Waitakere Coastal Communities Landslide Risk Assessment

Overall Report - Muriwai

Auckland Council

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→ The Power of Commitment

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1. Introduction

1.1 Purpose of this report

GHD has been engaged by Auckland Council (AC)[1] to carry out Quantitative Landslide Risk Assessments (QRA) as well as to provide associated landslide risk management advice and geotechnical investigations in the Muriwai area ('the study area'). The purpose of this assessment is to carry out a Quantitative Landslide Risk Assessment (QRA) for the Muriwai area ('the study area'). The QRA is to estimate the risk of Loss of Life to individuals at these properties. The outcome of the QRA will be used to inform subsequent property risk categorisation and building placard designation review by AC. This report version is the final issue. It has taken into account any information provided by the landowner either through the Auckland Council feedback portal or through Auckland Council Recovery Office communication channels.

The purpose of this 'overall report' is to combine and summarise the various GHD geotechnical assessments for Muriwai in a single document. The focus of the report is on the large-scale hazard from the 80 m-high escarpment to the east of Muriwai township that experienced damaging landslides from the escarpment in February 2023 (see Figure 1). Our study includes elements that support a risk assessment that provides a quantified loss-of-life risk from landslides to occupants of dwellings.

This report contains appended reports, which should be read in conjunction with it.

1.2 Background

Two significant rainfall events affected the Waitakere area in late January and early February 2023, resulting from the impacts of ex-tropical cyclones Hale and Gabrielle, respectively.

The Cyclone Gabrielle weather event of 14 February 2023 resulted in widespread catastrophic flooding and slope instability in the settlement of Muriwai where several debris avalanches (which included rocks and trees) occurred, some of which turned into saturated debris flows as they travelled downslope. These flows resulted in damage to buildings and infrastructure. Two fatalities occurred due to impact of landslides on private dwellings. This tragic event was similar to a 1965 storm event that also claimed two lives.

Following the recent event, rapid building assessment of residential properties was undertaken in Muriwai, with some houses having access by owners restricted (a yellow placard – e.g. access in daylight hours only) and some for which no access was permitted (a red placard). Dwellings that retained unrestricted access were white placarded.

[1] As part of contract CW198379, Master Services Agreement CCCS: CW74240 dated 7/09/2019, subsequent work item 'Waitakere Coastal Communities Landslide Risk Assessment', dated 26/04/2023

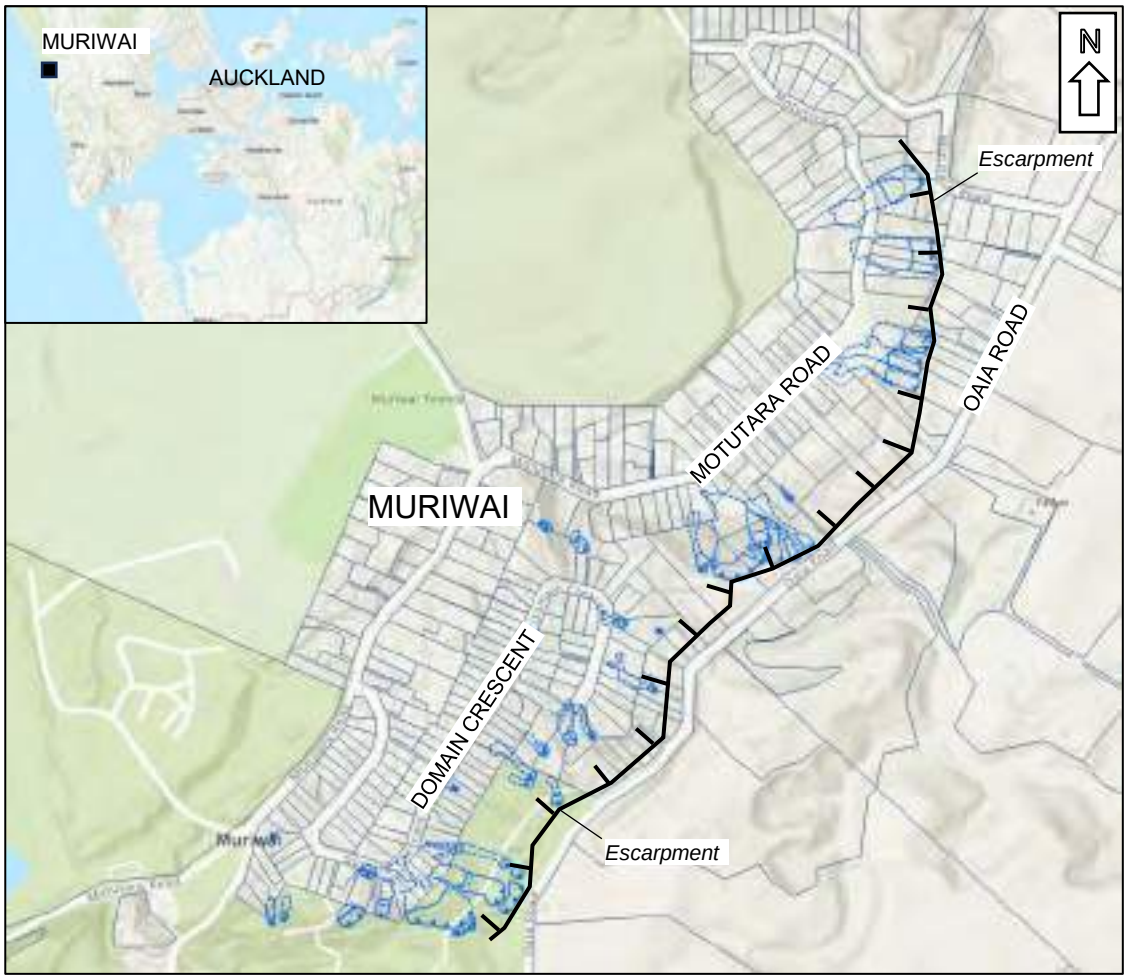

Figure 1 *Muriwai location showing the February 2023 landslides mapped by GHD (blue lines)*

1.3 Scope

AC would like to understand the risk-to-life of large-scale[2,3] slope instability in the settlement of Muriwai to inform possible future dwelling hazard designations, including the revision of building placards issued in February 2023. Landslides from the main escarpment to the east of Muriwai that were associated with Cyclone Gabrielle have demonstrated that some dwellings are exposed to an unacceptably high landslide risk. AC may designate these properties as being unsuitable for habitation. The approach to inform such decisions must be robust and defensible. The scope for this study is as follows:

- Establish a ground surface GIS model using data provided by AC.
- Conduct an engineering geological assessment of the area to understand the physical contributary factors that led to recent large-scale landslides and that may provide insight into future events.
- Conduct a ground borehole investigation of Muriwai to understand the geological materials in the area. This includes laboratory testing of recovered soil and rock to characterise their geotechnical properties.
- Simulate the slope stability of the main escarpment using a Limit Equilibrium slope stability analysis to quantify the failure conditions and to provide indications of two potential remedial measures.
- Undertake a simulation of the potential for future debris flow from the escarpment using RAMMS computer software. The focus for this is to identify which dwellings could be affected by potentially damaging, life-threatening debris flows.

[2] In this report 'large scale' landslide hazards refers to landslides originating from the main escarpment that typically have a volume of more than about 50 m^3 with the potential to cause total or partial collapse of a dwelling.
[3] Some limited, site-specific assessments by GHD have been appended to this report (see Appendix E-2, E-3, E-4) that do assess the risk to specific properties. This reflects an evolution in the scope of GHD's service as requested by Auckland Council.

- Quantify the risk to life of residents from potential future debris flows using data from the above items, in particular the RAMMS output.

AC requested that this study be limited to the assessment of the effect from 'large scale' landslide hazards originating from the main escarpment located to the south-east of Muriwai because the initial placard assessment was largely aimed at mitigating risks associated with these landslide hazards. Consequently, this report does not consider smaller, more localised landslide hazards that could originate (or may have already initiated) from other areas in Muriwai such as within the footprint of individual residential properties. Separate site-specific risk assessments have been undertaken by GHD for several individual properties at AC's request to further clarify risk outcomes within the area-wide study. The results of these are not included in this report.

This report has been prepared by GHD for Auckland Council and may only be used and relied on by Auckland Council for the purpose agreed between GHD and Auckland Council as set out in section 1.1 of this report.

GHD otherwise disclaims responsibility to any person other than Auckland Council arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

1.4 Report structure and revision version

The appended reports and figures provide the detail and calculations of our study. This overall report provides a framework to combine this information and summarises the contents of each report. A draft version of this report was submitted to AC on 24 August 2023 and they used it to inform their provisional Risk Categorisation[4] assignment. The report and Risk Categorisation was released to the public shortly after.

A final (Revision 0) report was an updated version of the draft report that included completed geotechnical investigation and materials testing that was ongoing at the time of the draft release. The report also partially responded to comments from AC's technical peer review committee and from community feedback.

This report (Revision 1) is a further update that is considered to be complete, with no further additions intended. It addresses all outstanding comments from AC's technical peer review committee and community feedback. In most cases the structure of the appended reports is unchanged, but their content is supplemented with more detail, including some additional figures (e.g. figures A127-A129).

Excluded from this report is consideration of the risk relating to dwellings located along the crest of the main escarpment (i.e. the west side of Oaia Road) that could be undermined by the regression of the escarpment edge during future landslide events. Commentary on escarpment edge regression is to be included in a separate, future study.

A list of report sections is presented in Table 1. A3 plans referred to in this report are presented in Appendix A.

Table 1 Summary of accompanying Muriwai landslide risk assessment reports

Report Section	Description
Overall Report	*Waitakere Coastal Communities Landslide Risk Assessment (Muriwai) Overall Report (this report)*
Appendix A	Figures
Appendix B	Engineering Geological Report
Appendix C	Slope Stability Assessment
Appendix D	RAMMS debris flow analysis
Appendix E	Landslide Risk Assessment
Appendix F	Geotechnical Investigations Report

[4] For an explanation of Risk Categories, see Property risk categories (aucklandcouncil.govt.nz)

2. Assessment work stages

This section summarises the project work stages and outlines the main conclusions.

2.1 Engineering geological report (Appendix B)

The purpose of the engineering geological report was to assemble existing data and combine it with observations and anecdotal evidence from the community to inform a model for the area that provides the context for the observed landslides and helps to assess the nature of and triggers for future occurrences. This appendix report has been substantially updated from the draft version.

The following conclusions were reached in the engineering geological assessment of the Muriwai landslide hazard:

1. The recent (2023) and historical (1965) landslides that have affected the Muriwai community were high-velocity debris flows originating on the escarpment that extends up to 80 m above the township.
2. The model proposed for the recent (2023) and historical (1965) landslides that damaged the Muriwai community is that of saturated and shallow translational slips that quickly become high-velocity debris flows, entraining significant volumes of unconsolidated sand and vegetation.
3. The formation of these landslides can be directly attributed to the saturation of surficial soil (colluvium and weathered rock) in the Awhitu Sand Formation which, upon losing its binding iron-cement, develops a shallow shear surface.
4. This process is probably influenced by a combination of surface water infiltration and subsurface pore pressure increases from perched aquifers and associated springs. However, as no groundwater or overland flow data is available from during the events, reliance is placed on anecdotal accounts which do not provide a clear picture.
5. From the data available, including continuous groundwater monitoring established after the 2023 event, it is inferred that surface water flow and infiltration/saturation of shallow soils has had the greater effect on the onset of landslides.
6. The speed, composition, and volume of the debris generated make these debris flows highly destructive to dwellings and property located within the run-out area. As a result, tragically, multiple fatalities were experienced in both the 1965 and 2023 events.
7. The debris flows follow local catchment valleys which often coalesce multiple landslides into confined areas. Consequently, the location and degree of damage to residential properties is variable along Domain Crescent and Motutara Road.
8. Deep-seated landslides resulting from large (i.e. ARI 100 year) rain events within the study area (escarpment) and geology (Awhitu Formation) sand, are not considered likely. Although evidence that may be plausibly attributed to larger historical landslides has been observed, the relative magnitude of these features compared with the 2023 event suggests much larger, less frequent environmental conditions would be required to instigate failure (most likely a very large earthquake). Such conditions and resultant hazards have not been considered for this assessment.
9. Six geomorphological landslide ‘zones’ have been defined based on the surface topography, 2023 landslide characteristics and general geomorphology of the study area. These differentiate areas according to their susceptibility to large-scale landslides (i.e. having a volume of more than approximately 50 m^3). Zones 2, 3 and 4 contain the Muriwai escarpment and have higher potential for future, large landslides.
10. The life risk to residents for each zone is considered separately in the risk assessment (Appendix E).

Interactive community sessions held in September 2023 in Muriwai provided clarification to residents by GHD and AC following the release of the draft version of this report and associated appended reports. We received a large response from the community after the release of the draft report, with additional observations and suggested amendments to the anecdotal information presented below.

2.2 Slope stability assessment (Appendix C)

The purpose of this report was to present a slope stability and back analysis assessment of one of the large, failed slopes at the escarpment to the east of Muriwai township. The objective of the analyses was to estimate rock or soil strength parameters that could be used to inform conceptual remediation options to demonstrate the likely effectiveness of engineering measures that could be required to stabilise the escarpment.

Slope stability analyses were carried out using Slope W version 2021.3 (a GeoStudio Package). As part of the back analyses and feasibility assessments, we examined non-circular, shallow, deep circular and irregular user-defined slip surfaces.

A two-dimensional Limit Equilibrium Analysis was carried out to estimate material parameters applicable to the failed zone. The analysis also assessed the influence of changing pore pressure levels. The seismic performance of the slopes was also assessed, considering factors such as design life, site soil class, peak ground acceleration, and compliance with the NZ Building Code. Based on this, we considered two engineering options that would provide long-term stability to the escarpment: widespread soil nails and benching of the slope. These highlighted the high cost of slope remediation on this scale.

2.3 RAMMS debris flow analysis (Appendix D)

The purpose of this assessment was to present the results of a RAMMS computer-simulated three-dimensional debris flow assessment undertaken to provide guidance on the potential effects of future events on dwellings in Muriwai. In addition, a sensitivity analysis of input parameters is presented. The analysis focus is on the large-scale hazard from the 80 m-high escarpment to the east of Muriwai township that experienced damaging landslides in February 2023. The results from the analysis provide an important part of the GHD loss of life risk study (see Appendix E) that will support decision-making by AC on the long-term suitability of sites and dwellings for occupancy.

The RAMMS debris flow analysis used simulated landslides from source areas similar to those of the damaging February 2023 Cyclone Gabrielle, and from potential, future sources. Geomorphological Zone 5 landslides as described in Appendix B were used to calibrate specific parameters for RAMMS analysis due to the relatively short debris flow runout distance when compared to other zones.

We conclude the following:

1. A quantitative comparison of the actual landslide runout areas with that determined from RAMMS simulation indicates a reasonable fit.
2. The predicted outcome of the simulation is that over 40 originally red-placarded dwellings could be subjected to impact by escarpment landslide debris that is greater than 0.5 m thick as shown on Figures A206 and A209. This has been assessed by GHD's risk assessment in Appendix E as having the potential to cause fatalities, especially if large trees are mobilised by the landslide.
3. Yellow placarded properties are largely beyond the extent of the escarpment landslide debris that is greater than 0.5 m thick.
4. The RAMMS predicted runout extent of damaging debris (i.e. more than 0.5 m maximum thickness) is in broad agreement with the 'F-angle' empirical landslide hazard prediction work undertaken by AC to allocate the original emergency property placards.

2.4 Landslide risk assessment (Appendix E)

The purpose of this assessment was to present the results of a Quantitative Landslide Risk Assessment (QRA) carried out to estimate[5] the risk of loss of life posed by large-scale landslides to individuals in dwellings at Muriwai.

[5] QRA is a systematic method that integrates knowledge and uncertainty to identify and quantify risks. In a QRA the life risk is determined by a calculation but the result is called an estimate because of the inherent uncertainty.

It was carried out in general accordance with the Australian Geomechanics Society Practice Note Guidelines for Landslide Risk Management, commonly known as AGS (2007c). A “risk to property” assessment has not been undertaken.

Occupants of dwellings that have been assessed to be in the path of landslide runout were considered as the elements at risk for this assessment. The risks posed to individuals in the ‘open’, such as people outside houses or situated on other public property such as roads, are not considered in this report. The ‘tolerable’ level of loss-of-life risk in AGS (2007c) is 10^{-4} per annum, which is the same as 1 in 10,000 fatalities pa.

The assessment considers the risk within the six geomorphological landslide ‘zones’ that have been introduced in Appendix B. The risk assessment relied on the outputs of the RAMMS modelling in Appendix D as the basis for determining areas of the site that could be affected by landsliding.

Where RAMMS predicts debris flow of greater than 0.5 m depth, the greatest present estimated risk to life (climate change not considered) is as follows:

- For Zone 1 the risk is ‘tolerable’.
- For Zone 2 the risk is ‘not tolerable’.
- For Zone 3 the risk is ‘not tolerable’.
- For Zone 4 the risk is ‘not tolerable’.
- For Zone 5 the risk is ‘not tolerable’.
- For Zone 6 the risk is ‘tolerable’.

The risks are judged ‘acceptable’ or ‘tolerable’ where the depth of the debris flow is less than 0.5 m.

2.5 Geotechnical investigations report (Appendix F)

The purpose of this report is to present data from a geotechnical borehole investigation and groundwater monitoring programme that was conducted as part of the landslide study. This report is a factual account of the work undertaken, the materials that were encountered and their geotechnical characterisation from laboratory testing. These results are used to inform the engineering geological characterisation in Appendix B.

Work undertaken was as follows:

Boreholes

– Nine cored boreholes advanced to a depth of between 11 m and 80 m below ground level (bgl) at locations at the top and below the escarpment, with the following distribution:
  - Three approximately 80 m deep boreholes at Oaia Road, east of (above) the Muriwai escarpment
  - Three boreholes below the Muriwai escarpment on Domain Crescent (two to approximately 11 m bgl and one to approximately 41 m bgl)
  - Three boreholes below the Muriwai escarpment on Motutara Road (two to approximately 11 m bgl and one to approximately 41 m bgl)
– Log the recovered material using NZGS (2005) guidelines
– Conduct Standard Penetration Tests (SPTs) at 1.5 m intervals
– Record data in AGS4 format and upload borehole logs to the New Zealand Geotechnical Database

Groundwater monitoring

– Install standpipe piezometer screens in some of the boreholes
– Measure initial water levels during drilling and following screen installation
– Supervise installation of water level data recorders and AC monitoring-compatible telemetry hardware to allow ongoing data collection (by AC)

Laboratory testing

– Testing of recovered soils and rocks including:

- Atterberg Limit testing
- Particle size distribution (wet sieve) tests
- Unconfined Compressive Strength tests
- Pinhole and Crumb dispersibility

This report may be updated in the future to include ongoing data.

3. Limitations

This report has been prepared by GHD Limited (GHD) for Auckland Council and may only be used and relied on by Auckland Council for the purpose agreed between GHD and Auckland Council as set out in Section 1 of this report.

GHD otherwise disclaims responsibility to any person other than Auckland Council arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer Section 1 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

An understanding of the geotechnical site conditions depends on the integration of many pieces of information, some regional, some site specific, some structure specific and some experienced based. Hence this report should not be altered, amended, abbreviated, or issued in part in any way without prior written approval by GHD. GHD does not accept liability in connection with the issuing of an unapproved or modified version of this report.

Verification of the geotechnical assumptions and/or model is an integral part of the design process - investigation, construction verification, and performance monitoring. If the revealed ground or groundwater conditions vary from those assumed or described in this report the matter should be referred back to GHD.

Appendices

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Te Kaunihera o Tāmaki Makaurau