Memorandum

To	s 6 – Maintenance of law
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From	s 7(2)(a) † Privacy
Office	Tauranga
Date	28 October 2022
File/Ref	
Subject	Mauao Base Track North Rock Risk Assessment & Mitigation Options Assessment

Dear s 6 ƒ Maintenance of law

1   Introduction

Further to your recent correspondence, WSP have undertaken a brief quantitative risk assessment of the rockfall potential at a location along The Mount base track and provided an options assessment of mitigation measures that could be implemented to reduce the risk to users.

As discussed at our recent meeting, TCC is proposing to install some seating in an area along the base track that has previously had slope instability issues with regards to rock and debris falling from a cliff onto the base track below. The site is located on the western side of Mauao close to an area known as North Rock.

2   Scope

Based on our meeting WSP understand you require the following:

- Preparation of a brief quantitative risk assessment to assess the risk of rockfall to users of the base track with the assumption that seating is installed close to the slip location.
- Preparation of mitigation options to mitigate the rockfall / debris hazard at the site which can be presented to the Mauao Trustees for discussion and approval.
- Discussion of the above into a memo style document.

3   Quantitative Assessment

The assessment below calculates the annual probability of the person most at risk of losing his or her life when using the proposed seating in the area of the debris slide or rockfall. WSP have assumed the proposed seating is positioned at a distance of approximately 5 m from the toe of the cliff, in an area where the debris will collect.

The quantitative assessment has been undertaken in accordance with the Australian Geomechanics Society Guidelines for landslide risk management (AGS 2007) which has generally been adopted in New Zealand and which we believe is appropriate for this level of assessment.

This assessment considers the type of hazard, the hours of exposure per annum to the public and the sensitivity of the person considered most at risk.

According AGS (2007), the individual loss of life risk can be calculated according to the following equation for any person or persons siting on the proposed seating by summing the risk from all landslide hazards, e.g., rockfall & debris slide.

R(LOL) is calculated as: R(LOL) = P(L) x P(T:L) x P(S:T) x V(D:T)

Where:

R(LOL) is the annual loss of life risk.
P(L) is the annual probability of a landslide or rockfall occurring
P(T:L) is probability of the landslide or rockfall reaching the element at risk (person/s).
P(S:T) is the temporal spatial probability of the persons (i.e. chances of the person being struck by debris).
V(D:T) is the vulnerability of the individual.

3.1   Risk Analysis

Danger (Landslide) characterisation

For this assessment we have assumed a landslide could comprise a discrete rockfall or debris slide. We have not distinguished between the two as either could occur at this site. However, we consider that debris slide is the primary failure mechanism and cause the worst possible harm. The debris slide could also contain boulders within the debris.

The volume of material is variable, however can be up to 5 m³ based on an estimate of the volume of debris material that has collected at the toe of the slope, however it could also be larger in rare events. Based on our site observations we believe that a rockfall or debris slide would likely travel far enough to impact the element at risk (i.e., a group of 4 people sitting on the seat below the cliff).

Figure 1: Seating that has subsequently been removed from the site. It is assumed the proposed new seating will be located in a similar position.

<u>Frequency Analysis</u>

Based on the site history there has been at least 2 debris slide events since 2011.

Assuming there has been 2 landslides in 11 years, the frequency of a landslide occurring is:

PL = 2 / 11 = 0.18 / annum

<u>Consequence analysis</u>

Temporal spatial probability P(S:T) of the persons is the probability of the location (seating) being occupied by persons given a spatial impact of a landslide or rockfall. We have assumed there will be no warning of a landslide occurring.

Based on the visitor data provided to us by Tauranga City Council which is derived from an electronic counter at the main beach side access to the track, there is an average of 1,420 people who use the track per day. The data does not differentiate between people using the base track or summit tracks, however we have assumed a large proportion, approximately 70% of persons would use the base track.

Based on the data the track is used generally from 5am to 5pm every day. We have assumed the seating at this location would be used for 50% of the time which would equate to 12 hours / 2 = 6 hours per day, 7 days per week. This is a conservative estimate, however we consider this to be appropriate given that the proposed seating and cultural area will encourage users to sit in the area.

Therefore, the temporal special vulnerability is calculated as follows:

- P(S:T) = 6/24 = 0.25 assuming no warning.

<u>Vulnerability of the persons</u>

As there is no protection without mitigation the vulnerability of the individual would be high. Therefore, we have assumed there would be a 50% chance a person would be killed if struck which is in accordance with the example vulnerability guidance values provided in Appendix F of AGS2007.

- Therefore V(D:T) = 0.5

<u>Risk Estimation</u>

The annual probability of the person most at risk losing their life which could be any user of the proposed seating is:

P(LOL) = P(L) x P(S:T) x V (D:T)

= 0.18 x 0.25 x 0.5

=**2.3×10^{-2} / annum**

3.2   Risk Assessment

According to the Bay of Plenty Regional Policy Statement (BoPRPS), Appendix L, High risk is defined as greater than 1×10^{-04}, Medium risk is less than 1×10^{-04} but greater than 1×10^{-05}, and Low risk is 1×10^{-5} or less for the annual individual fatality risk (AIFR).

With reference to the BoPRPS, the tolerable loss of life risk is 1×10^{-5} per annum or less and therefore, the calculated loss of life risk for the unmitigated case exceeds the tolerable level of risk (i.e the risk is very high).

To achieve the tolerable risk specified in the BoPRPS we would recommend implementing mitigation options to reduce the risk to future users. Possible options are discussed below in section 4.

4 Mitigation Options Assessment

4.1 Rockfall or Debris Slide Mechanisms

WSP have not undertaken a detailed inspection of the cliff face above the track. WSP understands from our observations that the cliff above the track has experienced instability on several occasions in the past (i.e., 2x debris slide events in the past 11 years).

The exposed slip scar is approximately 20 m high and comprises predominantly fine grained colluvial soils, however with some rhyolite boulders within the upper third of the slope. The slip debris at the base of the slope comprises predominantly fine soils with approximately 20% gravels, cobbles and few boulders up to 0.5 m in diameter. It appears that the fine-grained soils are prone to ongoing erosion from antecedent rainfall which may initiate failure of the larger boulders and also slippage during high rainfall events. Based in the site contours there may be an overland flow path above the site, however this should be confirmed with a detailed site (rope access) inspection.

4.2 Preliminary Mitigation Options

Based on our observations and brief risk assessment, it is apparent that rock fall and/ or debris slides will continue to occur at the site. There are various approaches to mitigate risk which seek to eliminate, reduce and / or manage the risk. Several options are discussed below.

4.3 Soil Nailing and Erosion Protection

With this option the rockfall risk would be eliminated where the face is treated. Soil nails reinforce the slope by creating a reinforced block of soil which is connected to a facing system. This option has been successfully implemented on the southern side of Mauao. This option would require further site investigation and design including stability analyses.

Figure 1: Soil Nails on southern side of Mauao.

4.4 Mesh Drape

This would involve pinning a high tensile steel wire mesh to the top of the slope. The mesh would take out the energy out of the rockfall or debris and guide it to the base of the cliff in a controlled manner. This would require periodic clearing. For this option further investigation and design would also be required.

Figure 2: Mesh drape (Source – Geofabrics Australia).

4.5 Installation of a Rockfall Protection System (RPS).

This could be designed to reduce the risk to tolerable levels by preventing rockfall and debris flows from impacting persons at risk who are using the seating in the event of a failure.

Typical RPS systems would involve constructing either an engineered earth bund or flexible (steel mesh) barrier. The design of these options would involve an abseil inspection of the face and rock fall modelling to determine the height and position of such systems. As these options are risk reduction measures, they don't completely eliminate the risk.

In conjunction with installing an RPS system, regular inspections, and hand scaling of the exposed slip face to remove loose boulders in a safe and controlled manner, can be undertaken. An annual programme of rockfall mitigation work through geotechnical inspection and physical hand scaling can further reduce risk levels to tolerable levels.

Programmes such as this tend to start with a high level of physical works to achieve a baseline of hazard control but then, dependent upon the erosional condition of the bluff, reduce over time to periodic phases of works based on annual inspections.

4.6 Example RPS systems

4.6.1 Typical earth bund rockfall barrier

Figure 3: Typical mechanically stabilised earthbund rockfall barrier (source MBIE)

Note: The above option could be designed to have topsoil at the face to enable planting and a green face, however the above picture demonstrates the physical geometry of a typical earthbund.

4.6.2   Typical flexible rockfall barrier

Figure 4: Flexible rockfall barrier (Source MBIE)

4.7   Rough Order Costs

The presented remediation options and rough order costs (ROC) are summarised in the table below. Note the below prices are estimates only based on previous experience and exclude design and construction, along with monitoring fees. WSP therefore recommend that TCC obtain quotes from a suitably qualified contractors to confirm rates once the preferred option has been selected. It must also be noted that actual dimensions and heights will need to be confirmed at the detailed design stage, following a programme of geotechnical investigations, monitoring and ground modelling, which could also affect prices.

Table 1: Options rough order costs summary.

Remedial Option	Estimated Cost Range
Soil nailing	
Mesh drape	s 7(2)(h) … Commercial activities
Earthbund	
Flexible (mesh) barrier	

4.8   Consent Requirements

Subject to which remediation option is preferred then Resource Consent and/ or Building Consent may be required. This can be confirmed once the preferred option has been selected.

## 4.9   Summary and Conclusions

- The calculated loss of life risk when considering a seat installed below the existing slip scarp on the site is unacceptable when considering both the BOPRPS and AGS guidance on tolerable risk levels.

- Options to eliminate or control the rockfall or debris slide include soil nails or a mesh drape system.

- Options to reduce the risk could include a rockfall protection system comprising either a earth bund or flexible mesh barrier, hand scaling and monitoring, and placing signage at the base of the cliff.

- It is likely that a Building Consent and/or Resource Consent will be required for mitigation such as an RPS system.
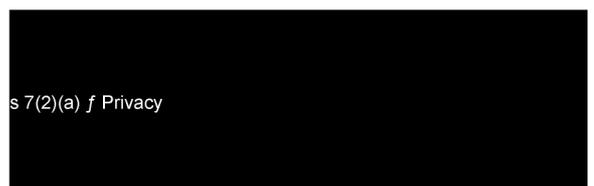
4.10 Further Work

If TCC would like to progress any of the above options, further investigation and design would be required. WSP would be happy to assist with this and I would be pleased to discuss this further with you, should you require.

Yours Sincerely

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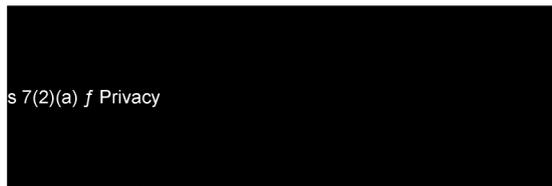
Senior Engineering Geologist

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Principal Geotechnical Engineer

4.11 References

Australian Geomechanics Landslide Risk Management (2007). Commentary on Practice Note Guidelines for Landslide Risk Management 2007.

Bay of Plenty Regional Policy Statement (Appendix L – Natural Hazards Risk Reduction Measures) https://www.boprc.govt.nz/your-council/plans-and-policies/policies/regional-policy-statement).

Ministry of Business, Innovation & Employment (2006). Rockfall: Design considerations for passive protection structures