Client:	Journeys - Gisborne District Council
From:	LDE Ltd.
Subject:	Tiniroto Road RP35.03, 35.88 & 37.03 Bluff inspection 2/2 and ROC
Date:	01/08/23
Project Ref:	19442
Document ID:	350144
Revision Status:	B

1 Background

LDE Ltd was engaged by Gisborne District Council (GDC) to undertake a high-level risk assessment and monitoring at three steep escarpments along Tiniroto Road at RP35.03 (Bluff 1), RP35.88 (Bluff 2) and RP37.03 (Bluff 3), known as the Hangaroa Bluffs. Our initial Site Inspection Report (LDE report 19442, Doc ID 343457) issued on the 6th July 2023, covers our first two site inspections, describes the nature of the hazard at each bluff and provides recommendations as to the status/useability of the road corridor in the affected areas. The following is intended to be read in conjunction with our initial inspection record and provides a summary of our third inspection alongside high level options and costings for mitigating/reducing the risk at each site.

2 Definition of Terms

The definitions adopted here are in accordance with those provided in the New South Wales Transport Roads and Marine Services guide to Slope Risk Analysis (V4) (NSW Government , 2014).

Hazard: A condition with the potential for causing an undesirable consequence. Descriptions of landslide hazard include the volumes or areas of influence of the landslides or potential landslides, the probability of their occurrence and the velocities of the landslide.

Landslide: The movement of a mass of rock, debris, or soil down a slope. The phenomena described are not limited to either “land” or to “sliding”, and the usage of the word has implied a much more extensive meaning than its component parts suggest. Can include mechanisms such as rock fall, rock topples, slumping, rock or debris avalanches.

Risk: A measure of the probability and severity of an adverse effect to health, property or the environment. Risk is often estimated as the product of probability x consequences.

Resilience: The National Emergency Management Agency defines resilience as the ability to anticipate and resist disruptive events, minimise adverse impacts, respond effectively, maintain or recover functionality and adapt in a way that allows for learning and thriving.

3 Site Location and Hazard Summary

The Hangaroa Bluffs are located on Tiniroto Road approximately 35 km west of the Gisborne CBD (Figure 1). The bluffs occupy north-facing slopes overlooking the Hangaroa River. The site characteristics are as follows:

- Bluff 1 is approximately 370 m in length with a face height of 122m, the slope angle is 40-50 degrees. The slope is comprised of siltstone with interbedded sandstone; bedding dips approximately 32 degrees toward the southwest (i.e. across and into the slope). The siltstone/sandstone rock mass is run through with persistent defects in multiple orientations, with evidence of exfoliation jointing. Soil overburden is present across a significant portion of the slope. Tension cracks were observed near the crest of the slope. Bluff 1 is considered to present an extreme risk to road users from slope instability hazards, including rock fall, block and wedge failure, and debris flow.

- Bluff 2 is approximately 360 m in length with a face height of 182 m, the slope angle is 45-50 degrees. The slope is comprised of siltstone with interbedded sandstone; bedding dips approximately 15 degrees toward the southwest (i.e. across and into the slope). The siltstone/sandstone rock mass is run through with persistent defects in multiple orientations, with evidence of exfoliation jointing. Defects form wedge-type failures, and this has resulted in the formation of two large chutes. Bluff 2 is considered to present an extreme risk to road users from slope instability hazards, including rock fall, block and wedge failure, and debris flow.

- Bluff 3 is approximately 235 m in length with a face height of 100 m, the slope angle is 65-70 degrees for the upper slope and 40 degrees for the lower slope. The slope is comprised of siltstone with interbedded sandstone; bedding dips approximately 5 degrees toward the southwest (i.e. across and into the slope). The mudstone/sandstone rock mass is run through with persistent defects in multiple orientations, with evidence of exfoliation jointing. Differential weathering forms large overhanging blocks of sandstone. Bluff 3 is considered to present an extreme risk to road users from slope instability hazards, including rock/block fall and debris flow.

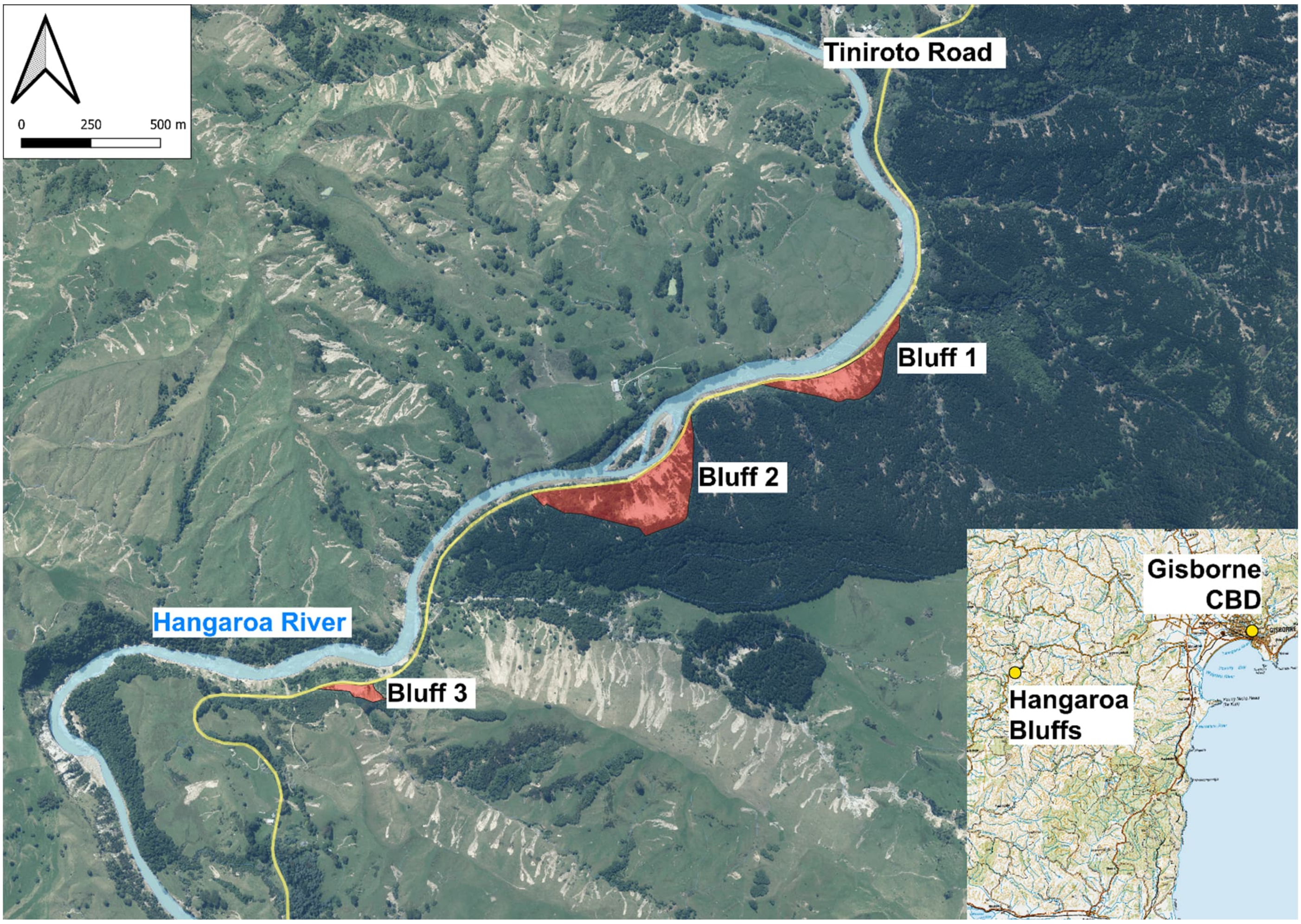

Figure 1: The location of the Hangaroa Bluffs.

4 Summary of Observations – Inspection 3

LDE undertook an inspection of the Hangaroa Bluffs on 18th July 2023. Our inspection consisted of a visual assessment aided by UAV aerial photography. Please see our original inspection report for broader descriptions of the hazards and risks at each bluff, the changes between our 2nd and 3rd inspections observed at each bluff were as follows:

<u>Bluff 1</u>

- Increased displacement was observed across tension cracks at the crest of the slope. Additionally, new tension cracks have formed where previously none were observed (e.g., Figure 2).
- The soil overburden, which covers the upper slope, exhibits signs of further movement/ deformation (refer Figure 3).
- Fresh boulders were present at the base of the slope, on the road, and on the opposite side of the road from the bluff. Boulders were sized approximately 100-600 mm in diameter.
- Seepage on the western side of the bluff has decreased, seepage on the eastern side remains unchanged.

Figure 2: Tension cracking near the crest of Bluff 1(marked by red line) exacerbated by recent low intensity rainfall.

Figure 3: Soil overburden in the upper slopes.

Bluff 2

- The soil overburden which covers the upper slope, and the flanks of Bluff 2 exhibits signs of further movement/deformation and tension cracking has been exacerbated (refer Figure 4 and Figure 5).
- Seepage across Bluff 2 has decreased significantly.
- Fresh boulders were present at the base of the slope, on the road, and on the opposite side of the road from the bluff. Boulders were sized approximately 400mm to 800 mm in diameter.
- The quantity of talus at the base of the slope has only increased marginally.

Figure 4: A portion of the soil overburden at the top of Bluff 2.

Figure 5: A portion of the soil overburden on the true-left flank of Bluff 2.

Bluff 3

- Cracks through and above two of the unstable blocks have dilated further and new cracks were observed in the surrounding rock mass (refer Figure 6). Apertures within the dilated joints are in the order of 100mm to 200mm suggesting a release of rock from the face is imminent.
- Seepage across Bluff 3 has decreased significantly.

Figure 6: Dilated cracks and defects through and surrounding an unstable block.

Following our initial site assessments, we determined that the risk to road users at the three bluffs was extreme, i.e., that the probability of a hazard being realised was moderate to high and that the impact of a given hazard was high to severe. Observations from our third site visit confirm this risk classification is appropriate.

5 Risk Mitigation Options

From our observations we interpret that regular wet/dry and freeze/thaw cycles in the short-term, and high-intensity rain fall events in the short-term to long-term will continue to exacerbate the risk of slope instability at the Hangaroa Bluffs. Further dilation of the cracks and joints identified is likely to continue, with a release of rock material from Bluff 3 considered imminent. As such, we recommend that measures be undertaken to reduce or mitigate the risk to road users at each of the bluffs. The following section provides options for risk mitigation/reduction at the Hangaroa Bluffs. Note that **cost and time estimates are rough order only** with costs presented in NZD.

The scale of the problems addressed within this study, and nature of remedial solutions, are considered comparable to those encountered in Kaikoura. Accordingly, to inform the assessment of the viability of the options presented herein, LDE consulted with an experienced specialist contractor, who played an integral role in the Kaikoura recovery.

5.1 No mitigation

- There is an option to re-open the road without undertaking any mitigation measures.
- Residual risk rating: extreme.
- No initial cost, however, we anticipate high ongoing costs associated with clearing debris, and repairing the roadway after subsequent instability triggering events. There is also significant liability with this option, given the extreme level of risk to which road users would be exposed.

5.2 Bluff 1 and Bluff 2

LDE consider the risk presented by Bluffs 1 and 2 to be higher than that posed by Bluff 3. Of particular note with Bluffs 1 and 2 is that the specialist contractor categorically stated that these bluffs carry sufficient risk that they would not be prepared to have any of their team working on them. This may fundamentally affect the viability of implementing remedial solutions for these sites. It is possible that alternative providers may perceive this risk differently. GDC may wish to canvas opinion from specialist contractors in this regard.

5.2.1 Option 1a: Heavy Scaling and Blasting.

- Residual risk: High to extreme.
- Resilience: Minimal resilience.
- Rough order design cost: $20,000.
- Approximate design time: 6 to 8 weeks.
- Rough order construction cost: $3.6 million.
- Approximate construction time: 12 months.
- Description: Undertake controlled heavy scaling and blasting to remove high risk material from the slopes.

Scaling and blasting would be undertaken by an experienced contractor to remove potentially unstable and high-risk material from the slope. Scaling methods can include, but are not limited to, removal of material with hand tools, air bags, or excavators. Controlled blasting would be used to remove the largest material from the slope. Given the scale of Bluffs 1 and 2, scaling and blasting would incorporate require high rope (abseil) access methods. Scaled material would be cast to road level and loaded into trucks using long-reach excavators.

This option presents significant risks for the constructors. To carry out the scaling and blasting, constructors would be required to work on the slope up to two full rope lengths from the point of egress. This, combined with the height of the bluffs, the quantity of material to be removed, and time specialist crews would be required to be on the slope to do so, was deemed to present an unacceptably high risk by the specialist provider LDE consulted in the development of this options assessment.

It should be noted that the heavy scaling and blasting option is likely to provide limited additional resilience and/ or risk reduction for road users. Given the weak, weathering-prone rock mass, any prolonged or intense rainfall events, following the completion of scaling, would have the potential to result in the release of significant amounts of additional material from the slope face.

5.2.2 Option 1b: Scaling, sluicing and Installation of Anchored Mesh System

- Residual risk: Moderate.
- Resilience: Moderate resilience.
- Rough order design cost: $30,000.
- Approximate design time: 10 weeks.
- Rough order construction cost: $12 million.
- Approximate construction time: 24 months: 12 months for scaling, 12 months for installation of anchored mesh.
- Description: Heavy scaling of slope, sluicing and installation of rock anchors and rockfall protection mesh.

To install an anchored mesh system, sluicing and scaling of the rock slope to bare rock, and removal of all vegetation will first be required.
In order to mitigate rock mass degradation due to chemical and mechanical weathering of the slope, a weather-resistant membrane (suitable geo-fabric membrane) would be installed over the entire slope following sluicing and scaling. An anchored mesh system would then be installed over the top of the membrane to retain material on the rock face. The anchored mesh system would consist of a specialist high-tensile steel netting fixed to the rock face with rock bolts/ anchors. The density and pattern of the rock bolts/anchors, and the type of netting required, would be subject to the conditions of the rock mass and engineering design. Specialist contractor/s will be required to install the membrane and the anchored mesh system. Additional rows of support anchors will be required to prevent the mass of the mesh distorting its profile towards an 'hourglass' type shape. These would need to be installed in the upper and middle reaches of the slope, where the risk is perceived to be higher than in the lower reaches, where mobile working platform arrangements are likely to provide viable access.

Section 5.2.1 discusses the specialist contractor's assessment of the level of risk associated with wholesale, heavy scaling of the rock face. This remains assessment relevant to this option. Additionally, the area of mesh required to secure each slope is on the order of 200,000 m^2, and the time frames to install the anchors and the mesh are significant.

5.2.3 Option 1c: Attenuator/Hybrid Fence

- Residual risk: High.
- Resilience: Moderate resilience.
- Rough order design cost: $30,000.
- Approximate design time: 6 weeks.
- Rough order construction cost: $3.4 million.
- Approximate construction time: 34 weeks excluding 6-week lead in from engagement, 12-week lead time for shipping of attenuator components.
- Description: Light scaling to remove critical blocks, heavy scaling to remove large blocks, installation of attenuator fence.

Installation of an attenuator/hybrid fence would include enabling works consisting of light blasting and scaling, and limited heavy scaling and blasting to remove the highest risk materials from within reach of a mobile working platform. Once these materials have been removed, a hybrid/attenuator fence system would be installed partway up the slope (location to be determined through engineering analysis and design). The specialist contractor has advised that the installation of the hybrid/attenuator fence would be limited to a height accessible via a mobile work platform. The slope profile and the location and realistic height of any attenuator fence means that falling blocks could easily bypass the system as the bounce off the face on decent. Additionally, any blocks of significant size could overwhelm the attenuator/hybrid fence through the force they would impart.

5.3 Bluff 3

The following section provides mitigation options for Bluff 3, please note this section addresses options relating to rock fall/ over-slippage from the rock face above the road and does not cover mitigation of the under-slip which also threatens the resilience of this section of road.

5.3.1 Option 2a: Heavy Scaling and Blasting

- Residual risk: High to extreme.
- Resilience: Minimal resilience.
- Rough order design cost: $15,000.
- Approximate design time: 6 weeks.
- Rough order construction cost: $ 1.2 million .
- Approximate construction time: 4 months.
- Description: Undertake controlled, heavy scaling and blasting to remove material from the slopes.

Scaling and blasting would be undertaken by an experienced contractor to remove potentially unstable material from the slope. Scaling methods can include, but are not limited to, removal of material with hand tools, air bags, or excavators. Controlled blasting would be used to remove the largest material from the slope. Scaling and blasting would likely be undertaken using a variety of vertical rope-accessible methods, e.g. abseiling. Scaled material would be cast to road level and loaded into trucks using long-reach excavators.

This option presents significant risks for the constructors; however, these could be managed at Bluff 3. The heavy scaling and blasting option is likely to provide limited additional resilience and/ or risk reduction for road users. Given the weak, weathering-prone rock mass, any prolonged or intense rainfall events, following the completion of scaling, would have the potential to result in the release of significant amounts of additional material from the face.

5.3.2 Option 2b: Installation of Anchored meshed system

- Residual risk: Moderate.
- Resilience: Moderate resilience.
- Rough order design cost: $25,000.
- Approximate engineering design time: 6 weeks.
- Rough order construction cost: $5 million for scaling and mesh/anchor installation.
- Approximate construction time: 4 months for scaling, 5 months for installation of anchored mesh.
- Description: Heavy scaling of slope and installation of rock anchors and mesh to secure the slope.

To install an anchored mesh system, sluicing and scaling of the rock slope to bare rock, and removal of all vegetation will first be required.
In order to mitigate rock mass degradation due to chemical and mechanical weathering of the slope, a weather-resistant membrane (suitable geo-fabric membrane) would be installed over the entire slope following sluicing and scaling. An anchored mesh system would then be installed overtop the membrane to retain material on the rock face. The anchored

mesh system would consist of a specialist high-tensile steel netting fixed to the rock face with rock bolts/anchors. The density and pattern of the rock bolts/anchors, and the type of netting required, would be subject to the conditions of the rock mass and engineering design. Specialist contractor/s will be required to install the membrane and the anchored mesh system. The mesh would require interim support from anchors which would need to be installed in the upper and middle reaches of the slope. The location of these supports would be determined through engineering design and assessments.

As discussed in Section 5.3.1 the risk level associated with broadscale, heavy scaling of the rock face is high. This coupled with the duration of the works required in high-risk areas (upper to and middle reaches of the slope) was seen as unfavourable by the contractor consulted.

5.3.3 Option 2c: Attenuator/Hybrid Fence

- Residual Risk: Moderate.
- Resilience: High resilience.
- Rough order design cost: $25,000.
- Approximate design time: 4 weeks.
- Rough order construction cost: $ 1.4 million.
- Approximate construction time: 14 weeks excluding 6-week lead in from engagement 12-week lead in for shipping of attenuator/hybrid components.
- Description: Light scaling to remove critical blocks, heavy scaling to remove large blocks, installation of attenuator fence.

Installation of an attenuator/hybrid fence would include enabling works consisting of light blasting and scaling, and limited heavy scaling and blasting to remove the highest risk materials from the slope. Once these materials have been removed, a hybrid/attenuator fence system would be installed partway up the slope (location determined through engineering analysis and design). The specialist contractor advised that the installation of the hybrid/attenuator fence could be undertaken using mobile work platforms which would not require personnel to be on the slope. Additionally, the slope profile provides for increased efficacy of the attenuator/ hybrid fence when compared to that of Bluffs 1 and 2.

After two weeks of the contractors being on site, following completion of the light scaling and blasting, it is likely that limited/ managed traffic movements could be reinstated at the site.

At Bluff 3 LDE did not observe evidence of large-scale block or wedge failures on a scale similar to Bluffs 1 and 2. However, it is possible that larger failures could be generated at Bluff 3 and this may come to light during detailed engineering geological assessment. In the instance that a larger failure occurred, closure and repair of the road and repair of the attenuator/hybrid barrier would likely be required.

5.4 Bypass Options

We understand that a business case to bypass Bluffs 1 and 2 is well advanced by GDC. We recommend this option be pursued in earnest, given the inherent level of risk with Bluffs 1 and 2.

5.5 Alternative Considerations

In addition to the above options, LDE considered other possible solutions, however these were found to be unsuitable for the sites, these included:

- **Bulk earthworks to remove the upper reaches of the slopes followed by scaling of the lower reaches.** This option was found to be impractical due to site conditions, including slope size and morphology, and cost preclusive. This option would still require permanent slope retention or other in-place solutions.
- **Lifting and/or moving the roadway to form a larger catch**
  Given the limited space and the magnitude of the blocks on the slopes, this option was found to insufficiently reduce the risk at the sites. i.e., the road could not be modified sufficiently such that a block failure (similar to that triggered by the June 2023 rain event) would not overwhelm these mitigation efforts.
- **Debris barriers**
  Given the magnitude of the material on the slope this solution would not offer sufficient protection to the roadway and road users. Additionally, there is insufficient space to construct adequate debris arrest systems at the road level.

6 Conclusions and Recommendations

LDE consider that the risk to road users at the Hangaroa Bluffs, remains extreme. This has been validated by observations and monitoring of the bluffs across the past few weeks.

No preferred solution was identified for Bluffs 1 and 2 due to the extreme risk posed by the slopes. The specialist contractor, consulted as part of this study, considered the risk level and complexities to be such that the risk could not be managed sufficiently for work to be undertaken safely on theses slopes. It is possible that alternative providers may perceive this risk differently. GDC may wish to canvas opinion from specialist contractors in this regard.

We recommend Option 2c, the attenuator/hybrid fence, for the mitigation of Bluff 3 due to the relatively favourable balance between cost, residual risk and resilience.

LDE recommend the realignment option to bypass Bluffs 1 and 2, which we understand is already well advanced by GDC, be pursued to provide a long-term solution with increased resilience and a lower risk profile.

LDE have developed a high-resolution 3D model for each of the bluffs from aerial imagery, as part of this study. We would be happy to present our findings, and these models, in person, to facilitate a more thorough understanding of the risks inherent in each of the subject bluffs.

7 LIMITATIONS

This report should be read and reproduced in its entirety including the limitations to understand the context of the opinions and recommendations given.

This report has been prepared exclusively for Journeys Gisborne District Council in accordance with the brief given to us or the agreed scope and they will be deemed the exclusive owner on full and final payment of the invoice. Information, opinions, and recommendations contained within this report can only be used for the purposes with which it was intended. LDE accepts no liability or responsibility whatsoever for any use or reliance on the report by any party other than the owner or parties working for or on behalf of the owner, such as local authorities, and for purposes beyond those for which it was intended.

This report was prepared in general accordance with current standards, codes and best practice at the time of this report. These may be subject to change.

Opinions given in this report are based on visual methods discrete locations designed to the constraints of the project scope. It must be appreciated that the nature and continuity of the subsurface materials between these locations are inferred and that actual conditions could vary from that described herein. We should be contacted immediately if the conditions are found to differ from those described in this report.

8 REFERENCES

NSW Government . (2014). *Roads and Maritime Services Guide to Slope Risk Analysis Version 4.* Roads and Maritime Services.