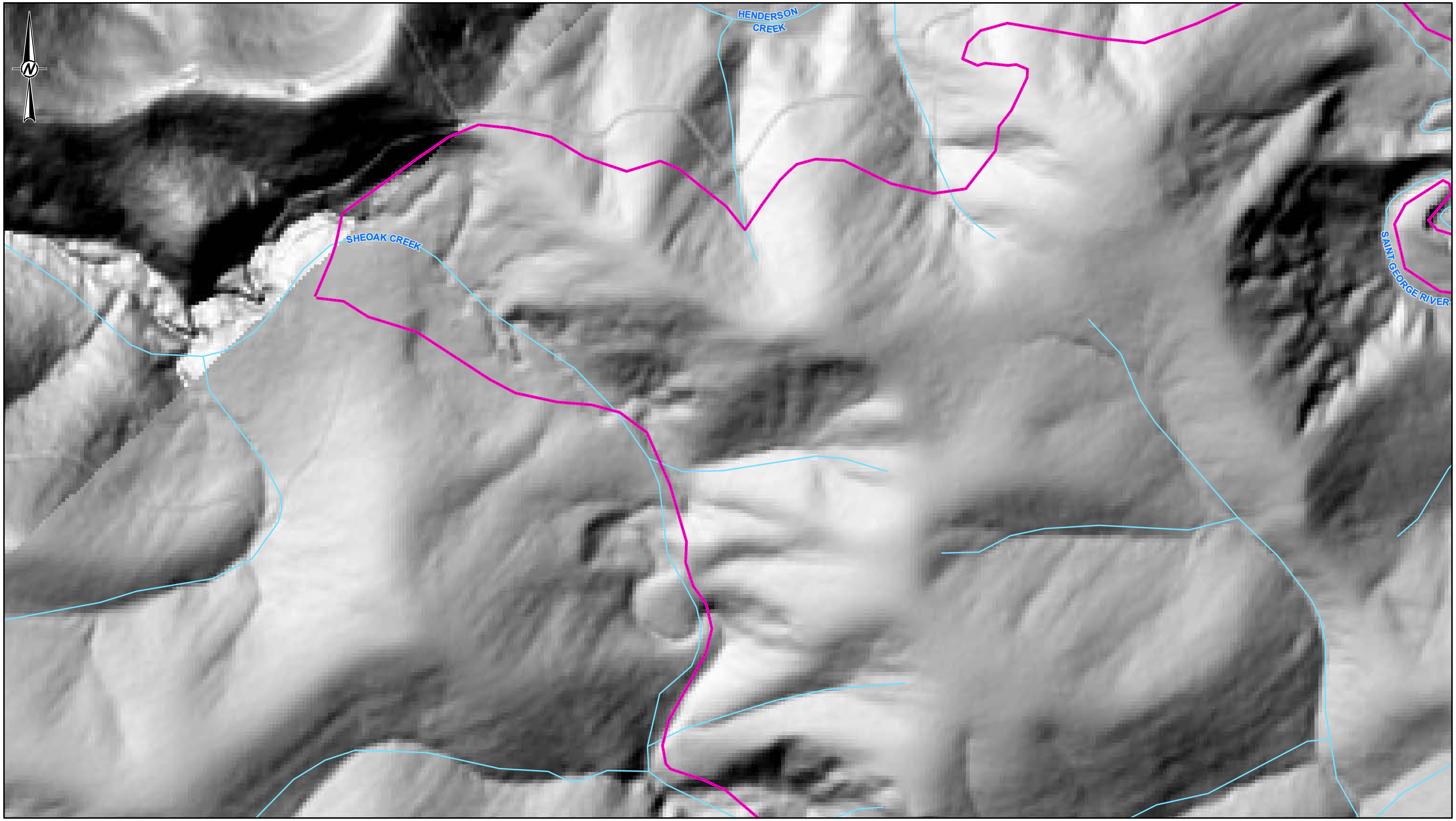


REFERENCE(S)
1. PROJECTION: GDA2020 MGA ZONE 54
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

0 75 150 225 300
Scale @ A3 1:5,000 METRES

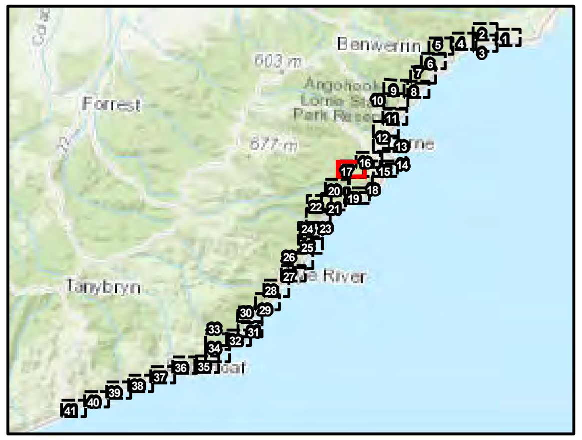
CLIENT	WORLD TRAIL
PROJECT	GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT
CONSULTANT	GOLDER MEMBER OF WSP
YYYY-MM-DD	2021-12-22
DESIGNED	-
PREPARED	DN
REVIEWED	GM
APPROVED	GM
TITLE	SOIL CUT AND FILL BATTER FAILURE HAZARD
PROJECT NO.	21468192
CONTROL	001-R
REV.	A
FIGURE	3.16

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



LEGEND

- Watercourses
- Trail Concept Route 2



0 75 150 225 300

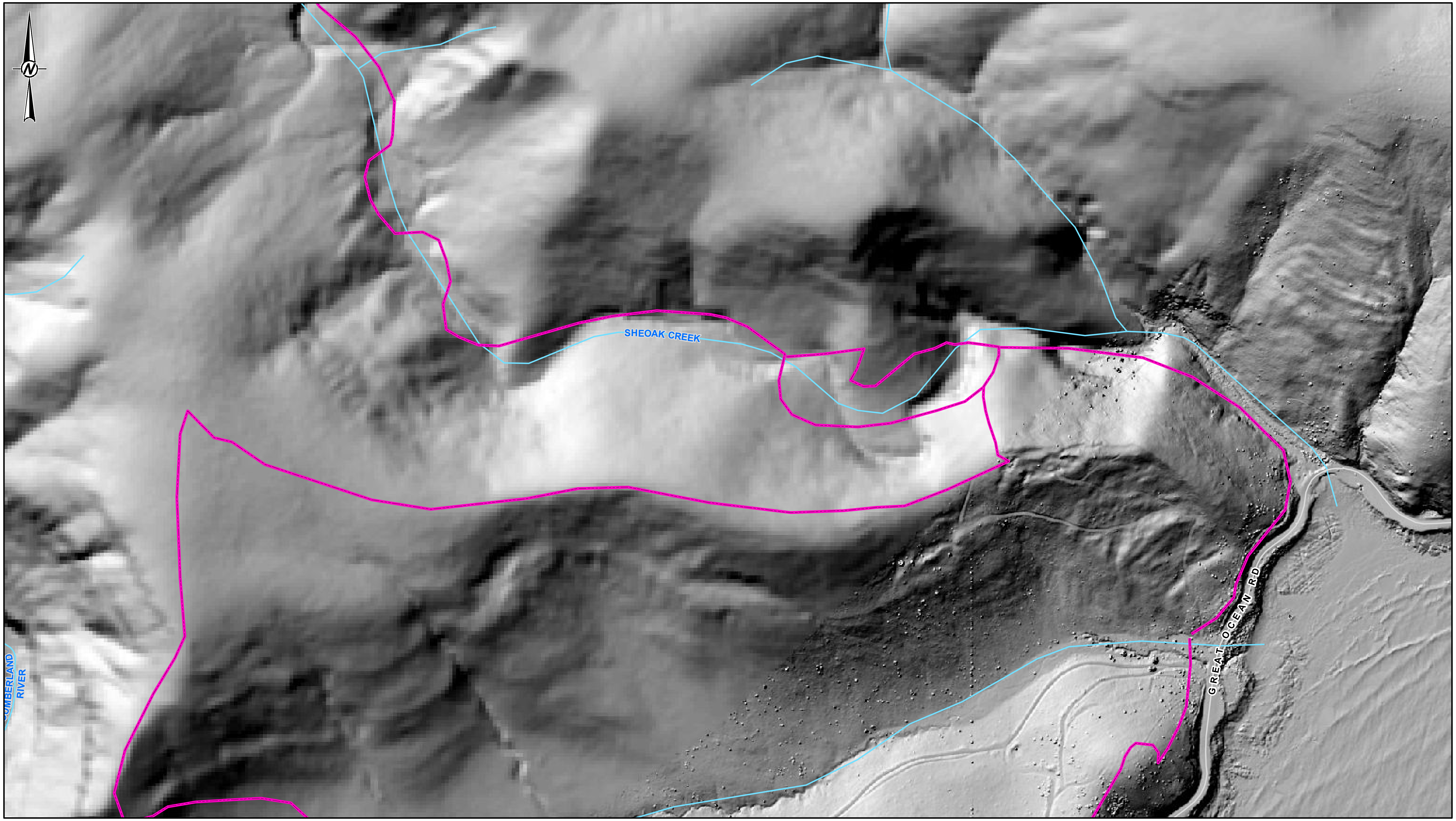
Scale @ A3 1:5,000 METRES

REFERENCE(S)
1. PROJECTION: GDA2020 MGA ZONE 54
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

CLIENT	WORLD TRAIL	PROJECT	GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT
CONSULTANT	GOLDER MEMBER OF WSP	TITLE	SOIL CUT AND FILL BATTER FAILURE HAZARD
YYYY-MM-DD	2021-12-22		
DESIGNED	-		
PREPARED	DN		
REVIEWED	GM		
APPROVED	GM		

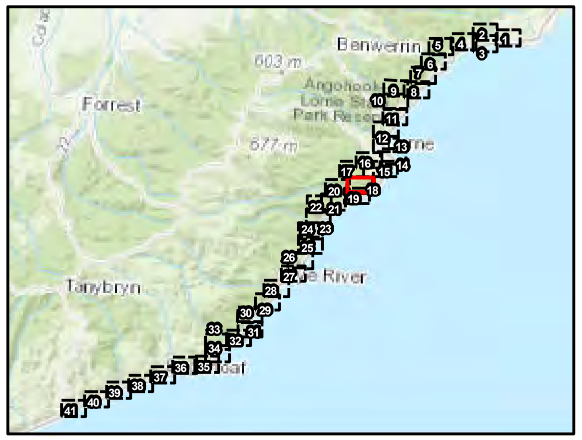
PROJECT NO.	CONTROL	REV.	FIGURE
21468192	001-R	A	3.17

25mm



LEGEND

- Major Roads
- Watercourses
- Trail Concept Route 2



REFERENCE(S)
1. PROJECTION: GDA2020 MGA ZONE 54
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

0 75 150 225 300

Scale @ A3 1:5,000 METRES

CLIENT
WORLD TRAIL

PROJECT
GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT

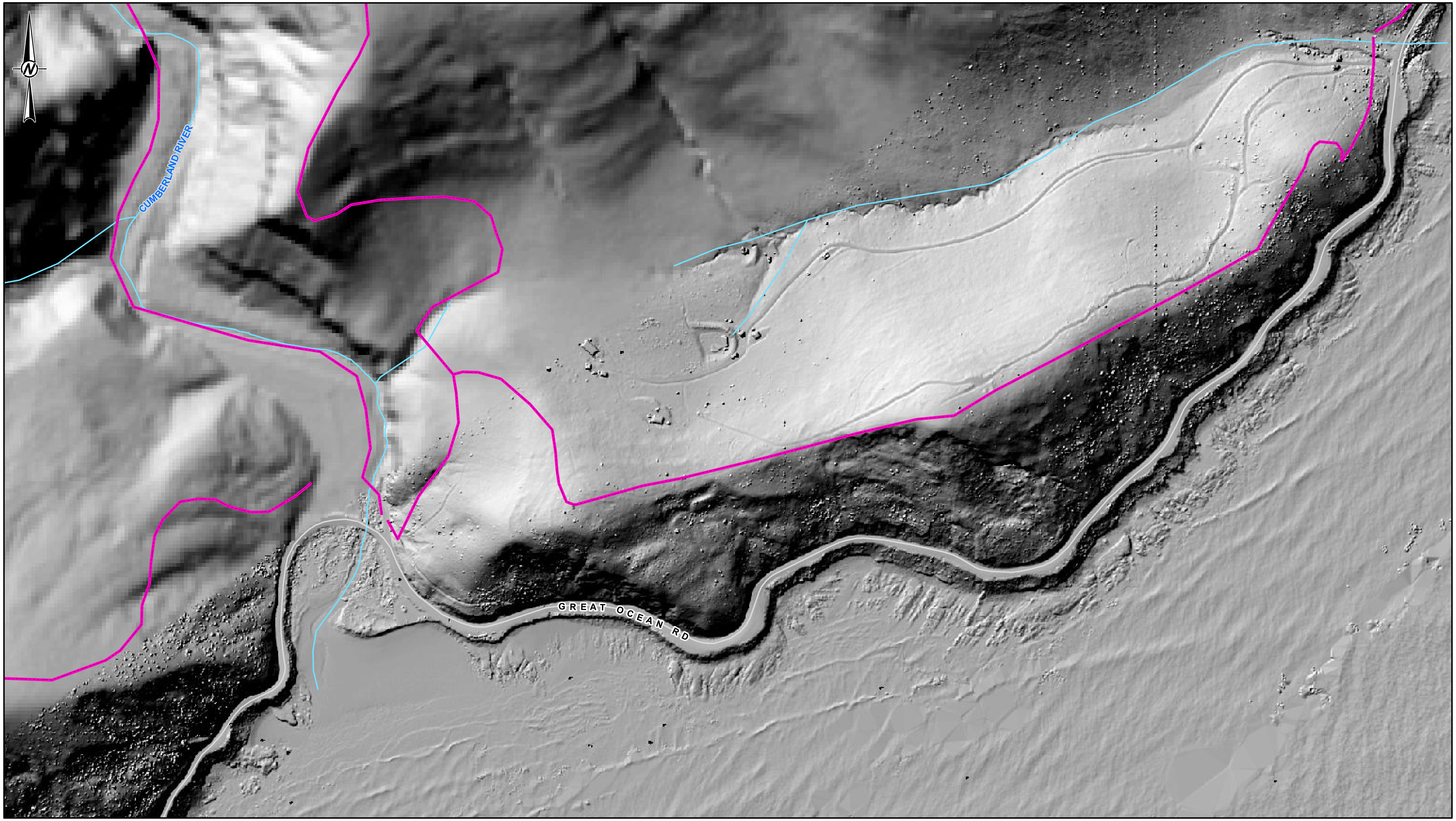
CONSULTANT

GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-12-22
DESIGNED	-
PREPARED	DN
REVIEWED	GM
APPROVED	GM

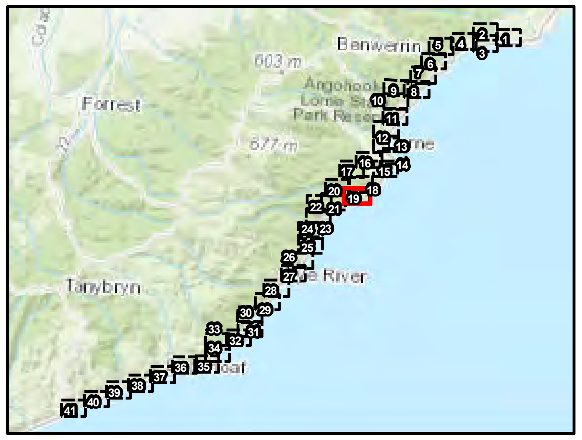
TITLE
SOIL CUT AND FILL BATTER FAILURE HAZARD

PROJECT NO.	CONTROL	REV.	FIGURE
21468192	001-R	A	3.18



LEGEND

- Major Roads
- Watercourses
- Trail Concept Route 2



REFERENCE(S)
1. PROJECTION: GDA2020 MGA ZONE 54
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

0 75 150 225 300

Scale @ A3 1:5,000 METRES

CLIENT
WORLD TRAIL

PROJECT
GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT

CONSULTANT
GOLDER
MEMBER OF WSP

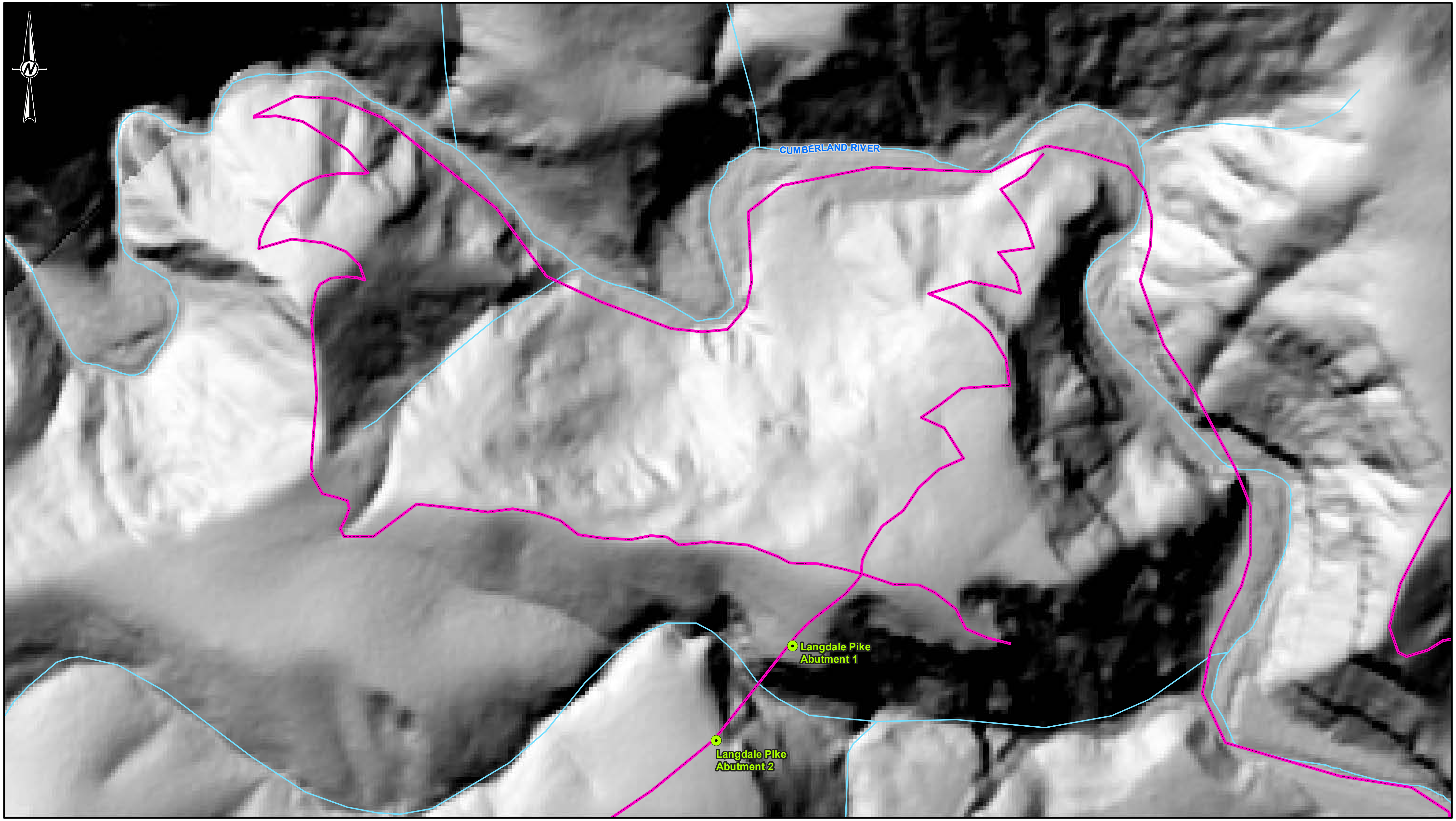
YYYY-MM-DD	2021-12-22
DESIGNED	-
PREPARED	DN
REVIEWED	GM
APPROVED	GM

TITLE
SOIL CUT AND FILL BATTER FAILURE HAZARD

PROJECT NO.	CONTROL	REV.	FIGURE
21468192	001-R	A	3.19

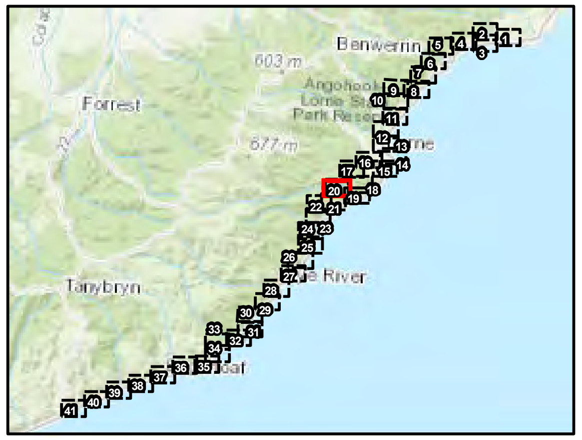
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3

25mm 0



LEGEND

- Bridge Locations
- Watercourses
- Trail Concept Route 2



REFERENCE(S)
1. PROJECTION: GDA2020 MGA ZONE 54
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

0 75 150 225 300

Scale @ A3 1:5,000 METRES

CLIENT
WORLD TRAIL

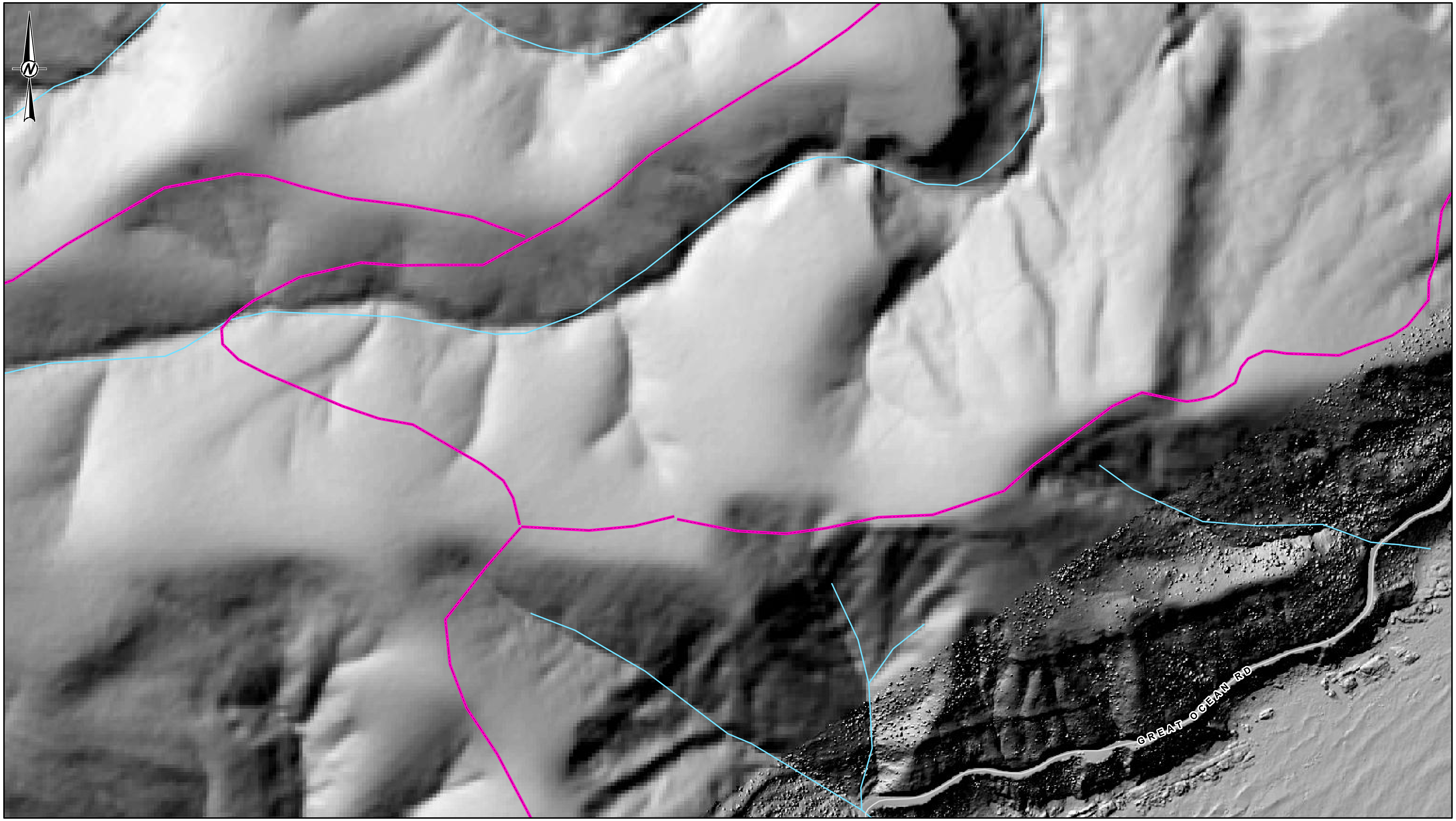
PROJECT
GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-12-22
DESIGNED	-
PREPARED	DN
REVIEWED	GM
APPROVED	GM

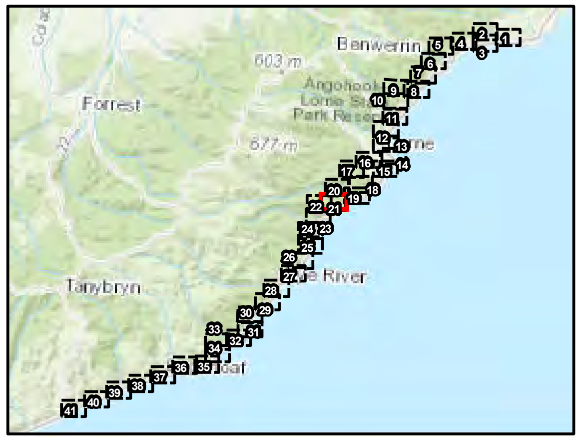
TITLE
SOIL CUT AND FILL BATTER FAILURE HAZARD

PROJECT NO.	CONTROL	REV.	FIGURE
21468192	001-R	A	3.20



LEGEND

- Major Roads
- Watercourses
- Trail Concept Route 2



REFERENCE(S)
1. PROJECTION: GDA2020 MGA ZONE 54
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

0 75 150 225 300
Scale @ A3 1:5,000 METRES

CLIENT
WORLD TRAIL

PROJECT
GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-12-22
DESIGNED	-
PREPARED	DN
REVIEWED	GM
APPROVED	GM

TITLE
SOIL CUT AND FILL BATTER FAILURE HAZARD

PROJECT NO.	CONTROL	REV.	FIGURE
21468192	001-R	A	3.21

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
25mm
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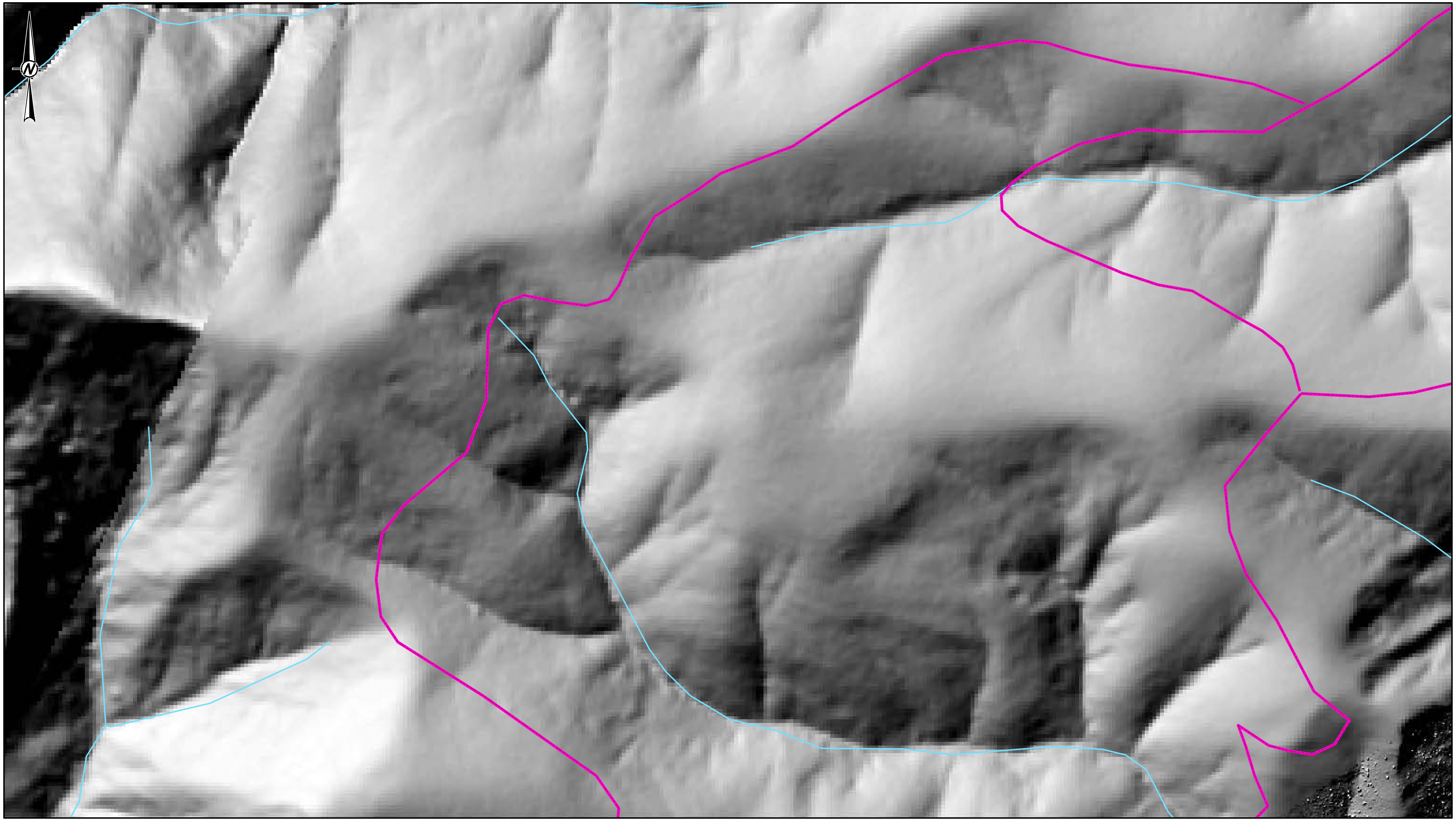


LEGEND

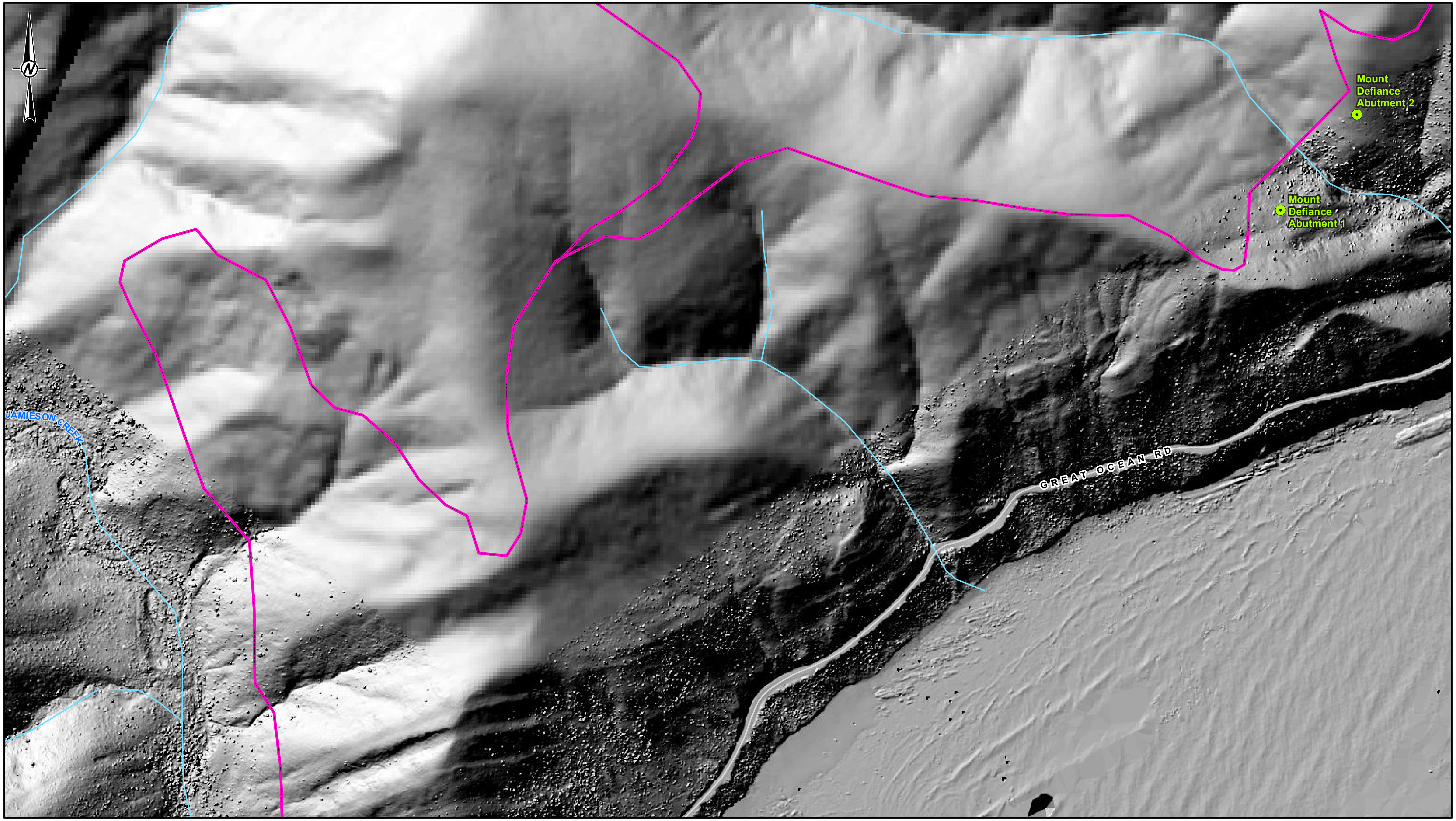
- Watercourses
- Trail Concept Route 2

REFERENCE(S)
1. PROJECTION: GDA2020 MGA ZONE 54
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

0 75 150 225 300

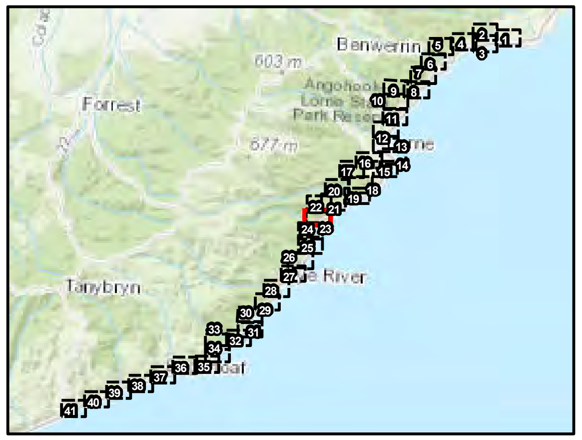
Scale @ A3 1:5,000 METRES

CLIENT	WORLD TRAIL
PROJECT	GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT
CONSULTANT	GOLDER MEMBER OF WSP
YYYY-MM-DD	2021-12-22
DESIGNED	-
PREPARED	DN
REVIEWED	GM
APPROVED	GM
TITLE	SOIL CUT AND FILL BATTER FAILURE HAZARD
PROJECT NO.	21468192
CONTROL	001-R
REV.	A
FIGURE	3.22



LEGEND

- Bridge Locations
- Major Roads
- Watercourses
- Trail Concept Route 2



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Scale @ A3 1:5,000 METRES

REFERENCE(S)
1. PROJECTION: GDA2020 MGA ZONE 54
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

CLIENT
WORLD TRAIL

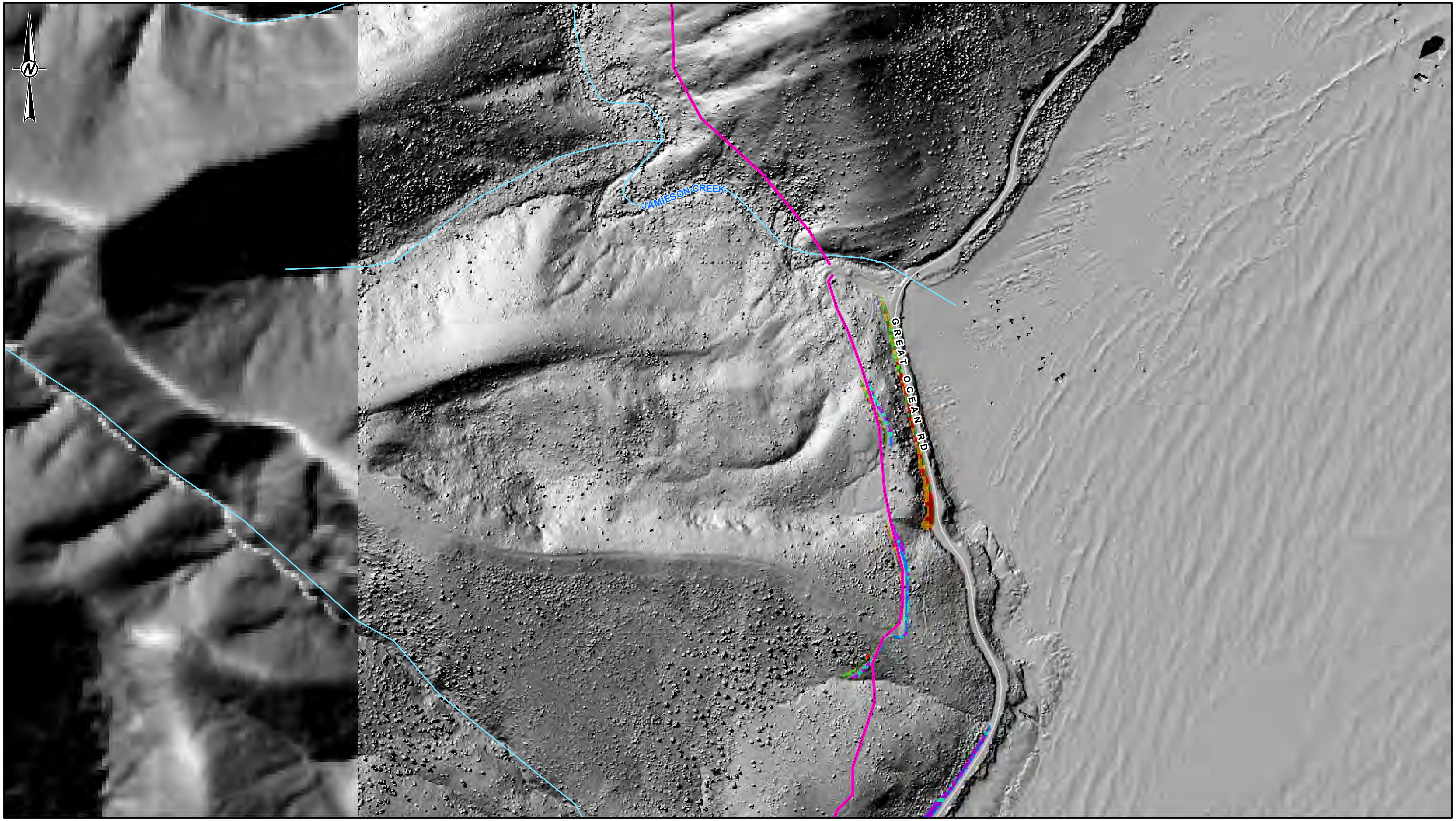
PROJECT
GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-12-22
DESIGNED	-
PREPARED	DN
REVIEWED	GM
APPROVED	GM

TITLE
SOIL CUT AND FILL BATTER FAILURE HAZARD

PROJECT NO.	CONTROL	REV.	FIGURE
21468192	001-R	A	3.20



LEGEND

- Major Roads
- Watercourses
- Trail Concept Route 2

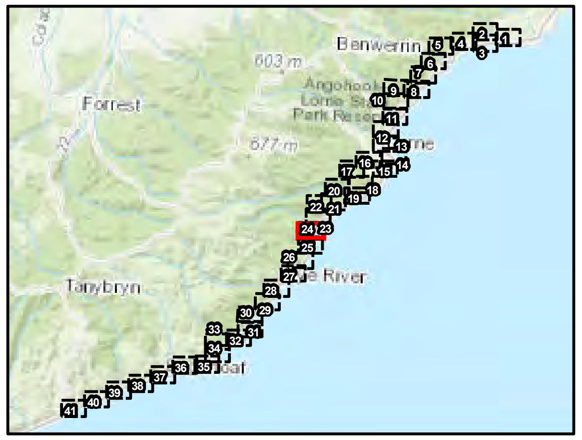
Hazard Levels

Cut

- Very High
- High
- Low
- Very Low

Fill

- High
- Moderate
- Very Low



0 75 150 225 300

Scale @ A3 1:5,000 METRES

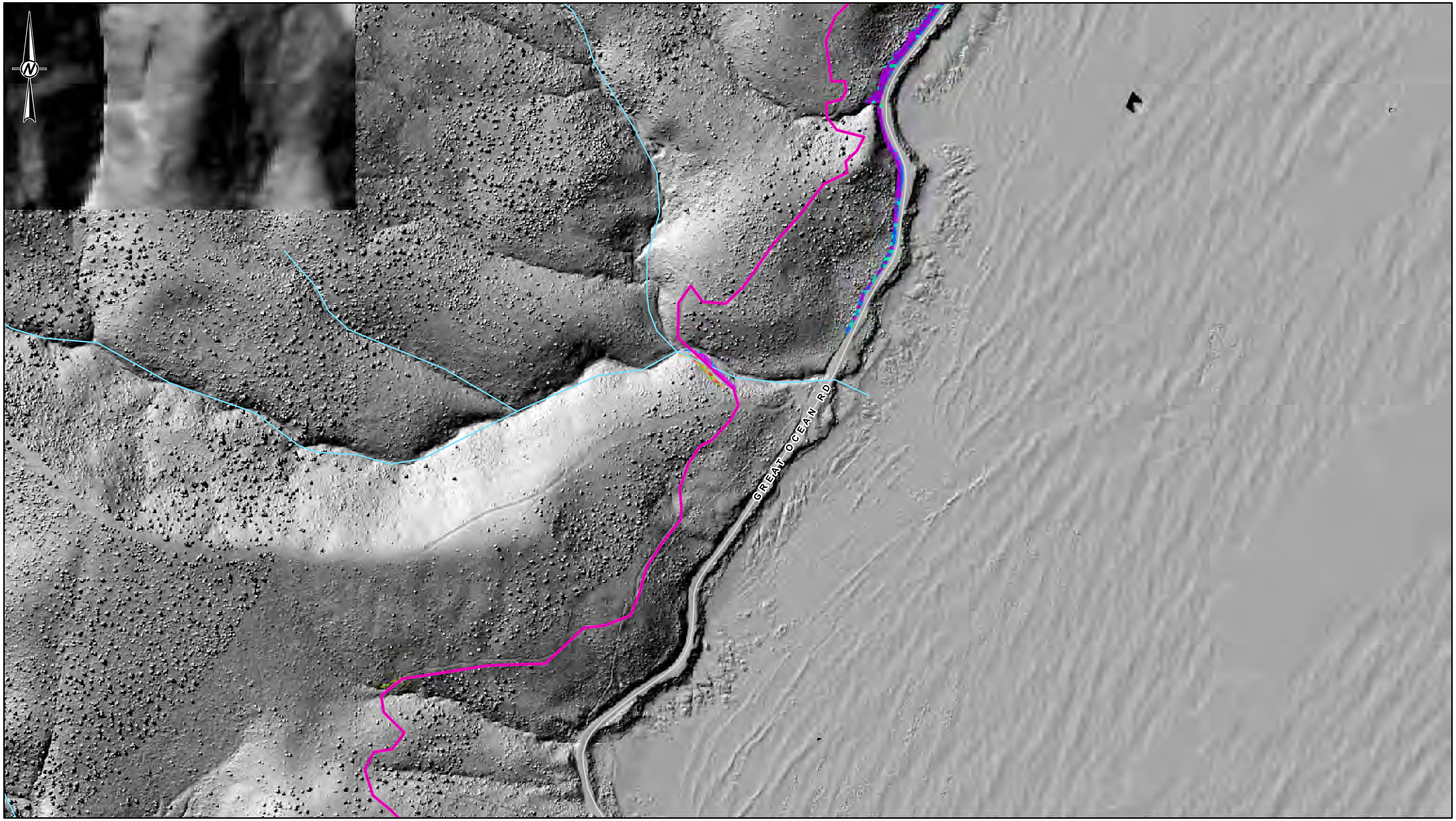
REFERENCE(S)
1. PROJECTION: GDA2020 MGA ZONE 54
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

CLIENT	WORLD TRAIL
CONSULTANT	GOLDER MEMBER OF WSP
YYYY-MM-DD	2021-12-22
DESIGNED	-
PREPARED	DN
REVIEWED	GM
APPROVED	GM

PROJECT
GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT

TITLE
SOIL CUT AND FILL BATTER FAILURE HAZARD

PROJECT NO.	CONTROL	REV.	FIGURE
21468192	001-R	A	3.24



LEGEND

- Major Roads
- Watercourses
- Trail Concept Route 2

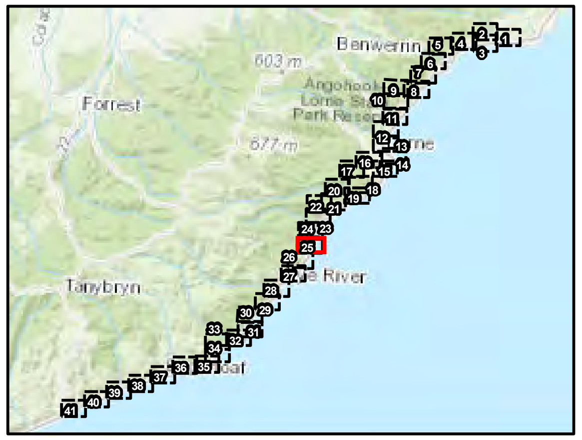
Hazard Levels

Cut

- Very High
- High
- Low
- Very Low

Fill

- High
- Moderate
- Very Low



0 75 150 225 300
Scale @ A3 1:5,000 METRES

REFERENCE(S)
1. PROJECTION: GDA2020 MGA ZONE 54
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

CLIENT
WORLD TRAIL

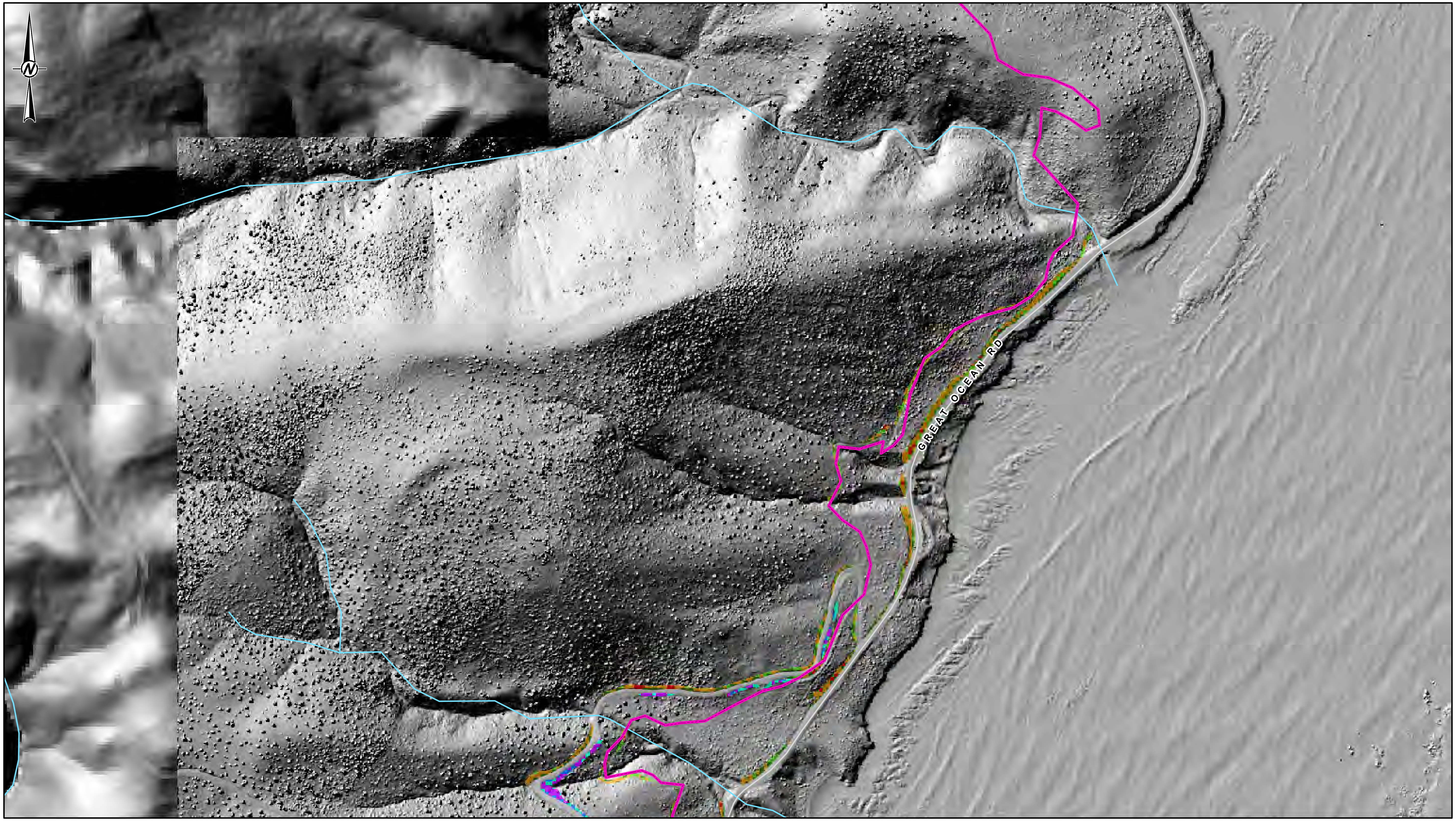
PROJECT
GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-12-22
DESIGNED	-
PREPARED	DN
REVIEWED	GM
APPROVED	GM

TITLE
SOIL CUT AND FILL BATTER FAILURE HAZARD

PROJECT NO.	CONTROL	REV.	FIGURE
21468192	001-R	A	3.25



LEGEND

Major Roads
Watercourses
Trail Concept Route 2

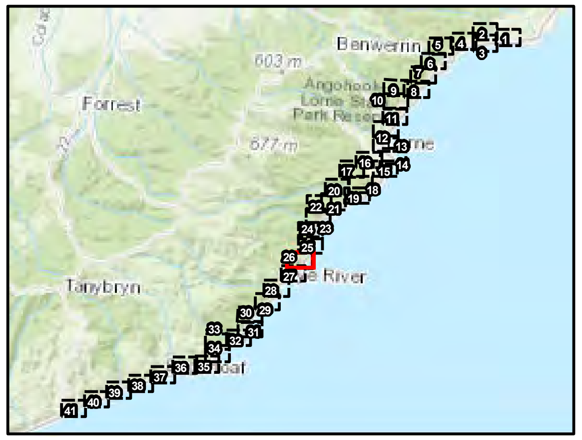
Hazard Levels

Cut

Very High
High
Low
Very Low

Fill

High
Moderate
Very Low



0 75 150 225 300
Scale @ A3 1:5,000 METRES

REFERENCE(S)
1. PROJECTION: GDA2020 MGA ZONE 54
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

CLIENT
WORLD TRAIL

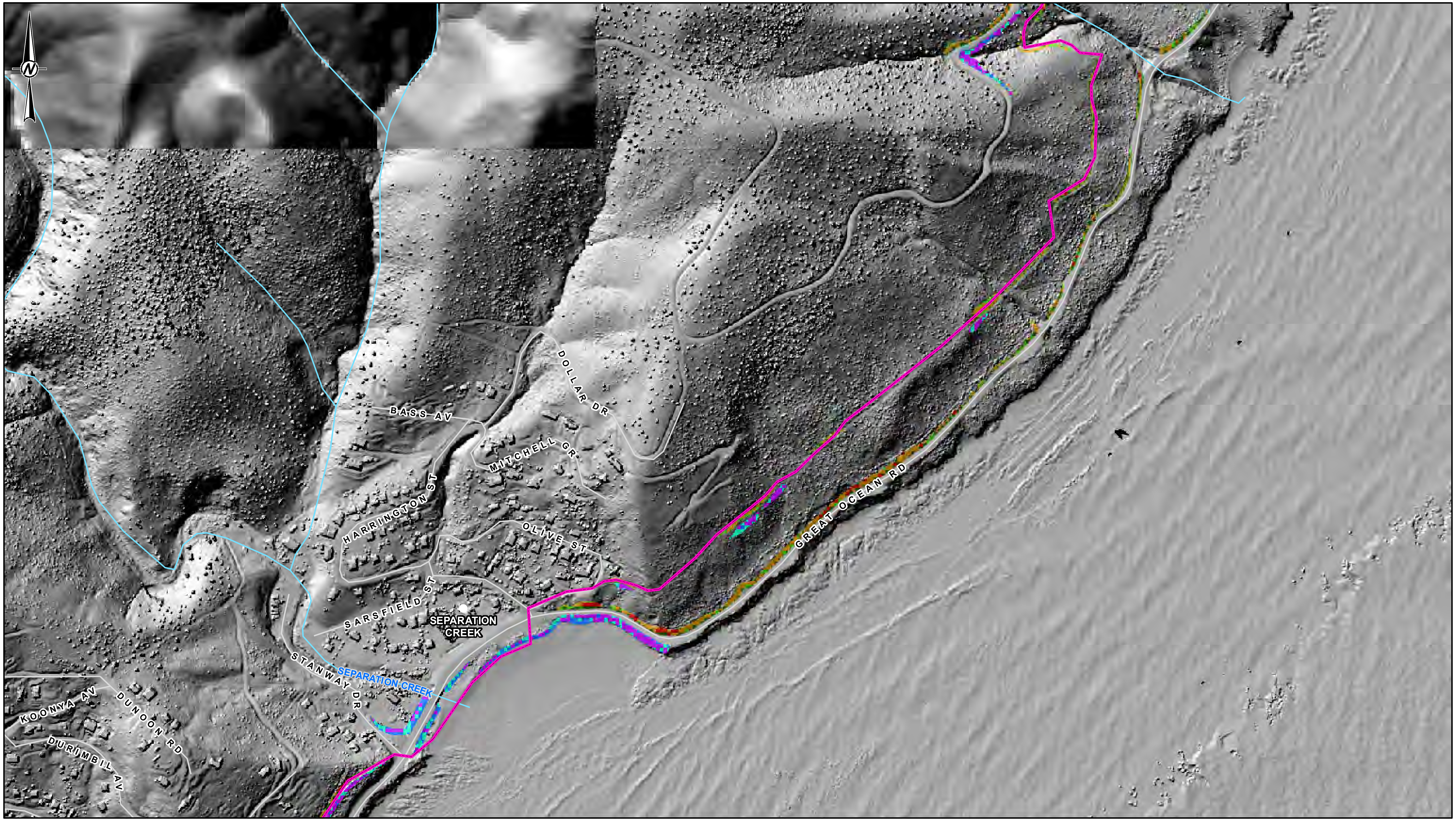
PROJECT
GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT

CONSULTANT
GOLDER MEMBER OF WSP

YYYY-MM-DD	2021-12-22
DESIGNED	-
PREPARED	DN
REVIEWED	GM
APPROVED	GM

TITLE
SOIL CUT AND FILL BATTER FAILURE HAZARD

PROJECT NO.	CONTROL	REV.	FIGURE
21468192	001-R	A	3.26



LEGEND

- Major Roads
- Watercourses
- Trail Concept Route 2

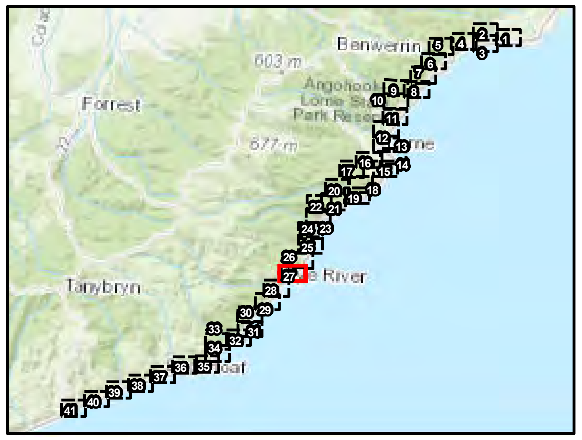
Hazard Levels

Cut

- Very High
- High
- Low
- Very Low

Fill

- High
- Moderate
- Very Low



0 75 150 225 300

Scale @ A3 1:5,000 METRES

REFERENCE(S)
1. PROJECTION: GDA2020 MGA ZONE 54
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

CLIENT
WORLD TRAIL

PROJECT
GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT

CONSULTANT
GOLDER
MEMBER OF WSP

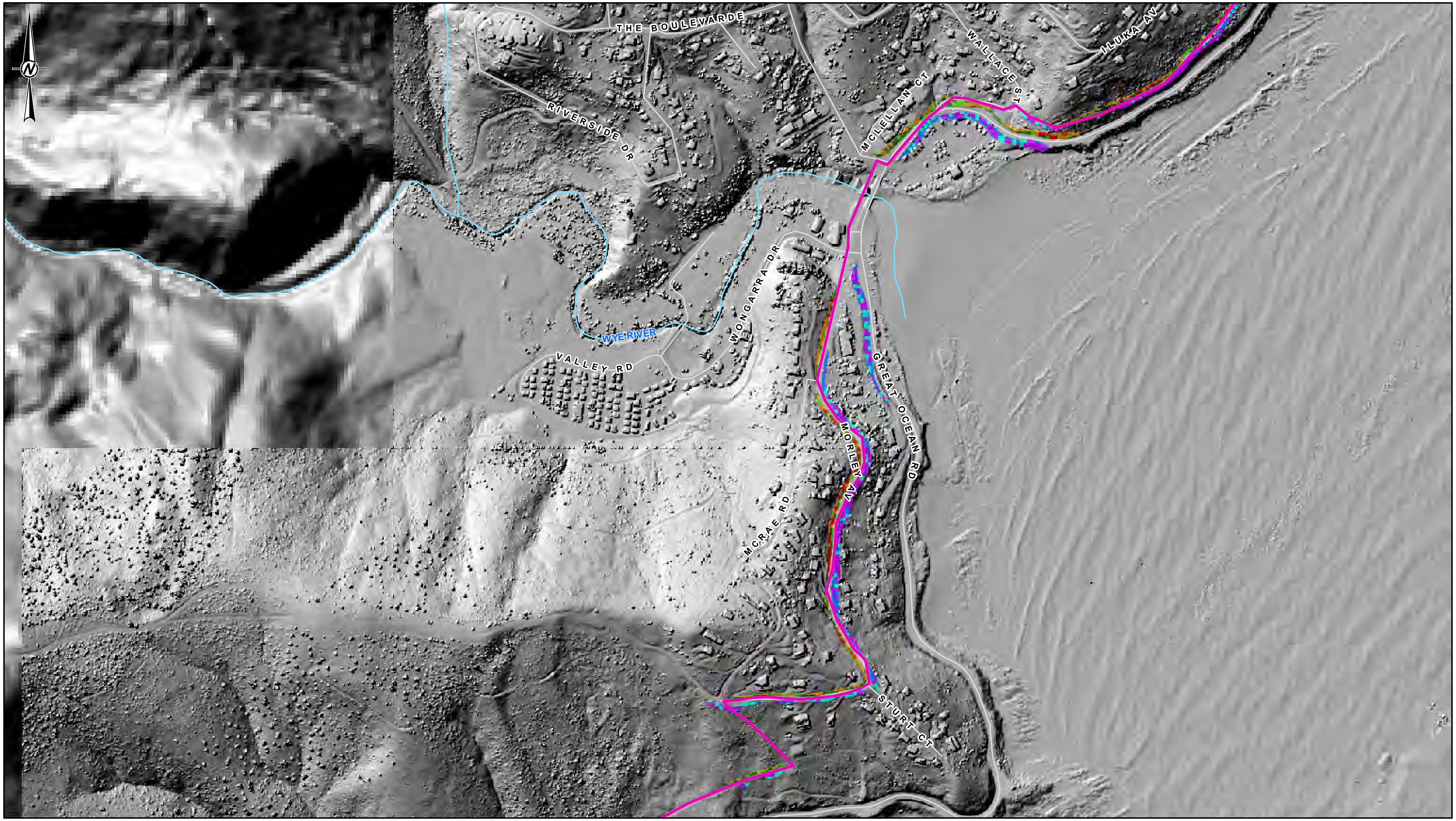
YYYY-MM-DD	2021-12-22
DESIGNED	-
PREPARED	DN
REVIEWED	GM
APPROVED	GM

TITLE
SOIL CUT AND FILL BATTER FAILURE HAZARD

PROJECT NO.	CONTROL	REV.	FIGURE
21468192	001-R	A	3.27

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

25mm



LEGEND

Major Roads

Watercourses

Trail Concept Route 2

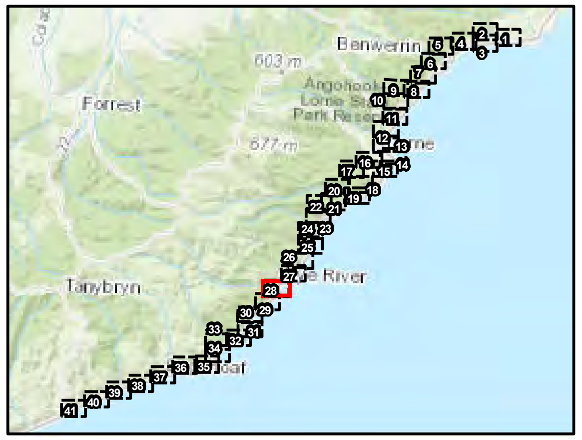
Hazard Levels

Cut

- Very High
- High
- Low
- Very Low

Fill

- High
- Moderate
- Very Low



0 75 150 225 300

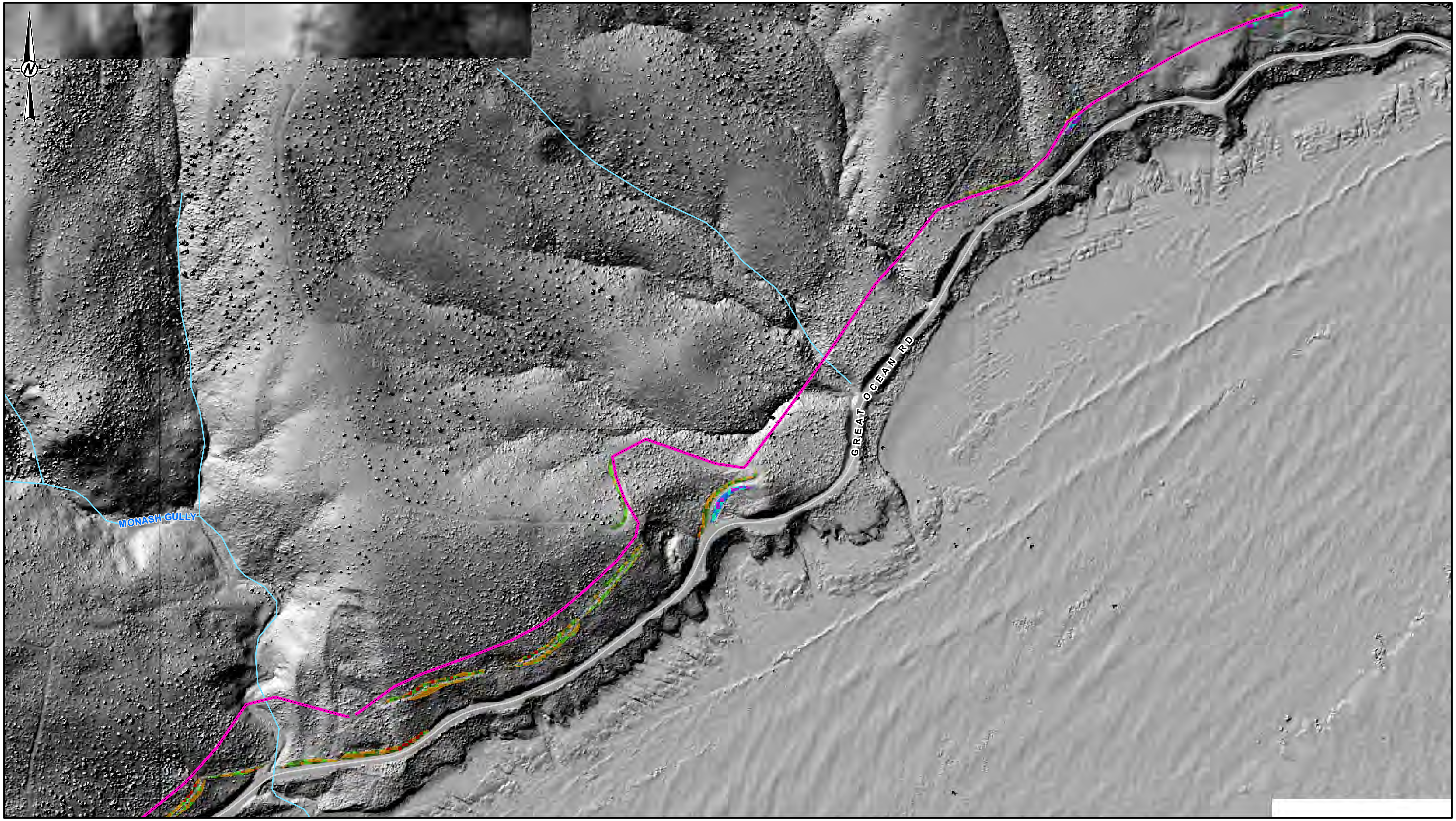
Scale @ A3 1:5,000 METRES

REFERENCE(S)
1. PROJECTION: GDA2020 MGA ZONE 54
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

CLIENT	WORLD TRAIL	PROJECT	GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT
CONSULTANT	GOLDER MEMBER OF WSP	TITLE	SOIL CUT AND FILL BATTER FAILURE HAZARD
YYYY-MM-DD	2021-12-22		
DESIGNED	-		
PREPARED	DN		
REVIEWED	GM		
APPROVED	GM		

PROJECT NO.	CONTROL	REV.	FIGURE
21468192	001-R	A	3.28

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



LEGEND

- Major Roads
- Watercourses
- Trail Concept Route 2

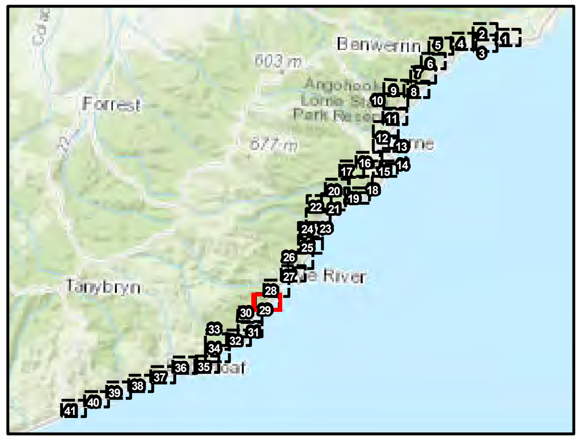
Hazard Levels

Cut

- Very High
- High
- Low
- Very Low

Fill

- High
- Moderate
- Very Low



0 75 150 225 300

Scale @ A3 1:5,000 METRES

REFERENCE(S)
1. PROJECTION: GDA2020 MGA ZONE 54
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

CLIENT
WORLD TRAIL

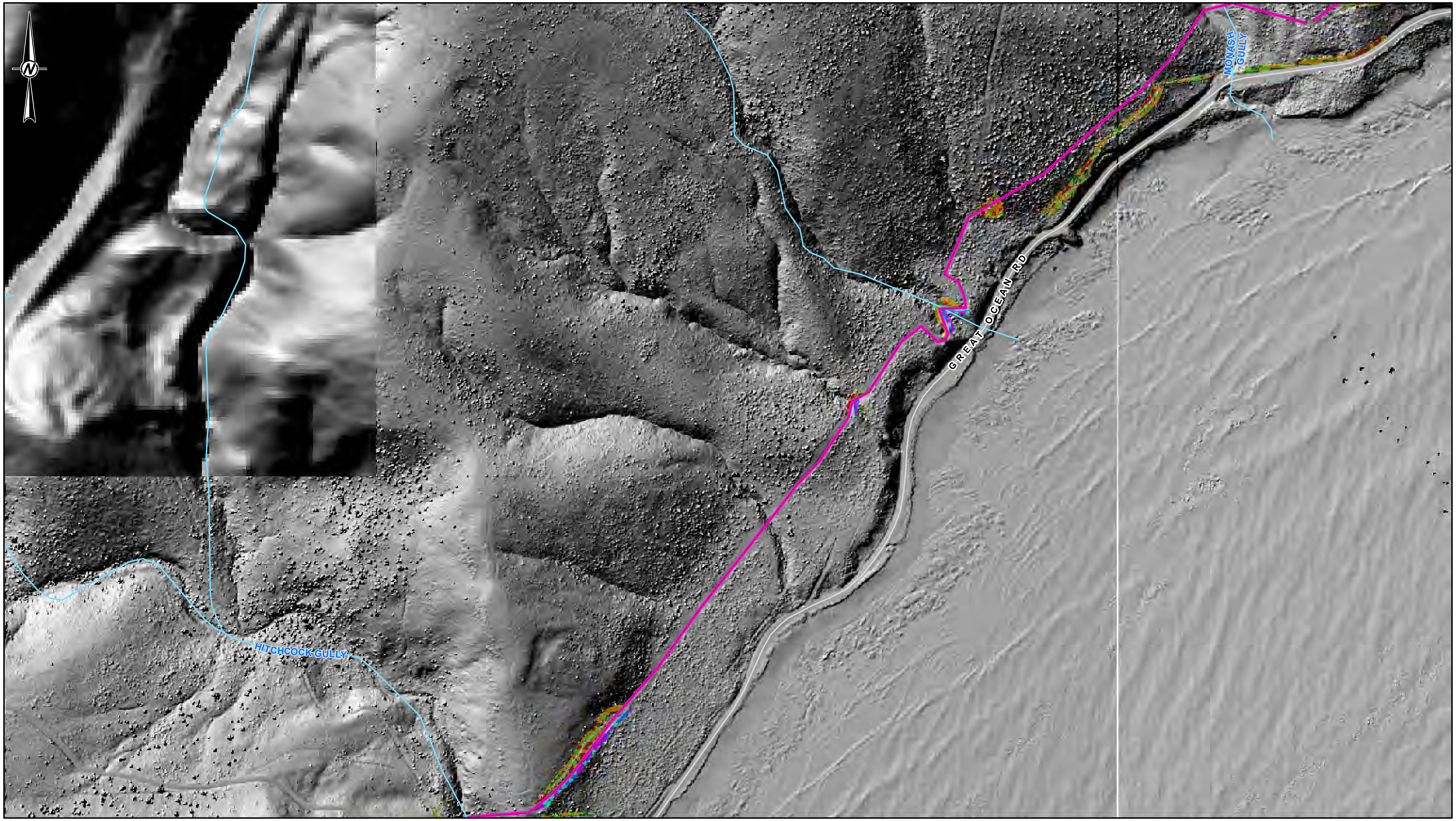
PROJECT
GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-12-22
DESIGNED	-
PREPARED	DN
REVIEWED	GM
APPROVED	GM

TITLE
SOIL CUT AND FILL BATTER FAILURE HAZARD

PROJECT NO.	CONTROL	REV.	FIGURE
21468192	001-R	A	3.29



LEGEND

- Major Roads
- Watercourses
- Trail Concept Route 2

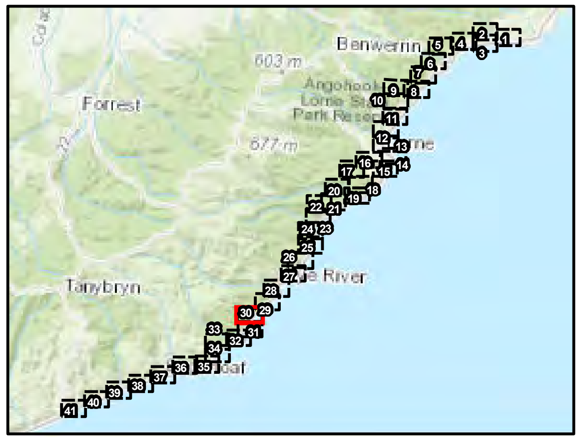
Hazard Levels

Cut

- Very High
- High
- Low
- Very Low

Fill

- High
- Moderate
- Very Low



0 75 150 225 300

Scale @ A3 1:5,000 METRES

CLIENT
WORLD TRAIL

CONSULTANT
GOLDER
MEMBER OF WSP

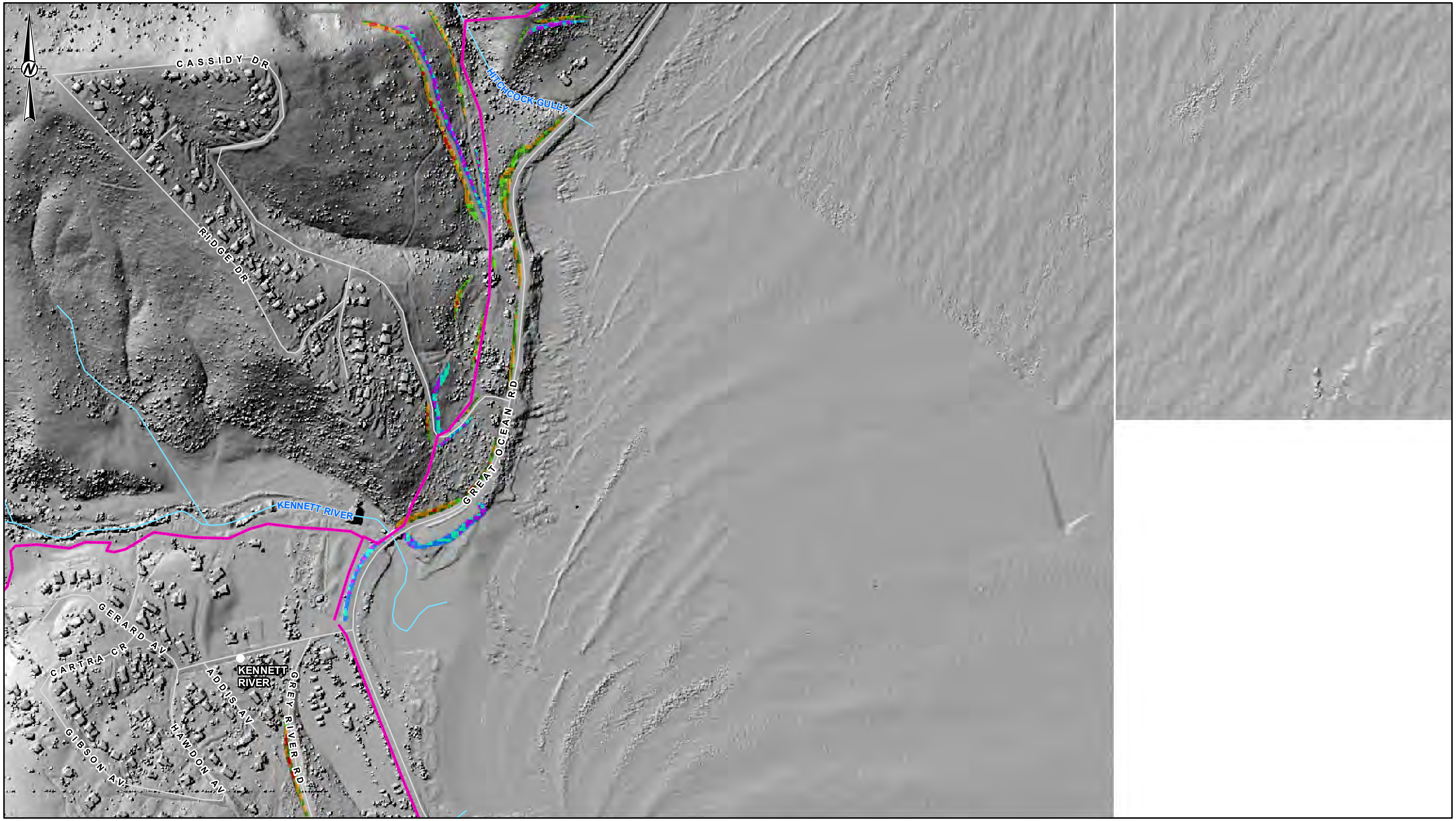
YYYY-MM-DD	2021-12-22
DESIGNED	-
PREPARED	DN
REVIEWED	GM
APPROVED	GM

REFERENCE(S)
1. PROJECTION: GDA2020 MGA ZONE 54
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

PROJECT
GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT

TITLE
SOIL CUT AND FILL BATTER FAILURE HAZARD

PROJECT NO.	CONTROL	REV.	FIGURE
21468192	001-R	A	3.30



LEGEND

- Major Roads
- Watercourses
- Trail Concept Route 2

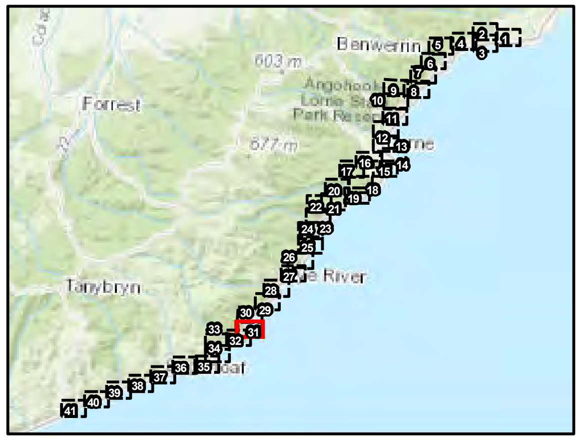
Hazard Levels

Cut

- Very High
- High
- Low
- Very Low

Fill

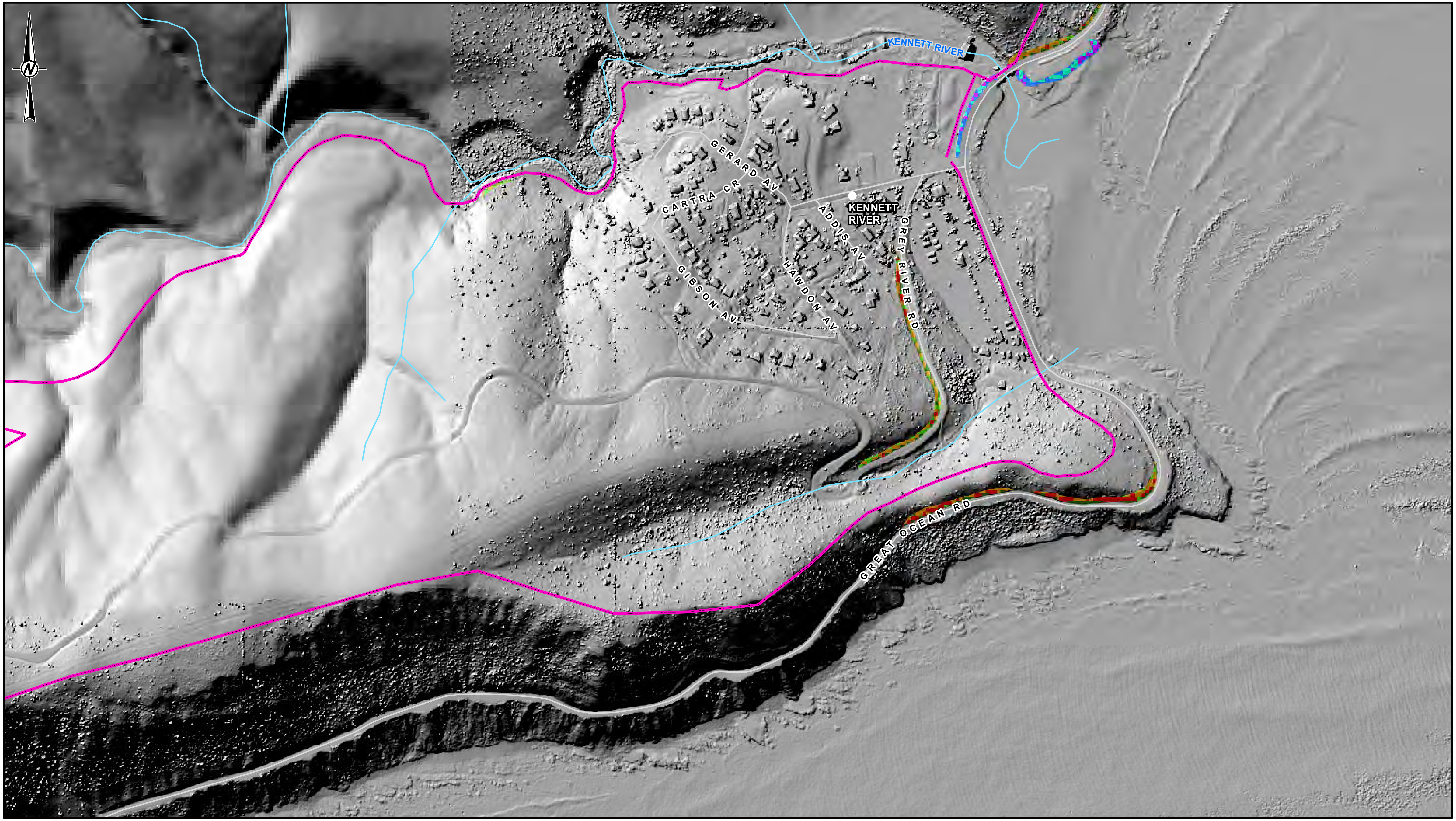
- High
- Moderate
- Very Low



0 75 150 225 300
Scale @ A3 1:5,000 METRES

REFERENCE(S)
1. PROJECTION: GDA2020 MGA ZONE 54
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

CLIENT	WORLD TRAIL
PROJECT	GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT
CONSULTANT	GOLDER MEMBER OF WSP
YYYY-MM-DD	2021-12-22
DESIGNED	-
PREPARED	DN
REVIEWED	GM
APPROVED	GM
TITLE	SOIL CUT AND FILL BATTER FAILURE HAZARD
PROJECT NO.	21468192
CONTROL	001-R
REV.	A
FIGURE	3.31



LEGEND

- Major Roads
- Watercourses
- Trail Concept Route 2

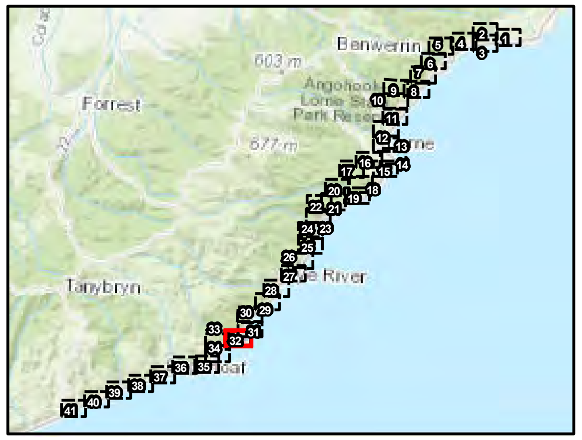
Hazard Levels

Cut

- Very High
- High
- Low
- Very Low

Fill

- High
- Moderate
- Very Low



0 75 150 225 300

Scale @ A3 1:5,000 METRES

REFERENCE(S)
1. PROJECTION: GDA2020 MGA ZONE 54
2. HILLSHADE
3. VICMAP AND DATA.VIC DATA DISPLAYED IN THIS MAP.

CLIENT
WORLD TRAIL

PROJECT
GREAT OCEAN ROAD TRAIL - GEOTECHNICAL HAZARD ASSESSMENT

CONSULTANT

GOLDER
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YYYY-MM-DD	2021-12-22
DESIGNED	-
PREPARED	DN
REVIEWED	GM
APPROVED	GM

TITLE
SOIL CUT AND FILL BATTER FAILURE HAZARD

PROJECT NO.	CONTROL	REV.	FIGURE
21468192	001-R	A	3.32