Bluff Road Coromandel: Rockfall Risk Management, Public Perception and Influence

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Keywords: risk management, rockfall, public perception, public influence.

ABSTRACT

Bluff Road is a low use, single lane, coastal road linking two beach resorts on the north east coast of the Coromandel Peninsula. It is a popular pedestrian short cut between the two beaches, is the access way to attractive fishing marks and provides important options for access to a number of properties.

At one location, close to the western end of the road, the road is overhung by a steep rock bluff at a point where it is partly formed on reclaimed land and supported by retaining structures. Following significant rockfalls and erosion damage in the years since Cyclone Wilma in 2011 a detailed assessment of possible remedial works to improve the safety and resilience was instigated.

Remedial works comprising blasting, scaling, bolting and a passive netting scheme commenced in late 2015. During this work further significant rockfalls occurred, promoted by previously unseen fractures. Following further risk and cost benefit assessment the decision was made to close the affected section of the road. This meant the popular recreational route for pedestrians and cyclists was no longer available and that the Matarangi fire service had a potential additional 11km route to reach the east end of Rings Beach.

Throughout 2016 the public repeatedly removed fences, barriers and warning signs erected to warn of the high risk of rockfalls and prevent access.

In this paper we describe the history of the site, the works carried out and discuss issues around rockfall risks, road closure and public perception of risk.

1 INTRODUCTION

Bluff Road is a low use, single lane, coastal road linking two beach resorts on the northeast coast of the Coromandel Peninsula, Figure 1. It is a popular pedestrian short cut between the two beaches, is the access way to attractive fishing marks and provides important options for private and emergency access to several properties.

At one location close to the western end of the road, the road is overhung by a near vertical 20m high bluff of variably weathered and hydrothermally altered andesite, that is also locally sheared and closely fractured, Figure 2. Three major discontinuity sets are present. Two of them, dipping out of the face at angles of between 30 and 50° and a second dipping out of the face at 70 to 80° promoted planar and toppling failure respectively. The third, near vertical set, has a strike at almost 90° to the face and act as release planes for block failures. Weathering and hydrothermal alteration has particularly picked out the vertical discontinuities trending into the face, which are locally concentrated and may be localised fault or shear zones. The published geological information indicates these to be the Matarangi Andesite of the Coromandel Group of Miocene age (New Zealand Geological Survey 1976).

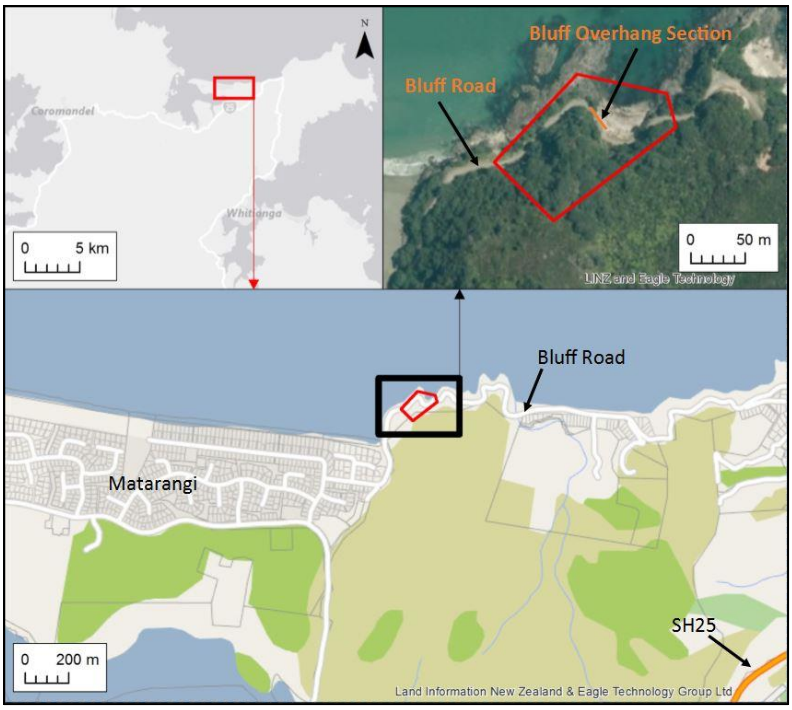

Figure 1: Site location

Figure 2: Views of Bluff Road section of concern showing overhang, fracturing and weathering/alteration

The section of road of concern has had a history of rockfalls coupled with coastal erosion which necessitated regular clearance and maintenance of the road. Following erosion and rockfalls associated with cyclone Wilma in early 2011 Thames Coromandel District Council (TCDC) set in train regular inspections and monitoring of the road and rock face.

Minor rock falls continued, typically following severe weather and were generally individual cobble to boulder sized block falls. Thames Coromandel District Council (TCDC) subsequently engaged Opus International Consultants (Opus) to carry-out stability and risk assessments for possible remedial works.

2 LANDSIDE RISK MANAGEMENT

Subsequent work generally followed the framework for landslide risk management as set out in the Australian Geomechanics Society (2007) guidelines. Hazard analysis (rockfall characterisation, frequency assessment), consequence analysis, risk assessment and finally risk management (risk mitigation options) activities were all carried out

Hazard Analysis: Site inspections and reporting in April 2011, November 2014 and a more detailed assessment of the site in March 2015 all found that the overhanging section clearly had unfavourable discontinuity orientations with respect to rock slope stability. The failure modes that appeared to be kinematically possible across the Bluff were planar, wedge and toppling.

There was a section at the east end of the overhang where three distinct blocks were visible and where if these were to fail the rockfall volumes could be significant (>10m^3), Figure 3.

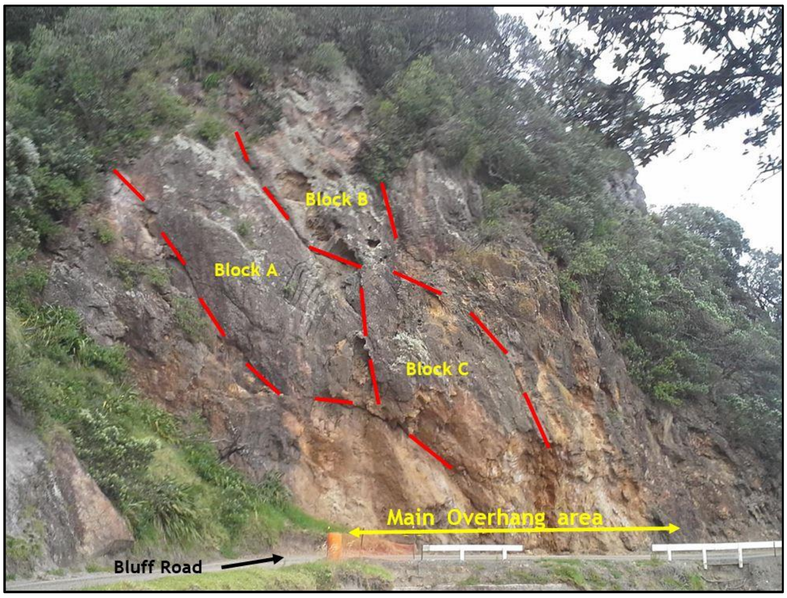

Figure 3: Potential failure masses observed in 2014.

At that time, we considered there was a high likelihood of small rock blocks (up to 0.5m diameter) continuing to fall onto the road. However we also considered that there was a high likelihood of a large volume (>10m^3) planar / wedge type rockslide that would block the road, sourced from any of, or all the blocks A to C shown on Figure 3.

Risk Assessment: The road was used by as little as five vehicles a day and a small number of pedestrians. With the greatest likelihood of failure occurring during or shortly after extreme weather events, the risk to life and limb was therefore considered low. However the road has a strategic importance of enabling emergency access to adjacent properties from two different directions, and this played a relatively greater role in the risk assessment by Thames Coromandel District Council.

Risk Management: An assessment was carried out for 4 treatment options and a 'do nothing' option, using the NZTA "Risk Management Process Manual" as a basis (Transit New Zealand, 2004). The criteria used and outcomes are given on Tables 1 and Table 2 below. Table 1 was generated for the bolt and mesh option (treated risk), similar tables were generated for the other options considered.

Table 1: Risk matrix for mesh and bolt option

Ref	OPTIONS AND RISK: The risk: What can happen and how can it happen?		Qualitative Risk Analysis			Risk Evaluation		Risk Score	Risk Priority	Threat Rank
		Threat or Opportunity	How likely is the event?	Consequence Rating	What are the consequences of the event?	Likelihood Rating	Consequence Rating			
E	**OPTION E: Rock bolting + Rock mesh**									
E1	**RISK 1 : Risk to Walkers**									
E1.1	Direct rockfall impact on member(s)of the public.	**Threat**	Rare	Major	Liklihood reduced as bolting and mesh will be designed to mitigate the risk such that impact on public would likely be negligible.	1	70	70	High Threat	2
E2	**RISK 2 : Risk to Road Users**									
E2.1	Direct rockfall impact on vehicle.	**Threat**	Rare	Major	Liklihood reduced as bolting and mesh will be designed to mitigate the risk such that impact on public would likely be negligible.	1	70	70	High Threat	2
E2.2	Vehicle accident due to rockfall debris in road / road blockage	**Threat**	Rare	Medium	Liklihood reduced as bolting and mesh will be designed to mitigate the risk such that impact on public would likely be negligible.	1	40	40	Moderate Threat	5
E3	**RISK 3 : Risk to Road Asset / Contractors in clean up**									
E3.1	Road blockage and damage to downhill side.	**Threat**	Unusual	Minor	Likely damage not exceeding $100k.	2	10	20	Low Threat	6
E3.2	Risk to contractors in the clear up of debris on road from rockfall event	**Threat**	Rare	Major	Digger drivers and contractors on site potentially at risk, especially if not carefully managed. Reasonable to assume measures can be put in place to manage risk during construction.	1	70	70	High Threat	2
E4	**RISK 4 : Reputation Risks**									
E4.1	Client and Opus image damaged due to costs and insurance / claims made	**Threat**	Unusual	Medium	Lower liklihood than blasting option.,	2	40	80	High Threat	1

Table 2: Summary of outcomes

Option	Very high threats	High threats	Weighted Score
"Do nothing"	1	4	18
Close the Road	0	1	5
Move Road Over Seaward	0	5	17
Scaling Works	0	5	17
Rock bolting / mesh works	0	4	15

The scoring reflected that whilst remedial work reduced the likelihood of key threats being realised the consequences of these were still very serious. It also reflected the responsibility felt by all parties to protect the public, and the client and consultant reputation risks around this.

Closing the road was considered by the client and the public to be a move of last resort, Other options such as a retreat of the cliff face, a rock block bolting and active mesh system and a rockfall protection structure were ruled out on environmental, cost or cultural grounds. Work was subsequently commenced to remove the overhang and improve safety by a combination of a passive mesh system secured to the rock face by bolt anchors.

2 SITE WORK

Work commenced in November 2015 to remove blocks B and C plus a section of material to the right of these blocks (Figure 3). This work was to consist of scaling and blasting to remove approximately 350m^3 of rock and the installation of 350 m^2 of passive mesh held in place by bolt anchors at the top and bottom of the slope. Scaling and blasting was completed prior to the Christmas holiday shutdown after which the placement of mesh was to be carried out. As works were not complete the road was temporarily closed over his period with signage and fencing erected.

A significant rock-fall occurred after heavy rain on the 25th of December (Figure 4). It is unclear if this was also related in part to the effects of the work, such as blasting and stress relief opening fractures.

Figure 4: Rockfall of 25 December 2015.

3 POST SITE WORK RISK AND RISK TAKING

A review of the discontinuity and weathering profile exposed after the December 2015 rockfall concluded that previously unknown discontinuities and deeper weathering and alteration of the rock mass indicated there was a greater risk of ongoing and potentially large volume rockfalls than previously understood.

Significant additional costs would be incurred to continue and the decision was made to discontinue work and close the road. The community was informed and barriers and signs erected to prevent pedestrian access. Rockfall debris was left in place to deter vehicle access. There is a footpath over the bluff that allows alternative pedestrian access.

However, over the next year the fences and barriers were repeatedly cut and broken down by members of the public seeking to use the road as a short cut between the two communities and to popular fishing and diving marks (Figure 5 and 6).

Figure 5: Vandalised fencing

Figure 6: Footpath past debris

This was despite clearly hazardous conditions, as exhibited by wide open fractures, isolated fallen blocks (Figure 7 and 8), signage / barriers and warnings in the press.

Figure 7: Open fractures above path

Figure 8: Fallen blocks on footpath

During site inspections by Opus and Council staff, members of the public would typically linger by the fences and barriers until they thought they could pass through unobserved.

4 DISCUSSION AND UPDATE

We used a well tried procedure to weigh factors in our decision making which, though still appearing to give a significant risk, did after consideration of factors beyond and behind the scoring system point to meshing and bolting as the preferred option.

The technical risk of finding more unknown and unfavourable discontinuities together with deeper weathering and alteration forced a rethink and change of policy to close the road. This was a decision that should have eliminated the risk, and elimination is always seen as the preferred option over mitigation.

As engineering geologists and geotechnical engineers, we make almost daily assessments of risk, assessing hazards, likelihoods and consequences. We are used to the concept and application of 'Factors of Safety' and basing our engineering and policy decisions on these.

However in this case, it is clear that certain members of the public did not agree to the 'no risk' option as evidenced through their actions at the site. Threats of prosecution, publicity (Figure 9) and signs warning of the danger (Figure 10) were ineffective and ignored, as was the actual occurrence of further rockfalls following road closure.

Road remains closed

The Thames District council has warned those ignoring the signs that Bluff Road between Matarangi and Rings Beach risk their own safety. The roads have been closed to the public due to safety concerns around slips and anyone trying to remove protective fences is likely to be prosecuted.

Figure 9: Regional Newspaper Article (Waikato Times)

Figure 10: Signage during site work

Despite the continued rockfalls and clear evidence of danger, even families with young children are willing to take a risk if it will save them a 10-minute detour over the hill instead of around it. Ignoring the signage and barriers infers that the public made their own assessment of risk every time they use the road.

At the time of preparing this paper work was starting for a second phase of scaling and removal of the remaining hazardous block(s) and to install a passive mesh retention system so the road can be re-opened as a public footpath. It will remain closed to all but emergency vehicles.

5 CONCLUSIONS

We consider that two lessons can be drawn from this project.

The first is that there is always a risk that conditions exposed in a rock face do not fully reflect those behind it. In this case deeper weathering and alteration of the rock together with the presence of significant unfavourable discontinuities not exposed on the rock face meant that the scope of work to achieve an acceptable degree of safety increased to a point where it was concluded that it was no longer cost effective to continue mitigation works.

Reliance on engineering geological mapping of the exposed rock, with acknowledgement of possible variation, led to the bolt and mesh solution adopted. However unknown and unfavourable discontinuities together with more pervasive alteration than anticipated forced a reconsideration and change in risk management policy.

The second was confirmation that the perception of an acceptable level of risk is very dependent on the view of the beholder and what they stand to lose or gain. In this case the rockfall assessment procedure identified the mechanisms of rockfall, likelihood and threat, and concluded that these were significant. The management of those risks, threats and consequences fell to the Council who are responsible for the protection of the public and ensuring their safety as far as possible on the Council roads. Councils and Engineers have to act in what they consider to be the best interests of the public, and seek cost effective ways of achieving those aims. In this case road closure was adopted but not accepted by the public that it was intended to protect.

What the authors have taken from this is that you cannot underestimate the willingness of people to put themselves at risk if they consider the advantage gained (even minor) outweighs the likelihood of an adverse and unacceptable outcome.

6 ACKNOWLEDGEMENTS

The authors wish to thank Thames Coromandel District Council for their permission to prepare this paper.

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